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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

BY
CHARLES D. WALCOTT

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

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CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 1

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 1. NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS

BY
CHARLES D. WALCOTT

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 1.—NOMENCLATURE OF SOME CAMBRIAN CORDILLERAN FORMATIONS

By CHARLES D. WALCOTT

CONTENTS

INTRODUCTION

This is the second title on this subject, the first having appeared in 1908.[1] Since that date a few new names for formations of Cambrian age in the Cordilleran area have been proposed, and I now have two new ones and a definition of one used by me in 1912.[2]

THE PTARMIGAN FORMATION

The name Ptarmigan formation is proposed for a series of limestones and interbedded shales that occur above the Mount Whyte formation of the Lower Cambrian and beneath the Cathedral formation of the Middle Cambrian in Alberta and British Columbia, Canada.

Type locality.—Southeast slope of Ptarmigan Peak above Ptarmigan Lake 4.75 miles (7.6 km.) northeast of Lake Louise Station on the Canadian Pacific Railroad, Alberta.

[1] Smithsonian Misc. Coll., Vol. 53, 1908, No. 1, pp. 1-12.
[2] Fort Mountain. Monogr. U. S. Geol. Surv., No. 51, p. 131, footnote a.

Derivation.—From Ptarmigan Peak and Lake, the type locality.

Character.—Arenaceous gray limestones with interbedded bands of thinner bedded, dark bluish-black limestones and some interbedded bands of shale.

Thickness.—At Ptarmigan Peak 516 feet (157.3 m.). At Ross Lake, 8.5 miles (13.6 km.) west-southwest of Ptarmigan Lake, 664 feet (202.4 m.).

Organic remains.—Middle Cambrian fauna (lower) including the *Albertella* fauna of Alberta and British Columbia.

Section at Ptarmigan Pass and Peak

The typical section was measured on the east and northeast face of Ptarmigan Peak above the Pass and Lake. It is 5.5 miles (8.8 km.) northeast of Lake Louise Station on the Canadian Pacific Railroad, Alberta, Canada. The summit of Ptarmigan Peak is formed from the Cathedral limestone, and a fine section is exposed from the summit down to the lake and on the northeast slope down to the pre-Cambrian.[1]

Cathedral Formation: Middle Cambrian — Feet

1. Massive-bedded, arenaceous, cliff-forming limestone, mostly of a light gray color but with a few dark, lead-colored bands of more or less irregular boundaries above and below. The dark bands are usually formed of more thinly bedded and a finer arenaceous limestone........ 2,100

No fossils except traces of annelid borings.

The thickness of 2,100 feet is an estimate based on the height of the mountain and the height of the base of the light gray arenaceous limestone above Ptarmigan Lake.

Ptarmigan Formation

1*a*. Thin-bedded, fine-grained, hard, dark gray to grayish-black arenaceous limestone 46

Fauna: (63b) *Zacanthoides cimon* Walcott
Neolenus constans Walcott

This bed usually breaks down to form a slope beneath the massive Cathedral limestone, but in places it forms a steep, low escarpment.

1*b*. Finely arenaceous limestone in thick alternating bands of a light gray and dark lead gray color. The lower 20 feet is a light gray, finely arenaceous laminated limestone, the lamellæ showing finely on the weathered surface 270

Fauna: Traces of annelid borings occur abundantly within the layers and on their surface. The Ross Lake shale member of the Ptarmigan formation, if present, should occur about 100 feet down in this section.

[1] Smithsonian Misc. Coll., Vol. 53, 1910, p. 429.

	Feet
1*c*. Massive-bedded, bluish-gray and light gray more or less finely arenaceous limestone with many dark layers of oolitic limestone, the oolites varying from 5 to 25 mm. in diameter........................	110
Fauna: A few minute fragments of trilobite tests were seen.	
1*d*. Thin-bedded, dark, bluish-gray limestone that may or may not form a portion of the cliff..	28
Fauna: (63d) *Lingulella* sp. undt.	
Wimanella?	
Ptychoparia (granulated species)	
Ptychoparia ? cilles Walcott	
Crepicephalus chares Walcott	
1*e*. Finely laminated and shaly bluish-gray limestone with a few intercalated thin hard layers..	62
This band of almost fissile limestone and shale is a marked feature in the section. It is crossed diagonally by joint planes that cause it to weather into projecting points that give the effect of the irregular surface of dogtooth spar. This may be seen on the face of the cliffs of Ptarmigan Mountain for a long distance, also on Fort Mountain on the southeast side of the Pass.	
Total thickness of Ptarmigan formation........................	516

Observations.—The Ptarmigan formation is indicated in the Ross Lake section by 664 feet (202.4 m.) of hard, thin layers of more or less arenaceous limestones above the Mount Whyte formation and beneath the massive Cathedral limestones. Owing to the rapid change in character of many of the limestones within a short distance in many instances it is difficult to trace the upper and lower boundaries of a series of beds, like those of the Ptarmigan formation. Frequently a modified alteration resulting from compression or magnesian infiltration will completely change the appearance of the beds, and often what appears to be a solid, massive-bedded limestone, when seen in a cliff, may be a thin-bedded fossiliferous limestone where broken down by erosion. On Mount Stephen I measured the horizon of the Ptarmigan formation in the great eastern cliffs of the mountain and there all the beds appeared to form one great series of massive layers 1,560 feet (475.6 m.) in thickness.[1] To determine the distribution and thickness of the Ptarmigan formation in the Cordilleran area will require the extensive and thorough examination of most if not all of the accessible sections of the Middle Cambrian strata of the Canadian Rocky Mountains. It is possible that the formation is only a broad local lentile that was deposited in a depression of the Lower Cambrian sea bed. My first field impression was that the Ptarmigan limestone was deposited locally in a

[1] Canadian Alpine Club Journal, Vol. I, 1908, p. 239.

shallow basin largely as oolites before the coming of the physical change that produced the great Cathedral limestones.

It may be that it is an error to include the Ross Lake shale with its *Albertella* fauna in the Ptarmigan formation. That is one of the problems for the future worker in this field to determine.

THE ROSS LAKE SHALE MEMBER OF THE PTARMIGAN FORMATION (ALBERTELLA ZONE)

A name proposed for the fine siliceous shale carrying the *Albertella* fauna in the Ptarmigan ? formation.

Type locality.—In cliffs above Ross Lake, 1 mile (1.6 km.) south-southwest of Stephen Station on the Continental Divide and south of the Canadian Pacific Railroad.

Derivation.—From Ross Lake where the shale is finely exposed in the cliffs above the Lake.

Character.—Dark gray, fine siliceous shale with local fillets and thin layers of gray limestone.

Thickness.—From 7 to 11 feet (2 to 3.3 m.).

Organic remains.—The known fauna includes the following:

Sponge spicules
Eocystites ? sp. undt.
Micromitra (*Paterina*) *wapta* Walcott
Obolus parvus Walcott
Acrothele colleni Walcott
Wimanella simplex Walcott
Hyolithellus flagellum (Matthew)
Hyolithellus hectori Walcott
Hyolithes cecrops Walcott
Agraulos stator Walcott
Olenopsis cf. *americanus* Walcott
Albertella bosworthi Walcott
Albertella helena Walcott
Vanuxemella nortia Walcott
Bathyuriscus rossensis Walcott

FORT MOUNTAIN FORMATION

In 1908 the quartzitic sandstones of this formation were described as the "Fairview formation."[1] As that name, however, was preoccupied in American geologic nomenclature, and as the lower part of the formation was subsequently found exposed at several places on the east side of the Bow River Valley, it was decided to apply the name Fort Mountain sandstone to the whole, from the typical

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 5.

exposures on Fort Mountain,[1] which is situated on the northeastern side of Bow Valley about 5 miles (8 km.) northeast of Lake Louise Station on the Canadian Pacific Railroad, Alberta, Canada. Here the basal conglomerate is seen in contact with the pre-Cambrian and above it there is a band of shale 44 feet (13.4 m.) thick. This basal conglomerate has a thickness of 360 feet (109.7 m.) and is much coarser than on Saddle Mountain or Mount Temple.

Ptarmigan Peak Section

Two miles (3.2 km.) to the north, on the northeast side of Ptarmigan Peak, the Fort Mountain formation is much thinner. A measured section gave:

	Feet
1. Thick-bedded, light gray, occasionally cross-bedded, quartzitic sandstone with a little trace of purple color in a few layers	260
2. Light gray to brownish gray sandstone in thin layers	22
3. Massive-bedded conglomerate, with white quartz pebbles and fragments of dark and greenish fine, arenaceous shale in a coarse sandstone matrix	170
Total	452

[Unconformity]

Pre-Cambrian arenaceous shales

The impression given by the above section is that the sediments were deposited on the slopes of a pre-Cambrian shore line and did not accumulate to the thickness of the deposits seen 3 miles (4.8 km.) to the south-southwest at Fort Mountain.

Fairview Mountain Section

On the north face of Fairview Mountain above Lake Louise, 6 miles (9.6 km.) southwest of Fort Mountain, the Lake Louise shale forms a slight break in the cliffs that affords a foothold for small coniferous trees and there is usually a quantity of green mosses or lichens. Below the green vegetation the Fort Mountain formation forms a wall of hard quartzitic sandstones. This same feature is also present on the north face of the adjoining Saddle Mountain and eastward on the cliffs of Mount Temple and in the Valley of the Ten Peaks, above Moraine Lake. At Fairview Mountain the section below the Lake Louise shale is as follows:

[1] See Monogr. U. S. Geol. Surv., No. 51, 1912, p. 131 footnote a.

FORT MOUNTAIN FORMATION

	Feet
1. Massive-bedded, purplish, hard cliff-forming fine-grained, quartzitic sandstone in layers 6 inches to 3 feet thick, forming a vertical cliff in its upper 150 feet (45.7 m.). Color gray in upper layers and gradually becoming purplish colored with gray bands. Some layers are slightly cross-bedded	350
On Mount Temple this sandstone has a strong purple color and in the lower portion bands of arenaceous purple shale.	
2. Hard gray, rather coarse-grained sandstone in the upper 200 feet (60.9 m.) with bands of shaly beds from a few inches to a foot or more in thickness. Below the sandstone becomes coarser and passes into a fine quartz conglomerate forming massive layers	570
3. Siliceous, gray and greenish gray shale	20+
Slope covered with débris.	

On the north slope of Saddle Mountain a mile (1.6 km.) southeast this shale has a thickness of 28 feet (8.5 m.) and below it about 100 feet (30.4 m.) in thickness of coarse gray sandstone to fine conglomerate is exposed. On the north slope of Mount Temple 2.5 miles (4 km.) northeast of Saddle Mountain the basal beds of the lower portion of the sandstone and fine conglomerate beds of the Fort Mountain formation rest on the dark, pre-Cambrian arenaceous shales. The section above is not accessible for measurement.

Ten miles (16 km.) further southeast on Little Vermilion Creek the basal conglomerate is in massive layers, but the contact with the pre-Cambrian is obscured by débris.

Summary.—The Fort Mountain formation consists of four members in its greatest development:

	Feet
a. Quartzitic sandstone	350
b. Coarse sandstone	570
c. Siliceous shale	44
d. Arenaceous, quartzitic conglomerate	360
Total	1,324

It is delimited above by the Lake Louise shale and below by the basal conglomerate resting on various beds of the arenaceous pre-Cambrian shales.

ELDORADO FORMATION

Type locality.—Prospect Peak, Eureka District, Nevada.

Derivation.—From Eldorado Mine on east slope of Prospect Peak.

Character.—Gray compact limestone in massive layers.

Thickness.—3,050 feet (929.8 m.) in the Eureka District, Nevada.

Organic remains.—Middle Cambrian fauna.

This formation is described in detail by Arnold Hague as the Prospect Mountain limestone,[1] but as the term Prospect Mountain quartzite preceded it the term Eldorado was proposed by Walcott,[2] and the term Prospect Mountain restricted to include only the quartzitic sandstone beneath.[3]

[1] Third Ann. Rept., U. S. Geol. Surv., 1883, p. 254.

[2] Smithsonian Misc. Coll., Vol. 53, 1908, p. 184 (footnote).

[3] Idem, p. 12.

DUNDERBERG FORMATION, WALCOTT[1]

Type locality.—Hamburg Ridge, Eureka Mining District, Nevada. Its distribution is shown on the geological map of the Eureka District accompanying the Third Annual Report of the United States Geological Survey (1883, pl. XXIV).

Derivation.—Dunderberg Mine, on Hamburg Ridge.

Character.—Arenaceous and calcareous shale with cherty nodules.

Thickness.—350 feet (106.7 m.) on Hamburg Ridge.

Organic remains.—Upper Cambrian.

This formation is described by Arnold Hague as the Hamburg shale, but as the Hamburg limestone preceded it the term Dunderberg was proposed by Walcott.[1]

GORDON SHALE

A name proposed for the fine argillaceous shales carrying the *Albertella* fauna in Montana.

Type locality.—On Gordon Creek 6 miles (9.6 km.) from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.), Powell County, Montana. The shale extends across the ridge between Gordon and Youngs Creeks, about half-way between Gordon Mountain and Cardinal Peak.

Derivation.—From Gordon Creek and Mountain.

Character.—Greenish and purplish fine argillaceous shale.

Thickness.—284 feet (86.3 m.) on ridge between Gordon and Youngs Creeks.

Organic remains.—The known fauna includes the following:

Algæ (4v)
Hyolithes cecrops Walcott (4v)
Micromitra (Iphidella) nyssa Walcott (4q)
Micromitra (Iphidella) pannula (White) (4v, 4q)
Obolus (Westonia) ella (Hall and Whitfield) (4v)
Lingulella sp. undt. (4v)
Acrothele colleni Walcott (4v, 4q)
Acrothele panderi Walcott (4v, 5j)
Wimanella simplex Walcott (4v, 4q, 4w)
Ptychoparia candace Walcott (4v, 4q)
Ptychoparia charax Walcott (4v, 4q)
Ptychoparia pylas Walcott (4q)
Zacanthoides cnopus Walcott (4v, 4q, 4w)
Olenopsis ? americanus Walcott (4v)
Albertella helena Walcott (4v, 5j)
Vanuxemella contracta Walcott (4v, 5j)
Bathyuriscus belesis Walcott (4v, 4q)
Bathyuriscus belus Walcott (4w)

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 184 (footnote).

Locality 4q=about 315 feet (96 m.) above the unconformable base of the Cambrian and 190 feet (57.9 m.) above the top of the quartzitic sandstones, on the ridge between Gordon and Youngs Creeks, about half-way between Gordon Mountain and Cardinal Peak.

Locality 4v=about 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River.

Locality 4w=same horizon as 4q above, on Youngs Creek, about 5 miles (8 km.) from its junction with Danaher Creek.

Locality 5j=above the quartzitic sandstones, about 6 miles (9.6 km.) west-northwest of Scapegoat Mountain, on the Continental Divide between Bar Creek and the headwaters of the south fork of North Fork of Sun River, Coopers Lake quadrangle (U. S. G. S.).

The first three localities are in Ovando quadrangle (U. S. G. S.); all four in Powell County, Montana.

CHISHOLM SHALE

See Smithsonian Miscellaneous Collections, Vol. 64, 1916, p. 409.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 2

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 2.—THE ALBERTELLA FAUNA IN BRITISH COLUMBIA AND MONTANA

(WITH PLATES 1 TO 7)

BY
CHARLES D. WALCOTT

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(With Plates 1 to 7)

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ILLUSTRATIONS

INTRODUCTION

When discussing the Dearborn River section in 1908[1] I stated: that the *Albertella* fauna of the Montana sections was placed in the Lower Cambrian as the fauna was strikingly similar to that occurring in the drift blocks which were believed to have come from the lower portion of the Mount Whyte formation of the Mount Bosworth section of British Columbia; that the Mount Whyte formation was

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 202, 203.

placed in the Lower Cambrian owing to the presence of trilobites of the genus *Olenellus;* that the presence of *Albertella* in the Mount Whyte formation was based on the occurrence of numerous trilobitic cranidia that appeared to be generically identical with the cranidia of *Albertella.*

The genus *Albertella* was subsequently identified in the Robson Peak District in a drift block supposed to have been derived from the *Middle Cambrian* Chetang formation limestone about 350 feet above the Hota formation which was referred to the Lower Cambrian.[1]

In 1914 Mr. L. D. Burling concluded after a thorough and admirable study that on paleontological evidence the *Albertella* fauna was of Middle Cambrian age and that the specimens of *Olenellus* found in the Mount Whyte formation were examples of recurrence.[2] On the basis of this conclusion Burling placed the Mount Whyte formation in the Middle Cambrian.

A notice of the discovery of the genus *Albertella* near the line of the North Kootenay Pass by Dr. Frank D. Adams and Mr. W. J. Dick,[3] when looking for deposits of phosphate of lime, escaped my attention until Dr. Adams mentioned it to me. There is nothing in the section, however, to indicate the stratigraphic position of the fossils in relation to a known Lower Cambrian fauna.

Recently (January, 1917) through the courtesy of Dr. Adams I have had the opportunity of looking over the fossils. They are not well preserved on the surface of the shaly limestone, but it is possible to tentatively determine the following genera and species:

Agraulos stator Walcott
Vanuxemella nortia Walcott
Albertella bosworthi Walcott
Asaphiscus rossensis Walcott

In 1916 Burling described a locality of the *Albertella* fauna *in situ* on Mount Bosworth and stated that the fauna was of Middle Cambrian age.[4]

Identification of the Genus Albertella

At the time of the preliminary identifications of the faunas, in connection with the publication of "Cambrian Sections of the Cordil-

[1] Smithsonian Misc. Coll., Vol. 57, 1913, p. 338.

[2] Canadian Geol. Surv., Museum Bull., No. 2, Geol. Ser., No. 17, 1914, p. 36.

[3] Commission of Conservation, Canada, Discovery of Phosphate of Lime in the Rocky Mountains. 8vo pamphlet. Ottawa, 1915, p. 13.

[4] Summed up in article in American Journal Science, Dec., 1916, 4th Ser., Vol. 42, pp. 469-472.

leran Area," in 1908,[1] I did not fully appreciate that trilobites with almost identical cranidia might have a dissimilar thorax and pygidium and belong to quite distinct genera. This conclusion came later, when studying groups of Cambrian trilobites retaining their entire dorsal shield so that the cephalon, thorax, and pygidium of many genera might be compared.[2]

During the winter of 1915-16 I studied all the material available of the genus *Bathyuriscus,* and found that my previous conception of that genus was inaccurate,[3] and that species from the Mount Whyte formation I had referred to a new genus, *Bornemannia,*[4] were to be included under a subgenus of *Bathyuriscus.*[5] Another result was to question the identification and presence of the genus *Albertella* in the Mount Whyte formation as it was based only on specimens of the cranidium. This was not carried further before I left for the field in June, 1916, but was taken up on my return in October. This review has now led to the elimination of the genus *Albertella* from the lists of the fauna of the Mount Whyte formation and this includes the lists from localities 35e and 57e as published in the description of *Bathyuriscus* (*Poliella*) *primus.*[5]

The available field notes and fossils of the Mount Whyte formation are now being studied, but it may be necessary for me to visit some of the typical localities before expressing an opinion as to the desirability of including a portion of the Mount Whyte formation in the Middle Cambrian as so strongly urged by Burling.[6]

STRATIGRAPHIC POSITION

The exact stratigraphic position of the typical *Albertella* fauna was unknown to me when I went to the field in June, 1916, although Burling had stated in a general way that he had found it on Mount Bosworth in the Cathedral formation and I had a specimen from the Cathedral limestone of Castle Mountain. The fauna was originally referred to the Lower Cambrian,[7] but neither in British Columbia nor Montana was there at that time a known occurrence of the fauna

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 167-220.

[2] See *Asaphiscus.* Smithsonian Misc. Coll., Vol. 64, 1916, pp. 382, 383.

[3] Smithsonian Misc. Coll., Vol. 64, 1916, p. 332.

[4] Idem, p. 352.

[5] Idem, p. 353.

[6] Geol. Surv. Canada, Museum Bull. No. 2, Geol. Ser., No. 17, 1914, pp. 112-115.

[7] Smithsonian Misc. Coll., Vol. 53, 1908, p. 202.

as a whole *in situ* in a section that proved to me beyond question its stratigraphic relation.

The position of the fauna found in drift blocks in British Columbia was assumed from the identification of cranidia in the Mount Whyte formation, and this was also extended to a similar fauna found in broken and isolated sections in Montana. During several field seasons in Alberta and British Columbia a gèneral outlook was kept for traces of the *Albertella* fauna, but at no time was it convenient for me to go back to Mount Bosworth to systematically search for it, but in July, 1916, I began a search for the fauna in the Mount Whyte formation and the superjacent Cathedral limestones. The latter were included as in 1907 the cranidium and pygidium of a species of *Albertella* were found in the limestones of the Cathedral formation 275 feet (84.6 m.) above the top of the Lower Cambrian on the east shoulder of Castle Mountain, Alberta, which is 19.5 miles (31.2 km.) east-southeast of the Ross Lake section of 1915 and I had also noted the presence of the cranidium and pygidium of *Albertella bosworthi* in débris of the Chetang formation which was referred to the Middle Cambrian.[1]

We knew from the collection of 1907 at Castle Mountain and from Burling's find on Mount Bosworth that the genus was present in the Middle Cambrian Cathedral limestone, but I did not know that the genus *Albertella was not present* in the Mount Whyte formation. I have not discussed the finds in the Middle Cambrian heretofore as I was waiting for the time when the *Albertella* fauna of Mount Bosworth should be accurately located in the section.

The first section examined was that of the eastern ridge of Mount Assiniboine 18 miles (28.8 km.) southwest of Banff, Alberta, but without finding any trace of the fauna. Section after section was then studied on the main range to the north and northwest, but it was not until August 24 that the *Albertella* fauna was located *in situ* in a hanging glacier cirque above Ross Lake and 1 mile (1.6 km.) south-southwest of Stephen on the Canadian Pacific Railway. After locating the stratigraphic horizon of the siliceous shale and included *Albertella* fauna I crossed to the north side of the broad Kicking Horse Pass and found it after a day's search *in situ* on the southern slope of Mount Bosworth west of Burling's locality. The band of shale is from 7 to 11 feet (2 to 3.3 m.) in thickness, and the little terrace formed by it is almost always covered by dirt, broken rock,

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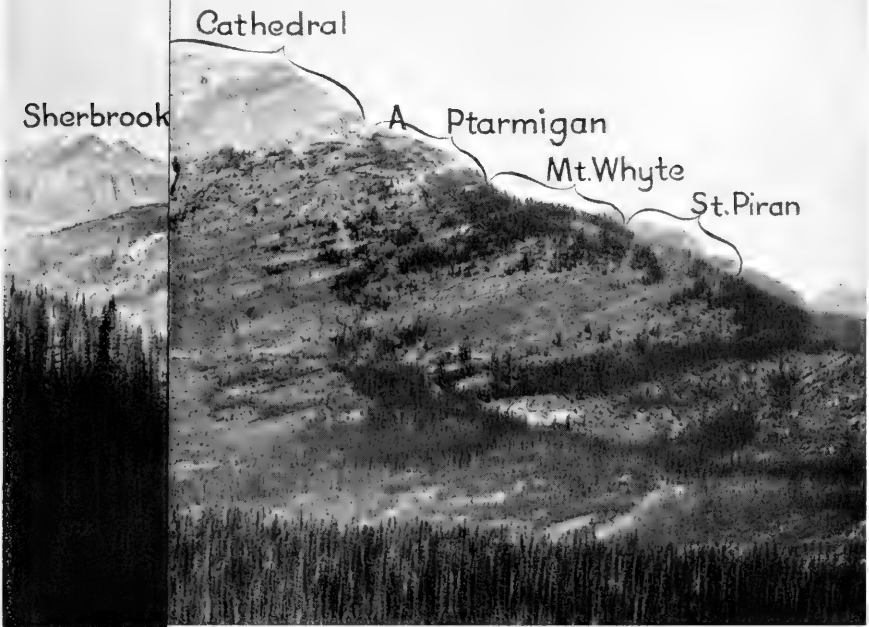
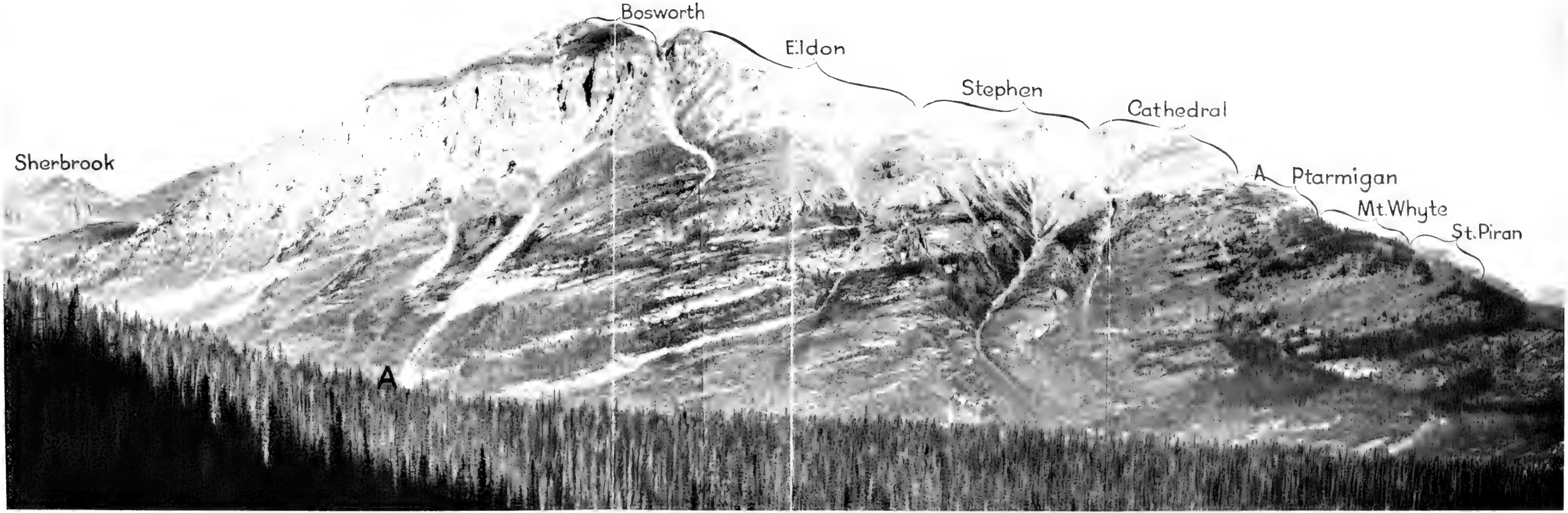
[1] Smithsonian Misc. Coll., Vol. 57, 1913, p. 338.



Panoramic he best exposed Cambrian sections in the Rocky Mountains.[1]
Including 4 m.) in thickness of strata are exposed. The approximate position of the fo of Burling is on the right toward or near *A*. (Photograph by Walcott, 1916.)



Panoramic view of Mount Bosworth, on the Continental Divide, from Ross Lake cirque, looking north across the Kicking Horse Pass. This is one of the best exposed Cambrian sections in the Rocky Mountains.[1]
Including the Lower Cambrian sandstones on the right (east) and the Upper Cambrian Sherbrook limestones on the left (west) over 12,000 feet (3,657.4 m.) in thickness of strata are exposed. The approximate position of the formation is indicated and the *Albertella* zone by *A. A.* We found the latter fauna *in situ* on the left at *A*, and I suppose that the locality of Burling is on the right toward or near *A*. (Photograph by Walcott, 1916.)

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 204-217.

trees, and brush. This so effectually conceals the band of shale that unless one knows just where to look there is little chance of finding it except in some such favorable locality as that above Ross Lake or the two known places on Mount Bosworth. The *Albertella* fauna is probably present all the way from Mount Assiniboine to Ross Lake, but conditions were not favorable for its discovery either in shale or limestone.

Stratigraphically the fauna as now known has a limited vertical range and a rather wide geographic distribution. The Ross Lake shale has a thickness of 7 feet (2 m.) in the Ross Lake section and about 10 feet (3 m.) on Mount Bosworth. *Albertella* also occurs in the adjoining limestone, but its vertical range there is unknown.

The genus is known from the Robson Peak District about 200 miles (320 km.) north-northwest of Mount Bosworth, also about 285 miles (456 km.) to the south in the vicinity of Gordon Mountain in the state of Montana.[1]

Albertella helena occurs in Montana and at Mount Bosworth, and *Albertella bosworthi* in the Robson Peak District.

Ross Lake Section

Ross Lake is situated on the south side of the Canadian Pacific Railway 1 mile (1.6 km.) south-southwest of Stephen Station on the Continental Divide. The section was measured on the northeast and northwest sides of the amphitheater above Ross Lake on the north end of the northern spurs of Popes Peak. The base of the Mount Whyte formation rests on the purplish-colored massive quartzites of the St. Piran formation on the west slope of the east spur and about 500 feet (152 m.) above Ross Lake; the summit of the section as given here is on the east face of the west spur.

Middle Cambrian

Cathedral Formation

Cliffs of massive-bedded rough arenaceous limestone rise one above the other to the summit of the ridge. At Mount Bosworth on the north side of the Kicking Horse Pass the Cathedral limestones have a thickness of 1,086 feet (334 m.) exclusive of a lower division of 509 feet[2] (156.6 m.), which I have now included in a recently recognized formation named Ptarmigan from its typical section on Ptarmigan Mountain above Ptarmigan Pass, 8 miles (12.8 km.) east-northeast of Ross Lake.

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 18-22.

[2] This is 1*c-f* of the Cathedral formation section of 1908 (Smithsonian Misc. Coll., Vol. 53, 1908, p. 212).

PTARMIGAN FORMATION	Feet
1. Thin-bedded, more or less arenaceous and mottled limestone...	155
1a. Bluish-gray limestone in thin irregular layers interbedded in a greenish siliceous shale..	3
2. Greenish and dark gray, compact siliceous shale weathering to a light gray color when long exposed. The shale forms compact, solid, hard layers from 2 to 3 feet (0.6 to 0.9 m.) thick that break first into blocks on joint planes and then split up into shale on long exposure to frost and water....................................	7

This is the Ross Lake shale member of the Ptarmigan formation which is characterized by the *Albertella* fauna which is most abundant in many places in it. At the Ross Lake section the fauna includes (Loc. 63j):

Siliceous sponge spicules
Eocystites ? sp. ?
Micromitra (*Paterina*) *wapta* Walcott
Obolus parvus Walcott
Acrothele colleni Walcott
Wimanella simplex Walcott
Hyolithellus flagellum (Matthew)
Hyolithes cecrops Walcott
Agraulos stator Walcott
Olenopsis cf. *americanus* Walcott
Vanuxemella nortia Walcott
Albertella bosworthi Walcott
Albertella helena Walcott
Bathyuriscus rossensis Walcott

On the slope of Mount Bosworth the shale is a little thicker and we collected from it *in situ* (Loc. 63m.):

Acrothele colleni Walcott
Wimanella simplex Walcott
Hyolithes cecrops Walcott
Agraulos stator Walcott
Vanuxemella nortia Walcott
Ptychoparia sp. undt.
Olenopsis cf. *americanus* Walcott
Albertella bosworthi Walcott
Albertella helena Walcott
Bathyuriscus rossensis Walcott

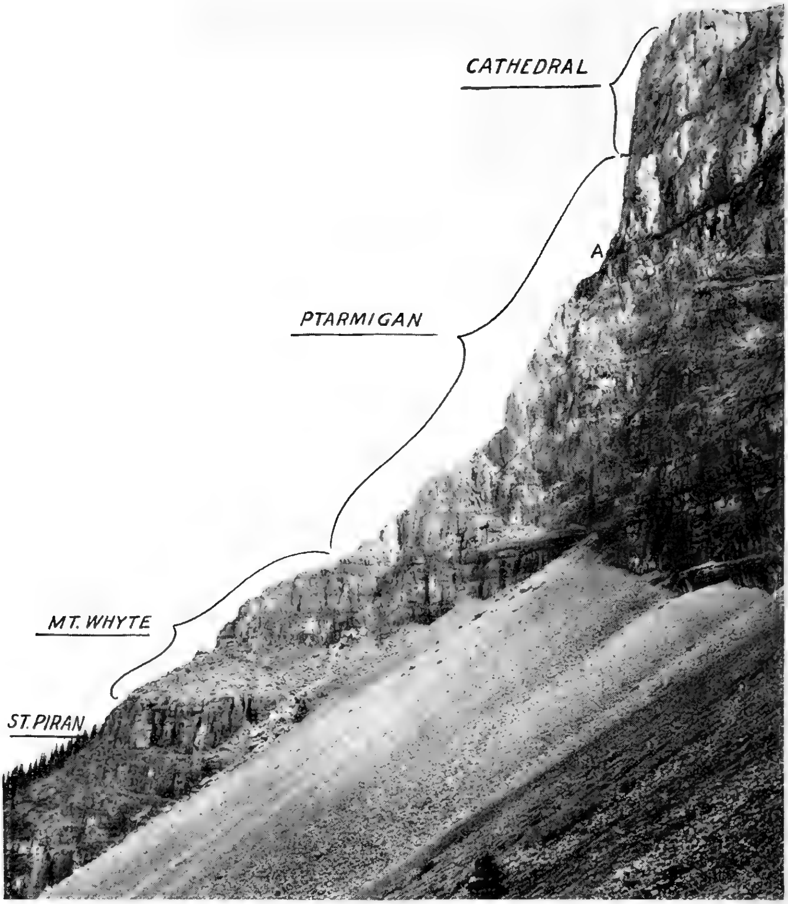
From the boulders (Loc. 35c) found below the outcrop on the south slope of Mount Bosworth in earlier years there have been collected:

Micromitra (*Paterina*) *wapta* Walcott
Obolus parvus Walcott
Acrothele colleni Walcott
Wimanella simplex Walcott
Hyolithellus flagellum (Matthew)
Hyolithellus hectori Walcott

View of Ross Lake cirque on the south side of Kicking Horse Pass and south of Stephen, Continental Divide, on the Canadian Pacific Railway, British Columbia, Canada.

Popes Peak in center, Narao Peak at right, and Ross Lake Ridge on the left. At *A* on the left the dark, narrow *Albertella* zone is clearly shown and also on the right where a narrow ledge is formed. Just above where the stream pours over the cliff the dark shales of the *Albertella* zone occur in huge blocks in the stream bed.

This view should be studied in connection with plate 3. (Photograph by George Vaux, Jr., 1901.)



North profile of ridge above and southeast of Ross Lake, 1 mile (1.6 km.) south of Stephen Station on the Canadian Pacific Railway.

The position of the Albertella zone is shown at *A* where the thin band of shale forms a dark, narrow band that may be seen from the Kicking Horse Pass.

The relative positions of the Cathedral, Ptarmigan, Mount Whyte, and St. Piran formations are indicated on the plate.

This view should be studied in connection with plate 2. (Photograph by Walcott, 1916.)

Hyolithes cecrops Walcott
Agraulos stator Walcott
Ptychoparia sp. undt.
Olenopsis cf. *americanus* Walcott
Vanuxemella nortia Walcott
Albertella bosworthi Walcott
Albertella helena Walcott
Bathyuriscus rossensis Walcott

	Feet
3. Massive-bedded, gray and mottled, rough weathering arenaceous limestone	160
4. Compact, dove-gray colored limestone in thin layers	12
5. Massive-bedded, dirty gray colored, rough weathering calcareous sandstone	275
6. Alternating layers of bluish-black and steel-gray hard limestone	52
Total referred to Ptarmigan formation	664

LOWER CAMBRIAN

MOUNT WHYTE FORMATION

1. Gray to grayish-black thin-bedded oolitic limestone	43

Fossils: Many small fragments of trilobites.

At this horizon 5.5 miles (8.8 km.) to the south at the west foot of Mount Shaffer, British Columbia (Loc. 61d), the following fauna has been collected:

Acrotreta sagittalis taconica Walcott
Nisusia (*Jamesella*) *lowi* Walcott
Scenella varians Walcott
Pelagiella sp. undt.
Micromitra (*Paterina*) *labradorica* (Billings)
Micromitra (*Iphidella*) *pannula* (White)
Corynexochus senectus (Billings)
Agraulos unca Walcott
Zacanthoides
Ptychoparia (*Emmrichella*) *lux* Walcott
Ptychoparia sp.
Mesonacis gilberti (Meek)

2. Finely banded gray sandstone and hard arenaceous limestone	5
3. Gray, finely oolitic limestone in thick beds that break down into thin irregular layers	18

Fauna: At 15 feet from summit (Loc. 63k):

Nisusia (*Jamesella*) *lowi* Walcott
Pelagiella sp. undt.
Helcionella elongata (Walcott)
Scenella varians Walcott
Hyolithes billingsi Walcott
Ptychoparia cercops Walcott
Ptychoparia pia Walcott
Olenopsis agnesensis Walcott

	Feet
4. Banded sandstone and finely arenaceous shale in massive beds that break down on weathering into shaly arenaceous layers usually covered more or less thickly with annelid trails and more rarely tracks of trilobites	70
5. Greenish, drab and buff-colored very fine siliceous shale with partings of thin layers of compact sandstone	85
Fossils: Noted a valve of *Micromitra* and cranidium of *Ptychoparia.*	
6. Calcareous sandstone with dirty brown and rusty layers and shaly sandstone partings	27
Fossils: *Corynexochus fieldensis* Walcott; *Olenellus* (many fragments)	
Total thickness of Mount Whyte formation	248

St. Piran Formation

Massive-bedded purplish quartzitic sandstones that form cliffs above Ross Lake.

The above sections of the Mount Whyte and Ptarmigan formations show that the *Albertella* fauna is located in the Ross Lake section some 500 feet (153.8 m.) above the top of the Mount Whyte formation and the *Olenellus* fauna. In the section of Castle Mountain 15 miles (24 km.) southeast of Ross Lake a specimen of the pygidium of *Albertella bosworthi* was found in 1907 260 feet (79.2 km.) above the Mount Whyte formation in a thin-bedded limestone that was then referred to the Cathedral formation, but which is now included in the Ptarmigan formation.

MONTANA AREA

In Montana the *Albertella* zone is well developed in Powell County at localities about 285 miles (456 km.) south of Kicking Horse Pass, British Columbia, and 135 miles (216 km.) south of Dr. Frank D. Adams' locality near North Kootenay Pass. The Cambrian section in this area, as I measured it in 1905, resembles that of Dearborn River and that of the Little Belt Mountains, but as the known fauna is different in the lower shale containing *Albertella,* I have named that shale the Gordon shale.

GORDON MOUNTAIN SECTION

The section is exposed along the ridge between Youngs Creek and Gordon Creek. The base of the section begins on the saddle beneath the limestone cliff half-way between Gordon Mountain summit and Cardinal Peak, and extends east-northeast along the ridge abovementioned. Beginning with the top of the section we have the following succession. The section above 1a of the Yogo limestone is cut off by a twist and a fault in the beds.

	Feet
YOGO LIMESTONE	
1a. Light gray limestone in layers 3 to 8 inches thick. It is oolitic in some layers and has many annelid borings and trails	430
1b. Dark gray limestone similar to 1a	190
Strike E. and W., dip 45° N. (Mag.).	
1c. Thin-bedded, bluish-gray limestone with many annelid borings and trails	215
Total of Yogo limestone	835
DRY CREEK SHALE	
2. Green, argillaceous shale with a few thin layers of limestone interbedded. The thickest of these is a band 3 feet thick 20 feet from the top	64
Fauna: *Micromitra*, *Hyolithes*, *Asaphiscus* (like *wheeleri*), *Ptychoparia*	
PILGRIM LIMESTONE	
3. Thin, irregular layers of bluish-gray limestone that form massive layers when not broken down by weathering	545
Traces of fossils	
Dip reaches 80° near the top.	
PARK SHALE	
4. Green and gray argillaceous and arenaceous shale	47
Fauna, locality 8j: *Micromitra* (*Paterina*) *superba* Walcott; *Bathyuriscus* sp. undt.; *Ptychoparia* sp.; *Zacanthoides* sp.	
MEAGHER LIMESTONE	
5. Thin-bedded, gray, arenaceous limestone becoming purer a little above the base	145
At 45 feet above the base the beds become more massive but break down into thin layers on weathering.	
Fragments of fossils occur.	
GORDON FORMATION	
6a. Chocolate or purple argillaceous and sandy shales	64
Fauna: Fragments of a fauna appear here which is well developed in 6b.	
6b. Dark greenish argillaceous shales, weathering a lighter green	35
Fauna, locality 4q: *Micromitra* (*Iphidella*) *nyssa* Walcott; *Micromitra* (*Iphidella*) *pannula* (White); *Acrothele colleni* Walcott; *Wimanella simplex* Walcott; *Ptychoparia candace* Walcott; *Ptychoparia charax* Walcott; *Ptychoparia pylas* Walcott; *Bathyuriscus belesis ?* Walcott (Pygidia); *Zacanthoides cnopus* Walcott	

Feet

6c. Layers of impure, gray weathering, buff-colored limestone with bands of dark greenish shale between them........................ 21

6d. Greenish and bluish-gray argillaceous shales with irregularly interbedded sandy shales and thin layers of compact gray sandstone... 164

At 82 feet (25 m.) from the base a thin layer of sandstone contains fragments of *Albertella* and the shales above carry quite a fauna.

Locality 4v at the foot of the ridge on Gordon Creek is considered to come in at about this horizon. It is 75 feet (22.9 m.) to 90 feet (26.8 m.) above the sandstone of 7a. It includes—

Algæ
Hyolithes cf. *cecrops* Walcott
Micromitra (*Iphidella*) *pannula* (White)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella sp. undt.
Acrothele colleni Walcott
Acrothele panderi Walcott
Wimanella simplex Walcott
Ptychoparia candace Walcott
Ptychoparia charax Walcott
Olenopsis americanus Walcott
Albertella helena Walcott
Bathyuriscus belesis Walcott
Vanuxemella contracta Walcott
Zacanthoides cnopus Walcott

Hyolithes and *Ptychoparia* occur below in several bands of greenish argillaceous shale between more sandy layers.

Total of Gordon formation................................ 284

FLATHEAD ? SANDSTONE

7a. Thin-bedded greenish and brown sandstone with shaly sandstone partings. Annelid borings and trails, mud cracks and ripple marks occur 43

Strike E. and W. (magnetic), dip 48° N.

Fauna: See footnote.[1]

7b. Gray sandstone in thick beds, some of which are a fine quartz conglomerate with pebbles up to one-fourth of an inch in diameter.... 82

In a thin arenaceous layer 20 feet (6 m.) above the contact with the Algonkian strata numerous fragments of a species of *Albertella* were found.

Total of Flathead ? sandstone................................ 125

[1] At locality 150d, on the Continental Divide, about 24 miles (38.6 km.) northwest of Scapegoat Mountain and 12 miles (19.2 km.) northeast of Gordon Mountain, the *Albertella* fauna occurs in a thin-bedded shaly, browish sandstone. The following species were found:

Cruziana sp. undt.
Agraulos cf. *stator* Walcott
Albertella cf. *helena* Walcott
Vanuxemella contracta Walcott

This locality is of importance as it extends the stratigraphic range of the fauna to the sandstones beneath the horizon of the Gordon shale.

RÉSUMÉ

	Feet
1. Yogo limestone	835
2. Dry Creek shale	64
3. Pilgrim limestone	545
4. Park shale	47
5. Meagher limestone	145
6. Gordon shale	284
7. Flathead ? sandstone	125
Total	2,045

The Cambrian section rests on gray and red shales and hard sandstones of the Camp Creek series (Walcott, 1906[1]) of the Algonkian. This section is, as far as known, on the western limit of the Cambrian strata in Montana. To the north the same series extends north up the valley of the South Fork of Flathead River.

FAUNAL CHARACTERISTICS

The fauna of the Ross Lake shale or *Albertella* zone is of interest both from its biological and stratigraphic aspects. Biologically, it represents a small subfauna of the Middle Cambrian that is rich in brachiopods and trilobites. The shale in which it occurs indicates very favorable conditions for the presence of a much more varied invertebrate life but as yet the fauna is limited to 14 known genera and 16 known species.

RELATIONS TO SUBJACENT FAUNA

The fauna of the subjacent Mount Whyte formation has been misunderstood very largely through tentatively including in it the *Albertella* fauna of the superjacent Ptarmigan formation. With this eliminated we find the fauna at the base of the Mount Whyte formation of a Lower Cambrian facies, and near the summit the Lower Cambrian fauna still predominating but with some genera that are much more developed in the Middle Cambrian fauna above, notably *Crepicephalus,* which is represented in the upper beds of the Mount Whyte formation.

I have already mentioned the difficulty met with in identifying the genus *Albertella* from fragments of the cephalon. The cranidium of *Albertella* is similar in form to some species of *Bathyuriscus,* notably that of *B.* (*P.*) *primus,* which occurs in the Mount Whyte formation. This is best seen by comparing the cranidia of the two genera as

[1] Bull. Geol. Soc. America, Vol. 17, 1906, p. 3.

illustrated for *Albertella* on plates 1 and 2, Vol. 53, Smithsonian Miscellaneous Collections, 1908, and for *Bathyuriscus primus* on plate 46, Idem, Vol. 64, 1916. Thinking that probably the specimens of *Albertella helena* and *A. bosworthi* found in loose blocks came from a siliceous shale of the Mount Whyte formation, I identified separate cranidia from that shale as *Albertella,* but now that I know that *Albertella helena* and *A. bosworthi* in the Canadian Rockies section occur in a siliceous shale 500 feet (152.4 m.) or more above the Mount Whyte formation and that no typical form of the *pygidium* or *thorax* of *Albertella* is known to have been found in the siliceous shales or limestones of the Mount Whyte formation I do not hesitate to refer the cranidia from the Mount Whyte formation to *Bathyuriscus (P.) primus.* This removes *Albertella* from the Mount Whyte formation and restricts it to the Ross Lake shale and the *Albertella* zone, and the limestones of the Ptarmigan formation in which the Ross Lake shale occurs.

The remaining species of the *Albertella* shale fauna that were identified as occurring in the Mount Whyte formation are:

Micromitra (Paterina) wapta Walcott
Obolus parvus Walcott
Acrothele colleni Walcott

Another species that occurs higher up in the Middle Cambrian section, but not in the *Albertella* zone, is *Micromitra (Iphidella) pannula* (White).

A careful study of the specimens that were hastily identified when writing out the geologic sections in 1908[1] results as follows in relation to the species assumed to be identical from the *Albertella* zone and the Lake Agnes shales of the Mount Whyte formation.

Micromitra (Paterina) wapta Walcott.—Fragments of larger specimens of *Micromitra (P.) pannula* White were identified as *Micromitra (Paterina) wapta* by me in 1908 and credited to (locality 35e) the Mount Whyte formation,[2] where they occur with *Acrothele* n. sp. In the form of fragments and with the outer surface injured or exfoliated it is exceedingly difficult to recognize characters that with better material indicate specific differences.

Obolus parvus Walcott from (locality 35c) the *Albertella* zone is a small species nearly circular in outline. The species identified with it from (locality 58t) the Mount Whyte formation is represented by the interior of a ventral valve that is distinctly elongate and with

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pp. 204-217.
[2] Idem, p. 214, 3 of section.

a very definite and nearly straight cardinal slope from the beak outward to the lateral margins of the valve, and it is not *Obolus parvus.* The specimens identified as *Obolus parvus* from (locality 35e) the Mount Whyte formation [1] were probably dorsal valves of young shells of *Acrothele* n. sp., which is abundant but usually poorly preserved.

Acrothele colleni was identified from Mount Stephen in 1*c* of section.[2] The specimens differ from the types of *A. colleni* from the *Albertella* zone in uniformly smaller size and the presence in the dorsal valve of a very long and strong median ridge, in this respect resembling *Acrothele bellula* of the Middle Cambrian of Alabama.[3]

By oversight *Mesonacis gilberti* is given as occurring in the fauna of the Lake Agnes locality (35e).[4] It occurs in the same stratigraphic section but at a lower horizon. On the opposite side of the Victoria Range at Mount Shaffer *M. gilberti* occurs above the horizon of the Lake Agnes shale fauna (35e) at locality 61d associated with a typical Lower Cambrian fauna (List, p. 15).

RELATION TO SUPERJACENT FAUNA

The *Albertella* fauna is a small subfauna that includes primitive forms usually found in the Lower Cambrian fauna, such as *Micromitra* (*Paterina*) *wapta, Agraulos stator,* along with typical Middle Cambrian forms. The next well-known superjacent fauna is the so-called *Ogygopsis* fauna of the Stephen formation and just above this the Burgess shale fauna, both of which are well-known Middle Cambrian subfaunas. Between the *Albertella* zone and the base of the Stephen formation there is a series of almost unfossiliferous limestones forming the upper 165 feet (50.3 m.) of the Ptarmigan formation and also the entire Cathedral formation of about 1,000 feet (304.8 m.) in thickness. That the period between the *Albertella* zone and the *Ogygopsis* zone was of considerable length is evidenced by the change in the faunas and by the appearance of a greater diversity of forms in the *Ogygopsis* zone. This latter statement is qualified by the possibility of the *Ogygopsis* fauna being an immigrant fauna from outside of the area where it is now found.

One of the problems now is to find the subfauna or faunas that existed in early and late Ptarmigan time and throughout the period

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 214, 3 of section.

[2] Idem, listed on p. 213.

[3] U. S. Geol. Surv. Monogr., No. 51, 1912, pl. 58, figs. 5*f*, 5*h*.

[4] Idem, p. 130.

of deposition of the Cathedral formation. That this can be successfully accomplished by a systematic search in the Robson Peak District and to the north of it is quite possible as there are a number of interbedded bands of thin-bedded limestones in the Chetang formation and bands of shale in the Hitka formation which appears to be below the horizon of the *Ogygopsis* shale zone of the Stephen formation.

NOTES ON THE FAUNA

In order that the geologist and paleontologist may have before them what is known of the Ross Lake shale fauna as a whole, also the *Albertella* fauna of the Gordon shale and the limestone of the Ptarmigan formation and the Chetang formation, I have brought together on plates 4-7 illustrations of the species known to me as they have been found in the vicinity of Kicking Horse Pass, British Columbia; in Montana, and the Robson Peak District, Alberta. The following references are simply for the purpose of indicating where the old species are described, also the plates on which illustrations may be found in this paper.

The species from the Gordon shale have (Gordon) after the specific name; those from the Chetang limestone (Chetang); those from the Ptarmigan limestone (Ptarmigan), and those from the Ross Lake shale are without a designation.

Tholiasterella ? hindei n. sp., pl. 4, figs. 1, 1*a*
Eocystites ? sp. undt., pl. 4, fig. 2.
Micromitra (*Paterina*) *wapta* Walcott (Monogr. 51, U. S. Geol. Surv., 1912, p. 357), pl. 4, fig. 3
Micromitra (*Iphidella*) *nyssa* Walcott (Gordon) (Idem, p. 360, pl. 3, fig. 9)
Micromitra (*Iphidella*) *pannula* (White) (Gordon) (Idem, p. 361, pl. 4, fig. 1*g*)
Obolus parvus Walcott (Idem, p. 408), pl. 4, figs. 4, 4*a*
Obolus (*Westonia*) *ella* (Hall and Whitfield) (Gordon) (Idem, p. 455, pl. 47, fig. 1*b*)
Lingulella sp. undt. (Gordon)
Acrothele colleni Walcott (Idem, p. 640), pl. 4, figs. 5, 5*a-f*
Acrothele panderi Walcott (Gordon) (Idem, p. 651, pl. 59, fig. 5)
Wimanella simplex Walcott (Idem, p. 748), pl. 4, figs. 6, 6*a-c*, 7, 7*a-c*, 8, 8*a-c*
Nisusia cf. *alberta* Walcott (Chetang), pl. 4, fig. 9
Hyolithellus flagellum (Matthew) (Canadian Alpine Journ., Vol. 1, 1908, pl. 1, figs. 8, 8*a*), pl. 5, figs. 2, 2*a*
Hyolithellus hectori n. sp., pl. 5, fig. 1
Hyolithes cecrops n. sp., pl. 5, figs. 3, 3*a-c*
Agraulos stator Walcott (Smithsonian Misc. Coll., Vol. 64, 1916, p. 173), pl. 6, fig. 6
Agraulos sp. undt. (fragment of a cranidium)

Ptychoparia candace n. sp. (Gordon), pl. 6, figs. 3, 3*a*
Ptychoparia charax n. sp. (Gordon), pl. 6, fig. 1
Ptychoparia ? cilles n. sp. (Ptarmigan), pl. 6, fig. 2
Ptychoparia pylas n. sp. (Gordon), pl. 6, figs. 4, 4*a-c*
Ptychoparia sp. undt.
Crepicephalus chares n. sp. (Ptarmigan), pl. 6, figs. 5, 5*a-c*
Vanuxemella contracta Walcott (Gordon) (Smithsonian Misc. Coll., Vol. 64, 1916, p. 221, pl. 36, figs. 4, 4*a*)
Vanuxemella nortia Walcott (Idem, p. 222), pl. 7, fig. 7
Olenopsis americanus Walcott (Gordon) (Idem, Vol. 57, p. 243, pl. 36, figs. 8-11)
Olenopsis cf. *americanus* Walcott (Idem), pl. 6, figs. 8, 8*a-b*
Albertella bosworthi Walcott (Idem, Vol. 53, 1908, p. 22), pl. 7, figs. 2, 2*a-b*, 3, 3*a-d*
Albertella helena Walcott (Idem, p. 19), pl. 7, figs. 4, 5, 5*a*
Albertella levis n. sp. (Chetang), pl. 7, figs. 1, 1*a*
Zacanthoides charilla n. sp. (Chetang), pl. 6, figs. 9, 9*a*
Zacanthoides ? cimon n. sp. (Ptarmigan), pl. 7, figs. 6, 6*a*
Zacanthoides cnopus n. sp. (Gordon), pl. 6, figs. 10, 10*a*
Neolenus constans n. sp. (Ptarmigan), pl. 6, figs. 7, 7*a*
Bathyuriscus belesis Walcott (Gordon) (Smithsonian Misc. Coll., Vol. 64, 1916, p. 338, pl. 50, figs. 1, 1*a-i*)
Bathyuriscus belus Walcott (Gordon) (Idem, p. 339, pl. 50, figs. 2, 2*a-d*)
Bathyuriscus rossensis n. sp., pl. 5, figs. 5, 5*a-d*
Bathyuriscus cf. *rossensis* n. sp., pl. 5, figs. 6, 6*a*
Bathyuriscus (*Poliella*) *chilo* n. sp. (Ptarmigan), pl. 5, fig. 4
Bathyuriscus (*Poliella*) *sylla* Walcott (Chetang) (Smithsonian Misc. Coll., Vol. 64, 1916, p. 354, pl. 48, figs. 3, 3*a-f*)

The fauna of the Gordon shale in Montana includes (4q, 4v):

Algæ
**Hyolithes* cf. *cecrops* Walcott
Micromitra (*Iphidella*) *nyssa* Walcott
Micromitra (*Iphidella*) *pannula* (White)
Obolus (*Westonia*) *ella* (Hall and Whitfield)
Lingulella sp. undt.
**Acrothele colleni* Walcott
Acrothele panderi Walcott
**Wimanella simplex* Walcott
Ptychoparia candace Walcott
Ptychoparia charax Walcott
Ptychoparia pylas Walcott
**Olenopsis americanus* Walcott
**Albertella helena* Walcott
Bathyuriscus belesis Walcott
**Vanuxemella contracta* Walcott
Zacanthoides cnopus Walcott

* The species common to the Gordon shale and the Ross Lake shale are marked by an asterisk.

From the Chetang formation only six species were collected:

Nisusia cf. *alberta* Walcott
Albertella bosworthi Walcott
Albertella levis Walcott
Agraulos cf. *stator* Walcott
Zacanthoides charilla Walcott
Bathyuriscus (*Poliella*) *sylla* Walcott

The Ptarmigan formation limestones have yielded but six species:

Ptychoparia cilles Walcott
Crepicephalus chares Walcott
Albertella bosworthi Walcott
Zacanthoides ? cimon Walcott
Neolenus constans Walcott
Bathyuriscus (*Poliella*) *chilo* Walcott

DESCRIPTION OF GENERA AND SPECIES

THOLIASTERELLA Hinde

Tholiasterella HINDE, 1888, Monogr. British Fossil Sponges, Pal. Soc., London, Pt. II, p. 168. (Described and discussed.)

Dr. Hinde describes the sponge spicules referred to this genus as follows:

Form of Sponge unknown; the skeleton consists of spicules, which . . . bear a general resemblance to the handle and ribs of an umbrella. The handle or vertical ray of the spicule supports on its summit a variable number of rays which radiate from it in a generally horizontal direction. A central disc of variable proportions is formed by the union of the bases of the horizontal rays and the upper surface of this, and of the rays, may be either smooth or covered with tubercles or blunted vertical spines.

Dr. Zittel, in speaking of the genus, says: "As a rule, two of the rays lying in the same plane divide dichotomously from the nodes outward, so as to produce a six-armed instead of a four-armed cross." [1]

Stratigraphic range.—Carboniferous.

It is not probable that the Middle Cambrian species now described belongs in this genus, but with only the spicules flattened in the shale for comparison it does not seem best to found a new genus for them. The six-rayed spicule with a central nodule suggests some forms of the spicules referred to *Tholiasterella*. They appear to be more nearly related to the latter than to the spicules of *Astræospongia* Roemer from the Silurian.[2]

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[1] Text-book Pal., edited by Eastman, Vol. 1, 1913, p. 62.

[2] As defined by Hinde. Fossil Sponges, pp. 133-134, pl. 1, figs. 7, 7*a-d*.

THOLIASTERELLA ? HINDEI, new species

Plate 4, figs. 1, 1*a*

Six-rayed spicules with a central canal in the rays, a tubercle where the ray merges into the central disc of the spicule, also a central tubercle which suggests that it may have been the base of a central ray or shaft.

There is a trace of longitudinal, raised lines on one of the arms. The type spicule measures 16 mm. from tip to tip of opposite rays.

The original substance of the spicule has been replaced by the dark siliceous sediment forming the shale.

The doubtful character of the generic reference is mentioned in the note on the genus.

Formation and locality.—Middle Cambrian: (63j) Ross Lake shale member of the Ptarmigan formation; cliffs above Ross Lake 1.5 miles (2.4 km.) south-southwest of Stephen on the Canadian Pacific Railway, British Columbia, Canada.

EOCYSTITES ? species undetermined

Plate 4, fig. 2

A single crushed specimen of the calyx and arms of this species is all that is known of it. There is not sufficient evidence on which to base an accurate generic and much less a specific determination.

Formation and locality.—Middle Cambrian: (63j) Ptarmigan formation, Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway, British Columbia, Canada.

BRACHIOPODA

MICROMITRA (PATERINA) WAPTA Walcott

Plate 4, fig. 3

Micromitra (*Paterina*) *wapta* WALCOTT, 1912. (See Monogr. 51, U. S. Geol. Surv., 1912, p. 357, text figs. 29, A, B.)

OBOLUS PARVUS Walcott

Plate 4, figs. 4, 4*a*

Obolus parvus WALCOTT, 1912. (See Monogr. 51, U. S. Geol. Surv., 1912, p. 408, text figs. 37, A, B.)

ACROTHELE COLLENI Walcott

Plate 4, figs. 5, 5*a-f*

Acrothele colleni WALCOTT, 1912. (See Monogr. 51, U. S. Geol. Surv., 1912, p. 640, text figs. 55, A-E; pl. 63, figs. 6, 6*a-b*.)

WIMANELLA SIMPLEX Walcott

Plate 4, figs. 6, 6*a-c*, 7, 7*a-c*, 8, 8*a-c*

Wimanella simplex WALCOTT, 1912. (See Monogr. 51, U. S. Geol. Surv., 1912, p. 748, text fig. 64; pl. 89, figs. 2, 2*a-c*.)

NISUSIA cf. ALBERTA Walcott

Plate 4, fig. 9

Nisusia alberta WALCOTT, 1889. (See Monogr. 51, U. S. Geol. Surv., 1912, p. 726, pl. 100, figs. 3, 3*a-d*.)

Only one small ventral valve of this type has been found in the Chetang limestone. It is strikingly similar to the small shells referred to *Nisusia alberta* as found in the shales and limestones of the central and lower portions of the Stephen formation at Mount Stephen, British Columbia.

The narrow, rather strong radiating ribs with nodes on them indicating spines and minute pores penetrating some of the layers of the shell indicate the genus *Nisusia*.

Formation and locality.—Middle Cambrian: (61 o) Chetang formation; gray shaly limestone in massive beds; on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

HYOLITHELLUS FLAGELLUM (Matthew)

Plate 5, figs. 2, 2*a*

Urotheca flagellum MATTHEW, 1899, Trans. Roy. Soc. Can., 2d ser., Vol. 5, Sec. 4, p. 40, pl. 1, fig. 1. (Species described and figured.)

Hyolithellus flagellum WALCOTT, 1908, Canadian Alpine Journ., Vol. 1, No. 2, p. 14, pl. 1, figs. 8, 8*a*. (Changes generic reference and illustrates species.)

This species is represented in the collection by four small tubes that appear to have been attached to the dorsal valve of *Wimanella simplex*. The specimens are not very well preserved and it may be that they are the young or small tubes of *H. annulatus* (Matthew).

Formation and locality.—Middle Cambrian: (63j) Ptarmigan formation; Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway, British Columbia, Canada.

HYOLITHELLUS HECTORI, new species

Plate 5, fig. 1

This species is represented by a single specimen of a slender, rather thick tube, about 1 mm. in diameter, of which a portion 21 mm. in length is preserved. The tube has the form of the tube of *Hyolithellus flagellum* (pl. 5, fig. 4), but it is thicker and its surface is longitudinally ribbed by 24 or more narrow, sharp elevated lines or ribs; exceedingly fine transverse striæ of growth also occur between the crests of the ribs. A somewhat similar surface occurs on *Hyolithes* (*Orthotheca*) *rosmarus* Holm[1] and on *Hyolithes cymbium* Holm.[2]

Formation and locality.—Middle Cambrian: (35c) Ptarmigan formation; Ross Lake shale, *Albertella* zone; drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia, Canada.

HYOLITHES CECROPS, new species

Plate 5, figs. 3, 3*a-c*

Shell nearly if not quite straight; the angle of divergence of the lateral borders from the median line is from 12 to 14 degrees. The dorsal side gently arched or nearly flat. Ventral side rising from the lateral borders to a rounded angle at the median line. The transverse section forms a triangle, with the base two or three times as great as the height. Surface of shell with very fine transverse striæ and rather distinct lines of growth.

Dimensions.—A large shell has a length of 40 mm. with a breadth of the mouth of 16 mm. Another has a length of 42 mm.; breadth at the mouth, 13 mm. A small shell, 15 mm. in length, has a breadth at the mouth of 8 mm., but it has been shortened and widened by distortion in the shale. The specimen 42 mm. long and 13 mm. wide at the mouth is probably the nearest to the original size of the shell.

Operculum.—The associated operculum is illustrated by figure 3*c*. Although the shells are abundant, only three specimens of the operculum have been found.

Observations.—This species is uniformly larger than *Hyolithes billingsi* of the Mount Whyte formation, and has a more triangular

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[1] Sveriges Geol. Undersökning, Ser. C, No. 112, 1893, Sv.-Kambrisk.-Siluriska Hyolithidæ och Conularidæ, pl. 1, figs. 45, 46.

[2] Idem, pl. 3, fig. 7.

section. It differs from *Hyolithes carinatus* Matthew of the Stephen formation in absence of longitudinal ridges on the ventral side and also in its more triangular section.

Formation and locality.—Middle Cambrian: Ross Lake shale member of Ptarmigan formation; (**63j**) outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; (**63m**) south slope of Mount Bosworth, about 500 feet (152.4 m.) above the Canadian Pacific Railway track, 1 mile (1.6 km.) east of Hector, 1.25 miles (2 km.) west of Stephen on the Continental Divide; (**35c**) drift boulder below locality 63m, all in British Columbia, Canada.

AGRAULOS STATOR Walcott

Plate 6, fig. 6

Agraulos stator WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, p. 173, pl. 36, fig. 6. (Described and illustrated.)

This very neat and fine species is quite abundant in some localities of the Ross Lake shale.

Formation and locality.—Middle Cambrian: (**63j**) Ptarmigan formation; Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; also (**35c**) drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia, Canada.

An apparently similar species as far as can be determined from the cranidium occurs in the limestone of the Chetang formation: (**61w**) gray, thin-bedded limestone; float rock in Terrace Creek, the head of which comes from Terrace Glacier, which joins Coleman Glacier on the divide east of Chetang Cliffs. Terrace Creek enters Moose River about 6 miles (9.6 km.) below Moose Pass and 10 miles (16.1 km.) east-northeast of Robson Peak, northwest of Yellowhead Pass, eastern British Columbia, Canada.

PTYCHOPARIA CANDACE, new species

Plate 6, figs. 3, 3*a*

Dorsal shield.—Dorsal shield rather small but strong. Axial lobe relatively broad, and doubtless strongly arched before compression;

greatest width probably falling a little in front of the thorax and equal to a little less than two-thirds of the length.

Cephalon.—Cranidium only preserved. Glabella moderately large relatively, elongate trapezoidal; dorsal furrows moderately impressed, converging so rapidly that the width in front is but little more than half of that of the base; anterior extremity of the glabella broadly rounded or obscurely truncate; glabellar furrows broadened or deepened by compression in the somewhat flattened cranidium figured; posterior furrows oblique, posteriorly directed, medial pair somewhat cuneate, the anterior margin of the furrow at right angles to the axis of the shield, the posterior margin oblique; anterior pair of furrows also cuneate but anteriorly directed, the lobe between the anterior and medial furrows with parallel sides at right angles to the axis; occipital furrow quite deeply impressed distally but almost obsolete upon the crest of the glabella; occipital ring expanded medially and bearing a rather large median node. Fixed cheeks low and quite broad, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe very broad, trigonal in outline, the distal extremity tapering to an angle of about 45°; posterior groove broad but not very deep. Palpebral lobe very short, not very prominent, placed far forward opposite the anterior glabellar furrows. Palpebral ridge cordate, moderately elevated, cutting across the fixed cheeks almost at right angles to the shield, and intercepting the dorsal furrows about half-way between the anterior glabellar furrows and the anterior extremity. Frontal limb rather wide, probably evenly sloping before compression. Frontal border almost as wide medially as the medial portion of the limb and cut off from it by a shallow groove. Facial sutures angular, the posterior arm oblique, the anterior arm feebly convex; arc included between the facial sutures almost double the width of the base of the glabella. Free cheeks not preserved.

Thorax.—Thorax rather slender, tapering posteriorly. Thoracic segments 16 in number. Axial lobe flattened in the shale and relatively very broad, as a rule, decidedly more than half as wide as either of the pleural lobes; axial annulations conspicuously coarse. Pleural segments rather narrow, compactly arranged, obtusely angulated at the geniculation which falls about two-thirds of the distance from the axial furrow to the outer extremity; pleural furrows broad and rather shallow for the most part, narrower and much deeper toward the distal extremity; ends of segments feebly inclined posteriorly and acutely falcate.

Pygidium.—Pygidium very short, only about one-eighth the length of the entire shield, rudely lenticular in outline. Axial lobe coarse, wider than either of the pleural segments, becoming increasingly lower posteriorly but persisting almost to the extremity; axial annulations very obscure anteriorly, obsolete medially and posteriorly; component segments probably 4 or 5 in number. Pleural lobes trigonal, bearing traces anteriorly of an obscure grooving. Peripheral rim not defined. Peripheral margin an arc of a little less than 180°.

Surface.—Surface ornamentation lost or undeveloped.

Dimensions.—Length of shield, 12.5± mm.; greatest width of shield, 8.0± mm.

Type locality.—(4v) Gordon Creek, Powell County, Montana.

Observations.—The elongate body, small pygidium and small palpebral lobe all suggest *Agraulos stator* Walcott,[1] but the cranidium is that of *Ptychoparia* and there are 16 thoracic segments, while *A. stator* has 22. *P. candace* appears to be a form that unites strong characters both of *Agraulos* and *Ptychoparia.*

It differs from *Ptychoparia perola* of the subjacent Mount Whyte formation of British Columbia in details of the cranidium and in its broader thoracic lobes; its glabella is more elongate, frontal limb deeper, palpebral lobe larger. The largest dorsal shield has a length of 20 mm. A small dorsal shield 2.25 mm. in length has 10 thoracic segments and the cranidium indicates a narrowing of the glabellar lobe and widening of the fixed cheeks back of the palpebral lobes. The specimens occur in an argillaceous shale and do not retain the original surface characters. *Ptychoparia candace* is found in the *Albertella* fauna of Montana but not in that fauna in British Columbia. The genus is represented in the latter area by *Ptychoparia ? cilles,* which is quite distinct.

Formation and locality.—Middle Cambrian: (4v) Gordon shale; about 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

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[1] Smithsonian Misc. Coll., Vol. 64, p. 173, pl. 36, fig. 6. See p. 28, and pl. 6, fig. 6, this paper.

PTYCHOPARIA ? CHARAX, new species

Plate 6, fig. 1

Species known only from two cranidia.

Cephalon.—Glabella rather small relatively, not much more than half as long as the cranidium, low, elongate, trapezoidal in outline, the front between one-half and two-thirds as wide as the base; dorsal furrows moderately impressed, evenly converging toward the broadly rounded anterior extremity; glabellar furrows rather broad and obscure, obsolete medially; posterior pair somewhat oblique; medial pair approximately horizontal; anterior pair indicated merely by very feeble depressions a little behind the anterior extremity; occipital furrow rather broad but not very deep, approximately uniform in depth between the dorsal furrows; occipital ring not very wide, expanding medially, possibly bearing a small medial node. Fixed cheeks rather low, broad, the distance from the palpebral lobe to the dorsal furrow a little more than half as wide as the medial portion of the glabella; postero-lateral lobe narrow, not very long, cuneate, acutely rounded at the distal extremity; posterior groove broad and sharply defined excepting near the dorsal furrow, widest a little less than half-way from the inner to the outer extremity; posterior margin of the lobe narrow, elevated, uniform in width; anterior margin of the groove acute, excepting along the inner third of its extent, rudely bisecting the outer cuneate portion of the lobe. Frontal limb and border not sharply differentiated from one another, upturned and slightly thickened along the outer rim; width of limb and border in front of the glabella about three-fifths the length of the glabella; profile gently concave medially, convexo-concave in front of the palpebral ridge. Palpebral lobe approximately one-half as long as the glabella, obliquely arcuate, quite prominently elevated, placed quite far back, so that the medial portion of the lobe is opposite the posterior glabellar furrows. Palpebral ridge not sharply differentiated from the lobe, cutting obliquely across the fixed cheeks from the anterior extremity of the lobe, and intercepting the dorsal furrows a little behind the anterior extremity of the glabella. Facial sutures irregular in outline, the posterior section oblique, the outer margin of the palpebral lobe asymmetrically arcuate and the anterior section conspicuously broad and evenly convex. Other characters not preserved.

Surface.—External surface shagreened with an exceedingly fine punctation.

Dimensions.—Length of cranidium, 9.6 mm. Length of glabella, 6.0 mm. Width of anterior extremity of the glabella, 3.0 mm. Width of base of the glabella, 5.0 mm.

Type locality.—(4v) Gordon Creek, Montana.

Observations.—This is one of the *Ptychoparia*-like cranidia with a broad concave frontal border and rim that will undoubtedly be placed in a subgenus of *Ptychoparia* when the American species of the latter genus are clearly studied. The genus *Agraulos* is suggested, but that is forcing a form in that genus that apparently belongs elsewhere.

Formation and locality.—Middle Cambrian: (4v) Gordon shale; about 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River; and (4q) about 315 feet (96 m.) above the unconformable base of the Cambrian and 190 feet (57.9 m.) above the top of the quartzitic sandstones in a shale on the ridge between Gordon and Youngs Creeks, about half-way between Gordon Mountain and Cardinal Peak, both in Ovando quadrangle (U. S. G. S.), Powell County, Montana.

PTYCHOPARIA ? CILLES, new species

Plate 6, fig. 2

Species known only from imperfect cranidia.

Cephalon.—Cranidium very strongly contoured. Glabella conspicuously elevated, approximately two-thirds the length of the cranidium and as broad at the base as it is long; medial section broad and obtuse, very gradually disappearing toward the anterior extremity; dorsal furrows very obscurely defined, converging so rapidly that the broadly rounded anterior extremity is only half as wide as the base; glabellar furrows sharply impressed upon the sides of the glabella but obsolete upon the crest; posterior pair cuneate, widening toward the crest, obliquely directed; medial pair not quite so broad nor so oblique; anterior pair linear but deeply incised at right angles to the axis of the shield; occipital furrow rather broad, extending across the crest of the glabella but deepening toward the dorsal furrows; occipital ring imperfectly preserved, expanded medially, and probably of moderate width. Fixed cheeks rising abruptly to almost the level of the summit of the glabella, the slope from the dorsal furrow to the crest of the glabella very similar to the slope from the dorsal furrow to the palpebral lobe; postero-lateral lobe almost if not quite as broad as it is long, obtuse at the outer extremity; postero-lateral groove narrow toward the axis and in line with the occipital groove, broadening and deepening away from the axis. Palpebral lobe small but conspicuously high, arcuate, placed far forward opposite the lobe between the medial and anterior glabellar furrows. Palpebral ridge very narrow and rather obscure, forming an acute angle with the anterior extremity of the palpebral lobe, and slightly inclined posteriorly in crossing the fixed cheek so that it intercepts the dorsal furrows near the origin of the anterior glabellar furrows. Frontal limb narrow, feebly convex in front of the glabella and merging into the frontal border which is as wide or wider than the limb, and very strongly upturned so that the outline of the anterior portion of the cranidium is decidedly concave. Facial sutures following a sine curve from the genal angle along the anterior margin of the postero-lateral lobe to the eye lobe; anterior section of the suture more strongly convex than the posterior. A single imperfectly preserved free cheek, terminating in a rather short but acutely tapering spine, is associated with the cranidia.

Surface.—External surface microscopically shagreened.

Dimensions.—Length of cephalon, 3.0 mm. Length of glabella, 2.0 mm.

Type locality.—(**63d**) Ptarmigan formation; Ptarmigan Peak.

Observations.—This small species is quite distinct from any other known to me. Its high eyes, concave frontal border and convex, strongly marked glabella distinguish it and also indicate a distinct subgenus or genus.

Formation and locality.—Middle Cambrian: (**63d**) Ptarmigan formation; dark, thin-bedded finely arenaceous limestone, east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

PTYCHOPARIA PYLAS, new species

Plate 6, figs. 4, 4*a-c*

Dorsal shield.—Dorsal shield rather small, elongate oval or cuneate in outline, doubtless quite strongly contoured before being compressed in the shale.

Cephalon.—Head shield exclusive of the genal spines approximately one-third of the length of the dorsal shield, and a little less than twice as broad as it is long. Glabella angular, elongate-trapezodial in outline; only about half as wide at the anterior extremity as it is at the base; dorsal furrows deeply impressed, intercepting the frontal furrow at an acute angle; glabellar furrows very obscure but persistent, in some individuals, across the crest of the glabella; posterior and medial pairs oblique and approximately parallel to one another, the anterior pair shorter, transverse to the axis, and in some individuals apparently undeveloped; occipital furrow broad and conspicuously deep, in most individuals, completely isolating the occipital ring; occipital ring similar in character to the anterior segments of the thorax, probably not spinose medially.

Fixed cheeks quite wide and rather plump; postero-lateral lobe narrow, moderately produced, angulated at the outer extremity; posterior groove narrow, deeply impressed, in line with the occipital furrow; posterior margin sharply elevated. Palpebral lobe large, conspicuously elevated, quite strongly crescentic. Palpebral ridge not sharply differentiated from the lobe as a rule, cutting across the fixed cheek almost at right angles to the axis and almost in line with the anterior furrow, and forming with the palpebral lobes and the anterior furrow of the glabella a rudely elliptical area. Frontal limb quite wide, evenly declining, or more frequently somewhat convex especially towards the sides. Frontal border moderately wide, not thickened, upturned, cut off from the limb by a shallow, ill-defined groove. Facial sutures roughly a spreading W with a broad arcuate base, a rather long, oblique, posterior limb and a rather short, convex, anterior limb. Free cheeks quite wide and smoothly inflated, the outer margin flattened and produced posteriorly into acutely tapering genal spines which terminate opposite the third thoracic segment.

Thorax.—Thoracic segments probably 14 in number. Axial lobe quite prominent, moderately broad, cut off from the pleura by deep furrows. Pleural segments flexuous, even in the shale, obtusely angulated at the geniculation which falls, in the majority of individuals, a little less than half-way from the proximal to the distal extremity; pleural furrows very narrow and deeply incised, submedial in position. Ends of segments cut away along the posterior margin, slightly inclined posteriorly, and acutely falcate.

Pygidium.—Pygidium very small and very imperfectly known.

Surface.—Character of external surface not preserved.

Dimensions.—Length of dorsal shield, 4.7 mm. Greatest width of dorsal shield, 3.2 mm. Length of the cranidium of another individual, 6.5 mm. Length of glabella, 4.0 mm.

Type locality.—(4q) Gordon Creek, Montana.

Observations.—This species is strongly characterized by its small pygidium, straight, deep pleural grooves on the thoracic segments, and broad frontal limb of the cranidium.

Formation of locality.—Middle Cambrian: (4q) Gordon shale; about 315 feet (96 m.) above the unconformable base of the Cambrian and 190 feet (57.9 m.) above the top of the quartzitic sandstones in a shale on the ridge between Gordon and Youngs Creeks, about half-way between Gordon Mountain and Cardinal Peak, both in Ovando quadrangle (U. S. G. S.), Powell County, Montana.

CREPICEPHALUS CHARES, new species

Plate 6, figs. 5, 5*a-c*

Species known only from a few imperfect cranidia and associated pygidia.

Cephalon.—Cephalon as restored from cranidium and free cheeks rather short and broad. Glabella a little less than two-thirds the length of the cranidium, low and moderately broad, rudely trapezoidal in outline, elevated along an obscure medial ridge which gradually disappears toward the front; dorsal furrows not sharply defined, converging toward the squarely truncate anterior extremity with such rapidity that the front of the glabella is only half as wide as the base; glabellar furrows also rather obscure and, upon the crest of the glabella, entirely obsolete; posterior pair rather broad, obliquely directed; medial and anterior pairs also rather broad and almost at right angles to the axis; occipital furrow of the same general character as the glabellar furrows, not very deep but uniformly impressed throughout its extent; occipital ring of only moderate width, expanded medially and possibly obtusely angulated along the posterior margin. Fixed cheeks very low and broad, the distance from the palpebral lobe to the dorsal furrows more than half the width of the medial portion of the glabella; more strongly convex along the axis of the shield than at right angles to it; posterolateral lobe not preserved but necessarily narrow; groove in front of the posterior margin shallow toward the axis and in line with the occipital ring. Palpebral lobe imperfectly preserved, apparently short, crescentic, rather low and placed far back opposite the posterior lobe and furrow. Palpebral ridge cordate, moderately elevated, curving across the fixed cheek from the anterior extremity of the eye lobe and intercepting the dorsal furrows a little behind the anterior extremity of the glabella; palpebral ridges and lobes forming roughly a semi-ellipse interrupted by the glabella. Frontal limb moderately wide, gently convex. Frontal border almost as wide as the limb, gently concave. Facial sutures very imperfectly preserved. Associated free cheek rather narrow, smoothly convex; peripheral border very wide and flattened, terminating posteriorly in a rather short but acute spine.

Pygidium.—Associated pygidium rudely cordate in outline, exclusive of the posterior constriction, the length and breadth approximately equal. Axial lobe not quite half as long as the caudal shield including the spines, but approximately two-thirds the length measured along the axis; limiting furrows not impressed, the lobe differentiated only by its low convexity and the rather obscure annulation; component segments apparently five in number including the terminal section. Pleural lobes somewhat flexuous, broadest a little in front of the median line, produced posteriorly into a pair of acute subspinose processes; margin between these tapering extremities sharply constricted. Pleural furrows ill defined; three or four shallow grooves usually developed parallel to the outer margin, least obscure anteriorly but on the posterior portion of the shield entirely obsolete. Peripheral margin very slightly raised anteriorly, not differentiated from the rest of the shield posteriorly.

Surface.—Entire external surface crowded with a fine granulation; very sparse macroscopic granulation also developed on the cephalon and less so on the pygidium; granules most numerous and most regularly arranged upon the frontal border.

Dimensions.—Length of cephalon, 8.5 mm. Length of glabella, 5.0 mm. Width of glabella at base, 4.6 mm. Length of pygidium, including spines, 5.6± mm. Length of pygidium, excluding spines, 3.7 mm. Breadth of pygidium, 5.6 mm.

Type locality.—(**63d**) Ptarmigan formation; Ptarmigan Peak.

Observations.—The most nearly related species appears to be *Crepicephalus camiro* Walcott.[1] It differs from the latter in the details of form of the various parts of the cranidium and associated pygidium and in its granulated surface. *C. camiro* is from the Upper Cambrian of the southern Appalachian area and *C. chares* is from the Middle Cambrian of the Canadian Rocky Mountains.

The cranidium of *C. cleora,* a new species from the Mount Whyte formation, is much like that of *C. camiro* but differs in its wider frontal border and other details of the cranidium.

Formation and locality.—Middle Cambrian: (**63d**) Ptarmigan formation; dark, thin-bedded finely arenaceous limestone, east base

[1] Smithsonian Misc. Coll., Vol. 64, 1916, p. 205, pl. 32, figs. 2, *2a*.

of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

VANUXEMELLA NORTIA Walcott

Plate 7, fig. 7

Vanuxemella nortia WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, p. 222, pl. 36, fig. 5. (Described and illustrated.)

Nothing has been added to our information of this species by recent collections.

Formation and locality.—Middle Cambrian: (**63j**) Ptarmigan formation; Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway, British Columbia; and (**35c**) drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia, both in Canada.

OLENOPSIS cf. AMERICANUS Walcott

Plate 6, figs. 8, 8*a-b*

Olenopsis americanus WALCOTT, 1912, Smithsonian Misc. Coll., Vol. 57, p. 243, pl. 36, figs. 8-11. (Description and illustration of species.)

Cranidia that appear to be identical with the cranidium of this species occur in association with *Albertella helena* in British Columbia, and the latter species is also associated with the type specimen of *Olenopsis americanus* in the Gordon shale of Montana.

Formation and locality.—Middle Cambrian: (**63j**) Ptarmigan formation; Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; also (**35c**) *Albertella* shale; drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, eastern British Columbia, Canada.

The Montana locality of the type specimens of the species is (**4v**) Middle Cambrian; Gordon shale; about 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones, in a shale which corresponds in stratigraphic position to shale No. 6 of the Dearborn River section,[1]

[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 202.

Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.), Powell County, Montana.

ALBERTELLA BOSWORTHI Walcott

Plate 7, figs. 2, *2a-b*, 3, *3a-d*

Albertella bosworthi WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 22, pl. 1, figs. 4-7. (Description and illustration of the species.)

Albertella bosworthi WALCOTT, 1913, The Cambrian Faunas of China, Pub. No. 54, Carnegie Inst. of Washington, p. 106, pl. 12, fig. 2. (Figured on same plate with *A. pacifica* for purpose of comparison.)

The type specimen of this species was found in a drift boulder on the slopes of Mount Bosworth. Since 1908 entire specimens of the species have been found *in situ* on Mount Bosworth, also above Ross Lake south of Mount Bosworth and represented by fragments in the limestones of Castle Mountain, British Columbia, and in the Robson District of Alberta and British Columbia.

The specimens of the cranidium and pygidium from the limestones (figs. 3, *3b*) are more convex and narrower than those from the shale in the Mount Bosworth area, owing to their not having been widened and distorted by compression as are the shale specimens.

Formation and locality.—Middle Cambrian: Ptarmigan formation; Ross Lake shale; (**63j**) outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; (**35c**) drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector; also (**63m**) Ross Lake shale; south slope of Mount Bosworth, about 500 feet (152 m.) above the Canadian Pacific Railway track, 1 mile (1.6 km.) east of Hector and 1.25 miles (2 km.) west of Stephen on Continental Divide, all in British Columbia, Canada.

At the locality **63m** the species was found in thin layers of limestone interbedded in the shale: (**58h**) about 275 feet (85 m.) above the top of the Lower Cambrian in thin-bedded bluish-black limestone (272 feet=84 m.) forming 13 in Ptarmigan formation, Castle Mountain section; just below the big cliff on the east shoulder of Castle Mountain, north of Canadian Pacific Railway, Alberta, Canada.

Also from (**61p**) Chetang formation; gray shaly limestone in massive beds; on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

ALBERTELLA HELENA Walcott

Plate 7, figs. 4, 5, 5*a*

Albertella helena WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, p. 19, pl. 2, figs. 1-9. (Description and illustration of species.)

Albertella helena GRABAU and SHIMER, 1910, North American Index Fos., Vol. 2, p. 274, fig. 1572*c*. (Characterized and figured.)

Albertella helena WALCOTT, 1913, The Cambrian Faunas of China, Pub. No. 54, Carnegie Inst. of Washington, p. 106, pl. 12, fig. 1. (Figured on same plate with *A. pacifica* for purpose of comparison.)

This species was described at length in 1908. Recent collections have added very little to the information about it.

Formation and locality.—Middle Cambrian: (**63j**) Ptarmigan formation; Ross Lake shale; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; (**35c**) Drift blocks of siliceous shale from the Ptarmigan formation, found on the south slope of Mount Bosworth, about 500 feet (152 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector; and (**63m**) Ross Lake shale; south slope of Mount Bosworth, about 500 feet (152 m.) above the Canadian Pacific Railway track, 1 mile (1.6 km.) east of Hector and 1.25 miles (2 km.) west of Stephen on Continental Divide, all in British Columbia, Canada.

ALBERTELLA LEVIS, new species

Plate 7, figs. 1, 1*a*

This species is represented by the cranidium and associated pygidium. The cranidium differs from that of *A. bosworthi* by its glabella being more expanded towards the front, much fainter glabellar furrows, relatively shorter palpebral lobes and almost smooth instead of finely granulated outer surface of the test. A minute median node occurs near the posterior margin of the occipital ring in both *A. levis* and *A. bosworthi.*

The pygidium associated with the cranidia, also the cranidium and pygidium of *A. bosworthi,* in two blocks of limestone, are quite unlike the pygidia of typical *Albertella,* as the two spines emerge from the border at the postero-lateral margins and the pygidium is wider posteriorly and shorter. The axial lobe is narrow, strongly convex and with five segments and a terminal section; pleural lobes marked by three slightly impressed narrow furrows.

Surface of cranidium and pygidium smooth except when a strong lens is used to bring out a very fine irregular, closely inosculating series of ridges.

The largest cranidium has a length of 7.5 mm.

Formation and locality.—Middle Cambrian: (**61p**) Chetang formation; gray shaly limestone in massive beds, on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

ZACANTHOIDES CHARILLA, new species

Plate 6, figs. 9, 9*a*

Species known only from an imperfect cranidium and from two pygidia.

Cephalon.—Glabella large relative to the size of the cranidium, broadest anteriorly, gradually contracting toward the rather slender base, slightly expanding at the occipital ring, broadly and feebly arched, the curvature greatest a little in front of the median line; dorsal furrows quite deeply impressed, slightly concave, most strongly constricted opposite the posterior lobe; anterior extremity broadly arcuate; posterior glabellar furrows linear, converging toward the occipital groove, obsolete upon the summit of the glabella; medial glabellar furrows suggested by a very shallow and obscure depression extending across the glabella at right angles to the axis, about half way between the anterior extremity and the occipital ring; anterior glabellar furrows even more obscure than the medial, directed forward, but entirely obsolete upon the summit of the glabella; occipital groove moderately wide, uniform in depth between the dorsal furrows; occipital ring quite wide and flattened. Fixed cheeks very much reduced; the area between the eye lobe and the dorsal furrow not much greater than the lobe; postero-lateral lobe very narrow, deeply furrowed in front of the posterior margin; outer extremity of lobe not preserved. Anterior limb very narrow and merging into the antero-lateral margin of the glabella; frontal limb obsolete, frontal border a narrow wire-like rim. Palpebral lobe very large, approximately half as long as the glabella, feebly arcuate, quite prominently elevated, cut off from the fixed cheek by a shallow groove; posterior extremity of the eye lobe opposite the posterior lobe of the glabella, the anterior extremity of the eye lobe intercepting the dorsal furrows at the origin of the anterior glabellar furrows. Other characters of the cephalon not preserved.

Pygidium.—Associated pygidium rather large for the cephalon, trigonal in outline, exclusive of the peripheral fringe of spines. Axial lobe decidedly wider than the pleural exclusive of their spinose annulations rather coarse, obscure only near the posterior extremity, indicating three component segments and a large terminal section. Pleural lobes very narrow, only the two anterior retaining any semblance to anchylosed segments of the thorax; extremities of extremities, prominently elevated, acutely tapering posteriorly; segments attenuated and spinose, the spines drooping posteriorly and approximately parallel; second spine from the thorax the longest of all, the third nearly in line with it; four shorter subequal spines included between these two pairs.

Surface.—External surface smooth under low magnification but minutely roughened by very fine, irregular anastomosing ridges when examined with a strong lens.

Dimensions.—Length of glabella, 3.5 mm. Breadth of glabella in front, 2.7 mm. Breadth of glabella at base, 1.5 mm.

Type locality.—(61 o) Middle Cambrian: Chetang formation; Chetang Cliffs, 7 miles (11.2 km.) north-northeast of Robson Peak.

Observations.—This species recalls at once *Zacanthoides idahoensis.* It is closely allied to it but differs in its narrower antero-lateral limb of the fixed cheek, shorter palpebral lobe, and apparent absence of the frontal limb. The associated pygidium differs in the size and arrangement of the spines of the flattened border.

Formation and locality.—Middle Cambrian: (61 o) Chetang formation; gray shaly limestones in massive beds; on northeast slope of Chetang Cliffs above Coleman Glacier Creek, 7 miles (11.2 km.) north-northeast in direct line from summit of Robson Peak, northwest of Yellowhead Pass, western Alberta, Canada.

ZACANTHOIDES ? CIMON, new species

Plate 7, figs. 6, 6*a*

Species known only from imperfect cranidia and fragments of a pygidium.

Cephalon.—Cranidium rather small. Glabella very long relatively, more than nine-tenths the length of the cranidium, but not quite twice as broad as its length, broadly and quite prominently elevated medially, very feebly constricted laterally but expanding anteriorly, both in the direction of the axis and at right angles to it; glabellar furrows rather broad and shallow, cutting up the glabella into obscure annulations which are perceptible even upon the crest of the glabella; occipital furrow moderately broad, uniform in depth between the dorsal furrow; occipital ring rather low, broad, expanded medially and possibly nodose. Fixed cheeks exclusive of the postero-lateral lobe appearing as semielliptical extensions on either side of the medial posterior portion of the glabella; greatest width of the fixed cheek, exclusive of the postero-lateral lobe which has not been preserved, rarely more than half the width of the medial portion of the glabella. Palpebral lobe and ridge not differentiated, the two together forming a cordate, strongly arcuate ridge with one extremity near the occipital ring, the other directly in front of the anterior glabellar furrows, the ridge cut off from the fixed cheek by a clearly defined groove; medial portion of the palpebral arc nearly in line with the posterior glabellar furrows. Frontal limb obliterated medially. Frontal border very narrow, upturned, probably somewhat thickened. Facial sutures imperfectly preserved, the anterior section apparently diverging rapidly from the anterior extremity of the palpebral arc. Free cheeks not preserved.

Pygidium.—Pygidium known only from a couple of proximate, parallel, caudal spines attached to the peripheral rim and connected with a fragment of the axial lobe.

Surface.—External surface microscopically shagreened.

Dimensions.—Length of cranidium, 6.2 mm. Length of glabella, 5.7 mm. Width of medial portion of glabella, 3.2 mm.

Type locality.—(**63b**) Ptarmigan Peak, Alberta, Canada.

Observations.—The two caudal spines which have been preserved were probably about 10 mm. long before the loss of their tips. They are exactly parallel to one another and separated by a space no greater than the width of one of the slender spines.

The cranidium and the fragment of the associated pygidium both suggest *Zacanthoides,* but as the cranidium might possibly belong to a species of *Albertella* the generic reference is tentative. I do not know of a similar described form of cranidium or pygidium.

Formation and locality.—Middle Cambrian: (**63b**) Ptarmigan formation; bluish-black, more or less finely arenaceous limestone in layers 0.5 to 8 inches thick that form massive layers 450 feet (138 m.) thick beneath the great Cathedral limestone; east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise station on the Canadian Pacific Railway, Alberta, Canada.

ZACANTHOIDES CNOPUS, new species

Plate 6, figs. 10, 10*a*

Species known only from an imperfect cephalon and a portion of the thorax.

Dorsal shield.—Dorsal shield rather small for the group, elongate-oval in outline. Axial lobe convex, strong, as wide as the pleura exclusive of the spinose extremities and elevated high above them even in the shale.

Cephalon.—Cephalon apparently a little less than one-third of the length of the dorsal shield, and about twice as broad as it is long. Cranidium exclusive of the postero-lateral lobes somewhat pitcher-shaped, broadly convex medially and posteriorly, flaring anteriorly. Glabella rather low but relatively long, expanding slightly anteriorly both with the axis and at right angles to it, broadly and very feebly constricted medially; dorsal furrows not very deeply impressed and, between the posterior glabellar furrows and the occipital ring, almost obsolete; anterior furrow also shallow, broadly arcuate; glabellar furrows quite pronounced; posterior pair oblique, quite deeply gouged toward the dorsal furrows but obsolete upon the subangular crest of the glabella; medial pair similar in general character to the posterior but shorter and less oblique; anterior pair reduced to very obscure, lateral depressions at some little distance behind the anterior extremity; occipital furrow deeply incised distally but broad and shallow upon the summit of the glabella; occipital ring low and broad, expanded medially and bearing near the posterior margin traces of an occipital node. Fixed cheeks narrow, the distance from the palpebral lobe to the dorsal furrow less than half the width of the glabella, auriculate in outline, exclusive of the postero-lateral lobe; postero-lateral lobe not preserved but doubtless very slender, and probably petaloid. Palpebral lobe and palpebral ridge not differentiated, the two together forming a cordate, sickle-shaped ridge with one extremity near the occipital ring, the other directly in front of the anterior glabellar furrows but at some little distance behind the anterior extremity of the glabella; palpebral lobe and ridge cut off from the cheek by a narrow deeply incised groove. Frontal limb narrow, flattened, but little wider than the cordate frontal border. Free cheeks wide and probably rather low, peripheral border abruptly constricted and produced posteriorly into very slender, acutely tapering spines which apparently terminate opposite the fourth thoracic segment.

Thorax.—Thoracic segments eight or nine in number, probably nine. Axial lobe very coarse, wider than the pleural lobes and strongly convex; annulations sharply defined and bearing a medial node, probably indicating the former presence of a medial spine; the slender spine upon the seventh thoracic segment still preserved, probably about 10 mm. long, or more than half the length of the dorsal shield. Pleural segments, exclusive of the attenuated spinose extremities, very short; pleural furrows broad, almost as wide as the including segment and moderately deep; extremity of first thoracic segment apparently not spinose; extremity of second thoracic segment attenuated, posteriorly inclined and produced into a slender spine a little longer than the unflexed portion of the segments; extremities of the medial and posterior thoracic segments between two and three times the length of the rest of the segment, strongly inclined posteriorly.

Pygidium.—Pygidium not very well preserved, short. Axial lobe relatively large and strong, obtusely truncate posteriorly; caudal annulations almost as prominent as those of the thorax, four in number with a terminal section. Pleural lobes of the pygidium not preserved except the spinose extensions of the pleura which extend backward approximately parallel to the axis of the shield, and almost twice the length of the axial lobe.

Surface.—Character of external surface not preserved; surface of spines covered with a microscopically fine lacy venation.

Dimensions.—Length of dorsal shield, 13.5± mm. Length of cephalon, 4.0± mm. Greatest width of thorax, including the spinose extremities, 11.0± mm. Greatest width of thorax, excluding the spinose extremities, 6.0± mm.

Type locality.—(**4v**) Gordon Creek, Montana.

Observations.—The cranidium of this species is much like that of *Z. idahoensis*,[1] but the thorax has the great median spine on the eighth segment instead of the fifth and the spinose extensions of this pleura are relatively longer. The imperfection of the specimens prevents closer comparison. *Zacanthoides cnopus* differs from *Z. typicalis* and *Z. spinosus* very much as *Z. idahoensis* differs from them.[2]

Formation and locality.—Middle Cambrian: Gordon shale; (**4v**) about 200 feet (61 m.) above the unconformable base of the Cambrian and 75 feet (22.9 m.) above the top of the quartzitic sandstones,

[1] Smithsonian Misc. Coll., Vol. 53, 1908, pl. 3, figs. 1-11.

[2] Idem, p. 29.

Gordon Creek, 6 miles (9.6 km.) from South Fork of Flathead River, Ovando quadrangle (U. S. G. S.), Powell County Montana.

NEOLENUS CONSTANS, new species

Plate 6, figs. 7, *7a*

Species known only from a single caudal shield.

Pygidium.—Pygidium large and coarse, roughly semielliptical in outline, about four-fifths as long as it is broad; component segments five in number including the terminal section. Axial lobe elongate-conic in outline, almost as broad anteriorly as one of the pleural lobes, evenly tapering toward the sharply rounded posterior extremity of the lobe; annulations distinct, becoming less prominent and more closely spaced posteriorly. Lateral lobes strongly convex; segments feebly anchylosed especially toward the thorax; pleural furrows broad and, toward the posterior extremity, obscure, arcuate anteriorly, approximating more and more closely to the axis of the shield posteriorly; outer extremities of segments discrete and falcate or even semispinose. Peripheral rim not very sharply defined, outlined by the flattening of the shield and by a series of shallow pits which mark the terminations of the pleural furrows; outer margin serrated by four broad-based, rather short spines quite sharply concave opposite the extremity of the axial lobe.

Surface.—External surface finely punctate, having the appearance under high magnification of having been very finely etched with acid.

Dimensions.—Length of caudal shield, 20± mm. Greatest breadth of caudal shield, 25.0± mm.

Type locality.—(**63b**) Ptarmigan Peak, Alberta, Canada.

Observations.—Although the extremity of the axial lobe is sharply defined, there is a very obscurely elevated cuneate area extending backward from the extremity and wedging out at the margin.

I do not usually like to found a species on a pygidium, but this form is so distinct and strong that it seems worthy of such recognition. It differs from the pygidium of *Neolenus serratus* in having one less pair of border spines, one less pleural segment indicated on the pleural lobes, and a relatively shorter, broader axial lobe.

Formation and locality.—Middle Cambrian: (**63b**) Ptarmigan formation; bluish-black, more or less finely arenaceous limestone in layers 0.5 to 8 inches thick that form massive layers 450 feet (138 m.) thick beneath the great Cathedral limestone; east base of Ptarmigan Peak 5.5 miles (8.8 km.) in an air line northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

BATHYURISCUS ROSSENSIS, new species

Plate 5, figs. 5, 5*a-d*

Bathyuriscus (*Poliella*) sp. undt. WALCOTT, 1916, Smithsonian Misc. Coll., Vol. 64, No. 5, p. 355, pl. 46, fig. 7. (Described and illustrated.)

Dorsal shield.—Dorsal shield a very smooth elongated oval, the greatest breadth in the type less than two-thirds of the length. Axial lobe well differentiated, moderately convex; pleura flattened in the shale but retaining traces of rather a strong downward flexure at the genal angle.

Cephalon.—Cephalon, exclusive of the genal spines, about two-fifths as long as the entire dorsal shield, strongly contoured even in the shale. Glabella quite low, almost as long as the cephalon, strictly clavate in outline; dorsal furrows distinct, deepening anteriorly; anterior extremity expanded and broadly arcuate; posterior lateral furrows rather broad and deeply intrenched, directed backward at an angle of approximately 45° but evanescing abruptly before reaching the medial line; other lateral furrows obsolete; occipital ring distinct, trigonal; occipital furrow deeply gouged toward the distal extremities but shallow and rather ill defined upon the crest of the glabella; occipital ring posteriorly produced and sharply angulated, and bearing a short acute spine at the apex of the angle. Fixed cheeks lower than the glabella, rather wide relatively, the distance from the palpebral lobe across to the dorsal furrow a little more than half the width of the medial portion of the glabella; postero-lateral lobes very narrow and petaloid; groove behind the posterior margin very broad, especially toward the outer extremity. Palpebral lobe narrow, strongly crescentic, about one-third as long as the glabella, set so far back that the posterior extremity of the lobe is almost in line with the occipital furrow. Palpebral ridge often rather obscure, arching obliquely across from the anterior extremity of the palpebral lobe and intercepting the dorsal furrow about half-way between the outer extremity of the posterior lateral furrow and the anterior extremity of the glabella. Facial sutures conspicuously sinuous, following along the low arch of the postero-lateral lobes of the fixed cheeks, around the strongly convex palpebral lobe and the shorter but almost equally convex anterior lobe; arc included between the extremities of the facial sutures approximately one-third the periphery of the cephalon exclusive of the genal spines.

Free cheeks of about the same width as the fixed cheeks, but more plump, bearing short and rather broad infragenal spines and very long, slender acute, scimiter-like genal spines which lie close to the outer extremities of the thoracic segments and are produced backward at least as far as the pygidium. Frontal border very narrow anteriorly, widening slightly laterally.

Thorax.—Thoracic segments moderately wide, eight in number. Axial lobe not quite so wide as the pleura and arched well above them; distal extremities of the axial segments produced into falcate extremities about one-third as long as the pleural segments which they overlie; medial portion of the axial segment probably elevated into an obtuse node. Pleural segments doubtless rather strongly flexed at their falcate outer extremities; pleural furrows broad and quite deep, much more steeply channeled along the anterior margin than along the posterior, gradually disappearing distally; outer extremities of the pleura acute and posteriorly directed, rounded away along the underlapping anterior margin.

Pygidium.—Pygidium quite large, contained between three and four times in the length of the shield, sharply differentiated from the thorax; axial lobe of the pygidium subcylindrical, relatively slender, abruptly evanescing at some little distance in front of the posterior extremities; included segments probably five in number, annulations obsolete posteriorly but strongly defined anteriorly, that in front and often the next behind it bearing an acute spine. Lateral furrows broad and rather ill defined, approximately parallel, and inclined at an angle of about 45° to the axis of the shield. Anterior segment of the fused portion of the pygidium produced into a rather short, posteriorly directed spine. Periphery of pygidium indented at the caudal spine, squarely truncate or broadly constricted posteriorly.

Surface.—There is very little trace of an external sculpture excepting upon the genal spines which are longitudinally striated with very fine anastomosing groovings. One cranidium, however, is shagreened with rather a coarse granulation and on this same individual there are traces of three pairs of short, horizontal glabellar furrows in front of the oblique posterior pair.

Dimensions.—Length, 49.5 mm. Maximum width, 35.0 mm. Length of cranidium, 21.0 mm. Length of pygidium, 13.0 mm.

Type locality.—(63j) Ptarmigan formation, *Albertella* shale zone; above Ross Lake, British Columbia, Canada.

Observations.—*B. rossensis* Walcott is, perhaps, best characterized by the very much produced genal spines. They certainly extend as far back as the pygidium and their attenuated extremities may persist even to the posterior margin of the shield. There is a strong tendency in this species toward the development of spines and nodes.

There are infragenal as well as genal spines developed, and the occipital ring and the axial ring both of the thorax and the pygidium are nodulated. The triangular axial extensions in the pleural grooves so characteristic of the genus are unusually well developed in this species. The glabella is broad relatively, and only the posterior lateral furrows are perceptible on the majority of the individuals. The caudal shield is moderately large but less strongly annulated and furrowed than in the majority of *Bathyuriscus*. The number of thoracic segments is the same in the half-dozen individuals in which the complete shields have been preserved.

The pygidium of *B. adæus*[1] has a somewhat similar marginal spine on each side, but otherwise the pygidia differ in many details. The cranidium of *B. belesis*[2] is very similar but the associated pygidia are quite dissimilar.

The pygidium described and illustrated as *Bathyuriscus* (*Poliella*) sp. undt. 1[3] is now referred to this species. The two specimens then known of were broken along the outer border and did not show the spine on each side. By error the locality of the specimens was given as 35e. They came from 35c as defined below.

In the collection made by Dr. Frank D. Adams and Mr. W. J. Dick, 4 miles (6.4 km.) north of North Kootenay Pass, Alberta, there are specimens of large species of *Bathyuriscus* that are apparently identical with *B. rossensis*. They occur on the surface of very thin layers of bluish-gray limestone in association with a typical *Albertella* fauna as follows:

Agraulos stator Walcott
Vanuxemella nortia Walcott
Albertella bosworthi Walcott
Asaphiscus rossensis Walcott

Formation and locality.—Middle Cambrian: **(63j)** Ross Lake shale member of the Ptarmigan formation; outlet of cirque above and south of Ross Lake on north slope of Popes Peak, 1.5 miles (2.4 km.) south-southwest of Stephen on Canadian Pacific Railway; **(63m)** *Albertella* zone; south slope of Mount Bosworth, about 500 feet (152.4 m.) above the Canadian Pacific Railway track, 1 mile (1.6 km.) east of Hector and 1.25 miles (2 km.) west of Stephen on Continental Divide; and **(35c)** also *Albertella* zone; drift blocks of silice-

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[1] Smithsonian Misc. Coll., Vol. 64, 1916, pl. 47, figs. 3, 3*b*.
[2] Idem, p. 338, pl. 50, figs. 1, 1*b*.
[3] Idem, p. 355, pl. 46, fig. 7.

ous shale from the Ptarmigan formation,[1] found on the south slope of Mount Bosworth about 500 feet (152.4 m.) northwest of the Canadian Pacific Railway track between Stephen and Hector, all in British Columbia, Canada.

Also 4 miles (6.4 km.) north of North Kootenay Pass, Alberta, Canada. Specimens in Museum of McGill University, Montreal.

BATHYURISCUS cf. ROSSENSIS, new species

Plate 5, figs. 6, 6*a*

Cephalon.—Cranidium large and strongly contoured. Glabella long and relatively narrow, somewhat clavate in outline, slightly expanded anteriorly both along the transverse and the longitudinal axis, the maximum elevation falling in front of the transverse median line; glabellar furrows obscure in the majority of individuals, the posterior pair rather broad and very strongly oblique, the pair in front of them approximately horizontal or feebly inclined posteriorly, the two anterior pairs very slightly inclined anteriorly; occipital furrow broad but not very deep, persisting across the crest of the glabella; occipital ring rather wide, cuneate, the posterior margin produced, acutely ridged and angulated and bearing an obtuse spine at the apex of the angle; dorsal furrows moderately impressed, broad and feebly constricted medially, in the majority of individuals more strongly divergent anteriorly than posteriorly; anterior extremity of the glabella broadly arched. Fixed cheeks low, rather broad relatively, the distance from the palpebral lobe across to the dorsal margin approximately half the width of the medial portion of the glabella; postero-lateral lobe narrow but produced laterally; posterior furrow broad, oblique, its anterior margin in line with the oblique posterior margin of the occipital ring; palpebral lobe moderately wide, reniform, about three times the length of the glabella, the median transverse line of the lobe falling a little behind the median transverse line of the glabella; palpebral ridge obscure in the majority of individuals, arching across from the palpebral lobe and intercepting the dorsal furrows at or a little in front of the next to the anterior pair of lateral furrows. Facial sutures outlined as in figure, the anterior limb broadly arched. Character of free cheeks not known.

Surface.—Smooth or slightly roughened by obscure granulation.

Dimensions.—Length of cranidium, 30.0 mm. Length of glabella, 28.5 mm.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 214.

Type locality.—(63m′) Mount Bosworth, British Columbia, Canada.

Observations.—This form is known only from cranidia and pygidia occurring in thin limestone lentiles in the shale with *B. rossensis.* The glabella is longer and more slender proportionally than that of *rossensis.* These differences are apparently too great to be due to individual variation, or to compression and distortion. The glabellæ of *Bathyuriscus* sp. are strongly convex and on some specimens the median ridge is strongly defined, especially toward the anterior portion.

The associated pygidia are closely related if not identical with those of *B. rossensis* except that the limestone form is narrower and more elongate proportionally.

Formation and locality.—Middle Cambrian: (63m′) Ptarmigan formation (Ross Lake shale); thin lentiles of limestone included in the shale; south slope of Mount Bosworth, about 500 feet (152.4 m.) above the Canadian Pacific Railway track, 1 mile (1.6 km.) east of Hector and 1.25 miles (2 km.) west of Stephen on Continental Divide, British Columbia, Canada.

BATHYURISCUS (POLIELLA) CHILO, new species

Plate 5, fig. 4

Dorsal shield.—Dorsal shield rather small, quite slender, elongate-oval in outline, the greatest width, exclusive of the free cheeks which have not been preserved, a little more than half the length. Axial lobe relatively broad in all three divisions of the shield and conspicuously elevated above the flattened pleura.

Cephalon.—Cephalon more than one-third the length of the dorsal shield. Glabella large relatively, rather tumid, subrectangular in outline, expanding very slightly near the front; dorsal furrows feebly impressed, rudely parallel excepting near the anterior extremity where they tend to diverge; front of glabella ill defined, very broadly and very feebly arcuate; glabellar furrows obscure, the posterior pair oblique, the medial and anterior pairs more nearly transverse; occipital furrow shallow; occipital ring imperfectly preserved, apparently rather wide and similar in character to the anterior segments of the thorax. Fixed cheeks imperfectly known, apparently rather wide and broadly convex, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe narrow, short, obtusely petaloid at its extremity; posterior groove not very deep, in line with the occipital ring; margin behind the groove increasingly wide away from the axis. Palpebral lobe conspicuously elevated and not differentiated from the palpebral ridge which cuts obliquely across the fixed cheek and intercepts the dorsal furrows near the origin of the posterior glabellar furrows; raised margin of the lobe probably cut off from the surface of the cheek by a broad and rather deep furrow. Other characters of the cephalon not preserved.

Thorax.—Thoracic segments nine in number. Axial lobe strongly convex, broader than the pleural lobes. Pleura short, the anterior medial segments the most produced; pleural furrows rather shallow, almost as wide as the including segment; extremities of the anterior and medial segments apparently obtuse; last three segments in front of the caudal shield acutely falcate distally.

Pygidium.—Pygidium short, rudely lenticular in outline. Axial lobe, strongly convex, relatively broad, subcylindrical, tapering slightly toward the broadly rounded posterior extremity; annulations distinct but not conspicuous, indicating two component segments and a terminal section. Pleural lobes somewhat flexuous, of approximately the same width as the axial; pleural grooving very obscure, rudely parallel to the anterior margin. Peripheral rim narrow, smooth, flattened, broadly arcuate.

Surface.—External surface microscopically shagreened.

Dimensions.—Length of dorsal shield, 12.5± mm. Greatest width of dorsal shield, exclusive of the fixed cheek, 7.0± mm.

Type locality.—(**63n**) Ptarmigan formation; Wonder Pass, west of Gog Lake, British Columbia, Canada.

Observations.—When in the field I referred this species to *B.* (*P.*) *sylla*[1] of the Chetang formation, but comparison with the type specimen of the latter showed that they differed in the nearly straight sides of the glabella and narrower and shorter associated pygidium. The most nearly related species appear to be *B.* (*P.*) *primus* and *B.* (*P.*) *anteros*[2] from which it differs in many details.

Formation and locality.—Middle Cambrian: (**63n**) Ptarmigan ? formation; bluish thin-bedded limestone northwest side of Wonder Pass at east base of ridge west of Gog Lake, on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Canada.

[1] Smithsonian Misc. Coll., Vol. 64, 1916, p. 354, pl. 48, figs. 3, 3*a-e*.

[2] Idem, pl. 46, figs. 5, 6, 6*a-c*.

DESCRIPTION OF PLATE 4

PAGE

Tholiasterella ? hindei Walcott 25

FIG. 1. (× 2.) A six-rayed spicule showing a central nodule. U. S. National Museum, Catalogue No. 63711. (**63j.**)

1*a*. (× 6.) Central portion of the disk of fig. 1 enlarged to show structure.

Eocystites ? sp. undt. 25

FIG. 2. (Natural size.) The only specimen known to me of this form. U. S. National Museum, Catalogue No. 63712.

The specimens represented by figs. 1, 1*a*, and 2 are from (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

Micromitra (Paterina) wapta Walcott 25

FIG. 3. (× 2.) Exterior of ventral valve. The type specimen (U. S. National Museum, Catalogue No. 51402*a*). The figure 3 is copied from Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, pl. 7, fig. 6. Also Monogr. 51, U. S. Geol. Surv., 1912, text fig. No. 29A, p. 357.

The specimen represented is from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

Obolus parvus Walcott 25

FIG. 4. (× 4.) Exterior of a ventral valve, the type specimen (U. S. National Museum, Catalogue No. 51400*a*).

4*a*. (× 4.) Exterior of a dorsal valve. U. S. National Museum, Catalogue No. 51400*b*.

The specimens represented by figs. 4 and 4*a* are copied from Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, pl. 7, figs. 10, 10*a*. Also Monogr. 51, U. S. Geol. Surv., 1912, text figs. 37A and 37B, p. 408.

The specimens represented are from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

Acrothele colleni Walcott 25

FIG. 5. (× 4.) A large ventral valve. U. S. National Museum, Catalogue No. 51410*c*.

5*a*. (× 4.) Broken ventral valve showing false area. U. S. National Museum, Catalogue No. 51410*b*.

5*b*. (× 4.) Cast of a ventral valve showing the incurving of the growth lines across the false area. U. S. National Museum, Catalogue No. 51410*d*.

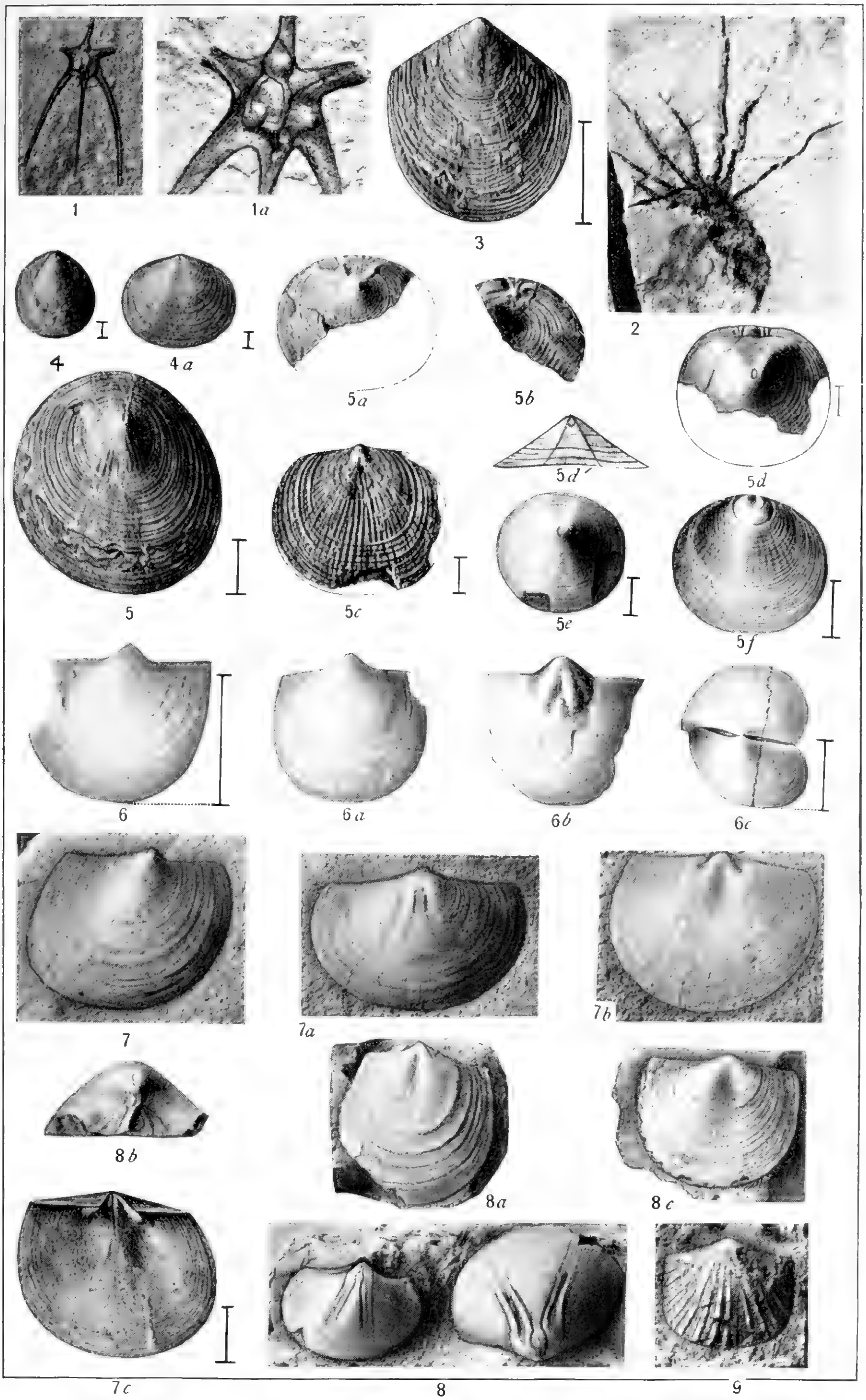
5*c*. (× 4.) Exterior of a dorsal valve. U. S. National Museum, Catalogue No. 51410*e*.

The figures 5, 5*a*-*c* are copied from Walcott, Monogr. 51, U. S. Geol. Surv., 1912, text figs. 55, B, C, D, and E, p. 641.

The specimens represented are from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

5*d*, 5*d'*. (× 4.) Top and back views of the posterior portion of a ventral valve. U. S. National Museum, Catalogue No. 51973*b*.

5*e*. (× 4.) Side view of the type specimen, a ventral valve. U. S. National Museum, Catalogue No. 51973*a*.



SPONGE, CYSTID, AND BRACHIOPODS

Acrothele colleni Walcott—Continued. PAGE

5f. (× 2.5.) Exterior of a dorsal valve with the cardinal slopes rounded in by pressure. An imperfect valve beside it has the outline of figure *5c*. U. S. National Museum, Catalogue No. 51973*c*.

The figures 5*d*, 5*e*, and 5*f* are copied from Walcott, Monogr. 51, U. S. Geol. Surv., 1912, pl. 63, figs. 6, 6*a*, 6*b*.

The specimens represented are from (Locality **4q**) Middle Cambrian: Gordon shale near Gordon Mountain, Ovando quadrangle (U. S. G. S.), Montana.

Wimanella simplex Walcott 26

FIGS. 6, 6*a*. (Natural size.) Ventral valves of varying outline owing to distortion in the shale. U. S. National Museum, Catalogue Nos. 52277*a* and 52277*b*.

6*b*. (Natural size.) Cast of interior of a ventral valve. U. S. National Museum, Catalogue No. 52277*d*.

6*c*. (× 2.) Ventral and dorsal valves compressed and resting against each other at the posterior margins. U. S. National Museum, Catalogue No. 52278*b*.

The figures 6, 6*a-c* are from Walcott, Monogr. 51, U. S. Geol. Surv., 1912, pl. 89, figs. *2a, 2b, 2c, 2e*.

The specimens represented are from (Locality **4w**) Middle Cambrian: Gordon shale on Youngs Creek, Ovando quadrangle (U. S. G. S.), Montana.

7, 7*a*. (× 2.) Ventral valves of varying outline owing to distortion in the shale. U. S. National Museum, Catalogue Nos. 63713 and 63714. (**63j.**)

7*b*. (× 2.) Cast of interior of a dorsal valve. U. S. National Museum, Catalogue No. 63715. (**63j.**)

7*c*. (× 3.) Interior of a compressed dorsal valve. U. S. National Museum, Catalogue No. 51407. This figure is from Walcott, Monogr. 51, U. S. Geol. Surv., 1912, text fig. No. 64, p. 748.

The specimen represented by 7*c* is from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale): Mount Bosworth, British Columbia.

8. (× 2.) Cast of two ventral valves in limestone. U. S. National Museum, Catalogue No. 63716. (**63m.**)

8*a*. (× 3.) Exterior of a ventral valve. U. S. National Museum, Catalogue No. 63717. (**63m.**)

8*b*. (× 3.) Area of a ventral valve. U. S. National Museum, Catalogue No. 63718. (**63m.**)

8*c*. (× 2.) Exterior of a dorsal valve. U. S. National Museum, Catalogue No. 63719. (**63m.**)

The specimens represented by figs. 7, 7*a-b* are from siliceous shale (Locality **63j**), Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake; and figs. 8, 8*a-c* from limestone interbedded in the shale of locality **63m**, Middle Cambrian: Ptarmigan formation; Mount Bosworth, both in British Columbia.

Nisusia cf. *alberta* Walcott.. 26

FIG. 9. (× 3.) Imperfect exterior of a small ventral valve. U. S. National Museum, Catalogue No. 63720.

The specimen represented by fig. 9 is from limestone (Locality **61 o**), Middle Cambrian: Chetang formation; Robson District, Alberta.

DESCRIPTION OF PLATE 5

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Hyolithellus hectori Walcott.. 27

FIG. 1. (× 8.) Section of a tube enlarged to show surface characters. U. S. National Museum, Catalogue No. 63721.

The specimen represented is from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

Hyolithellus flagellum (Matthew).. 26

FIG. 2. (× 3.) A long curved tube. U. S. National Museum, Catalogue No. 63722. The figure 2 is the same as fig. 8, pl. 1, Walcott, Canadian Alpine Journ., Vol. 1, 1908.

From (Locality **14s**) Middle Cambrian: Stephen formation; Mount Stephen, British Columbia.

2a. (× 4.) A group of four small tubes attached to a valve of *Wimanella simplex.* U. S. National Museum, Catalogue No. 63723.

From (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

Hyolithes cecrops Walcott.. 27

FIG. 3. (Natural size.) Dorsal view with shell broken away. The type specimen. U. S. National Museum, Catalogue No. 63724.

3a. (× 4.) Ventral view of a small specimen that is only slightly compressed. U. S. National Museum, Catalogue No. 63725.

3b. (Natural size.) Dorsal view of a small wide specimen flattened in the shale. U. S. National Museum, Catalogue No. 63726.

3c. (× 2.) Inner side of an operculum associated with the specimen illustrated by figs. 3, *3a-b.* U. S. National Museum, Catalogue No. 63727.

The specimens represented by figs. 3, *3a-c* are from (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

Bathyuriscus (Poliella) chilo Walcott.. 50

FIG. 4. (× 3.) Small dorsal shield a little injured by weathering. U. S. National Museum, Catalogue No. 63728.

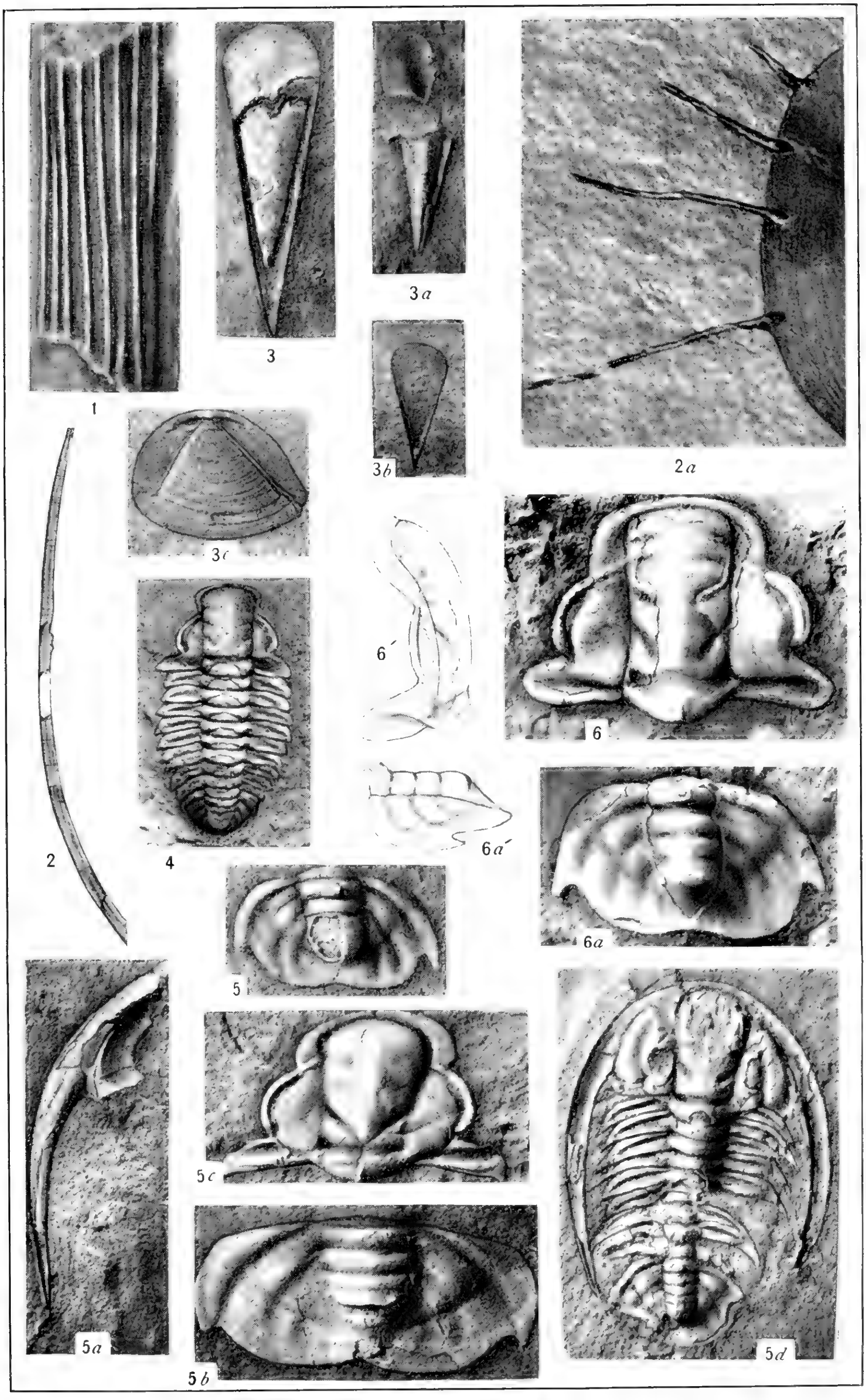
From limestone (Locality **63n**), Middle Cambrian: Ptarmigan formation: Wonder Pass, British Columbia.

Bathyuriscus rossensis Walcott.. 46

FIG. 5. (× 1.5.) A nearly perfect cranidium. U. S. National Museum, Catalogue No. 63729.

5a. (Natural size.) Interior of a large free cheek. U. S. National Museum, Catalogue No. 63730.

5b. (× 2.) A pygidium somewhat crushed in the shale. U. S. National Museum, Catalogue No. 63731.



PTEROPODS, ANNELIDS, AND TRILOBITES

Bathyuriscus rossensis Walcott—Continued. PAGE

5*c*. (× 2.) A small, fairly well-preserved pygidium. U. S. National Museum, Catalogue No. 63732.

5*d*. (Natural size.) A crushed dorsal shield, illustrating the general characters of the species. U. S. National Museum, Catalogue No. 63733.

The specimens represented by figs. 5, 5*a-d* are from (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

Bathyuriscus cf. *rossensis* Walcott.................................... 49

FIG. 6. (Natural size.) A large, partially exfoliated cranidium. U. S. National Museum, Catalogue No. 63734.

6′. Side outline of fig. 6.

6*a*. (× 3.) Pygidium associated with the cranidium represented by fig. 6. U. S. National Museum, Catalogue No. 63735.

6*a*′. Side outline of fig. 6*a*.

The specimens represented by figs. 6, 6*a* are from thin limestone layers interbedded in the Ross Lake shale (Locality **63m′**), Middle Cambrian: Ptarmigan formation; Mount Bosworth, British Columbia.

DESCRIPTION OF PLATE 6

PAGE

Ptychoparia charax Walcott.. 31

FIG. 1. (× 2.) A cranidium, and the type specimen of the species. U. S. National Museum, Catalogue No. 63736.

From locality **4v**, Middle Cambrian: Gordon shale; Gordon Creek, Montana.

Ptychoparia ? cilles Walcott.. 32

FIG. 2. (× 5.) A small cranidium and the type specimen of the species. U. S. National Museum, Catalogue No. 63737.

From limestone of locality **63d**, Middle Cambrian: Ptarmigan formation; Ptarmigan Mountain, Alberta.

Ptychoparia candace Walcott.. 28

FIG. 3. (× 2.) A flattened dorsal shield with its pygidium broken and pressed down and free cheeks detached. They are outlined from another cephalon which has one free cheek on which there appears to be the base of a postero-lateral spine. U. S. National Museum, Catalogue No. 63738.

3a. (× 6.) Specimen of a dorsal shield with ten thoracic segments. U. S. National Museum, Catalogue No. 63739.

From locality **4v**, Middle Cambrian: Gordon shale; Gordon Creek, Powell County, Montana.

Ptychoparia pylas Walcott.. 33

FIG. 4. (× 6.) A small dorsal shield. The palpebral lobes and some details restored from other specimens. U. S. National Museum, Catalogue No. 63740.

4a. (× 4.) A badly crushed dorsal shield well illustrating thoracic segments and parts of cranidium. U. S. National Museum, Catalogue No. 63741.

4b. (× 2.) A small cranidium flattened in the shale. U. S. National Museum, Catalogue No. 63742.

4c. (× 2.) The largest cranidium observed, illustrating the rapid increase in size of the frontal limb with increase in size of cranidium. U. S. National Museum, Catalogue No. 63743.

From locality **4q**, Middle Cambrian: Gordon shale; on ridge between Gordon and Youngs Creeks, Powell County, Montana.

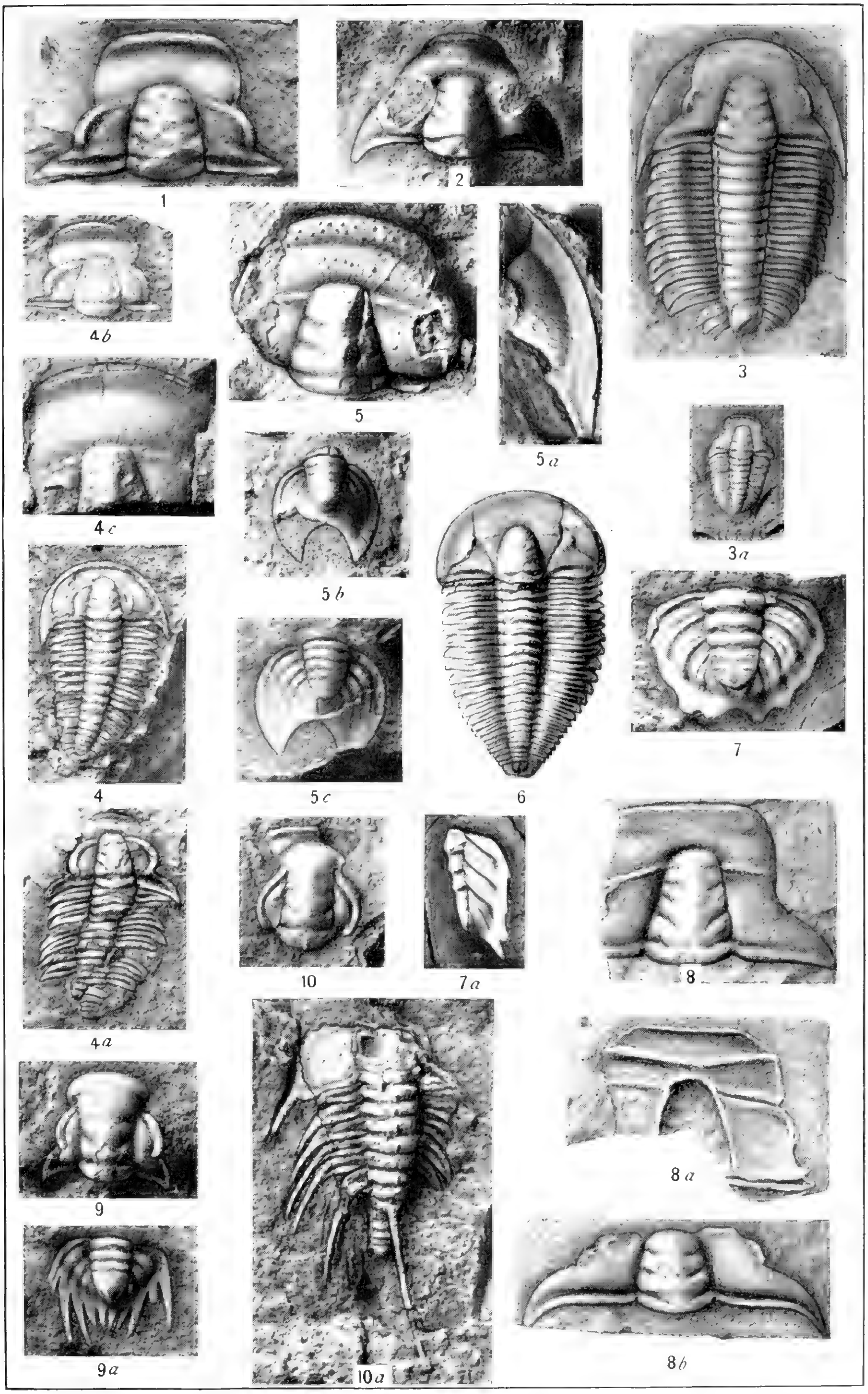
Crepicephalus chares Walcott.. 35

FIG. 5. (× 3.) Broken cranidium showing surface characters. U. S. National Museum, Catalogue No. 63744.

5a. (× 3.) Free cheek associated with fig. 5. U. S. National Museum, Catalogue No. 63745.

5b, *5c*. (× 3.) Pygidia associated with specimen represented by fig. 5. U. S. National Museum, Catalogue Nos. 63746 and 63747.

From locality **63d**, Middle Cambrian: Limestone of Ptarmigan formation; Ptarmigan Peak, Alberta.



CAMBRIAN TRILOBITES

PAGE

Agraulos stator Walcott.. 28

Fig. 6. (Natural size.) A nearly perfect dorsal shield, the type specimen. U. S. National Museum, Catalogue No. 61729. After Walcott, Smithsonian Misc. Coll., Vol. 64, pl. 36, fig. 6.

From locality **35c**, Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

Neolenus constans Walcott.. 45

Figs. 7, 7*a*. (Natural size.) Top and side views of the type specimen of pygidium. U. S. National Museum, Catalogue No. 63748.

From locality **63b**, Middle Cambrian: Limestone of Ptarmigan formation; Ptarmigan Peak.

Olenopsis cf. *americanus* Walcott.. 37

Figs. 8, 8*a*, 8*b*. (× 1.5.) Broken cranidia that illustrate the form and details of the cranidium. U. S. National Museum, Catalogue Nos. 63749, 63750, 63751.

From locality **63j**, Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake.

Zacanthoides charilla Walcott.. 40

Fig. 9. (× 4.) The type specimen of the cranidium, which is preserved in limestone and retains its original convexity. U. S. National Museum, Catalogue No. 63752.

9*a*. (× 4.) Pygidium associated with fig. 9. U. S. National Museum, Catalogue No. 63753.

From locality **61 o**, Middle Cambrian: Limestone of Chetang formation; Robson Peak district, Alberta.

Zacanthoides cnopus Walcott.. 43

Fig. 10. (× 3.) A broken dorsal shield illustrating thorax. U. S. National Museum, Catalogue No. 63754.

10*a*. (× 2.) A cranidium associated with fig. 10. U. S. National Museum, Catalogue No. 63755.

From locality **4v**, Middle Cambrian: Gordon shale; Gordon Creek, Montana.

DESCRIPTION OF PLATE 7

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Albertella levis Walcott.. 39

Fig. 1. (× 3.) The type specimen of cranidium. U. S. National Museum, Catalogue No. 63757.

1*a*. (× 4.) Pygidium associated with fig. 1. U. S. National Museum, Catalogue No. 63758.

From locality **61w**, Middle Cambrian: Chetang formation limestone; Terrace Creek, Robson district, Alberta.

Albertella bosworthi Walcott.. 38

Fig. 2. (× 4.) A cranidium preserving its natural convexity. U. S. National Museum, Catalogue No. 63759.

2*a*. (× 3.) A small associated free cheek. U. S. National Museum, Catalogue No. 63760.

2*b*. (× 4.) An associated pygidium preserving its convexity and narrow form. U. S. National Museum, Catalogue No. 63761.

From locality **61p**, Middle Cambrian: Chetang formation limestone; Coleman Creek, Robson district, Alberta.

3, 3*a*. (× 1.5.) Almost entire dorsal shields somewhat flattened in the shale. U. S. National Museum, Catalogue Nos. 63762 and 63763.

The specimens represented are from (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

3*b*, 3*c*. (× 2.) Cranidium and pygidium for comparison with those of *Albertella helena*. U. S. National Museum, Catalogue Nos. 53413 and 53415. The figs. 3*b*, 3*c* are after Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, pl. 1, figs. 4 and 6.

The specimens represented by figs. 3*b* and 3*c* are from (Locality **35c**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

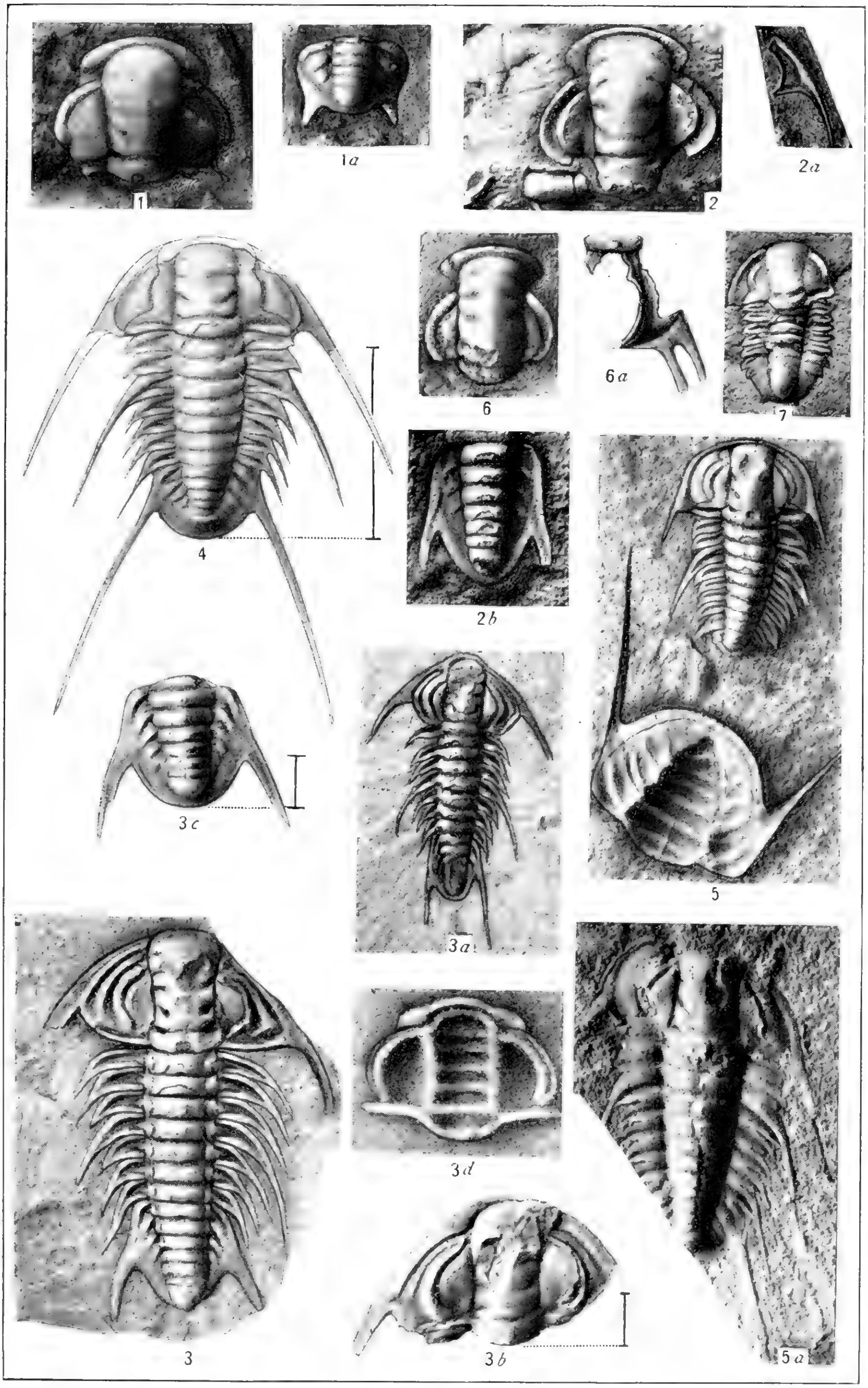
3*d*. (× 12.) Matrix of a minute cranidium impressed on the surface of a valve of *Wimanella simplex*. U. S. National Museum, Catalogue No. 63764.

From locality **63j**, associated with figs. 3, 3*a*.

Albertella helena Walcott.. 39

Fig. 4. (Natural size.) A nearly entire dorsal shield, the type specimen. U. S. National Museum, Catalogue No. 53410. The fig. 4 is after Walcott, Smithsonian Misc. Coll., Vol. 53, 1908, pl. 2, fig. 1.

The specimen represented by fig. 4 is from (Locality **5j**) Middle Cambrian: Gordon shale; Scapegoat Mountain, Powell County, Montana.



CAMBRIAN TRILOBITES

Albertella helena Walcott—Continued. PAGE

5. (× 2.) A dorsal shield with a more perfect cephalon than that on fig. 5*a*. A matrix of a fine pygidium occurs just below on the same fragment of rock. U. S. National Museum, Catalogue No. 63765.

5*a*. (× 3.) A nearly entire dorsal shield. U. S. National Museum, Catalogue No. 63766.

The specimens represented by figs. 5, 5*a* are from the siliceous shales of (Locality **63j**) Middle Cambrian: Ptarmigan formation (Ross Lake shale); above Ross Lake, British Columbia.

Zacanthoides ? cimon Walcott.. 41

FIG. 6. (× 3.) Cranidium preserved in limestone. U. S. National Museum, Catalogue No. 63767.

6*a*. (× 3.) Fragment of an associated pygidium. U. S. National Museum, Catalogue No. 63768.

From locality **63b**, Middle Cambrian: Ptarmigan formation; Ptarmigan Peak, Alberta.

Vanuxemella nortia Walcott.. 37

FIG. 7. (× 2.) A nearly entire dorsal shield somewhat crushed in the shale. The type specimen. U. S. National Museum, Catalogue No. 61728. After Walcott, Smithsonian Misc. Coll., Vol. 64, pl. 36, fig. 5.

The specimen represented is from locality **35c**, Middle Cambrian: Ptarmigan formation (Ross Lake shale); Mount Bosworth, British Columbia.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 3

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 3.—FAUNA OF THE MOUNT WHYTE FORMATION

(With Plates 8 to 13)

BY
CHARLES D. WALCOTT

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 3.—FAUNA OF THE MOUNT WHYTE FORMATION

By CHARLES D. WALCOTT

(With Plates 8 to 13)

CONTENTS

ILLUSTRATIONS

Plates

INTRODUCTION

The name Mount Whyte formation was proposed in 1908[1] for a series of alternating bands of limestone and siliceous and calcareous shale found on the north slope of Mount Whyte with a total thickness of 386 feet (117.7 m.); on the south slope of Mount Bosworth 390 feet (118.9 m.); on the north slope of Mount Stephen above railroad tunnel 315 feet (96 m.), and on the southeast slope of Castle Mountain 248 feet (75.5 m.). The Mount Whyte and the Castle Mountain sections are on the eastern slope of the Continental Divide in Alberta, and the Mount Bosworth and Mount Stephen sections on the western slope in British Columbia, Canada.

The included fauna was referred to as of Lower Cambrian age and with it by inference a fauna of undetermined stratigraphic position,[2] now known as the *Albertella* fauna of the Middle Cambrian.

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[1] Smithsonian Misc. Coll., Vol. 53, 1908, p. 4.

[2] For explanation of this reference see Smithsonian Misc. Coll., Vol. 67, pp. 9-12.

In 1914 Mr. L. D. Burling concluded after a thorough and admirable study that on paleontological evidence the *Albertella* fauna was of Middle Cambrian age and that the specimens of *Olenellus* found in the Mount Whyte formation were examples of recurrence.[1] On the basis of this conclusion Burling placed the Mount Whyte formation in the Middle Cambrian.

The discovery that the *Albertella* fauna occurs at an horizon 500 feet (152.4 m.) above the Mount Whyte formation materially affects this conclusion.[2]

Several stratigraphic sections that include the Mount Whyte formation have been published [3] and others will be after the conclusion of field work in 1917. The presentation and discussion of all sections studied will be given in a future paper on the stratigraphy of the formation.

STRATIGRAPHIC POSITION OF THE FAUNA

All of the stratigraphic sections in their upper portion have varying thicknesses of calcareo-arenaceous beds and bands of oolitic limestone. In the upper layers of limestone there is usually a well-marked fauna and at this horizon in three sections, at Mount Assiniboine, Ptarmigan Peak, and Mount Stephen, the fauna includes a representation of the genus *Crepicephalus,* which attains its greatest development in the Middle and Upper Cambrian of America, where 16 species or more are known, the greater proportion being in the Upper Cambrian.[4] The central portions of the sections include siliceous shales and finely arenaceous beds and relatively few fossils, while the beds toward the base are usually thin-bedded, more or less slightly calcareous sandstones, and contain a characteristic Lower Cambrian fauna with abundant fragments of both *Olenellus* and *Mesonacis,* and without traces of forms usually considered characteristic of the Middle Cambrian fauna.

The fauna of the upper oolitic limestone in the Mount Stephen section at locality **58k,** about 5 feet (1.5 m.) below the top of the Lower Cambrian in thin-bedded bluish-black and gray limestone (3 feet) forming 1 of Mount Whyte formation, and the interbedded limestone at the top of 2, Mount Stephen section; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, includes:

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[1] Canadian Geol. Surv., Museum Bull., No. 2, Geol. Ser., No. 17, 1914, p. 36.

[2] Smithsonian Misc. Coll., Vol. 67, 1917, pp. 12-18.

[3] Idem, Vol. 53, 1908, pp. 212-215.
Canadian Alpine Journal, Vol. 1, No. 2, 1908, pp. 240-242.
Smithsonian Misc. Coll., Vol. 67, 1917, pp. 15, 16.

[4] Idem, Vol. 64, 1916, pp. 203-204.

Acrotreta sagittalis taconica (Walcott)
Helcionella elongata Walcott
Scenella varians Walcott
Parmophorella sp.
Hyolithes billingsi Walcott
Ptychoparia clusia Walcott
Ptychoparia thia Walcott
Ptychoparia (pygidia)
Olenopsis agnesensis Walcott
Crepicephalus celer Walcott
Bathyuriscus (*Poliella*) *primus* Walcott

In the Ptarmigan Peak section the upper oolitic limestone at locality **63a**, east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise station on the Canadian Pacific Railway, Alberta, includes:

Nisusia (*Jamesella*) *lowi* Walcott
Wimanella catulus Walcott
Hyolithes billingsi Walcott
Ptychoparia ? cercops Walcott
Crepicephalus cecinna Walcott

At the Gog Lake section, locality **62w**, No. 1 of section; oolitic limestone; about 400 feet (123 m.) below summit of ridge above Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, the fauna has several species that occur at localities **58k**, **63a** above,[1] and **61d** (Footnote, p. 64), and includes:

Archæocyathus (*A.*) *atreus* Walcott
Kutorgina cf. *cingulata* Billings
Micromitra (*Paterina*) *labradorica* (Billings)
Nisusia (*Jamesella*) *lowi* Walcott
Acrotreta sagittalis taconica (Walcott)
Helcionella elongata Walcott
Scenella varians Walcott
Hyolithellus ? sp. undt.
Hyolithes billingsi Walcott
Crepicephalus cecinna Walcott
Ptychoparia cf. *gogensis* Walcott
Ptychoparia skapta Walcott
Ptychoparia thia Walcott
Olenopsis cleora Walcott
Dorypyge damia Walcott

The fauna listed from the three localities gives a general conception of the fauna associated with *Crepicephalus* in the upper portion of the formation. Its relations now appear to be more with the

[1] It must be recalled that all collections were obtained as incidental to stratigraphic work and are necessarily a very imperfect representation of the entire fauna at each locality and horizon; future thorough collections should yield much additional data.

Mount Whyte than with the Ptarmigan fauna, but further field work may change this view.[1]

The fauna of the central and lower portions of the formation is given in the following table of genera and species:

Genera and species	Position in formation		
	Lower	Middle	Upper
Archæocyathus (*A.*) *atreus* Walcott	..	..	×
Gogia prolifica Walcott	..	×	..
Micromitra (*Paterina*) *charon* Walcott	..	×	..
Micromitra (*Paterina*) *labradorica* (Billings)	..	..	×
Micromitra (*Iphidella*) *pannula* (White)	..	×	×
Kutorgina cf. *cingulata* Billings	..	..	×
Obolus damo Walcott	..	×	..
Acrotreta sagittalis taconica (Walcott)	..	×	×
Acrothele clitus Walcott	..	×	..
Nisusia (*Jamesella*) *lowi* Walcott	..	×	×
Nisusia festinata (Billings)	×	..	..
Wimanella catulus Walcott	..	..	×
Helcionella elongata Walcott	..	×	×
Hyolithes billingsi Walcott	×	×	×
Hyolithes cf. *carinatus* Matthew	..	×	..
Hyolithes sp. undt.	×	..	..
Hyolithellus cf. *micans* Billings	×	×	..
Hyolithellus sp. undt.	..	..	×
Pelagiella sp. undt. (a)	..	..	×
Pelagiella sp.	..	..	×
Parmophorella sp.	..	..	×
Scenella varians Walcott	×	×	×
Shafferia cisina Walcott	..	..	×
Bradoria (large species)	..	×	..
Hymenocaris sp. undt.	..	×	..
Aluta (small species)	..	×	..
Agraulos charops Walcott	×	..	..

[1] Almost at the top of the oolitic limestone in the Mount Shaffer section at locality **61d**, southwest slope of Mount Shaffer on Canyon side, on trail to Lake McArthur, 5.5 miles (8.8 km.) south of Hector Station, on Canadian Pacific Railroad, British Columbia, the fauna is Lower Cambrian in character and includes:

Micromitra (*Paterina*) *labradorica* (Billings)
Micromitra (*Iphidella*) *pannula* (White)
Acrotreta sagittalis taconica (Walcott)
Nisusia (*Jamesella*) *lowi* Walcott
Scenella varians Walcott
Pelagiella sp. undt. (a)
Shafferia cisina Walcott
Corynexochus senectus (Billings)
Agraulos ? unca Walcott
Zacanthoides
Ptychoparia lux Walcott
Ptychoparia sp. undt.
Mesonacis gilberti (Meek)

Genera and species	Position in formation		
	Lower	Middle	Upper
Agraulos ? unca Walcott	..	..	×
Olenopsis agnesensis Walcott	..	×	×
Olenopsis cleora Walcott	..	×	×
Olenopsis crito Walcott	×	..	..
Olenopsis leuka Walcott	..	×	..
Ptychoparia adina Walcott	..	×	..
Ptychoparia carina Walcott	..	×	..
Ptychoparia cf. *carina* Walcott	..	×	..
Ptychoparia ? cercops Walcott	..	×	×
Ptychoparia ? cleadas Walcott	×	×	..
Ptychoparia cleon Walcott	×	..	..
Ptychoparia clusia Walcott	..	..	×
Ptychoparia cossus Walcott	..	..	×
Ptychoparia cuneas Walcott	×	..	..
Ptychoparia cf. *cuneas* Walcott	..	×	..
Ptychoparia gogensis Walcott	..	..	×
Ptychoparia lux Walcott	..	..	×
Ptychoparia perola Walcott	..	×	..
Ptychoparia pia Walcott	×	×	..
Ptychoparia cf. *pia* Walcott	..	×	..
Ptychoparia skapta Walcott	..	..	×
Ptychoparia thia Walcott	×	×	×
Ptychoparia sp. undt	..	..	×
Crepicephalus cecinna Walcott	..	..	×
Crepicephalus celer Walcott	..	..	×
Dorypyge damia Walcott	..	..	×
Corynexochus senectus (Billings)	..	×	×
Corynexochus (Bonnia) fieldensis Walcott	×	×	..
Mesonacis gilberti (Meek)	×	×	×
Olenellus canadensis Walcott	×	×	×
Olenellus sp. undt	..	..	×
Bathyuriscus (Poliella) primus Walcott	..	×	×
Bathyuriscus sp. undt	..	×	..

NOTES ON THE FAUNA

One of the striking features of the 28 genera and 60 species of the Mount Whyte fauna is the presence of several species common to it and to the Lower Cambrian fauna of Newfoundland and the Champlain Valley of Vermont. In order to make this clear I have illustrated on plate 10, *Corynexochus* (*Bonnia*) *parvulus* (Billings) from the Atlantic Province (figs. 1, 1*a*-*c*) and beside it *C.* (*B.*)

fieldensis (Walcott) (figs. 2, *2a-c*) from British Columbia; and on plate 9, *Corynexochus senectus* (Billings) from the Atlantic Province (figs. 1, 1*a-d*) and beside it specimens considered identical from British Columbia (figs. 2, 2*a-c*). *Mesonacis vermontana* (Hall) (fig. 3) from the Atlantic Province is the representative of *Mesonacis gilberti* (Meek) (fig. 4) from British Columbia. All of these species have about the same range of individual variation both in the Atlantic Province and British Columbia.[1]

Other species common to the Atlantic Province Lower Cambrian fauna and the Mount Whyte fauna are *Micromitra* (*Paterina*) *labradorica* (Billings), *Kutorgina* cf. *cingulata* (Billings), *Acrotreta sagittalis taconica* (Walcott), and *Nisusia festinata* (Billings).

There are several species of *Ptychoparia* from Lower Cambrian formations elsewhere that are very closely related to species from the Mount Whyte formation. These are now illustrated on plates 11 and 12, for the Mount Whyte species, and on plates 14 and 15,[2] for the species of other formations. *Ptychoparia cuneas* and *P. cossus* (pl. 11) may be compared with *P. crates* and *P. crantos* (pl. 15) from Bic Harbor on the Lower St. Lawrence River, *P. skapta* (pl. 12, fig. 9) and *P. deldon* (pl. 15, fig. 2), *P. thia* (pl. 12, fig. 6) and *P. adamsi* (pl. 14, fig. 8*a*). With larger collections the allied species from the two sides of the continent would undoubtedly be much increased in number.

The presence of such a strong connecting series of forms at such widely separated localities and so far north on the continent indicates a northern origin of the later phases of the Lower Cambrian or *Olenellus* fauna.

The trilobites, other than the Mesonacidæ, indicate the rapid approach of the large series of genera and species that mark the Middle Cambrian fauna of North America. The Conocoryphidæ is represented by forms that range throughout the Cambrian although their range of variation may be sufficient to justify applying specific names to the varieties from the Lower, Middle and Upper Cambrian. *Ptychoparia pia* (pl. 12, fig. 8) is an illustration, also *P. ? cleadas* (pl. 12, fig. 2).

[1] Comparisons of the eastern and western forms of *Corynexochus senectus* may be found in observations on the species made by me in 1916. Smithsonian Misc. Coll., Vol. 64, 1916, pp. 321-322.

[2] Plates 14 and 15 will accompany a paper on certain Lower Cambrian genera and species of trilobites which will be issued as Number 4 of this volume on Cambrian Geology and Paleontology.

The generic relations of the Mount Whyte fauna to the superjacent Ptarmigan formation *Albertella* fauna is close despite the 500 feet (152.4 m.) of barren strata between the two faunas. Of the 28 genera of the Mount Whyte fauna 13 are represented in the *Albertella* fauna, and of the genera not present in the *Albertella* fauna 3 occur above it in the Stephen formation. More complete collections will undoubtedly increase the number of genera common to the two and at the same time may increase the number that are restricted to the Mount Whyte fauna.

Acknowledgments.—The drafts of the descriptions of species of *Ptychoparia* for this and other papers to follow were drawn up by Dr. Julia Gardner, who studied the material with great care.

The profiles used in illustration are by Miss Frances Wieser, and where it was necessary to have the photographs retouched in order to bring out characters not readily photographed the work has been done by her.

DESCRIPTION OF GENERA AND SPECIES

ARCHÆOCYATHUS (ARCHÆOCYATHELLUS) ATREUS, new species

Plate 8, figs. 2, 2*a*

This species is represented by two examples that are illustrated by figures 2, 2*a*. The specimen represented by figure 2 varies in diameter from 2.2 mm. to 1.4 mm., and has a total length of 14 mm. A cross section shows a thick outer wall (fig. 2′) but no structural detail, as the calcite forming it is in a crystalline condition except in one place of the section where there is a trace of what may have been two septa. On the exterior surface in addition to the swelling of the wall there are concentric growth lines and slight depressions; no cells have been observed.

The nearest related species as indicated by exterior form is *A.* (*A.*) *dwighti* Walcott[1] from the Lower Cambrian of eastern New York. Both are small undulating forms, but unfortunately no further comparison can be made as we do not know the structure of the wall of *A.* (*A.*) *atreus.*

Formation and locality.—Lower Cambrian: (**62w**) Mount Whyte formation; oolitic limestone, about 400 feet (123 m.) below summit of ridge above Gog Lake, below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

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[1] Tenth Ann. Rept. U. S. Geol. Survey, 1891, pl. 54, figs. 4, 4*a*.

Family Eocystidæ Bather

Eocystidæ Bather, 1900, Treatise on Zoölogy, Lankester, Pt. 3, p. 48.

GOGIA, new genus

All that is known of *Gogia* is included in the description of the genotype, *Gogia prolifica*. The form of the calyx and the character of the plates distinguish it from *Eocystites* as represented by the single plate described by Billings or by the species *E. ? ? longidactylus* Walcott,[1] which is the only described species sufficiently well preserved to indicate what *Eocystites* may possibly include.

Genotype.—Gogia prolifica Walcott.

Stratigraphic range.—As far as known *Gogia* is confined to a massive band of calcareo-arenaceous shales 250 feet (76 m.) below the oolitic limestone at the summit of the Mount Whyte formation of the Lower Cambrian.

Geographic distribution.—As far as known, it is confined to the vicinity of Wonder Pass southwest of Banff, Alberta.

GOGIA PROLIFICA, new species

Plate 8, figs. 1, 1*a-b*

Calyx.—Form: As seen flattened on the shale the outline is that of a narrow isosceles triangle pointing downward. The stem is attached to the apex of the triangle as inverted. A calyx 27 mm. in length has a width across the top of 12 mm. The largest specimen has a length of 30 mm. The plates of the calyx are polygonal, varying in size and form. The outer surface of the plates appears to have been roughened and the inner surface to have had a groove running from the central depressed area out to each angle on the margin of the plate; the casts of these grooves are shown by figure 1*a*. The exterior of the plates is known only from the casts in the shale as the plates have usually been removed by solution of the calcite forming them.

The arms (eight on one specimen) are long, very slender, and formed of numerous plates in a biserial arrangement and with a narrow ambulacral furrow on the inner side.

The stem is slender, tapering gradually and formed of numerous elongate and round, thick, tumid plates varying in size. The elongate plates form the upper part of the stem to where it joins the calyx, and the round plates the lower portion out to near the end where a group of minute round plates occur. The round plates appear to have been smooth, and the oval elongate plates tuberculated.

[1] Bull. U. S. Geol. Surv., No. 30, 1886, p. 94.

Observations.—This genus and species differ from described forms by the shape of the calyx and plates. The elongate arms and stem resemble the arms and stem of *Eocystites ? ? longidactylus* Walcott,[1] but they differ in details.

So far as known to me, this is the oldest cystidian of this type. It occurs at an horizon 1,000 feet (304.8 m.) or more below the zone of *Eocystites ?? longidactylus.*

Formation and locality.—Lower Cambrian: (**62x**) Mount Whyte formation; Silici-calcareous shale, on ridge above Gog Lake, below Wonder Pass, on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

MICROMITRA (PATERINA) CHARON, new species

Plate 10, figs. 3, 3*a-b*

Some specimens of this species were confused with *M.* (*P.*) *wapta* Walcott [2] when collected in the field. It differs from the latter in form and in having a finely reticulated surface. It is more closely related to *M.* (*I.*) *pannula,*[3] but it differs in having a much more finely reticulated surface and in the more elongate outline of the valves when they are undistorted (see figs. 1, 1*b*).[3] The largest valve observed has a length of 8 mm.

This shell is abundant on Mount Odaray at the type locality.

Formation and locality.—Lower Cambrian: (**61c**) Mount Whyte formation; dark siliceous shale, east slope of southeast ridge of Mount Odaray, 7.5 miles (12 km.) south of Hector, on the Canadian Pacific Railway, British Columbia, Canada.

OBOLUS DAMO, new species

Plate 10, figs. 6, 6*a*

This little shell is related to *Obolus smithi* from the Lower Cambrian Montevallo shales of Alabama,[4] from which it differs in its more circular outline. It also differs in the same manner from another Lower Cambrian species, *O. prindlei*[5] from the *Olenellus*-bearing limestone of eastern New York.

The shells occur in a fine-grained, hard shaly arenaceous rock in which very little of the original shell is preserved. The interior cast

[1] Bull. U. S. Geol. Survey, No. 30, 1886, p. 94, pl. 6, figs. 1, 1*a-c*. Pack: Journ. Geol., Chicago, Vol. 14, 1906, p. 3, pl. 1, figs. 1, 1*a*.

[2] Monogr. U. S. Geol. Survey, No. 51, 1912, p. 357.

[3] Idem, p. 361, pl. 4.

[4] Idem, p. 416.

[5] Idem, p. 409, pl. 27, figs. 3, 3*a-e*.

of a ventral valve shows a broad visceral area of the type of that in *Obolus apollinis* Eichwald.[1]

Formation and locality.—Lower Cambrian: (63g) Mount Whyte formation; greenish arenaceous shale, southwest slope of Mount Temple, about 600 feet (184.6 m.) above base of Pinnacle Pass, and 1500 feet (461.5 m.) above upper portion of Paradise Valley, and south of Lake Louise, Alberta, Canada.

ACROTHELE CLITUS, new species

Plate 10, figs. 4, 4*a-c*

This species differs from *Acrothele colleni* of the Ross Lake shale of the Ptarmigan formation, with which I had identified it in my field notes of 1908,[2] in having a uniformly smaller size and in the presence in the dorsal valve of a very long and strong median ridge, in this respect resembling *Acrothele bellula* of the Middle Cambrian of Alabama.[3]

The largest specimens in the collection have a diameter of 4 mm. and are very much flattened in the fine siliceous shale. The outer surface is marked by concentric striæ and lines of growth and a few fine radiating lines.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (35e) Lake Agnes shale, amphitheater between Popes Peak and Mount Whyte, southwest of Lake Agnes and 3 miles (4.8 km.) west-southwest of Lake Louise station, on the Canadian Pacific Railroad, in western Alberta; also (57e) Mount Stephen section; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

WIMANELLA CATULUS, new species

Plate 10, figs. 5, 5*a-c*

This is a more elongate form than *Wimanella simplex* Walcott of the Ptarmigan formation when specimens preserved in a similar matrix are compared. This is best shown by examining figure 8,[4] which illustrates a specimen of *W. simplex* from the limestone of the Ptarmigan formation, and figures 5, 5*b*, plate 10, illustrating *W. catulus* in this paper. Several of the specimens from the two limestones have the same outline, but in such instances the convexity of

[1] Monogr. U. S. Geol. Survey, Vol. 51, 1912, pl. 7, figs. 1-6.

[2] Smithsonian Misc. Coll., Vol. 53, p. 214, 3 of section.

[3] U. S. Geol. Survey, Monogr. No. 51, 1912, pl. 58, figs. 5*f*, 5*h*.

[4] Smithsonian Misc. Coll., Vol. 67, 1917, pl. 4.

the specimens is quite different. Thus figure 5, plate 10 (this paper) is a strongly convex ventral valve and yet in outline it is much like the dorsal[1] valve represented by figure 8*a*, plate 4 (Vol. 67, No. 2, Smithsonian Misc. Coll.).

The two species are closely related although there is about 500 feet (152.4 m.) of limestone between their respective positions in the section.

Of the known species of *Wimanella* three occur in strata referred to the Lower Cambrian and four to the Middle Cambrian.

Formation and locality.—Lower Cambrian: (**63a**) Mount Whyte formation; oolitic limestone about 130 feet (40 m.) above arenaceous shaly beds; east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise station on the Canadian Pacific Railway, Alberta, Canada.

SHAFFERIA, new genus

The species on which this genus is based does not appear to fall under any described genus. It has a carapace that suggests that of *Burgessia*,[2] but it has a thick, strong, and ornamented carapace, while that of *Burgessia* is smooth and very delicate. It may be that I misinterpret the species and that it is one of the Discinocarina and the notch is anterior and not posterior in position. The thick test and deep notch certainly suggest its belonging with the Discinocarina.

All that is known of the genus is given under the description of the type species.

Genotype.—*Shafferia cisina* Walcott.

Stratigraphic range.—This is limited to a thin layer of limestone near the summit of the Mount Whyte formation.

Geographic distribution.—Southwest slope of Mount Shaffer on trail to Lake McArthur, British Columbia, Canada.

The generic name is derived from Shaffer, the name of the mountain from which *Shafferia cisina* was collected.

SHAFFERIA CISINA, new species

Plate 11, figs. 8, 8*a*

Of this species only a single carapace is known. This is bent over along the median line and strongly notched posteriorly. The general form is shown by figure 8 and a side view by figure 8*a*. The test is

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[1] By misprint named ventral valve.

[2] Smithsonian Misc. Coll., Vol. 57, 1912, p. 177, pl. 27, figs. 1, 3.

rather thick and marked by flat, irregular ridges that are subparallel to the outer margin and almost transverse across the central portion.

The carapace is 3 mm. in length along the medial line and about 5 mm. in width.

Formation and locality.—Lower Cambrian: (**61d**) Mount Whyte formation; oolitic limestone, southwest slope of Mount Shaffer on Canyon side, on trail to Lake McArthur, 5.5 miles (8.8 km.) south of Hector Station, on Canadian Pacific Railroad, British Columbia, Canada.

AGRAULOS CHAROPS, new species

Plate 13, figs. 2, *2a*

Species known from an imperfect cranidium.

Cephalon.—Cranidium small, evenly convex. Glabella a little more than two-thirds the length of the cranidium, rather strongly elevated along the medial line which is highest near the occipital ring and slopes very gradually from the ring to the anterior extremity; dorsal furrows linear, distinct, gradually converging to the broadly rounded anterior extremity which is about three-fourths as wide as the base; anterior furrow narrow and shallow; glabellar furrows very obscure; occipital groove rather broad, a little broader and more shallow medially than laterally; occipital ring narrow laterally, slightly expanded medially. Fixed cheeks low, wide and gently convex, the distance from the palpebral lobe to the dorsal furrow almost as great as the width of the glabella; postero-lateral lobe imperfectly preserved; posterior groove narrow and quite deep at the axial termination opposite the occipital ring, neither so narrow nor so deep away from the axis, and cutting off an increasingly wider posterior margin. Palpebral lobe small and inconspicuous, medial in position with respect to the glabella exclusive of the occipital ring. Palpebral ridge indicated only by the obtuse angulation of the cheek. Frontal limb and border not clearly differentiated, the two together forming a gently inclined frontal margin of approximately the same width as the fixed cheek, exclusive of the postero-lateral lobe. Facial sutures imperfectly preserved, the anterior section of the suture merging smoothly into the anterior extremity.

Surface.—Exterior surface minutely shagreened.

Dimensions.—Length of cranidium, 4.3 mm.; length of glabella, 3.0 mm.; width of glabella in front, 1.5 mm.; width of glabella at base, 2.1 mm.

Type locality.—(**35f**) Mount Stephen.

Observations.—This species is unlike *A.* (*?*) *unca* (fig. 1, pl. 13) and *A. stator* (Smithsonian Misc. Coll., Vol. 67, 1917, pl. 6, fig. 6) or any other species from the Lower Cambrian terrane.

Formation and locality.—Lower Cambrian: (**35f**) Mount Whyte formation; about 300 feet (95 m.) below the top of the Lower Cambrian in bluish-black and gray limestone (18 feet=5.5 m.), forming 6 of Mount Whyte formation; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

AGRAULOS (?) UNCA, new species

Plate 13, figs. 1, 1*a*

Species known from cranidia.

Cephalon.—Cranidium very simple in outline, broadly and evenly rounded in front with two deltoid flanges at the base. Glabella three-quarters or more as long as the cranidium, subcylindrical, arcuate anteriorly; dorsal furrows linear, very faintly impressed, roughly parallel; glabellar furrows obsolete; occipital groove relatively broad but very shallow, uniform in depth between the dorsal furrows; occipital ring moderately broad, expanded medially, not nodose. Fixed cheeks and frontal limb and border not differentiated, together forming a rather broad and evenly declining brim around the glabella. Fixed cheeks rather narrow, the distance from the palpebral lobe to the dorsal furrow a little more than half the width of the medial portion of the glabella; postero-lateral lobe short and wide, obtusely cuneate at the distal extremity. Palpebral lobe very inconspicuous, defined merely by the outward arching in the facial sutures, very short and slightly anterior with respect to the glabella. Palpebral ridge faintly developed and not observable on most specimens. Frontal limb and border about one-third the length of the glabella, gently and evenly sloping, somewhat thickened toward the periphery. Facial sutures obtusely V-shaped, the anterior section feebly arcuate. Free cheeks not preserved.

Surface.—Exterior surface shagreened but not granulated.

Dimensions.—Length of cranidium, 2.5 mm.; width of cranidium at base, 3.0 mm.; length of glabella, 1.5 mm.; width of glabella in front, 1.9 mm.; width of glabella at base, 2.0 mm.

Type locality.—(**61d**) Mount Shaffer, British Columbia.

Observations.—*Agraulos ? unca* is exceedingly abundant at the type locality, but has been rarely observed elsewhere. The first comparison suggested is with *Ptychoparia thia.* It is a smoothed out, rounded form, differing in the practical absence of glabellar furrows and palpebral ridges and in slight variations of the frontal limb and border. The two species are associated at locality 35f. The generic reference is doubtful, but with only the cranidia for study nothing better seems possible.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (61d) southwest slope of Mount Shaffer on Canyon side, on trail to Lake McArthur, 5.5 miles (8.8 km.) south of Hector Station, on Canadian Pacific Railroad; and (35f) Mount Stephen section; about 300 feet (93.8 m.) below the top of the Lower Cambrian in bluish-black and gray limestone, just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, both in British Columbia, Canada.

OLENOPSIS CLEORA, new species

Plate 13, figs. 3, 3*a*

Species known from imperfect cranidia.

Cranidium.—Cranidium elongate. Glabella only about three-fifths as long as the cranidium, rather strong, elevated along a low but sub-acute ridge which becomes obsolete at some little distance behind the anterior extremity; dorsal furrows quite broad and not very deeply impressed, gradually converging so that the width at the truncate anterior extremity is only about two-thirds of that at the base; glabellar furrows broad and shallow, obsolete upon the crest of the glabella, the posterior and medial pairs oblique, the anterior pair reduced to a couple of obscure lateral pits; occipital furrow broad and shallow, deepening a little toward the dorsal furrows; occipital ring low, flattened, moderately wide and carrying a small medial node. Fixed cheeks low and broad, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe imperfectly preserved, narrow and probably petaloid at its extremity; posterior furrow very shallow, in line with the occipital ring. Palpebral lobe moderately elevated, about one-third as long as the glabella, asymmetrically arcuate, sub-medial in position with respect to the glabella. Palpebral ridge narrow, cordate, cutting somewhat obliquely across the fixed cheeks and intercepting the dorsal furrows at the origin of the anterior glabellar furrows. Frontal limb and border not sharply differentiated, the profile in front of the glabella gently concave. Frontal limb narrow, evenly declining medially, slightly convex laterally, cut off from the border by a shallow, ill-defined groove. Frontal border very wide, expanded medially, and broadly concave. Outline of facial sutures and fixed cheeks not well preserved; anterior portion of facial suture apparently quite strongly arched.

Surface.—Exterior surface shagreened with an exceedingly fine and close granulation.

Dimensions.—Length of cranidium, 16.0 mm.; length of glabella, 9.4 mm.; width of glabella in front, 4.6 mm.; width of glabella at base, 7.6 mm.

Type locality.—(**62w**) Above Gog Lake, Wonder Pass.

Observations.—There is a single pleural lobe of a thoracic segment associated with the cranidia which may perhaps be referable to this species. The segment is slender, not very deeply furrowed, and bent backward at an obtuse angle about halfway between the proximal and distal extremities.

The cranidium of this species recalls that of *Olenopsis zoppi* by its broad frontal border, narrow frontal limb, elongate glabella and strong palpebral ridge. It is quite distinct from any associated form or forms from the same geological formation. It differs from *O. ? agnesensis*[1] in shorter frontal limb and broad frontal border (see figs. 5, 5*a*, pl. 13).

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**62w**) oolitic limestone, about 400 feet (123 m.) below summit of ridge above Gog Lake, below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff; (**57s**) about 160 feet (49 m.) below the Middle Cambrian, in gray oolitic limestone, on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen; and (**63i**) thin layer of sandstone; between two eastern gullies on southern slope of Mount Bosworth, at about 6000-foot contour; 1 mile (1.6 km.) west-northwest of Stephen on the Canadian Pacific Railway, British Columbia.

OLENOPSIS CRITO, new species

Plate 11, figs. 6, 6*a-b*

Species known from detached portions of the cephalon.

Cephalon.—Cranidium large, and moderately convex. Glabella three-fifths as long as the cranidium, slender, subconical in outline, elevated along a rather prominent medial ridge which persists almost to the anterior extremity; dorsal furrows shallow but distinct, rounding sharply into the more shallow anterior furrow; anterior

[1] Smithsonian Misc. Coll., Vol. 57, 1912, p. 242, pl. 36, fig. 2.

extremity broadly rounded and half as wide as the base; posterior and medial pairs of glabellar furrows broad, deeply impressed, subequal and parallel to one another, extending obliquely backward and disappearing abruptly a little more than halfway up the lateral slope; third pair linear, transverse, shorter and much more shallow than those behind it; and an anterior pair indicated by slight indentations close to the dorsal furrow; occipital groove very shallow medially, similar in character laterally to the posterior glabellar furrows; occipital ring slightly expanded medially and apparently bearing near the posterior margin a very inconspicuous medial node. Fixed cheeks low, flattened, and very wide, the distance from the palpebral lobe to the dorsal furrow almost as great as the width of the medial portion of the glabella; postero-lateral lobe slender and elongate, probably acutely angulated at its distal extremity. Palpebral lobe imperfectly preserved, crescentic, approximately one-third the length of the glabella, the posterior end of the lobe on a line with the base of the posterior glabellar furrows. Palpebral ridge obscure, narrow, cordate, arching obliquely across the cheek and intercepting the dorsal furrows directly in front of the third pair of glabellar furrows. Frontal limb wide, very gently declining in front of the glabella, but rather steeply in front of the palpebral ridge. Frontal border also wide and gently concave, delimited from the limb by a low cord-like ridge. Facial sutures imperfectly preserved, posterior section extended outward at from 10° or 15° off the transverse line; anterior section also oblique and gently convex. Associated free cheek rather broad; inner portion of about the same width as the border, arching gently away from the palpebral lobe; border very wide, not conspicuously differentiated, produced posteriorly into moderately long, acutely tapering genal spines.

Surface.—Character of exterior surface not preserved.

Dimensions.—Length of a large cranidium, 25.0 mm.; length of glabella, 15.0 mm.; width of glabella in front, 6.6 mm.; width of glabella at base, 13.0 mm.

Type locality.—(60e) Ptarmigan Pass.

Observations.—This is the largest species of the genus *Olenopsis* from the Mount Whyte formation. It compares in size with *O. americanus* of the Gordon shale,[1] but it differs from that species in the character of the frontal limb and border and elongate postero-lateral limb of the cranidium. It occurs about 700 feet (213 m.) lower in

[1] See Smithsonian Misc. Coll., Vol. 67, 1917, p. 37, pl. 6, figs. 8, 8*a*-*b*.

the section than *O. americanus*. *O. crito* is unlike either *O. ? agnesensis*, *O. cleora*, or *O. leuka*, of the Mount Whye formation.

Formation and locality.—Lower Cambrian: (**60e**) Mount Whyte formation; about 75 feet (22.8 m.) from the base of the formation; Ptarmigan Lake Pass at head of Corral Creek, 6 miles (9.6 km.) northeast of Laggan, Alberta, Canada.

OLENOPSIS LEUKA, new species

Plate 13, fig. 4

Species known from imperfect cranidia.

Cranidium.—Glabella approximately two-thirds the length of the cranidium, trapezoidal in outline, broadly convex; anterior extremity broadly rounded and almost three-fourths the width of the base; dorsal furrows linear, deeply impressed, evenly converging; glabellar furrows almost obsolete, owing probably to the absence of the outer test; traces of the posterior and medial pairs preserved in some individuals in the form of lateral pits, just within the dorsal furrows, the posterior pair somewhat elongated oblique to the axis; occipital groove rather narrow, partially dissecting the crest of the glabella and deepening toward the dorsal furrows; occipital ring of an elevation similar to that of the glabella, expanded medially; the median node if originally present has been destroyed. Fixed cheeks plump and wide, the distance from the palpebral lobe to the dorsal furrow approximately equal to the width of the medial portion of the glabella; postero-lateral lobe imperfectly preserved, rather narrow, moderately extended, obtusely tapering at the distal extremity; posterior groove quite deep, broadening away from the axis and cutting off an increasingly wider posterior margin. Palpebral lobe also imperfectly preserved but apparently low, short and submedial with respect to the glabella. Palpebral ridge obscure. Frontal limb narrow, flattened medially, merging into the fixed cheeks laterally. Frontal border defined by a shallow groove, thickened, upturned, and slightly expanded medially so that the width in front of the glabella is greater than that of the limb. Free cheeks unknown but probably narrow and produced posteriorly into slender spines. Other characters not preserved.

Surface.—Exterior surface unknown owing to the character of the matrix, a fine and very tough quartzitic sandstone.

Dimensions.—Length of cranidium, 7.5 mm.; length of glabella, 4.8 mm.; width of glabella in front, 2.3 mm.; width of glabella at base, 3.0 mm.

Type locality.—(**58g**) Mount Bosworth.

Observations.—The groove which separates the frontal limb from the border is obsolete medially, and the rim often has the appearance of being slightly produced posteriorly directly opposite the glabella. This character recalls *P. lux,* a smaller species with a more slender glabella, quite sharply rounded at the anterior extremity. The obscurity of the glabellar furrows is probably due in large measure to the character of the matrix, a rather firm quartzitic sandstone.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**58g**) about 200 feet (60 m.) below the top of the *Olenellus* zone in sandstones and shales, a few yards north of the Canadian Pacific Railroad track, midway between Stephen and Hector, on south slope of Mount Bosworth, British Columbia, Canada.

PTYCHOPARIA ADINA, new species

Plate 12, figs. 3, *3a-b*

Species known from the cranidia and associated free cheeks, pygidia and disjointed thoracic segments.

Cephalon.—Cranidium small and approximately twice as broad at the base as it is long. Glabella quite strongly elevated along an obtuse median ridge, about three-quarters of the length of the cranidium, elongate-trapezoidal in outline, the squarely truncate anterior extremity only a little more than two-thirds as wide as the base; dorsal furrows linear, deeply impressed, evenly converging; anterior furrow not quite so deep as the lateral furrows; glabellar furrows very obscure, in most individuals practically obsolete, indicated in others by very feeble depressions toward the dorsal furrows, the posterior pair oblique, the medial and anterior pairs at right angles to the axis of the shield; occipital furrow moderately broad and quite deep, especially toward the dorsal furrows; occipital ring rather broad, expanded medially and bearing, midway between the margins, a small node. Fixed cheeks rising obliquely from the dorsal furrows, moderately wide, the distance from the palpebral lobe to the dorsal furrow approximately half the width of the medial portion of the glabella; postero-lateral lobe rather wide, extended laterally and obtusely angulated at the distal extremity; posterior furrow deeply channeled, cutting off an increasingly wider posterior margin away from the axis. Palpebral lobe not greatly elevated, rather short, contained a little less than three times in the length of the glabella, quite strongly crescentic, slightly anterior in position. Palpebral ridge obscure, somewhat oblique to the axis, intercepting the dorsal furrows a little behind the anterior extremity. Frontal limb of moderate width, moderately convex. Frontal border cut off from the limb by a shallow linear groove, not so wide as the limb, flattened but not thickened. Facial sutures imperfectly preserved, apparently a rather symmetric W, the posterior section oblique, the base convex, the anterior section broadly arcuate. The associated free cheeks moderately wide, rather plump, the peripheral margin a flattened band cut off from the rest of the cheek by an ill-defined groove; outer margin abruptly constricted posteriorly and produced into very slender acutely tapering genal spines.

Thorax.—Thoracic segments rather narrow, deeply sulcated medially, slender and acutely falcate at their distal extremities.

Pygidium.—Associated pygidium comparable in dimensions to the cephalon, rudely lenticular in outline. Axial lobe broad, strongly convex, obtusely truncate at the posterior extremity; axial annulations distinct anteriorly, obscure posteriorly, indicating 4 component segments and a terminal section. Pleural lobes of approximately the same width anteriorly as the axial, wedging out posteriorly; pleural furrows rudely parallel to the anterior margin, increasingly shallow toward the posterior extremity. Peripheral rim narrow, smooth, defined only by the abrupt disappearance of the pleural grooving. Posterior extremity very broadly rounded or obtusely truncate.

Surface.—Exterior surface microscopically granulated.

Dimensions.—The largest cranidium in the collection has a length of 8 mm., but the average size is 4 mm. or less in length.

Type locality.—(57q) Mount Bosworth, British Columbia.

Observations.—The limestone at the type locality is densely packed with the cranidia, free cheeks, and less frequently the thoracic segments and pygidia of this species.

P. lux, of the Mount Whyte formation, has a more slender glabella, which tapers to a rounded anterior extremity instead of being squarely truncate as in *P. adina;* furthermore, the fixed cheeks are wider in *lux* than in *adina,* the palpebral lobe is not placed so far forward, the frontal limb is narrower medially, and the frontal border is expanded and tends to be somewhat produced posteriorly directly opposite the anterior extremity of the glabella. *P. adina* is quite distinct from *P. thia* and *Agraulos ? unca.*

Formation and locality.—Lower Cambrian: (57q) Mount Whyte formation ? (Mount Bosworth section); drift block supposed to be from about 200 feet (61.2 m.) below the top of the Lower Cambrian in bluish-gray limestone (60 feet) forming 16*c* in Mount Whyte formation, slopes of Mount Bosworth, a little north of the Canadian Pacific Railway track, between Stephen and Hector, British Columbia, Canada.

PTYCHOPARIA CARINA, new species

Plate 13, figs. 6, *6a*

Species known from a single imperfect cranidium.

Cranidium.—Cranidium apparently short and broad. Glabella not far from three-quarters the length of the cranidium, moderately broad and moderately elevated along an obtuse medial ridge which becomes obsolete at some little distance behind the anterior extremity; dorsal furrows rather shallow; anterior extremity of the glabella more strongly rounded than the frontal border and only about two-thirds as wide as the base; glabellar furrows conspicuously deep, the posterior pair much more produced than the medial and more strongly oblique; medial pair short, but deeply gouged toward the dorsal furrows; anterior pair reduced to a couple of obscure lateral pits; character of occipital furrow and ring not preserved. Fixed cheeks low and broad, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe imperfectly preserved but apparently slender and elongated; posterior groove rather broad and moderately deep. Palpebral lobe not preserved but probably short, inconspicuous and placed far back, in line with either the posterior glabellar furrows or the posterior lobe of the glabella. Palpebral ridge narrow, cordate, arching obliquely across the fixed cheeks and intercepting the dorsal furrows at some little distance behind the anterior extremity. Frontal limb flattened, very narrow medially. Frontal border a rather broad fillet, cut off from the limb by a sharply defined groove, and a little wider medially than the limb. Other characters not preserved.

Surface.—Exterior surface shagreened with a fine and close granulation; a few coarser macroscopic granules scattered sparsely over the surface of the cranidium.

Dimensions.—Length of cranidium, 13.2± mm.; length of glabella, 9.5±mm.; width of glabella in front, 4.5 mm.; width of glabella at base, 6.8 mm.

Type locality.—(35m) 3 miles (4.8 km.) southwest of head of Lake Louise, Alberta.

Observations.—This species has such a thickly granulated and pustulose surface and such a strong frontal border that it is readily distinguished from other species of this horizon and fauna. The granulation recalls that of *P. permulta,* a species occurring in the *Albertella* shale about 700 feet (213.4 m.) higher in the section.

Formation and locality.—Lower Cambrian: (35m) Mount Whyte formation; 3 miles (4.8 km.) southwest of the head of Lake Louise, on east slope of Mount Whyte, Alberta, Canada.

PTYCHOPARIA (?) CERCOPS, new species

Plate 12, figs. 1, 1*a-d*

Species known from imperfect cranidia, free cheeks, and pygidia.

Cephalon.—Cephalon not found entire. Cranidium large, feebly contoured. Glabella long relatively, almost four-fifths the length of the cranidium, slightly elevated along a narrow but rather distinct ridge which becomes obsolete at some little distance behind the anterior extremity; dorsal furrows shallow, gradually converging toward the broadly arcuate anterior extremity; glabellar furrows broad and exceedingly obscure, the posterior pair oblique, the medial pair transverse to the axis, the anterior pair probably very short, and parallel to the medial furrows, but in the majority of individuals entirely obsolete; occipital furrow very broad and very shallow especially upon the crest of the glabella; occipital ring low and flattened, expanded medially, bearing near the posterior margin a small but prominent node. Fixed cheeks low, narrow, the distance from the palpebral lobe to the dorsal furrow a little less than half the width of the medial portion of the glabella; postero-lateral lobe wide, cuneiform, obtusely angulated at the distal extremity, not quite twice as long as its greatest width; posterior groove broad and shallow, narrowest and deepest toward the dorsal furrow, its proximal extremity in line with the occipital ring. Palpebral lobe very inconspicuous, very short, only about one-fifth as long as the glabella, scarcely at all elevated, and placed far forward opposite the anterior glabellar furrows. Palpebral ridge not defined, obscurely suggested. Frontal limb and border slightly differentiated from one another, the profile between the anterior extremity of the glabella and the outer margin gently concave. Facial sutures rudely and asymmetrically V-shaped, the posterior arm oblique, the anterior arm broadly and quite strongly arched. Associated free cheeks low and broad, gently and smoothly convex, bordered by a wide and ill-defined band, and without traces of genal spines.

Thorax.—Associated thoracic segments of moderate width. Axial lobe not preserved. Pleural segments flexuous, posteriorly directed and acutely falcate at their distal extremities; pleural furrows obsolete toward the axis, very deeply channeled medially, gradually wedging out distally; anterior margin a little narrower and more sharply elevated than the posterior.

Pygidium.—Associated pygidia twice as broad as long. Axial lobe broadly but not very strongly arched, subcylindrical, obtusely tapering posteriorly, rather sharply annulated even to the posterior extremity, including, apparently, 4 component segments. Pleural lobes differentiated from the axial merely by the contour, not cut off by incised furrows; annular ridges of the axial lobe persistent across the pleura, for the most part without change in direction or character, the posterior ridges, however, obsolete upon the pleura. Peripheral rim narrow, flattened, reduced to a mere thread posteriorly, widening gradually toward the thorax. Posterior extremity sharply rounded.

Surface.—Exterior surface shagreened but not distinctly granulated.

Dimensions.—Length of a cranidium, 20.4 mm.; length of glabella, 16.1 mm.; width of base of glabella, 12.5 mm.; width of front of glabella, 6.3 mm.

Type locality.— (63c) Ptarmigan Peak.

Observations.—The cranidium of *P. cercops* Walcott is relatively large and relatively long, and the relief upon the cranidium is conspicuously low. It is quite abundant at the type locality, but is not found commonly elsewhere.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (63c) 85 feet (26 m.) up in alternating oolitic limestone and thin-bedded compact sandstones forming 1 of section, and (63a) oolitic limestone about 130 feet (40 m.) above arenaceous shaly beds; both from east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise station on the Canadian Pacific Railway, Alberta, Canada.

Small cranidia in a compact shaly sandstone matrix from the Mount Whyte horizon of Castle Mountain appear to be identical with cranidia of similar size of this species. Locality 58t, Lower Cambrian: Mount Whyte formation; sandy shale about 150 feet (45.7 m.) below the Middle Cambrian, just below the big cliff on the east shoulder of Castle Mountain, north of the Canadian Pacific Railway, Alberta.

Somewhat similar cranidia occur in the oolitic limestone of Ross Mountain, but they have a slightly more distinct glabellum and are not quite so much smoothed out. Locality **63k**, Lower Cambrian: Mount Whyte formation; above and southeast of Ross Lake, 1 mile (1.6 km.) south of Stephen, Canadian Pacific Railway, on Continental Divide, British Columbia, Canada.

PTYCHOPARIA (?) CLEADAS, new species

Plate 12, fig. 2

Species known from cranidia.

Cephalon.—Cranidium minute, angular in outline, narrow and truncate in front, relatively wide at the base. Glabella long, approximately three-fourths the length of the cranidium, quite strongly elevated along the sharply rounded medial ridge, trapezoidal in outline; dorsal furrows linear, incised, converging with a moderate degree of rapidity toward the squarely truncate anterior extremity; glabellar furrows rather obscure, the posterior pair inclined to the median axis at an angle of about 45°, not persistent across the crest of the glabella, the medial pair a little shorter and less oblique, and the anterior pair much reduced and in some individuals entirely obsolete; occipital groove narrow and deep, uniform in character between the dorsal furrows; occipital ring flattened, constricted laterally, widely expanded medially and bearing near the posterior margin a small medial node. Fixed cheeks wide and evenly declining from the dorsal furrows; postero-lateral lobe very wide, deltoid in outline, probably obtusely angulated at its distal extremity; posterior furrow narrow but deeply incised, cutting off an increasingly wider posterior margin away from the axis. Palpebral lobe imperfectly preserved but apparently very short, inconspicuous, and placed far forward opposite the medial glabellar furrows. Palpebral ridge very narrow but usually distinct, arching across the fixed cheeks and intercepting the dorsal furrows directly behind the anterior extremity of the glabella. Frontal limb narrow, flattened. Frontal border a little wider than the limb, thickened, cordate, and somewhat expanded medially. Facial sutures very imperfectly preserved, the posterior section very long relatively and probably oblique, the anterior arm short and probably arcuate. Other characters not preserved.

Surface.—Exterior surface felt-like.

Dimensions.—Length of cranidium, 2.0 mm.; length of glabella, 1.5 mm.; width of cranidium at base, 3.0± mm.

Type locality.—(**57s**) Mount Bosworth.

Observations.—*P.* (?) *cleadas* Walcott may be readily separated from other species of the genus by its very small size and angular outline, its sharply defined trapezoidal glabella, its very small anterior eye placed far forward and the consequently very wide posterior lobe, its very narrow limb and almost equally narrow cordate border roughly parallel to the base of the cranidium.

These carbon-black cranidia, though so minute, show up quite well in the gray limestone of the type locality.

The specimens from the arenaceous shale at Ptarmigan Pass (Locality **60e**) are in the form of casts and do not show the glabellar furrows, but this appears to result from the condition of preservation. The glabella is also relatively shorter than that of the specimen illustrated but not shorter than some of those in the same hand specimen of limestone containing the type specimen.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**57s**) about 160 feet (49 m.) below the Middle Cambrian, near the base of the gray oolitic limestone, on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen, on the Continental Divide between British Columbia and Alberta; (**58u**) drift block supposed to have come from about 240 feet (73.8 m.) below the top of the Lower Cambrian in limestone interbedded in sandstone (31 feet); slopes of Mount Bosworth, a little north of the Canadian Pacific Railway track, between Stephen and Hector, British Columbia; also (**60e**) about 75 feet (22.8 m.) from the base of the Mount Whyte formation; Ptarmigan Lake Pass at head of Corral Creek, 6 miles (9.6 km.) northeast of Laggan, Alberta, Canada.

PTYCHOPARIA CLEON, new species

Plate 12, fig. 10

Species known from an imperfect cranidium.

Cephalon.—Cranidium small and moderately convex. Glabella low, elevated along an obscure median ridge which is moderately elevated posteriorly and increasingly lower anteriorly; dorsal furrows linear, rather shallow, converging so that the width of the truncate anterior extremity is about three-fifths of that at the base; glabellar furrows obscure, the posterior and medial pairs subparallel, disappearing about halfway up to the median line; anterior pair obsolete; occipital groove rather shallow, deepening slightly toward the dorsal furrows; occipital ring imperfectly preserved. Fixed cheeks low, wide, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe imperfectly preserved but probably strong and moderately extended; posterior groove very narrow toward the axis, terminating opposite the occipital ring, broader and more shallow away from the axis, and cutting off an increasingly wider posterior margin. Palpebral lobe narrow, crescentic, contained about three times in the length of the glabella, in line with the posterior glabellar furrows. Palpebral ridge oblique, defined only by the angulation of the cheek, not outlined by a raised cord or liration. Frontal limb rather narrow in front of the glabella and flattened, rather steeply declining in front of the palpebral ridge. Frontal border narrow, thickened, the medial portion posteriorly produced and acutely angulated. Facial sutures imperfectly preserved; anterior section apparently very strongly convex.

Surface.—Exterior surface microscopically shagreened. Venation upon the frontal limb very fine.

Dimensions.—Length of cranidium, 3.5 mm.; length of glabella, 2.5 mm.

Type locality.—(**35f**) Mount Stephen.

Observations.—The cranidium of this species is much like that of *Ptychoparia thia* except that the frontal limb is longer in front of the glabella and there is a swelling or elongate tubercle on the frontal rim opposite the glabella. The species is known only by a single specimen of the cranidium from the limestone at the type locality (**35f**).

Formation and locality.—Lower Cambrian: (**35f**) Mount Whyte formation; about 300 feet (95 m.) below the top of the Lower Cambrian in bluish-black and gray limestone (18 feet = 5.5 m.) forming 6 of Mount Whyte formation; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

PTYCHOPARIA CLUSIA, new species

Plate 11, figs. 3, *3a*

Species known from imperfect cranidia.

Cephalon.—Glabella a little more than two-thirds as long as the cranidium, quite strongly elevated along a subacute medial ridge which disappears gradually toward the front; outline trapezoidal, the broadly rounded anterior extremity not more than half as broad as the base; dorsal furrows rather wide, deeply impressed, converging quite rapidly anteriorly and rounding sharply into the more shallow, transverse anterior furrow; glabellar furrows also broad and deep, though not persistent across the crest; posterior pair inclined to the axis of the shield at an angle of a little more than 45°, almost completely isolating the tumid posterior lobe; medial pair neither so broad nor so deep as the posterior and nearly at right angles to the axis; anterior pair a little shorter than the medial, slightly inclined toward the front and placed nearer to the medial pair than to the anterior furrow; occipital groove broad and deep, completely dissecting the crest of the glabella, very slightly sinuous; occipital ring rather narrow, expanded medially, obtusely angulated at the medial posterior margin, and bearing a rather prominent medial node. Fixed cheeks plump and quite wide, the distance from the palpebral lobe to the dorsal furrow a little more than half the width of the medial portion of the glabella; postero-lateral lobe narrow and probably extended laterally; posterior furrow conspicuously broad and deep, its inner terminus in line with both the occipital furrow and ring; posterior margin narrow and sharply elevated. Palpebral lobe short, narrow, crescentic, set opposite the lobe between the posterior and medial furrows. Palpebral ridge rather prominent, cordate, arching across the fixed cheeks and intercepting the dorsal furrows directly in front of the anterior glabellar furrows. Frontal limb rather narrow, inflated laterally, gently declining medially. Frontal border wider medially than the limb, sharply upturned. Facial sutures imperfectly preserved.

Surface.—Exterior surface very finely and closely granulated or roughened by an irregular pitting with broken, depressed ridges that give the effect of obscure granulation.

Dimensions.—Length of cranidium, 7.5 mm.; length of glabella, 5.25 mm.; width of glabella in front, 2.0 mm.; width of glabella at base, 4.2 mm.

Type locality.—(**58k**) Mount Stephen.

Observations.—The glabella of this species recalls that of *P. gogensis* and less so that of *P. pia* (pl. 12, figs. 4 and 8). The frontal border is quite unlike that of either of the two species.

Formation and locality.—Lower Cambrian: (**58k**) Mount Whyte formation; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

PTYCHOPARIA COSSUS, new species

Plate 11, figs. 5, 5*a*

Species known from an imperfect cranidium.

Cephalon.—Cranidium small, moderately convex. Glabella a little more than three-fourths as long as the cranidium, moderately elevated along an obtuse median ridge, relatively broad; dorsal furrows well rounded and quite deep, converging so that the rounded truncate anterior extremity is only a little more than two-thirds as wide as the base; anterior furrow shallow and not sharply defined; glabellar furrows rather obscure and not persistent to the crest of the glabella, the posterior pair oblique, the medial pair more nearly horizontal, the anterior pair slightly inclined toward the anterior extremity; occipital furrow sinuous, arched forward upon the crest, deepening toward the dorsal furrows; occipital ring not preserved. Fixed cheek low, flattened, the distance from the palpebral lobe to the dorsal furrow a little more than half the width of the glabella; postero-lateral lobe imperfectly preserved, narrow and elongate; posterior groove narrow but well rounded, in line with the occipital ring. Palpebral lobe very short, not very prominent, in line with the posterior glabellar furrows. Palpebral ridge low, cordate, cutting obliquely across from the palpebral lobe and intercepting the dorsal furrows at the origin of the anterior glabellar furrows. Frontal limb narrow and flattened in front of the glabella. Frontal border wide, slightly convex, somewhat thickened, the inner margin almost at right angles to the axis, the outer margin strongly arcuate. Facial sutures imperfectly preserved.

Surface.—Exterior surface minutely shagreened.

Dimensions.—Length of cranidium, 8.0 mm.; length of glabella, 5.5 mm.

Type locality.—(**61a**) Yoho Canyon.

Observations.—The glabella of this species recalls that of *P. cuneas,* but the frontal limb differs in being narrower and in having a gently convex surface.

Formation and locality.—Lower Cambrian: (**61a**) Mount Whyte formation; gray oolitic siliceous limestone; Yoho Canyon, 1.5 miles (2.4 km.) above mouth of Yoho River and about 5.5 miles (8.8 km.) from Field on Canadian Pacific Railway, British Columbia, Canada.

PTYCHOPARIA CUNEAS, new species

Plate 11, figs. 4, 4*a*

Species known from an imperfect cranidium.

Cephalon.—Glabella relatively short, only about two-thirds as long as the cranidium, moderately convex, trapezoidal in outline; dorsal furrows moderately deep, rounding rather sharply into the shallow groove which outlines the truncated anterior extremity. Glabellar furrows imperfect; posterior pair rather broad, shallow and extending obliquely inward to a low, strong medial ridge that continues nearly to the front of the glabella; the medial and anterior pairs transverse; occipital groove broad and shallow upon the summit of the glabella, narrow and deep toward the dorsal furrows; occipital ring moderately elevated and expanded medially, bearing a small but rather sharp medial node. Fixed cheeks slightly convex, the distance from the palpebral lobe to the dorsal furrow approximately half the width of the medial portion of the glabella; postero-lateral lobe rather narrow, posterior groove narrow, deep, its axial terminus in line with the occipital ring. Palpebral lobe short, crescentic, not very prominent, placed rather far back opposite the posterior glabellar furrows. Palpebral ridge low and ill-defined, it arches obliquely across the fixed cheek and intercepts the dorsal furrow a little behind the anterior extremity. Frontal limb narrow, flattened in front and merging into the fixed cheeks laterally. Frontal border slightly elevated, flattened, and with a shallow, transverse median depression, slightly expanded both along the outer and the inner margin, wider than the frontal limb and cut off from it by a shallow sulcus. Facial sutures imperfectly preserved; anterior section gently arcuate.

Surface.—Exterior surface exhibiting a felt-like texture.

Dimensions.—Length of cranidium, 8.0 mm.; length of glabella, 5.1 mm.; width of glabella in front, 2.7 mm.; width of glabella at base, 4.5 mm.

Type locality.—(35f) Mount Stephen.

Observations.—The broad, short glabella and broad frontal border of this species serve to distinguish it from other species of *Ptychoparia* from the Mount Whyte formation. The frontal border has a slight resemblance to that of *P. gogensis* (pl. 12, fig. 4). The short, broad glabella recalls that of some undescribed species from the Lower Cambrian of the St. Lawrence Valley.

Formation and locality.—Lower Cambrian: (35f) Mount Whyte formation (Mount Stephen section); about 300 feet (93.8 m.) below the top of the Lower Cambrian in bluish-black and gray limestone, just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

PTYCHOPARIA GOGENSIS, new species

Plate 12, figs. 4, 4*a*

Species known from imperfect cranidia.

Cranidium.—Cranidium large and relatively broad, the maximum width exclusive of the free cheeks more than double the length;

glabella prominent, nearly three-fourths as long as the cranidium, conspicuously elevated along an obtuse medial ridge; dorsal furrows broad and deeply channeled, slowly converging toward the front; anterior extremity of glabella approximately two-thirds as wide as the base, obtusely truncate, and outlined by a shallow groove; glabellar furrows deep on the sides of the glabella but entirely obsolete upon the crest; posterior pair broad and deep, obliquely arcuate; medial pair not so deep as the posterior; anterior pair obscure, set very close to the medial pair; lobe between the occipital groove and the posterior pair of furrows quite strongly elevated, that between the posterior and medial pairs also rather prominent; occipital furrow broad, and quite deep, especially towards the dorsal furrows; occipital ring narrow, somewhat expanded medially; a median node is suggested by what appears to have been a broken-off base of a tubercle. Fixed cheeks rising abruptly from the dorsal furrows, then arching gently to the palpebral lobe, the distance from the palpebral lobe to the dorsal furrow more than half the width of the medial portion of the glabella; postero-lateral lobe slender and petaloid; posterior groove deep, broadening away from the axis, nearly in line with the occipital furrow. Palpebral lobe rather short, crescentic, moderately prominent, and placed opposite the posterior glabellar furrows. Palpebral ridge obtuse, cutting somewhat obliquely across the fixed cheeks and intercepting the dorsal furrows near the origin of the anterior glabellar furrows. Frontal limb very narrow and quite steeply declining medially, broadly inflated laterally. Frontal border separated by a shallow sulcus, nearly flat at the center and slightly concave at the sides posteriorly produced opposite the glabella and obtusely angulated.

Surface.—Exterior surface imperfectly preserved, but apparently shagreened by a fine granulation.

Dimensions.—Length of cranidium, 14.0 mm.; width of cranidium at base, 30.0± mm.; length of glabella, 10.0 mm.; width of glabella in front, 5.5 mm.; width of glabella at base, 8.5 mm.

Type locality.—(62w) Above Gog Lake, Wonder Pass.

Observations.—The more widely distributed *P. pia* is much smaller and not so coarse as *P. gogensis,* but it has much the same general appearance. The glabella of *P. gogensis* is more elevated and proportionally broader, the dorsal furrows are more deeply channeled, the glabellar furrows are also deeper, and the posterior and medial glabellar lobes consequently higher. The relative width of the fixed cheeks is approximately the same in both species, but they are lower in *P. pia*. There is a further resemblance in the outline of the frontal rim, but in *P. pia* the rim is thickened and flattened, while in *P. gogensis* it is not thickened and it is concave at the sides.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**62w**) oolitic limestone, about 400 feet (123 m.) below summit of ridge above Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta.

PTYCHOPARIA LUX, new species

Plate 12, fig. 5

Species known from cranidia.

Cephalon.—Relative proportions of cephalon varying quite widely, the length in the majority of individuals more than half the greatest width. Glabella short and rather slender, quite strongly elevated along an obtuse medial ridge which disappears a little behind the anterior extremity; dorsal furrows quite deeply impressed, converging with a moderate degree of rapidity toward the arcuate anterior extremity; curvature of front of glabella usually a little greater than that of the frontal margin; width of front of glabella only about half the width of the base of the glabella; glabellar furrows exceedingly obscure and in most individuals entirely obsolete, sometimes indicated by very feeble lateral depressions just within the dorsal furrows; occipital groove narrow, persistent across the crest of the glabella but deepening toward the dorsal furrows; occipital ring moderately broad, flattened, expanded medially, and bearing near the posterior margin a small node. Fixed cheeks broad and plump, the width from the palpebral lobe to the dorsal furrow equal, approximately, to the width of the medial portion of the glabella; postero-lateral lobe very narrow, moderately extended, petaloid at the distal extremity; posterior groove in line with the occipital ring, widening away from the axis and cutting off an increasingly wider posterior margin. Palpebral lobe not very prominent, contained about two and one-half times in the length of the glabella, feebly arcuate, submedial with respect to the glabella. Palpebral ridge narrow, and very obscure, curving obliquely across the fixed cheeks and intercepting the dorsal furrows a little behind the anterior extremity. Frontal limb narrow, flattened medially, feebly inflated laterally. Frontal border crescentic, wider medially than the frontal limb, and often somewhat produced posteriorly, cut off from the limb by a groove rather sharply impressed laterally but often very obscure medially. Facial sutures imperfectly preserved; posterior section rudely transverse to the axis, medial section relatively short, anterior section strongly convex.

Other characters of the cephalon and the thorax not preserved.

Surface.—Exterior surface shagreened with a microscopically fine but rather sharp granulation.

Dimensions.—Length of cranidium, 4.0 mm.; length of glabella, 3.0 mm.; width of glabella in front, 1.5 mm.; width of glabella at base, 2.0 mm.

Type locality.—(**61d**) Mount Shaffer.

Observations.—See observations under *P. adina.*

P. lux is very common at the type locality.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**61d**) southwest slope of Mount Shaffer on Canyon side, on trail to Lake McArthur, 5.5 miles (8.8 km.) south of Hector Station, on Canadian Pacific Railroad, British Columbia, Canada.

PTYCHOPARIA PEROLA, new species

Plate 12, figs. 7, 7*a*

Dorsal shield.—Dorsal shield small, elongate-oval in outline, flattened in the shale but probably quite strongly contoured originally. Axial lobe rather slender, arched well above the pleura and cut off from them by rather deep furrows.

Cephalon.—Cephalon about one-third as long as the dorsal shield, rudely semicircular in outline. Glabella of moderate dimensions, subrectangular or trapezoidal in outline, that of the type a little broader relatively than in the average individual; medial ridge low and obtuse, dorsal furrows deeply impressed, evenly converging toward the squarely truncate anterior extremity; glabellar furrows quite broad and moderately deep, but not persistent across the crest; posterior pair somewhat oblique; medial and anterior pairs almost at right angles to the axis, the anterior pair reduced, however, to nothing more than a couple of lateral pits; occipital groove partially dissecting the crest of the glabella, deeply impressed toward the dorsal furrows; occipital ring narrow, expanding slightly medially, and bearing near the posterior margin a small sharp node. Fixed cheeks low and moderately wide, the distance from the palpebral lobe to the dorsal furrow a half or a little more than half as wide as the medial portion of the glabella; postero-lateral lobe rather short, broad, and trigonal, quite acutely angulated at its distal extremity; posterior furrow broad and quite deep, almost in line with the occipital furrow. Palpebral lobe inconspicuous, almost straight, very slightly elevated, and less than one-third as long as the glabella including the occipital ring, placed rather far forward, opposite the medial glabellar furrows. Palpebral ridge narrow, sharply defined, cutting across the fixed cheeks almost at right angles to the axis and intercepting the dorsal furrows a little behind the anterior extremity of the glabella. Frontal limb rather narrow, slightly inflated, cut off from the flattened frontal border by a shallow groove parallel to the anterior extremity of the glabella. Frontal border thus forming a chord about two-thirds the length of the base of the cranidium, the medial portion of which is of approximately the same width as the medial portion of the frontal limb. Facial sutures interrupted medially by the small palpebral lobes, the posterior arm oblique, the anterior arm broadly convex. Free cheeks narrow, smoothly convex, bordered by a flattened band produced posteriorly into short, acutely tapering genal spines.

Thorax.—Thoracic segments 15 in number. Axial lobe quite strongly convex, very strongly annulated. Pleural segments compactly arranged, the flattened portion between the obtuse geniculation and the axial furrows not quite so wide, as a rule, as the axial lobe. Pleural furrows almost as wide as the including segment excepting toward the axis where they are narrower and anterior in position; anterior margin of the segment a little more sharply elevated than the posterior; extremities of segments imperfectly preserved but probably attenuated and acutely falcate.

Pygidium.—Associated pygidium small, short and broadly lenticular in outline. Axial lobe rather coarse, subcylindrical, tapering slightly toward the obtuse posterior extremity; annulations distinct, indicating possibly two component segments and a terminal section. Pleural lobes drooping, of approximately the same width anteriorly as the axial lobe, obscurely furrowed with one or two shallow grooves, parallel to the arcuate anterior margin. Peripheral rim narrow, flattened, obscurely defined; periphery broadly rounded, often obtusely truncate at the posterior extremity.

Surface.—Exterior surface shagreened but apparently not granulated.

Dimensions.—Length, 17.0± mm.; greatest width, 10.0± mm.

Type locality.—(35m) Mount Whyte.

Observations.—This is one of the relatively narrow, elongate forms of the genus that suggests *P. cordilleræ* of the Middle Cambrian. It differs from the latter species in having a stronger frontal border on the cephalon, less elongate glabella, narrower frontal limb, 15 thoracic segments instead of 18 or 19, and a narrower pleural thoracic lobe. It is most nearly related to *P. candace*[1] of the Middle Cambrian *Albertella* fauna of Gordon Creek, Montana, from which it differs in having a narrower frontal limb in front of the glabella and a less elongate glabella; otherwise the two species closely resemble each other.

All the specimens of *P. perola* are compressed in a hard siliceous, finely arenaceous shale from which the test of the trilobite has been removed, and the replacement shows only a finely roughened surface that may be a reproduction of the original surface, or it may be roughened by the fine-grained matrix having been impressed in the original test.

The largest dorsal shield has a length of 20 mm. The proportions of the various parts are well shown by figure 7, the original of which has a length of 16 mm. The relatively large cranidium, elongate thorax, and very small pygidium are finely brought out in this figure.

Formation and locality.—Lower Cambrian: (**35m**) Mount Whyte formation; Lake Agnes shale, 3 miles (4.8 km.) southwest of the head of Lake Louise on the east slope of Mount Whyte; also (**35e**) amphitheater between Popes Peak and Mount Whyte, southwest of Lake Agnes, and 3 miles (4.8 km.) southwest of the head of Lake Louise Station on the Canadian Pacific Railroad, both in western Alberta, Canada.

PTYCHOPARIA PIA, new species

Plate 12, fig. 8

Species known from imperfect cranidia and associated thoracic segments.

Cranidium.—Cranidium relatively short and broad, dissected by the dorsal furrows into three subequal areas. Glabella rather large relatively, quite prominently elevated along a very obtuse medial ridge which disappears a little behind the anterior extremity; dorsal furrows deeply channeled, converging to a slight degree toward the rounded truncate anterior extremity, so that the front of the glabella is not very much more than two-thirds as wide as the base. Glabellar furrows broad and, toward the dorsal furrows, moderately deep, obsolete, however, upon the summit of the glabella; posterior pair oblique, the medial pair a little shorter and at right angles to the axis, the anterior pair still shorter and rather obscure, transverse or inclined slightly toward the front; posterior and medial glabellar

[1] See pl. 6, fig. 3, Smithsonian Misc. Coll., Vol. 67, 1917.

lobes quite prominently elevated; occipital furrow broad, partially dissecting the crest of the glabella, deepening toward the dorsal furrows; occipital ring rather narrow, expanding medially and bearing on well-preserved individuals a small median node. Fixed cheeks wide and plump, the distance from the palpebral lobe to the dorsal furrow only a little less than the width of the medial portion of the glabella; postero-lateral lobe rather narrow and extended, somewhat falcate at its extremity; posterior furrow deeply concave, narrow toward the axis, broadening away from it, and cutting off an increasingly wider posterior margin. Palpebral lobe short, crescentic, quite prominently elevated, submedial or slightly anterior in position, with respect to the glabella. Palpebral ridge obscure, extending obliquely across the fixed cheeks and intercepting the dorsal furrows near the margin of the anterior glabellar furrows. Frontal limb narrow, evenly declining, in some individuals obscurely truncated in front of the glabella. Frontal border cut off from the limb by a shallow, ill-defined groove, narrow laterally but widening medially and slightly produced posteriorly so that in front of the glabella the border is wider than the limb. Facial sutures imperfectly preserved, the posterior section somewhat flexuous, the anterior section broadly arcuate. Associated free cheeks low and broad, bordered by a thickened cordate rim, cut off from the rest of the cheek by a shallow groove, and produced posteriorly into rather short, acutely tapering spines.

Thorax.—Associated thoracic segments rather wide, deeply channeled, the anterior margin undercut; extremities falcate.

Surface.—Exterior surface crowded with an irregular, very fine granulation which on slightly worn individuals assumes a felt-like aspect.

Dimensions.—Length of cranidium, 14.2 mm.; length of glabella, 9.8 mm.; width of glabella in front, 5.0 mm.; width of glabella at base, 8.5 mm.

Type locality.—(35f) Mount Stephen.

Observations.—*P. pia* Walcott is, perhaps, the most widely distributed member of the genus in the Mount Whyte formation. There are no described forms which approach close to *P. pia,* though *P. gogensis* and *P. skapta* resemble it in general outline and contour, and in the relative proportions of the glabella. *P. gogensis,* however, is almost double the dimensions of *P. pia,* the glabella is more convex, the dorsal and glabellar furrows are deeper, the fixed cheeks higher, and the frontal rim upturned but not thickened as in *pia*. *P. skapta,* on the other hand, is only about half the size of *pia*, and the frontal rim is very much narrower relatively and much more thickened than in *pia*.

Formation and locality.—Lower Cambrian: (**35f**) Mount Whyte formation (Mount Stephen section); about 300 feet (93.8 m.) below the top of the Lower Cambrian in bluish-black and gray limestone; just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field; (**35h**) about 375 feet (114 m.) below the Middle Cambrian, in shales of the Mount Whyte formation, on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen, on the Continental Divide between British Columbia and Alberta; (**63k**) north spur of Mount Whyte, above and southeast of Ross Lake, 1 mile (1.6 km.) south of Stephen, Canadian Pacific Railway on Continental Divide; and (**57r**) just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field.

A cranidium that may belong with this species occurs in the limestone of (3) of the Mount Stephen section, about 180 feet (54.8 m.) above the horizon of the type specimen, which occurs in (4) of that section:[1] Lower Cambrian: (**57e**) Mount Whyte formation; about 115 feet (35 m.) below the top of the Lower Cambrian near the top of the dark bluish-gray limestone (53 feet = 16 m.) forming 3 of Mount Whyte formation, just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, all in British Columbia, Canada.

PTYCHOPARIA SKAPTA, new species

Plate 12, figs. 9, 9*a*

Species known from an imperfect cranidium.

Cranidium.—Cranidium small, rather strongly contoured. Glabella relatively large, trapezoidal in outline, the anterior extremity truncate and approximately three-fourths as wide as the base; dorsal furrows linear, quite deeply incised; anterior furrow distinct but not so deep as the dorsal; glabellar furrows dissecting the sides of the glabella but entirely obsolete upon the crest; posterior pair more produced and more strongly oblique than the medial; anterior pair reduced to a couple of small pits just within the dorsal furrows; occipital groove narrow, very shallow upon the crest of the glabella, deep toward the dorsal furrows; occipital ring imperfectly preserved, narrow on the sides and widening towards the center. Fixed cheeks

[1] Canadian Alpine Journ., Vol. 1, 1908, pp. 240-242.

also imperfectly preserved but certainly wide and rather plump; postero-lateral lobe known only from the proximal portion; posterior groove in line with the occipital ring. Palpebral lobe not preserved. Palpebral ridge low and narrow, arching obliquely across the fixed cheeks and intercepting the dorsal furrows directly behind the anterior extremity of the glabella. Frontal limb flattened and in front of the glabella almost obliterated, expanded laterally, cut off from the frontal border by a wide and angular channel. Border thickened, elevated, rather narrow laterally, expanded medially. Other characters not preserved.

Surface.—Exterior surface finely granular.

Dimensions.—Length of cranidium, 4.5 mm.; length of glabella, 3.2 mm.; width of glabella in front, 1.8 mm.; width of glabella at base, 2.4 mm.

Type locality.—(**62w**) Above Gog Lake, Wonder Pass.

Observations.—*P. skapta* is, unfortunately, described from a unique type. *P. pia*, a much larger form, is probably the most closely allied of the known species. They resemble one another in the general contour, the outline of the glabella, the wide fixed cheeks, and the thickened frontal limb, posteriorly produced and angulated medially. *P. skapta* is, however, only about half as large as *P. pia*, the medial ridge of the glabella is a little more elevated, the dorsal and glabellar furrows are more deeply incised, the fixed cheeks more plump, the frontal limb much more reduced, and the frontal border heavier but not so wide.

Formation and locality.—Lower Cambrian: (**62w**) Mount Whyte formation; oolitic limestone, about 400 feet (123 m.) below summit of ridge above Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

PTYCHOPARIA THIA, new species

Plate 12, fig. 6

Species known from imperfect cranidia.

Cranidium.—Glabella small relatively, broadly convex, rudely trapezoidal in outline, quite truncate in front, the sides roughly parallel; dorsal furrows shallow and not sharply defined; glabellar furrows narrow, occasionally distinct but never conspicuous, obsolete upon the crest of the glabella; posterior pair oblique, the medial pair diverging slightly from the horizontal, the anterior pair normal to the axis; occipital groove moderately broad and moderately deep, uniformly depressed throughout its extent; occipital ring rather narrow, expanded medially, moderately elevated, not nodose. Fixed cheeks low and broad, and gently convex; postero-lateral lobe imperfectly preserved; posterior groove narrow and not very deep. Palpebral lobe short but quite prominent, feebly crescentic, placed quite far back in line with the lobe between the posterior and medial furrows. Palpebral ridge narrow and very obscure, arching obliquely across the fixed cheeks and intercepting the dorsal furrows directly behind the anterior extremity of the glabella. Frontal limb and border imperfectly differentiated, the two together of about the same width as the fixed cheeks and contoured very much like them. Frontal border a little more thickened and consequently a little more elevated than the limb, the medial portion posteriorly produced into an obtuse angle which closely approximates the anterior extremity of the glabella. Facial sutures imperfectly preserved, the anterior segment probably arcuate. Other characters not preserved.

Surface.—Exterior surface shagreened but not granulated.

Dimensions.—Length of cranidium, 4.2 mm.; length of glabella, 2.9 mm.; width of glabella in front, 2.0 mm.; width of glabella at base, 1.5 mm.

Type locality.—(**35h**) Mount Bosworth.

Observations.—The diagnostic characters of the species are the rudely rectangular glabella, the wide, gently convex fixed cheeks, and the ill-differentiated border and limb which together with the cheeks form a frame about the glabella of approximately uniform width and convexity.

Ptychoparia thia is smaller than either *P. lux* or *adina;* the fixed cheeks are much wider than in *adina;* the glabella is broader relatively and less tapering anteriorly, and the frontal border is much more obscurely differentiated than in *lux*. The distribution is wider in *thia* than in either of the other species in question.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**35h**) about 375 feet (114 m.) below the Middle Cambrian, in shales, on Mount Bosworth, north of the Canadian Pacific Railway between Hector and Stephen, on the Continental Divide between British Columbia and Alberta; (**35f, 58k**) just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia; **35f** is near the base of the Mount Whyte formation in stratum 6 and **58k** about 295 feet (89.9 m.) above near the summit of the formation in stratum 1;[1] and (**62w**) oolitic limestone, about 400 feet (123 m.) below summit of ridge above

[1] Canadian Alpine Journ., Vol. 1, 1908, pp. 240-242.

Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

PTYCHOPARIA, species undetermined

Fragments of the cranidia of what may be three species of *Ptychoparia* occur in the Mount Whyte formation, none of which have been identified with known species. As the genus is well represented by the described species I shall not now describe or illustrate the fragments.

Genus CREPICEPHALUS Owen

Crepicephalus OWEN, 1852. For synonymy and discussion of this genus see Smithsonian Misc. Coll., Vol. 64, 1916, pp. 199-204.

At the time I was studying the species referred to *Crepicephalus* the specimens of the species from the Mount Whyte formation and from the Mount Bosworth section were not to be found. The two species from the Mount Whyte formation are from the upper beds a short distance beneath the Middle Cambrian Ptarmigan formation. They are *C. cecinna* (pl. 11, figs. 1, 1*a*) and *C. celer* (pl. 11, fig. 2). The first species belongs to the *C. iowensis*[1] group of species, and *C. celer* to the *C. unca* form,[2] both of which are well represented in the Upper Cambrian. The two species from the Pioche formation of Nevada, *C. augusta* and *C. liliana,*[3] correspond in type, as far as we know them, to the Mount Whyte formation species, *C. cecinna* and *C. celer,* which occur at an horizon that is characterized by a Lower Cambrian fauna, although at the localities at which they were found neither of the genera *Olenellus* or *Mesonacis* was found in association with them. Very little attention was paid to searching for any particular grouping of species and the collections made except at two or three localities were very limited. The association of species that have been found with *Crepicephalus* and with *Olenellus* or *Mesonacis* is as follows. The localities are numbered and a similar number placed on each specimen.

[1] Smithsonian Misc. Coll., Vol. 64, 1916, p. 201.

[2] Idem, pl. 35, figs. 1*d*, 1*e*.

[3] Idem, pl. 29, figs. 5, 6.

Names	58k Mount Stephen	61d Mount Shaffer	62w Gog Lake	63a Ptarmigan Pass
Archæocyathus (*A.*) *atreus*	..	..	×	..
Micromitra (*Paterina*) *labradorica*	..	×	×	..
Micromitra (*Iphidella*) *pannula*	..	×	..	..
Kutorgina cf. *cingulata*	..	..	×	..
Acrotreta sagittalis taconica	×	×	×	..
Nisusia (*Jamesella*) *lowi*	..	×	×	×
Wimanella catulus	..	..	..	×
Helcionella elongata	×	..	×	..
Pelagiella sp. undt.	..	×	..	..
Scenella varians	×	×	×	..
Parmophorella sp.	×	..	..	..
Hyolithes billingsi	×	..	×	×
Hyolithellus sp. undt.	..	..	×	..
Shafferia cisina	..	×	..	..
Agraulos unca	..	×	..	..
Olenopsis agnesensis	×	..	..	..
Olenopsis cleora	..	..	×	..
Zacanthoides sp.	..	×	..	..
Ptychoparia cercops	..	..	..	×
Ptychoparia clusia	×	..	..	..
Ptychoparia cf. *gogensis*	..	..	×	..
Ptychoparia lux	..	×	..	..
Ptychoparia skapta	..	..	×	..
Ptychoparia thia	×	..	×	..
Crepicephalus cecinna	..	..	×	×
Crepicephalus celer	×	..	..	..
Dorypyge damia	..	..	×	..
Corynexochus senectus	..	×	..	..
Mesonacis gilberti	..	×	..	..
Bathyuriscus (*Poliella*) *primus*	×	..	..	..

CREPICEPHALUS CECINNA, new species

Plate 11, figs. 1, 1*a-b*

Species known from a cranidium and a few associated pygidia.

Cranidium.—Cranidium short and broad. Glabella relatively large, subtrapezoidal in outline, a little less than five-sixths as long as the cranidium, and about four-fifths as wide in front as it is at the base; dorsal furrows deeply impressed, terminating anteriorly in small pits; anterior furrow not quite so deep as the dorsal, very feebly arcuate; glabellar furrows moderately broad and quite deep, not persistent, however, across the low medial ridge; posterior pair a little more strongly oblique than the medial; anterior pair obscure, much shorter than the furrows behind them and nearly at right angles to the axis of the shield; occipital furrow sinuous, deep distally, bent forward upon the crest of the glabella and only partially dissecting it; occipital ring very narrow laterally, expanded medially, bearing near the posterior margin a small sharp node. Fixed cheeks low and broad, the distance from the palpebral lobe to the dorsal furrow decidedly more than half the width of the medial portion of the glabella; postero-lateral lobe not preserved but necessarily narrow; posterior furrow narrow, deep. Palpebral lobe not preserved, apparently small, not very prominent and placed far back opposite the posterior lobe of the glabella. Palpebral ridge narrow, cordate, quite sharply elevated, curving obliquely across the fixed cheeks, and intercepting the dorsal furrows a little behind the anterior extremity, thus enclosing a rudely elliptical area interrupted by the glabella. Frontal limb narrow medially, of approximately the same width as the thickened cordate frontal border, from which it is separated by a narrow but rather deeply incised groove. Other characters of the cephalon not preserved.

Pygidium.—Pygidium short and broad, the lateral margins diverging slightly posteriorly, the anterior and posterior margins exclusive of the spines roughly parallel. Axial lobe rather low and flattened upon its summit, obtusely truncate posteriorly; axial annulations quite distinct anteriorly, somewhat flexuous, indicating 5 or 6 component segments and a terminal section; pleural lobes exclusive of the spines, moderately convex, deeply furrowed, the grooves increasingly shallow and more closely spaced posteriorly; interspaces elevated parallel to the anterior lateral margin, the anterior ridges obtusely angulated and nodose at the angles, gradually dying out along an arc of about 180°; postero-lateral extremities flattened and produced into slender, slightly diverging spines of approximately the same length as the axial lobe of the pygidium.

Surface.—Exterior surface very finely granulated; a few much coarser granules scattered over the frontal limb and border.

Dimensions.—Length of cranidium, 4.3 mm.; length of glabella, 3.5 mm.; width of glabella in front, 2.0 mm.; width of glabella at base, 2.5 mm.; length of pygidium exclusive of the terminal spines, 5.0 mm.; length of pygidium including the terminal spines, 10.0 mm.; width of medial portion of pygidium, 8.5 mm.

Type locality.—(63a) Ptarmigan Peak.

Observations.—Two distinct systems of surface sculpture are developed in this species, a fine, close granulation over the entire surface and a coarse, sparse granulation upon the frontal limb and border and probably upon the pygidium. *P. carina,* the only other form which has a similar surface, is much larger and the glabella is much more strongly rounded anteriorly than in *C. cecinna.*

Both the cranidium and associated pygidium of this species are closely related to *Crepicephalus upis* of the Upper Cambrian Gallatin limestone of Montana.[1] They are also closely related in form to *C. liliana,*[2] from strata referred to the upper zone of the Lower Cambrian of Nevada. *C. cecinna* is not closely related to *C. chares* of the Ptarmigan formation.[3]

Formation and locality.—Lower Cambrian: Mount Whyte formation; (**63a**) oolitic limestone about 130 feet (40 m.) above arenaceous shaly beds; east base of Ptarmigan Peak, 5.5 miles (8.8 km.) in an air line northeast of Lake Louise station on the Canadian Pacific Railway, Alberta; also (**62w**) oolitic limestone, about 400 feet (123 m.) below summit of ridge above Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

CREPICEPHALUS CELER, new species

Plate 11, fig. 2

Species known from the pygidium.

Pygidium.—Pygidium rudely quadrate in outline exclusive of the posterior constriction, the lateral margins approximately parallel to the axis; anterior margin broken by the forward curve of the axial lobe; posterior margin very broadly and deeply insinuated. Axial lobe large and coarse, broadly conic in outline, acutely tapering posteriorly; axial annulations probably very distinct in perfectly preserved individuals, including apparently 6 component segments and a terminal section. Pleural lobes flexuous, irregular in outline, the anterior lateral margin an obtuse right angle; pleural furrows following the same general direction as the outer margin but less angulated, disappearing abruptly along an imaginary arc of about 180°; extremities of pleural lobes produced into cuneate appendages, acutely tapering.

Surface.—Exterior surface unknown.

Dimensions.—Length of pygidium including the lateral spines, 19.5 mm.; length of pygidium to the medial posterior margin, 12.5 mm.; greatest width of pygidium, 15.0 mm.

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[1] Smithsonian Misc. Coll., Vol. 64, 1916, pl. 33, figs. 4, 4*a-d*.

[2] Idem, pl. 29, figs. 5, 5*a-c*.

[3] Idem., Vol. 67, 1917, pl. 6, figs. 5, 5*a-c*.

Type locality.—(58k) Mount Stephen.

Observations.—*C. celer* is represented by a single specimen of a large pygidium of the *C. chares*[1] type from the Ptarmigan formation. It differs from the pygidium of the latter species in having a much larger axial lobe; in this character it approaches *C. unca* of the Upper Cambrian of Minnesota.[2]

A small cranidium associated with the pygidium may belong to this species, but it is too imperfect to identify even as belonging to the genus.

Formation and locality.—Lower Cambrian: Mount Whyte formation; (58k) about 5 feet (1.5 m.) below the top of the Lower Cambrian in thin-bedded bluish-black and gray limestone, just above the tunnel, north shoulder of Mount Stephen, 3 miles (4.8 km.) east of Field, British Columbia, Canada.

DORYPYGE DAMIA, new species

Plate 11, figs. 7, *7a*

Species known from imperfect cranidia and pygidia.

Cephalon.—Glabella broadly and rather strongly convex, subcylindrical in outline and slightly contracted anteriorly; dorsal furrows narrow but quite deeply impressed, terminating anteriorly in a couple of small pits; anterior furrow very narrow and separating a wire-like border from the glabella; anterior extremity rounded; glabellar furrows reduced to a posterior and medial pair of short shallow linear depressions just within the dorsal furrows; occipital furrow almost obsolete upon the summit of the glabella, narrow but quite deeply incised towards the dorsal furrows; occipital ring moderately wide, imperfectly preserved. Fixed cheeks also imperfectly preserved, rather narrow, and gently convex; groove of postero-lateral lobe quite broad but not very deep, in line with the occipital ring. Palpebral lobe not preserved. Palpebral ridge feebly indicated by an obtuse angulation of the cheek a little behind and parallel to the anterior extremity. Frontal limb practically obsolete in front of the glabella. Other characters unknown.

Pygidium.—Associated pygidium rather large, semielliptical in outline. Axial lobe quite strongly convex, of approximately the same width as the pleural lobe; tapering gradually toward the obtusely rounded posterior extremity which falls just within the peripheral rim; axial annulations coarse and distinct even toward

[1] Smithsonian Misc. Coll., Vol. 67, 1917, pl. 6, figs. *5b*, *5c*.

[2] Idem. Vol. 64, 1916, pl. 35, figs. *1d*, *1e*.

the posterior extremity, indicating 5 component segments and a terminal section. Pleural lobes flattened; traces of the anchylosed segments still retained in the broad and shallow pleural grooves, which become increasingly shallow and approach more and more closely to the axis of the shield toward the posterior extremity. Peripheral rim narrow, flattened and with 5 very sharp short spines on each side which are more strongly inclined posteriorly; they correspond in number and position to the component anchylosed segments.

Surface.—Exterior surface finely granulated.

Dimensions.—Length of type cranidium, 11.0± mm.; length of glabella, 10.0± mm.; width of glabella at base, 7.0± mm.; length of pygidium exclusive of serrations, 11.0± mm.; width of pygidium anteriorly, exclusive of serrations, 18.0± mm.

Type locality.—(**62w**) Wonder Pass.

Observations.—The cranidium of this species at once recalls that of *Dorypyge richthofeni* Dames, from China.[1] It differs in its finer squamose granulation. The associated pygidia are also quite unlike those associated with the Chinese species.

Formation and locality.—Lower Cambrian: (**62w**) Mount Whyte formation; No. 1 of section; oolitic limestone; about 400 feet (123 m.) below summit of ridge above Gog Lake below Wonder Pass on Continental Divide, in British Columbia, 19 miles (30.4 km.) southwest of Banff, Alberta, Canada.

[1] Research in China, Carnegie Inst. of Washington, Pub. No. 54, Vol. 3. 1913, pl. 8, figs. 1, 1*b*.

DESCRIPTION OF PLATE 8

PAGE

Gogia prolifica Walcott.. 68

FIG. 1. (Natural size.) Calyx with 5 arms and outline of stem. U. S. National Museum, Catalogue No. 64350.

1*a*. (× 3.) Stem and calyx of the specimen illustrated by fig. 1*b*. The plates have been removed by solution, so that the cast of the inner surface of the plate of the calyx and of the outer surface of the plates of the stem is shown.

1*b*. (Natural size.) Calyx, stem and arms of specimen shown by fig. 1*a*. A small calyx is seen on the upper end of the piece of rock. Note the long arms. U. S. National Museum, Catalogue No. 64351.

The specimens represented by figs. 1, 1*a-b*, are from locality **62x**, Lower Cambrian: Mount Whyte formation; above Gog Lake, Wonder Pass, British Columbia.

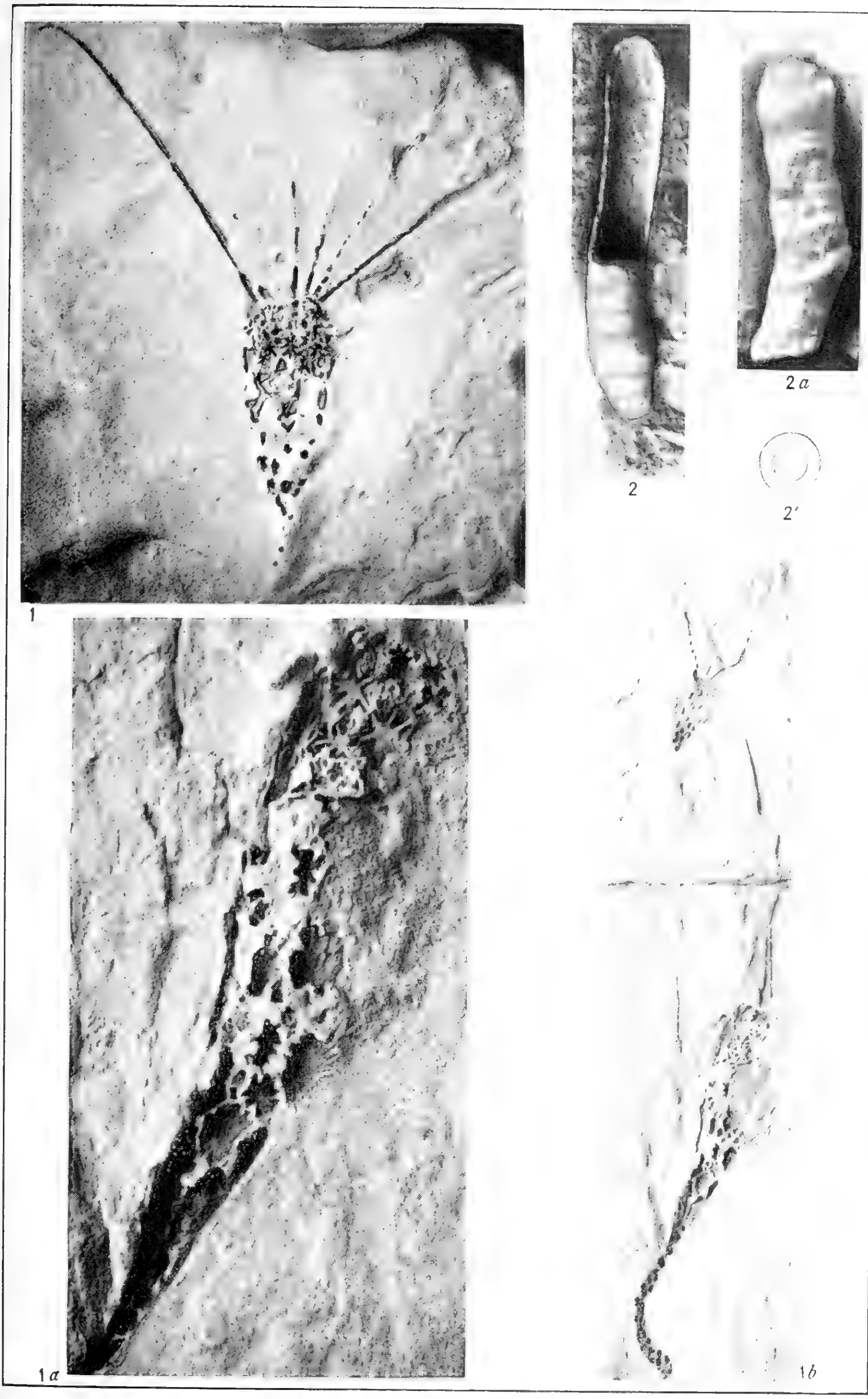
Archæocyathus (*Archæocyathellus*) *atreus* Walcott...................... 67

FIG. 2. (× 4.) Portion of a slender corolla with matrix of its extension.

2′. Cross section of fig. 2, showing thickness of wall.

2*a*. (× 4.) An irregular corolla with strong undulations of growth. (This is on the same block with fig. 2.) U. S. National Museum, Catalogue No. 64352.

The specimens represented by figs. 2, 2*a*, are from locality **62w**, Lower Cambrian: Mount Whyte formation; above Gog Lake, Wonder Pass, British Columbia.



LOWER CAMBRIAN CYSTIDS

DESCRIPTION OF PLATE 9

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Corynexochus senectus (Billings) 66

FIGS. 1, 1*a*. (× 3.) Dorsal view and side outline of cranidium with most of test exfoliated. U. S. National Museum, Catalogue No. 62726.

1*b*, 1*c*. (× 4.) Dorsal and side view of a pygidium. U. S. National Museum, Catalogue No. 62731.

1*d*. (× 4.) Small pygidium. U. S. National Museum, Catalogue No. 62733.

From limestone at locality **41l**, Lower Cambrian: Bonne Bay, Newfoundland.

The specimens represented by figs. 1, 1*a-d* have been figured by Walcott, Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pl. 56, figs. 1, 1′, 1*e*, 1*e*′, and 1*f*, respectively.

2, 2*a*. (× 3.) Dorsal and side views of a partially exfoliated cranidium, with slight indication of lateral glabellar furrows. U. S. National Museum, Catalogue No. 62722.

2*b*, 2*c*. (× 3.) An associated pygidium that has been slightly elongated. U. S. National Museum, Catalogue No. 62723.

From locality **61d**, Lower Cambrian: Mount Whyte formation; southwest slope of Mount Shaffer, British Columbia.

The specimens represented by figs. 2, 2*a-c*, have been figured by Walcott, Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pl. 55, figs. 7, 7′, 7*a*, and 7*a*′, respectively.

Mesonacis vermontana (Hall) 66

FIG. 3. (Natural size.) An entire dorsal shield from the type locality (**25**) at Georgia, Vermont, showing 14 thoracic segments of the *Olenellus* type, the spine-bearing segment, and ten segments of the *Mesonacis* type. U. S. National Museum, Catalogue No. 15399*a*.

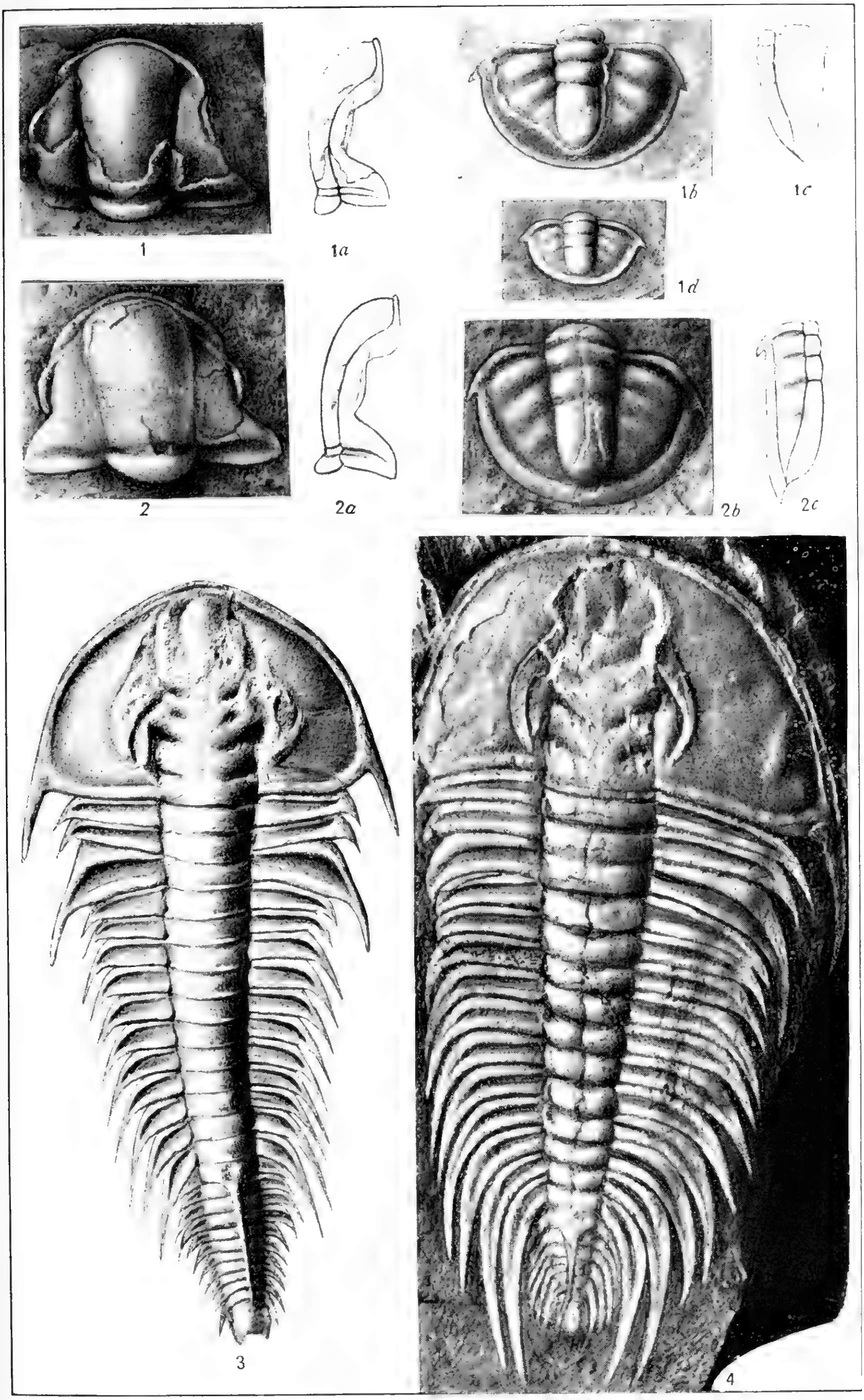
From locality **25**, Lower Cambrian: Siliceous or finely arenaceous shale just above Parker's quarry, Georgia township, Franklin County, Vermont.

The specimen represented by fig. 3 has been figured by Walcott, Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 26, fig. 1; also idem, Vol. 64, No. 5, 1916, pl. 45, fig. 2.

Mesonacis gilberti (Meek) 66

FIG. 4. (About ½ natural size.) The illustration is taken from a plaster cast of the specimen now in the Geological Museum of Princeton University, Princeton, New Jersey, which was from locality **35n**, Lower Cambrian: Mount Whyte formation; eastern slope of Mount Odaray, above McArthur Pass, British Columbia. Plastotype. U. S. National Museum, Catalogue No. 62619.

The specimen represented by fig. 4 has been figured by Walcott, Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pl. 45, fig. 3.



LOWER CAMBRIAN TRILOBITES

DESCRIPTION OF PLATE 10

PAGE

Corynexochus (*Bonnia*) *parvulus* (Billings) 65

FIGS. 1, 1*a*. (× 3.) Dorsal and side views of a finely preserved cranidium. U. S. National Museum, Catalogue No. 62744.

1*b*, 1*c*. (× 3.) Dorsal and side views of a pygidium. U. S. National Museum, Catalogue No. 62745.

From the limestone of locality **41k**, Lower Cambrian: Forteau Bay, Labrador.

The specimens represented by figs. 1, 1*a-c*, have been figured by Walcott, Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pl. 57, figs. 1*b*, 1*b'*, 1*c*, and 1*c'*, respectively.

Corynexochus (*Bonnia*) *fieldensis* (Walcott) 65

FIGS. 2, 2*a*. (× 3.) Dorsal and side views of the type cranidium. U. S. National Museum, Catalogue No. 62751.

2*b*, 2*c*. (× 3.) Dorsal and side views of a pygidium associated with the cranidium represented by fig. 2. U. S. National Museum, Catalogue No. 62752.

From the limestone locality **35l**, Lower Cambrian: Ptarmigan Pass, Alberta.

The specimens represented by figs. 2, 2*a-c* have been figured by Walcott, Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pl. 57, figs. 4, 4', 4*a*, and 4*a'*, respectively.

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FIG. 3. (× 3.) Ventral valve flattened by compression in the siliceous shale. U. S. National Museum, Catalogue No. 64353.

3*a*. (× 4.) Flattened dorsal valves, one of which shows the reticulated surface. U. S. National Museum, Catalogue No. 64354.

3*b*. (× 6.) Two small ventral valves with very little distortion. U. S. National Museum, Catalogue No. 64355.

The specimens represented by figs. 3, 3*a-b* are from siliceous shales of the Mount Whyte formation (**61c**) on Mount Odaray, British Columbia.

Acrothele clitus Walcott 70

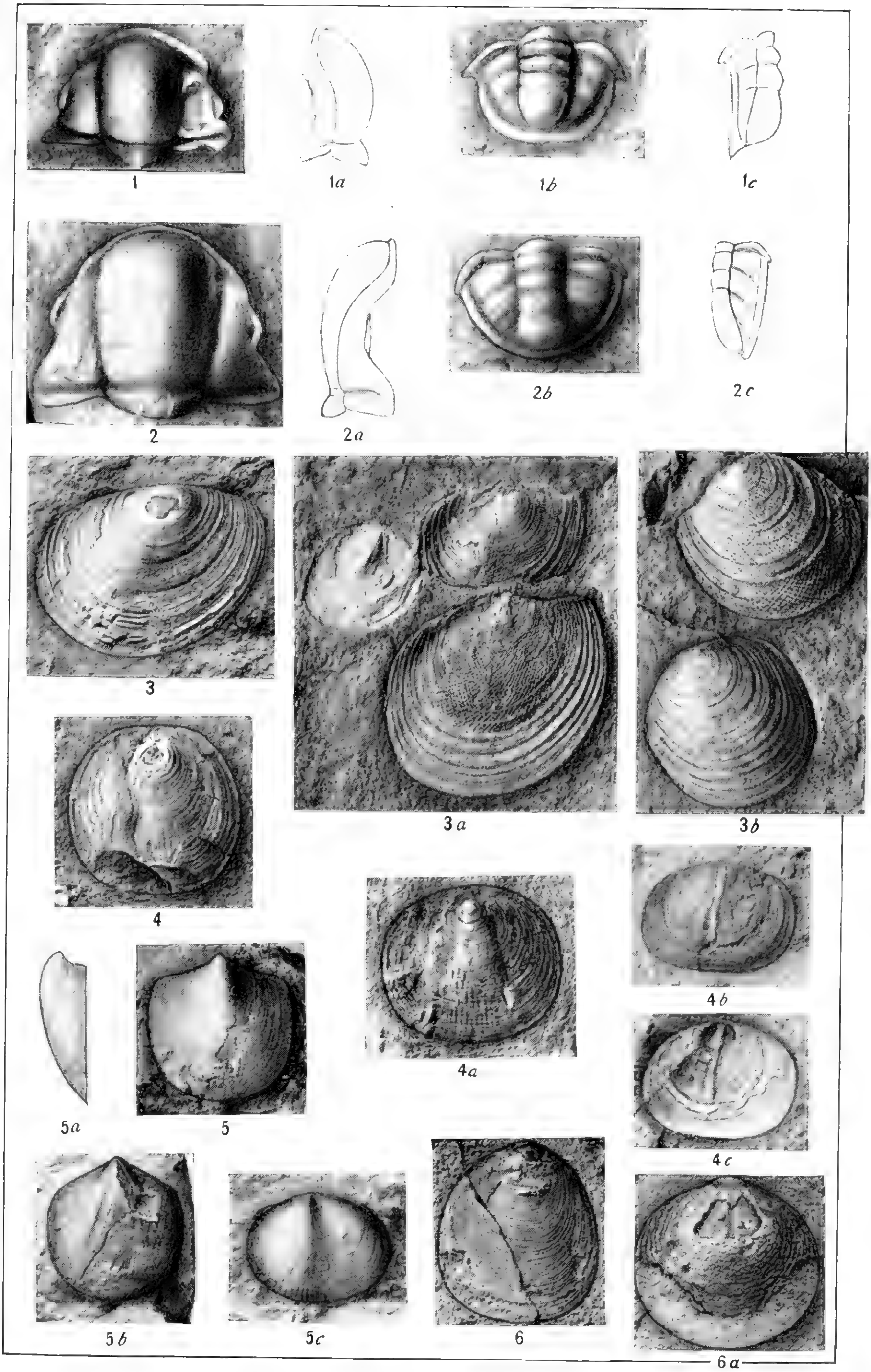
FIG. 4. (× 6.) An exfoliated and crushed ventral valve. U. S. National Museum, Catalogue No. 64356.

4*a*. (× 6.) A crushed ventral valve with the shell preserved. U. S. National Museum, Catalogue No. 64357.

4*b*. (× 6.) Cast in the shale of the interior of a dorsal valve. U. S. National Museum, Catalogue No. 64358.

4*c*. (× 6.) Interior of a dorsal valve. (On same piece as 4*b*.) U. S. National Museum, Catalogue No. 64359.

The specimens represented by figs. 4, 4*a-c* are from the fine siliceous Lake Agnes shale (**35e**) of the Mount Whyte formation, above the head of Lake Agnes, Alberta.



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5*b*. (× 1.5.) Cast of the interior of a ventral valve showing traces of the great vascular sinuses. U. S. National Museum, Catalogue No. 64361.

5*c*. (× 1.5.) Cast of the exterior of a dorsal valve. U. S. National Museum, Catalogue No. 64362.

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6*a*. (× 6.) Cast of interior of a ventral valve. U. S. National Museum, Catalogue No. 64364.

The specimens represented by figs. 6, 6*a* are from locality **63g**, Lower Cambrian: Mount Whyte formation; greenish arenaceous shale, southwest slope of Mount Temple, Alberta.

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Fig. 1. (× 4.) A broken cranidium, the type of the species showing the tuberculated surface. U. S. National Museum, Catalogue No. 64365.

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Figs. 3, 3*a*. (× 3.) Top view and side outline of the type cranidium of the species. U. S. National Museum, Catalogue No. 64368.

From locality **58k**, Lower Cambrian: Mount Whyte formation; Mount Stephen, British Columbia.

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From locality **35f**, Lower Cambrian: Mount Whyte formation; Mount Stephen, British Columbia.

Ptychoparia cossus Walcott 86

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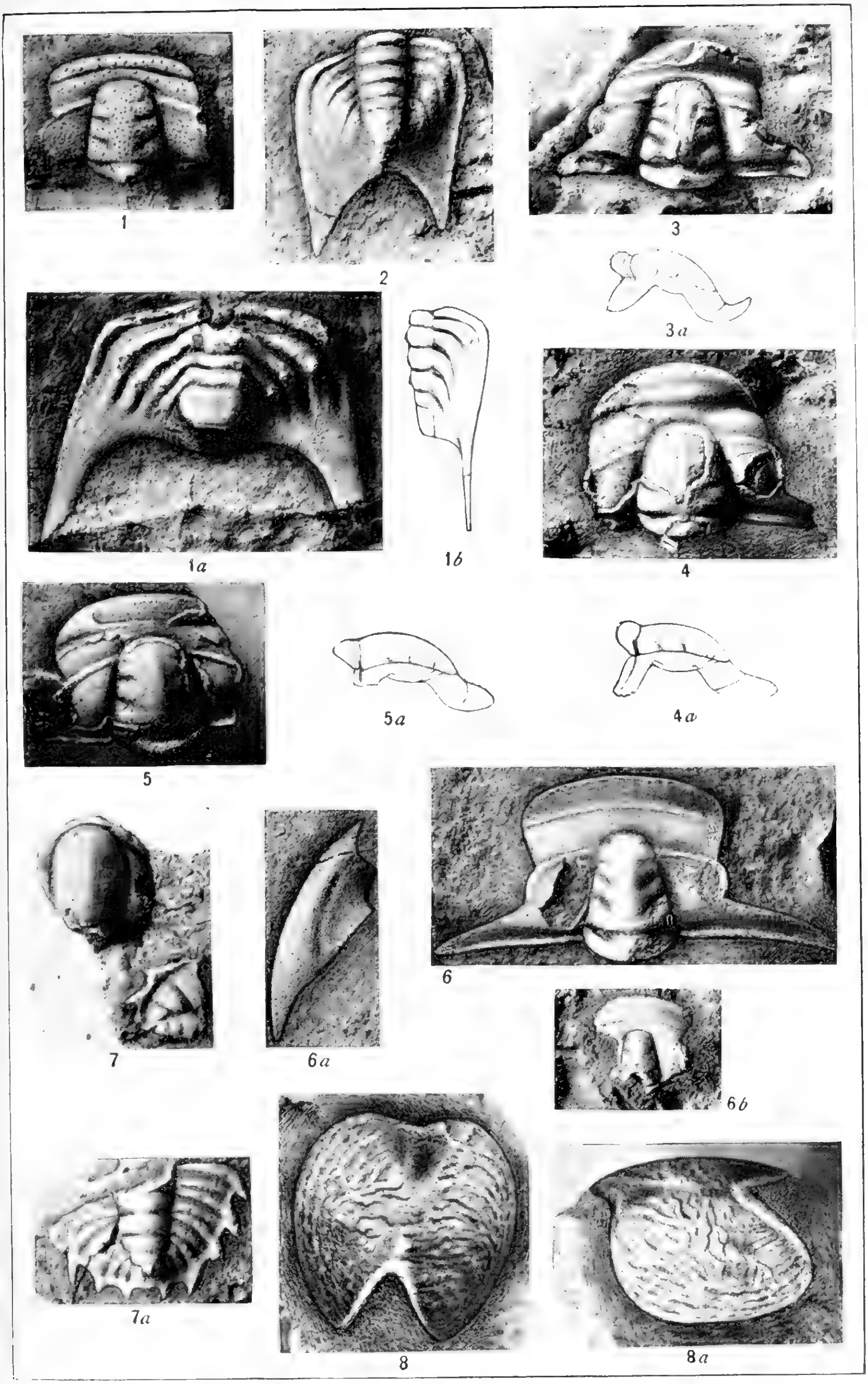
Fig. 6. (Natural size.) The type specimen of a large cranidium, which has been partially restored on the right side. U. S. National Museum, Catalogue No. 64371.

6*a*. (Natural size.) Interior of free cheek associated with the cranidium represented by fig. 6. U. S. National Museum, Catalogue No. 64372.



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6*b*. (Natural size.) A small broken cranidium associated in the same layer of shaly calcareo-arenaceous sandstone with the specimen represented by fig. 6. U. S. National Museum, Catalogue No. 64373.

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8*a*. (× 6.) Side view of the carapace illustrated by fig. 8.

From locality **61d,** Lower Cambrian: Mount Whyte formation; oolitic limestone, southwest slope of Mount Shaffer, British Columbia.

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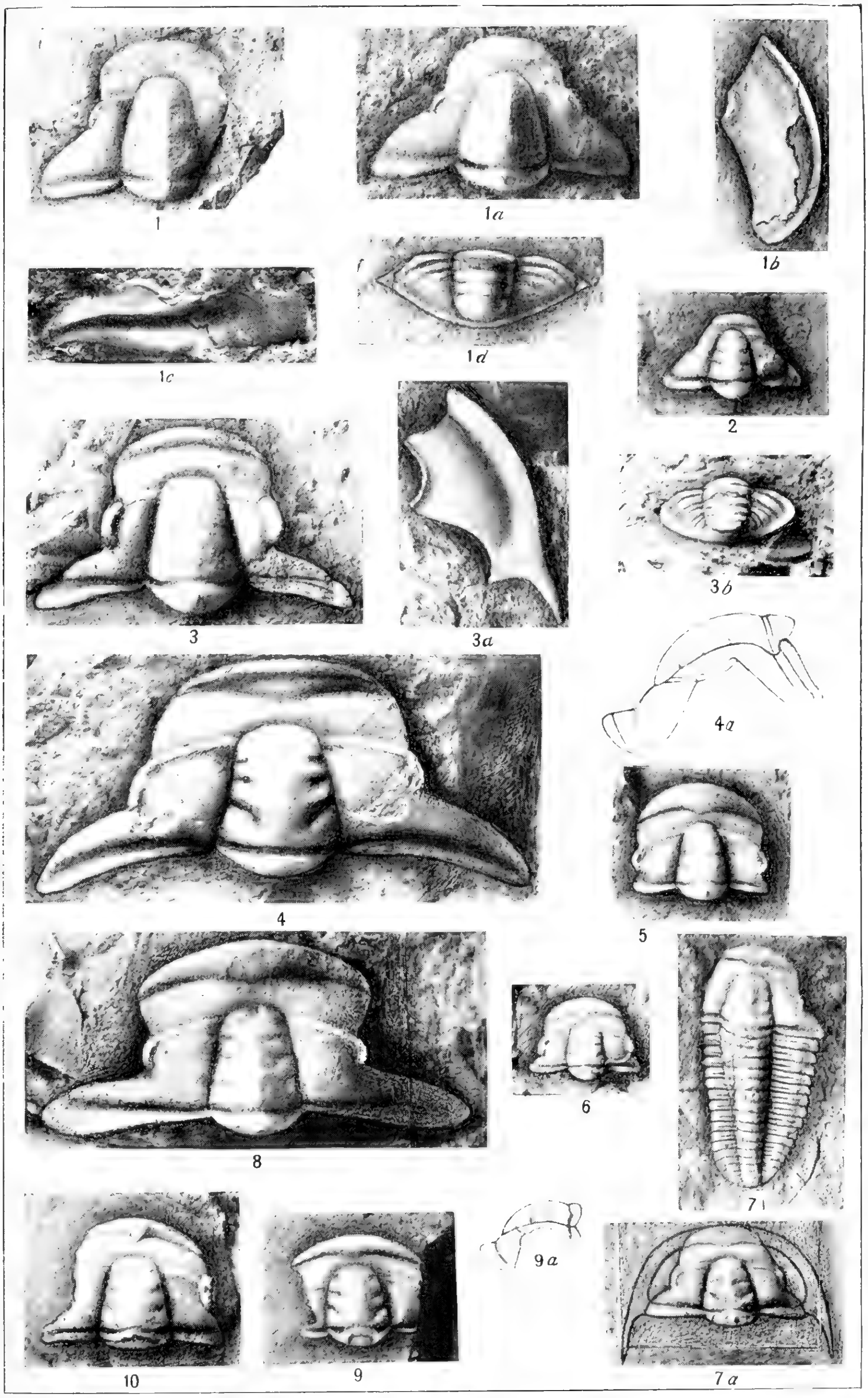
From locality **62w,** Lower Cambrian: Mount Whyte formation; above Gog Lake, Wonder Pass.



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From locality **35f,** Lower Cambrian: Mount Whyte formation; Mount Stephen.

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From locality **58g,** Lower Cambrian: Mount Whyte formation; south slope of Mount Bosworth.

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FIG. 5. (× 2.) A nearly entire dorsal shield with the free cheeks restored from another specimen. This is the type specimen of the species. A poor photograph of this specimen was reproduced on fig. 2, pl. 36, Smithsonian Misc. Coll., Vol. 57, 1912. U. S. National Museum, Catalogue No. 58364.

From locality **35m,** Lower Cambrian: Mount Whyte formation; Lake Agnes shale, above Lake Agnes.

FIGS. 5*a*, 5*b*. (× 4.) Top view and side outline of a cranidium from limestone identified with this species. U. S. National Museum, Catalogue No. 64398.

5*c*. (× 4.) Fragment of a thoracic segment, associated with fig. 5*a*. U. S. National Museum, Catalogue No. 64399.

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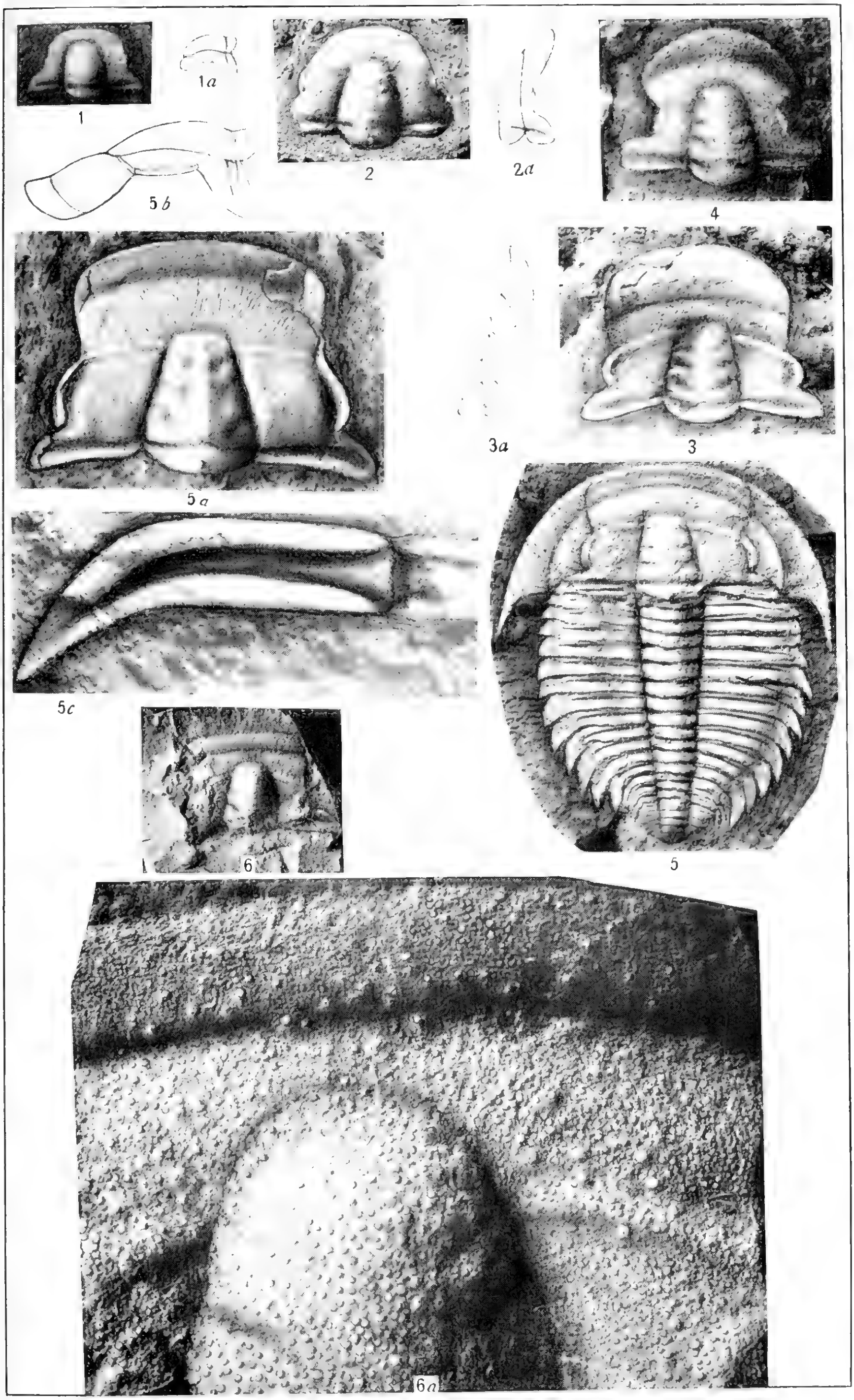
From locality **35m,** Lower Cambrian: Mount Whyte formation; Lake Agnes shale, above Lake Agnes.



LOWER CAMBRIAN TRILOBITES

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 4

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 4.—APPENDAGES OF TRILOBITES

(With Plates 14 to 42)

BY
CHARLES D. WALCOTT

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Smithsonian Miscellaneous Collections, Vol. 67, No. 4

SECTION 2

ILLUSTRATIONS

INTRODUCTION

In September, 1873, I said to Professor Louis Agassiz that if opportunity offered I would undertake as one bit of future research work to determine the structure of the trilobite. This promise has kept me at the problem for the past forty-five years, and except for the demands of administrative duties the investigations would have been advanced much more rapidly.

Since 1873 I have examined and studied all the trilobites that were available for evidence bearing on their structure and organization. The first summary of results was published in 1881 [1] and a restoration and cross-sections given of the ventral surface of *Calymene senaria* (*loc. cit.*, pl. VI) based on sections cut through the test, ventral cavity and appendages. These proved that the trilobite had a pair of biramous appendages for each segment of the thorax and abdomen and four pairs of cephalic appendages, the enlarged proximal joints of which served as organs of manducation. The restorations have since been shown to be essentially correct with the possible exception of the enlargement of the terminal joints of the posterior cephalic

[1] The Trilobite: New and Old Evidence Relating to its Organization. Bull. Mus. Comp. Zool., Cambridge, Mass., Vol. VIII, No. 10, 1881, pp. 191-224, pls. I-VI.

legs and the too short, proximal joints (protopodites). The placing of the Trilobita under the Class Pœcilopoda in 1881 was changed in 1894[1] when it was suggested that the Trilobita, Entomostraca, and Malacostraca were descendent from a common ancestor of pre-Cambrian time. In 1912[2] the Trilobita were represented as descendent from the Branchiopoda and on the line of descent of the Merostomata. The presence of antennules was not known positively until Valiant discovered antennules on *Triarthrus*[3] in 1892, and caudal rami until Walcott found them on *Neolenus* twenty years later.[4]

During the field seasons of 1910 to 1913 and 1917 I collected from the Burgess shale member of the Middle Cambrian Stephen formation of British Columbia with the aid of assistants a large fauna including specimens of the highly organized trilobite *Neolenus serratus,* some of which have beautifully preserved ventral appendages. *Neolenus* has a large head and tail, a short compact thorax, and is far advanced in the development of the Trilobita. Always hoping for more perfect specimens, a detailed description with illustrations was deferred, and only a few of the best specimens photographed and incidentally used in illustrations.[5] More data are desired, but I have decided to now record the evidence at hand as the Burgess shale quarry on the ridge connecting Mounts Wapta and Field is about exhausted and only a new locality or a chance specimen in the debris from the quarry will give further material from there for study.

For a description of the Burgess shale and the mode of occurrence of fossils the reader is referred to notes published in 1912.[6] In this paper I stated that [p. 192]

> In the near future I wish to review the conclusions published in my paper of 1881,[7] and those that have been entertained regarding *Triarthrus becki* and the new material from the Burgess shale.

As it is not probable that I shall again write on the structure of the trilobite I am now assembling in this paper notes and illustrations on the material studied from time to time since 1894. This includes the

[1] Proc. Biol. Soc. Washington, Vol. IX, p. 94.

[2] Smithsonian Misc. Coll., Vol. 57, p. 164.

[3] The Mineral Collector, New York, Vol. 8, No. 7, 1901, pp. 105-112.

[4] Smithsonian Misc. Coll., Vol. 57, 1912, p. 208, pl. 24, figs. 1, 1*a*.

[5] Idem, 1911, pl. 6, figs. 1, 2; 1912, pl. 24, figs. 1, 1*a;* pl. 45, figs. 1, 2, 3, 4.
Text-book Pal. (Zittel), Eastman 2d ed., 1913, Vol. I, p. 701, fig. 1343, p. 716, figs. 1376, 1377.

[6] Smithsonian Misc. Coll., Vol. 57, pp. 149-153.

[7] The Trilobite, New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, 1881, pp. 208-211.

specimens of the Cambrian genera *Neolenus, Kootenia,* and *Ptychoparia* and the Ordovician genera *Calymene, Ceraurus,*[1] *Isotelus,* and *Triarthrus.*[2] Of these, *Neolenus* has given the best and most instructive material of a trilobite in advanced development, and *Triarthrus* of a more primitive form.

The discussion of the appendages found in the several genera follows the description of the material known to me of each of the genera mentioned.

In a memoir soon to go to press by Dr. Percy E. Raymond I understand there will be a very complete statement of Beecher's work and a full review of what is known of the trilobite.

ACKNOWLEDGMENTS

I am indebted to the Museum of Comparative Zoology, Harvard University, for the opportunity of studying the Walcott collection of *Calymene senaria* and *Ceraurus pleurexanthemus* showing appendages. To the Peabody Museum, Yale University, for the loan of a portion of the Beecher collection of *Triarthrus becki.* To several assistants in the field collecting at Burgess Pass, notably Dr. Lancaster D. Burling, now of the Geological Survey, Canada. Mr. R. D. Mesler, of the U. S. National Museum, and to the members of my family who worked with me during several field seasons. In the office, Mr. Clarence R. Shoemaker, of the U. S. National Museum, made the final drawings of the restorations of the ventral surface of *Neolenus, Calymene,* and *Triarthrus,* using his knowledge of the crustacea to give a less diagrammatic appearance to my outline sketches. Mrs. Mary V. Walcott retouched the photographs used in illustration on plates 14, 18, 19, 20, 22, and 23. Miss G. R. Brigham, Ph. D., lettered the plates and read the text-proofs.

CORRECTION

In 1911 I referred figures 2 and 3, plate 2, also text figure 10, p. 206 (1912), of *Emeraldella brocki* to *Sidneyia inexpectans* in the paper on the latter species.[3] At the time I had not thoroughly studied *E. brocki,* and assumed that the specimens before me belonged to *Sidneyia.* In both cases the reference should be to *Emeraldella.* I expect in the near future to revise my preliminary work on the crustaceans from the Burgess shale.

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[1] Through the courtesy of the Museum of Comparative Zoology, Harvard College.

[2] Through the courtesy of the Peabody Museum, Yale University, and the U. S. National Museum.

[3] Smithsonian Misc. Coll., Vol. 57, 1911.

SECTION 1

NOTES ON SPECIES WITH APPENDAGES

Mode of Occurrence[1]

The two species of Ordovician Trilobites, *Calymene senaria* and *Ceraurus pleurexanthemus,* from which nine-tenths of the sections illustrating appendages were obtained, are the two most abundant forms in the Trenton limestone of Central and Northern New York. Their remains, or those of representative species, occur, usually in a fragmentary condition, in nearly every layer of the Trenton limestone, and range, above, into the Cincinnatian and, below, into the Black River limestone. Their geographic distribution is also great, as they occur in the Eastern Canadas and at nearly all the exposures of the Trenton series in the Northern United States, as far west as the Mississippi River. *Calymene* is much more abundant in Ohio, but at the locality from which the specimens of *Ceraurus* preserving appendages were obtained, the latter far exceeded it in numbers. The special interest attached to the occurrence of both species near Trenton Falls, Oneida County, New York, as well as of several other species, is their very perfect state of preservation in a thin layer of limestone outcropping in a small ravine half a mile east of the Trenton Falls canyon or gorge in the Township of Russia, Herkimer County, New York. An examination of the same horizon that this bed occupies, for several miles along the canyon, which is but half a mile away at one point, failed to give a single entire trilobite, and the fragmentary remains are rare. They are found both above and below the prolific layer of limestone, but not with any more of the animal preserved other than the dorsal shell and hypostoma. This indicates that in the vicinity of the outcrop in the small ravine there is a limited area, which was surrounded by conditions in Ordovician time that did not prevail elsewhere in the region, as the topography of the adjacent country permits of a close examination of the strata, and outcrops at about the same horizon were examined in all directions in the vicinity for the purpose of finding appendage-bearing trilobites.

[1] Walcott, C. D.: The Trilobite: New and Old Evidence relating to its Organization. Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII, 1881, No. 10, pp. 211-214.

The layer of limestone on which the prolific layer rests is about ten inches thick, and formed of the comminuted remains of crinoids, trilobites, etc., indicating the action of shore waves and a distributing current. A change supervened, and this surface was depressed beneath deeper water, or a barrier reef was formed, affording a quiet habitat in which flourished bryozoans, echinoderms, brachiopods, pteropods, entomostracans, and trilobites. The remains of all these are now found in a fine state of preservation attached to the lower surface of the superjacent layer of limestone which appears to have been a fine calcareous mud or ooze, deposited rapidly on the surface of the subjacent stratum, so as to form when solidified a layer from one-half to two inches in thickness. It did not destroy all the forms of life that existed on the surface prior to its deposition, but many species are not known to occur above it. The trilobites, however, flourished on the new upper surface as the beautifully preserved interiors of the dorsal shell testify, an illustration of which is given on plate 28.

Where the layer is over one inch in thickness, and there is no intermingled argillaceous shaly matter, as sometimes occurs, the best preserved specimens for cutting sections are found. They are usually with the dorsal surface downward, and partially enrolled. It was frequently noticed in polishing the sections that the imbedding rock showed dark laminations curving beneath the trilobite, as though the soft mud had been compressed by its sinking down into it. Similar traces proved that the mud flowed over into the half-enrolled shell, but buried the appendages, or such as were left of them, as often the laminations of the inflowing mud have not been disturbed since covering the viscera and fragments of the branchiæ and limbs.

In a former paper[1] it is stated that 1,110 trilobites out of a total of 1,160 had been found resting on their backs, and it was argued from this that that was their normal position when living, as Burmeister had shown for *Branchipus* and theoretically for the trilobite. In subsequent work the proportion was found to remain nearly the same, but with the discovery of ambulatory thoracic legs the view of their living in that position was necessarily abandoned. Mr. Henry Hicks writes that he had observed the same position in the Primordial Trilobites of Wales, the shell of the great *Paradoxides,* eighteen inches in length, occurring with its dorsal surface downward. He attributes it, and I think correctly, to the accumulation of gases in

[1] Ann. Lyc. Nat. History, Vol. XI, p. 159, 1875.

the viscera, which, with the boat-shaped shell, would cause the animal to turn over on the slightest motion in the water, and it would there remain to be buried beneath the next deposit of sediment.

Beecher calls attention to his finding nearly all of the specimens of *Triarthrus becki* with the back down. His explanation of the occurrence is as follows:[1]

It seems most probable that trilobites could both swim freely and crawl along the bottom, and that, on dying, they coiled themselves up in the same manner as the recent isopods. Then upon unrolling they would necessarily lie on their backs. Even if they did not coil up, any swimming animal having a boat-shaped form would settle downward through the water with the concave side up.

The specimens of *Neolenus* from the Burgess shale were obtained from blocks of shale after they had been blasted from the quarry, and there is no record of their position. In one case illustrated on plate 15, one specimen was ventral side up and the other showed the dorsal side. The appendages are about equally well preserved and do not show the bending under the edge of the dorsal shield, as suggested by Beecher in event of a trilobite being turned over after settling to the surface of the mud on the bottom of the body of water in which it was living.[1]

From the great abundance of trilobite tracks on shales and sandstones, and from the nature of their food, it is quite probable that they usually moved about with their dorsal shield uppermost, and turned over after death.

Conditions of Preservation

Trilobites preserving ventral appendages have been found in limestones and both argillaceous and siliceous shale. The specimen of *Isotelus* from the Trenton limestone at Ottawa, Canada, was found about 1860 in a thin slab of typical dark bluish-gray compact limestone. The animal had evidently settled in the calcareous mud without any considerable disturbance of its legs (endopodites) as the protopodites of the anterior three pairs of thoracic legs are now at nearly right angles to the median axis; the posterior legs are sloping backward as in the Ohio *Isotelus* (pls. 24, 25). From the fact that the legs occur near the under surface of the dorsal shield it is probable that the animal settled in the mud with the ventral surface up and that the accumulating sediment crowded the legs down into the concave shield and displaced them more or less, but did not tear them

[1] American Geologist, Vol. XIII, 1894, p. 40.

from their fastenings to the ventral surface. The appendages are preserved as limestone replacements of the original parts.

The Ohio *Isotelus* (pl. 24, fig. 3; pl. 25, fig. 1) also occurs in a fine-grained, compact limestone, and it shows the effect of compression in the sediment by the backward slope of the proximal joints (protopodites) of the legs. In both specimens mentioned the embedding mud was relatively soft and the animal must have been quickly covered over. The limbs are preserved as a limestone replacement of the original limbs, the integument having disappeared.

The specimens of *Isotelus* from the Trenton limestone, near Trenton Falls, New York, preserving traces of the thoracic limbs, occur in a compact, hard, bluish-gray limestone that was formed from a relatively soft, calcareous mud into which the animal readily sank and became embedded.

The specimens of *Calymene* and *Ceraurus* with ventral appendages preserved are from a thin layer of compact, fine-grained, bluish-gray limestone which was originally a relatively soft calcareous sediment that quickly covered the trilobites on the bottom or in some instances they sank into the mud and were buried without material disturbance of the appendages. The integument of the limbs and all parts have often been replaced by calcite, which makes it possible to obtain sections showing the outlines of the appendages in the dark limestone matrix.

Triarthrus with appendages occurs in a black, compact thin band of argillaceous shale and the appendages and often the dorsal shield are preserved by being replaced by iron pyrite. I have found hundreds of specimens of *T. becki* in other localities than that near Rome, New York, but none showed traces of appendages. Local conditions were favorable for their preservation in the thin band of shale near Rome just as they were favorable for those found in the Middle Cambrian Burgess shale.

The Burgess shale trilobites *Neolenus, Kootenia,* and *Ptychoparia* occur in a band of fine siliceous shale about one meter in thickness in which the appendages are preserved as a black, almost glistening, carbonaceous appearing substance that is not readily attacked by acids. The siliceous shale of the layers containing the trilobites with appendages is remarkably uniform throughout and it was evidently a fine, rapidly deposited silt. "That carbonic acid gas was present in the mud and immediately adjoining water is suggested by the very perfect state of preservation of the numerous and varied forms of life. These latter certainly would have been destroyed by the worms and predatory crustaceans that were associated with them, if the animals that dropped to the bottom on the mud or that crawled or were drifted onto it were not at once killed and preserved with little or no decomposition or mechanical destruction. This conclusion applies to nearly all parts of a limited deposit about six feet in thickness, and especially to the lower two feet of it."[1] The fact that there are few trilobites found in the deposit and that their fragmentary remains are unusually abundant in the rocks beneath indicates that those found with appendages were individuals that strayed in from more favorable surrounding areas.

Manner of Life[2]

Burmeister gives us, as his view of the manner of life the trilobites led, "that they most probably did not inhabit the open sea, but the vicinity of coasts, in shallow water, and that they here lived gregariously in vast numbers, chiefly of one species; that they moved only by swimming in an inverted position, and did not creep about on the bottom; that they lived on smaller water animals, and, in the absence of such, on the spawn of allied species."

Barrande supposed that they lived in deep water and swam on the surface of the sea.

Dr. Dohrn considers that they lived at the bottom of the sea, and with extremities like those of *Limulus* crawled about. This view was necessarily taken by all authors who considered the trilobite as related by its zoölogical affinities to *Limulus*.

Dr. Packard states[3] that Mr. Alexander Agassiz had captured the larva of *Limulus* swimming free on the surface of the ocean, three miles from the shore. From the comparisons made by Dr. Packard between the young *Limulus* and the young trilobites as described by M. Barrande, there is no reason to doubt that the young trilobite may have had the same power of distributing itself and its species over extended areas in the wide-spread paleozoic seas. As in *Limulus* its later growth changed its manner of life, and its movements were finally largely restricted to crawling about the sea bottom in search of food.

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[1] Smithsonian Misc. Coll., Vol. 57, 1911, No. 3, p. 42.

[2] Walcott, C. D.: The Trilobite: New and Old Evidence relating to its Organization. Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII, 1881, No. 10, pp. 214-215.

[3] Development *Limulus polyphemus,* Memoirs Boston Soc. Nat. Hist., p. 155, 1872.

We have seen from the views of Burmeister, Barrande, and others, that it has been thought to be both an inhabitant of shallow waters along the coasts and also of the deeper seas. It is found in both littoral and deep-water formations. Muddy or sandy, fine or coarse, hard or soft, argillaceous or calcareous deposits, it occurs in all. With these facts in view, it is probable that it ranged along the shore in quiet bays, and also in the habitat of the brachiopods and other deeper water invertebrates. In conclusion we may say that the trilobite in its younger stages of growth was active and a free swimmer, thus distributing itself over broad areas; that on reaching a larger growth it became more limited in its natatory powers and crawled about the bottom in search of soft-bodied organisms for food and during the spawning season for a place to deposit its eggs.[1] From the presence of broad setiferous exopodites on the limbs of *Neolenus* and *Triarthrus*, and endopodites (legs) with flattened joints on other species it is highly probable that the trilobite as we now know it may have had limited natatory powers, during its adult life, but it probably swam about in its local habitat, and rarely moved far away after once finding a favorable environment.

Method of progression.—The strong, long legs of trilobites enable them to crawl rapidly over the surface of hard or moderately compact sediments either under water or over the wet surface of the beach between tides. When searching for worms, their principal source of food, they evidently worked down into the mud very much as the horseshoe crab (*Limulus*) does and by means of their strong protopodites and legs pushed the dorsal shield along, thus forming deep trails and half burrows, which when made in moderately stiff clay or arenaceous mud retained the form of the trail and burrows until the next tide or current filled them up and a natural cast was formed; these trails and casts occur in great abundance as fossils, and thus preserved the record of the method of movement of the trilobite when crawling about and when feeding. Often the deeper trails appear as though the animal had settled in the mud and then lifted itself up on the ends of its legs, moved ahead a little, and then settled down again, repeating the movement for considerable distances.

Swimming was the method of more rapid progress by some species when the animal moved any considerable distance, or was avoiding immediate danger which it could not escape by burrowing or clinging

[1] See Dr. Packard's description of the spawning of *Limulus* and its probable occurrence in the same manner with the trilobite. *Ibid.*, p. 186.

to the bottom. Of the species of which we know something of their limbs, all had a limited development of swimming power either by using the flat, jointed legs or the exopodites or epipodites. It is not probable, however, that they were great swimmers with possibly the exception of *Triarthrus.*

Food.—The gnathobases of the cephalic limbs of trilobites clearly indicate that their food was largely worms and such soft bodied and small, minute life as came in their way, also rotting algæ and any decomposed animal matter.

The habitat of *Neolenus* abounded in worms, soft invertebrates, and fine, delicate algæ, and in all rocks where I have known entire trilobites to occur there has been strong evidence that worms and usually algæ were abundant. There is not any evidence that the trilobite possessed strong manducatory jaws similar to those of the Eurypterida or the more insignificant branchiopod *Apus.*

Defense and offence.—The known limbs of the trilobite were without offensive or defensive power. For defense many of them could enroll, and all could settle down closely on the bottom or burrow in the mud and thus present only a smooth, hard surface or a spiny shell to attack. *Calymene* is frequently found enrolled, the head and pygidium fitting closely together, so that no opening is left at any point, the legs being all drawn within the shell and entirely protected from injury from without. With *Ceraurus pleurexanthemus,* a perfect closing of the shell by enrolment is impossible, and the space formed by the partial enclosure of the spinous extension of the pleuræ affords but an incomplete protection to the numerous legs and branchiæ.[1] *Neolenus* and *Triarthrus* could not have rolled up effectively as compared with *Calymene.*

Without offensive or special defensive parts they were evidently peace-loving and depended on great reproductive power and favorable environment for continued existence. In Cambrian time they were the largest element in the fauna and had only two known species of Eurypterida to interfere with them. After this, enemies gradually increased and the number of species and of individuals decreased until the race became extinct in early Carboniferous time. Bacteria undoubtedly existed, but as yet we have no record of their presence in the trilobite.

[1] Walcott, C. D.: The Trilobite: New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, No. 10, 1881, p. 203.

DESCRIPTION OF SPECIES WITH APPENDAGES

Order OPISTHOPARIA Beecher

Family ORYCTOCEPHALIDÆ Beecher

Genus NEOLENUS Matthew

NEOLENUS SERRATUS (Rominger)

PLATES 14-23

Ogygia serrata ROMINGER, 1887, Proc. Acad. Nat. Sci. Philadelphia, p. 13, pl. 1, figs. 2, *2a*. (Description and illustration.)

Neolenus serratus MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. 5, sec. 4, p. 53. (Mentioned in proposing genus *Neolenus*.)

Neolenus serratus WALCOTT, 1908, Canadian Alpine Jour., Vol. 1, No. 2, pl. 4, fig. 3. (Figure of dorsal test.)

Neolenus serratus GRABAU and SHIMER, 1910, North Am. Index Fos., Vol. 2, p. 271, fig. 1566. (Reproduces Walcott figure.)

Neolenus serratus WALCOTT, 1912, Smithsonian Misc. Coll., Vol. 57, p. 190, pl. 24, figs. 1, *1a*. (Figures specimens showing appendages.)

Neolenus serratus EASTMAN, 1913, Text-book Pal. Zittel, 2d ed. by Eastman, Vol. 1, fig. 1343, p. 701, figs. 1376, 1377, p. 716. (Illustration of appendages from photographs furnished by Walcott.)

Neolenus serratus WALCOTT, 1916, Ann. Rept. Smithsonian Inst. for 1915, 1916, pl. 9. (Figured with appendages.)

The dorsal surface of the test or carapace is illustrated by figure 1, plate 14. The cephalon is formed of seven fused segments or somites, the thorax of seven free segments, and the pygidium of five fused segments, a total of 19 segments. The large cephalon and pygidium and thorax with only seven thoracic segments indicate an advanced form of trilobite as compared with *Ptychoparia, Triarthrus, Calymene,* and *Ceraurus*. *Neolenus* more nearly approaches *Isotelus* of the Cincinnati formation in form of its dorsal shield, but unfortunately only the protopodite and endopodite (leg) are known of the ventral appendages of *Isotelus* (pl. 25).

Cephalon of Neolenus.—The cephalon is formed of seven combined or fused segments. These include:

(*a*) The ocular or eye-bearing segment represented by the free cheeks;

(*b*) The palpebral or palpebral ridge-bearing segment which at the center is merged into the anterior lobe of the glabella.[1]

(*c*) The four segments fused in the glabella.

(*d*) The occipital or posterior (neck) segment.

The four posterior segments fused in the glabella are usually clearly indicated by the glabellar furrows, but owing to compression of the test in the shale the short, faint anterior pair of lateral furrows

[1] Smithsonian Misc. Coll., Vol. 53, 1910, p. 237, last paragraph.

indicating the division in the anterior lobe of the glabella are to be seen only in rare specimens that preserve the natural convexity of the test. The fusing of the segments of the cephalon of the trilobite is finely shown in the young of the Mesonacidæ.[1]

Cephalic Appendages

These consist of the antennules and four pairs of cephalic limbs. The first pair may represent the antennæ; the second pair the mandibles; the third pair the maxillulæ, and the fourth pair the maxillæ of the theoretical crustacean head.

Antennules.—The antennules are long, slender, and formed of short joints for the first half or more of their length and of longer segments in the distal portion. A flattened antennule projecting from beneath a dorsal shield 65 mm. in length has a width of 2 mm. at base and 13 segments in the first 12 mm. of its length; at 0.75 mm. in width the segments are 1 mm. in length. The exact point of attachment of the antennule is unknown, but from the contour of the sides of the hypostoma it probably was attached to the ventral surface near the posterior third of the side of the hypostoma as shown on plate 31. Its length and flexibility are well shown on plate 15. Short, fine acicular spines occur at the distal end of the joints.

Endopodites.—Several specimens show one or more well-preserved cephalic limbs. The limb is essentially the same as the thoracic limb with the large elongate basal joint (protopodite[2]) modified slightly for the purpose of aiding in manducation. In two examples this joint is seen to be narrowed at the proximal end, but owing to the flattening of the leg by compression its exact form is not preserved (fig. 1, pl. 16). The protopodite as flattened in the shale expands slightly midway and the inner margin is slightly rounded so that if the leg extends obliquely forward its proximal margin may be more or less parallel to the longitudinal axis of the dorsal shield. On one specimen rather strong, short spines occur on the inner margin of the protopodite of the third cephalic leg (pl. 16, fig. 1). The four following joints are strong, compact, and very gradually decreasing in size; the sixth and seventh are more slender and proportionally more elongate; the distal extremity is formed of a small, strong, curved

[1] Smithsonian Misc. Coll., Vol. 53, 1910, pl. 25, figs. 9-13, 19-22, and pl. 36, figs. 10-15.

[2] The protopodite is considered to be in all trilobites preserving their limbs to be formed by the fusion of the coxopodite and basopodite.

claw and two small spines, which give when they are spread out a tripartite termination to the leg.[1] Two or more short, fine spines occur on the margin of the distal end of each joint of the leg.

The four cephalic legs extend well out from beneath the dorsal shield in several specimens and appear to be essentially similar. As yet no "precoxal" joint has been observed connecting the large, long protopodite to the ventral surface and it is doubtful if one existed distinct from the latter. The protopodite appears to have been strongly attached to the ventral integument of the head, probably by a narrow connection that extended from the dorsal side of the joint directly to a transversely elongate opening in the ventral integument through which the muscles of the limb passed.

Exopodite.—A long, flat, membranaceous lobe with a terminal joint is fringed on its posterior margin by fine, long, slender, flattened setæ out to the distal joint which has fine, short setæ on its posterior and outer margins; it appears to be attached to the protopodite at its distal end and extends outward into the space beneath the lateral extension of the cephalon and above the cephalic legs (pl. 16, fig. 1; pl. 20, fig. 2; pl. 22, fig. 1; pl. 34, fig. 3). This lobe appears to be similar to that attached to the protopodite of the thoracic and abdominal legs. Nothing has been seen of any epipodites such as are attached to the thoracic and abdominal limbs.

Thoracic Appendages

Each of the seven thoracic segments has a pair of limbs formed of a simple walking or crawling leg (endopodite), a lobe-like jointed exopodite, and a jointed epipodite. In addition there is a small, simple epipodite that was probably present on each one of the legs and a short, broad lobe with fine, short setæ along the margin that may be an exite such as occurs in *Anaspides* and *Koonunga*[2] (pl. 35).

Endopodite.—Each thoracic leg (endopodite) is formed of a large elongate proximal joint (protopodite); four strong joints each about 1.5 times as long as wide (basopodite, ischiopodite, meropodite and carpopodite); two slender elongate joints (propodite and dactylopodite) and a claw-like, more or less tripartite termination (pls. 17-20).

The protopodite is about 2.5 times as long as wide when flattened by compression (pl. 18); it expands between its distal and proximal extremities so that the posterior margin (as flattened) has a gentle

[1] Smithsonian Misc. Coll., Vol. 67, No. 5.

[2] See figs. 1, 2, p. 171, this paper.

curvature from end to end; the proximal and posterior margins are lined with short, fine spines similar to those on the second joint and at the distal end of each joint of the leg. The exact method of attachment of the protopodite to the ventral surface is unknown, but from its form it necessarily was strongly attached to the ventral integument of the body at a point on its dorsal surface somewhat as the limb of the living *Apus* or *Limulus* is attached. The form of the protopodite and the presence of a series of sharp, short spines clearly indicate that it is to be compared with the gnathobase of the branchiopod limb. The second joint of the leg is flattened and slightly expanded on the dorsal and narrowed on the ventral side, as are the third, fourth, and fifth joints; a marked feature is the sudden contraction in size of the sixth (propodite) joint which is about one-half the diameter of the preceding joints; both it and the seventh joint (dactylopodite) expand slightly from their base to the distal extremity. The terminal claw is strong, slightly incurved, and with two spines nearly as long as the claw inserted beside and a little back of it. A side view of the claw is shown by figure 1, plate 18, and a view of the claw and spines spread out by figure 3, plate 16.

The protopodite in its natural condition was probably narrow on its ventral face, a little broader on its dorsal side and deep on its anterior and posterior sides. A beaded longitudinal line that is preserved on several specimens (pl. 17, fig. 3; pl. 18, fig. 1) clearly indicates the edge of the dorsal face, the other edge being the line along which the joint folded when flattened out by compression.

Exopodite.—Of this there are a number of fairly well-preserved specimens. It is a broad, long, flat plate or lobe of two joints with many fine, long, flattened setæ on its posterior margin so closely arranged that they are often in the fossil slightly overlapping (pl. 21, fig. 6) except on the distal joint where the setæ are fine and short. The exopodite appears to have been attached to the protopodite at its distal end and to have extended outward nearly as far as the jointed leg (endopodite). The close joint towards its distal end is similar to that of the large epipodite. The position of the exopodite is illustrated by figure 3, plate 19; figure 6, plate 21, and figures 1, 2, plate 23, and in all relatively undistorted specimens it extends obliquely forward from the side of the axial lobe. Its relation to the jointed legs (endopodites) is shown by figure 6, plate 21, where the leg is beneath the exopodite. Figure 1, plate 22, indicates that the jointed epipodite was between the endopodite and exopodite when they were pressed down upon each other. From their position and form it is probable that the exopodites were used for (*a*) swimming; (*b*) for directing a flow of water over the gills; and (*c*) possibly for directing minute food particles towards the mouth; they may also have functioned as gills.

Epipodites.—The presence of a jointed epipodite was not suspected prior to the present study, although a few traces of a thin, structureless lobe were met with in attempts to uncover a complete lobe-like exopodite. A fortunate splitting of a small fragment of shale opened up a crushed trilobite on the left side of which jointed legs were exposed and above them four finely preserved epipodites. These were attached to the protopodite toward its distal portion, judging from their present position in relation to the endopodite (pl. 20, figs. 3, 4). The epipodite is formed of a long, proximal lobe or joint and a short distal lobe separated from the proximal by a well-defined, close joint. The test of the epipodite was very tenuous; it has left only a film on the surface of the shale, but this retains the outline of the joints, the transverse line of the joint, and the large interior. There are traces of fine spines or setæ on the posterior margins of the lobe-like joints. The epipodite is beneath the exopodite and above the endopodite in the specimens where their relations are clearly shown (pl. 20, figs. 3, 4; pl. 22, fig. 1). The function of the epipodite was probably that of a gill or branchia. It has not been possible with the material available for study to determine if there is a small basal joint uniting the long, flattened joint and the protopodite as in *Anaspides*[1] (pl. 35, figs. 1, 2).

A small, oval, plate-like lobe is definitely shown on one specimen (fig. 1, pl. 18, right side), which indicates that there is a second and smaller epipodite that was probably attached to the protopodite; its proximal end rests on a protopodite, but owing to the crushing down and flattening of both, it is impossible to detect where the point of attachment may have been.

Exites.—There is still another series of plate-like lobes that it is difficult to locate. They are broadly oval in outline with fine, short setæ or spines all around the margin except on the inner side. They are best shown by figures 3 and 4, plate 20, where the endopodite or leg appears to be *above* them. The separate lobes overlap so that the anterior margin of each passes beneath the lobe in front. They were probably attached to the inner side of the protopodite somewhat as the lobes of the protopodite of the first thoracic limb of *Anaspides*[1] (pl. 35, fig. 2). My first thought was that the lobes were attached

[1] On the genus *Anaspides.* W. T. Calman. Trans. Royal Soc. Edinburgh, Vol. 38, pt. 4 (No. 23), 1896, p. 791, pl. 2, fig. 12.

to the ventral integument just beneath the proximal joint owing to their position along the side of the axis, as shown by figure 3, plate 20, but this is highly improbable.

Abdominal appendages.—These consist of five pairs of limbs similar to those of the thorax except that they diminish gradually in length and size. There are also two caudal rami.

Caudal rami.—The caudal rami are very long, slender, jointed and with numerous fine spines on the proximal portion and very fine spines or setæ on the distal segments; the segments are numerous and slightly longer than the diameter of the rami except toward the distal portion where they are more elongate. The rami are strongly attached (probably articulated) to the posterior margin of the ventral membrane (pl. 17, fig. 3) and suggest a sixth pair of abdominal appendages corresponding to the posterior or anal segment of the pygidium. This segment is fused so closely with the fifth segment of the pygidium that it is rarely that a slight transverse depression outlines it.

Anal aperture.—The anal aperture is probably beneath the posterior margin and between the caudal rami (pl. 17, fig. 3). This view is sustained by the fact that in *Ceraurus pleurexanthemus* the intestine has been traced to the posterior margin of the ventral integument of the pygidium.[1]

Further reference to the appendages of *Neolenus* will be found under the discussion of the appendages of the trilobite.

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

KOOTENIA DAWSONI (Walcott)

Plate 14, figs. 2, 3

Bathyuriscus (Kootenia) dawsoni WALCOTT, 1888, Proc. U. S. Nat. Museum, Vol. XI (issued 1889), p. 446. (Describes species.)

Dorypyge Dawsoni MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. V, sec. IV, p. 56, pl. 3, fig. 1. (Describes and illustrates, referring species to *Dorypyge.*)

Dorypyge (Kootenia) dawsoni WALCOTT, 1908, Canadian Alpine Journ., Vol. 1, No. 2, pl. 3, fig. 9. (Illustrates a dorsal shield.)

This species combines characters of *Dorypyge, Olenoides,* and *Neolenus.* It has the slightly expanded subquadrilateral glabella of *Olenoides* and *Neolenus* with the unfurrowed, fused, pygidial seg-

[1] Bull. Mus. Comp. Zool., Vol. VIII, 1881, pl. 4, fig. 6.

ments of *Dorypyge*. The fringing spines of the pygidium are similar to those of the two former genera and quite unlike those of *Dorypyge*. The glabella of *Kootenia* differs from that of *Dorypyge* in form.[1]

These characters serve to distinguish the genus *Kootenia* from *Dorypyge*.

Appendages.—Many specimens of *K. dawsoni* were collected from the Burgess shale, but only one preserved any of the ventral appendages and these were only on one side beneath the pleura (pl. 14, fig. 2).

The distal joints of several endopodites of the thoracic limbs appear from beneath the long exopodites which seem to be similar to those of *Neolenus serratus*. The proximal section of the endopodite is long, flat and fringed with strong setæ; the distal joint has fine, short setæ along the lower margin and is closely united to the proximal section. From what there is available for comparison it appears that *Kootenia* and *Neolenus* had essentially the same type of thoracic limb.

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

Family ASAPHIDÆ Burmeister

Subfamily Asaphinæ Raymond

There is little to add to published data on the appendages of *Isotelus,* the one genus of the Asaphinæ preserving remains of jointed appendages, except in relation to the form of the endopodites. The specimen described by Billings[2] proved that *Isotelus* had a series of strong, jointed legs, but without the Ohio specimen[3] of *Isotelus maximus* it would have been difficult to interpret the structure of the legs of the Canadian specimen.

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[1] Compare fig. 2, pl. 14, with the cranidia of *Dorypyge richthofeni* Dames (Research in China, Carnegie Institution, Vol. III, 1913, pl. 8, figs. 1, 1*a*).

[2] Quart. Jour. Geol. Soc. London, 1870, Vol. 26, pp. 479-486, pls. 31, 32.

[3] Science, Vol. 3, 1884, pp. 279-281, figs. 1-3.

ISOTELUS MAXIMUS Locke

Plate 24, figs. 3, 3*a*; plate 25, fig. 1

Asaphus megistos MICKLEBOROUGH, 1883, Cincinnati Jour. Nat. Hist., Vol. 6, p. 200, figs. 1-3. (Describes and illustrates specimen with appendages.)
Asaphus megistos WALCOTT, 1884, Science, Vol. 3, p. 279, fig. 1. (Illustrates some specimens used by Mickleborough and gives notes on same.)
Isotelus maximus ULRICH, MSS.[1]

The large cephalon of the dorsal shield of *Isotelus* is made up of fused segments, traces of which are indicated on the exterior surface, especially of the young. The number of segments is unknown, but it is probably the same as for *Neolenus,* where seven segments are indicated. The thorax has eight free segments and a large pygidium (fig. 2, pl. 24) clearly shows fourteen fused segments. If this interpretation is correct there are twenty-nine segments included in the dorsal shield of *Isotelus,* and there may have been one or two more not now discernible in the end of the median lobe of the pygidium.

The unique Ohio specimen shows the protopodites of twenty-six pairs of limbs (pls. 24, 25). Of these nine are situated directly beneath the eight segments of the thorax; one beneath the posterior margin of the cephalon, and sixteen beneath the pygidium. That this was their natural position is not probable as they must have been more or less displaced when the animal was pressed down by or in the mud. That the displacement was not destructive is indicated by the regularity of arrangement of the legs and the approximation of the inner ends of the protopodites of the limbs. It is also probable that the protopodites sloped obliquely forward towards the median line instead of backward as in the specimen. This is spoken of under the subheading *Position of the Limbs,* page 162.

The proximal joint (protopodite) (pl. 25) of each leg is large, elongate, flattened vertically and extends well in towards the median line as in *Neolenus* (pl. 31) and *Triarthrus* (pl. 32). The second and following five joints appear to be slender and much like those found in *Calymene senaria,* but the first four were probably flattened and the distal ones rounded as in *Neolenus* (pl. 31) and *Triarthrus* (pl. 32). The drawing, plate 25, shows all that is preserved of the appendages on both the cast and matrix of the specimen (figs. 3, 3*a*, pl. 24).

[1] Dr. E. O. Ulrich has done much work on the genus and species of *Isotelus* and he very kindly permits me to use his illustrations of this and a second species, *I. walcotti,* a form from the trilobite quarry near Trenton Falls, New York, that I discovered about 1870.

The few traces of setæ such as might occur on exopodites of the type of those of *Neolenus* are not satisfactory proof that such exopodites existed in *Isotelus,* but they strongly suggest that such was the case.

Formation and locality.—Ordovician: Cincinnatian (Richmond); Oxford, Ohio.

ISOTELUS COVINGTONENSIS Ulrich ? MSS.

Asaphus platycephalus BILLINGS, 1870, Quart. Jour. Geol. Soc. London, Vol. XXVI, pp. 479-486, pls. XXXI, XXXII. (Describes and illustrates specimen with fragments of thoracic limbs.)

Isotelus latus RAYMOND, 1913, Bull. Victoria Mem. Museum, Vol. I, 1913, p. 45, pl. V. (Species described and figured.)

Isotelus covingtonensis ULRICH MSS., 1918. Dr. E. O. Ulrich identifies the specimen described by Billings, which was found at Ottawa, Canada, with his *Isotelus covingtonensis,* which occurs at Covington, Kentucky, also at Montreal, Canada, in the upper portion of the Trenton limestone.

Billings described the legs as follows:[1]

The legs are arranged in eight pairs, the bases of each pair being situated exactly under one of the eight segments of the thorax, and at the sides of the sternal groove.

The legs of the first pair are better-preserved than the others. They curve forwards and can be traced to a point nearly under the outer edge of the eye, or, rather, between the eye and the outside of the head. The other seven pairs follow at the average distance of two and a half lines from each other. The eight pairs thus occupy about twenty lines of the length of the ventral surface. This is exactly the length of the thorax, measured on the upperside. This trilobite has always eight segments in the thorax; and there is thus on the underside one pair of appendages to each segment. Although some of them are very imperfect, and the portions that remain are somewhat displaced, with a little study of the specimen it can be seen that they all curve forwards, and are thus, most probably, ambulatory rather than natatory legs.

There appear to be several joints in each of these appendages; but the exact number cannot be made out. On the left side, the first four legs show very clearly that there are at least two, one at five lines from the side of the groove, and another about three lines further out. The position of each of these is indicated by a small protuberance. On the right side the preserved portions of the legs are longer, and thus indicate a greater number of articulations, although they cannot be distinctly seen. I think that each leg consisted of at least four or five articulations.

Through the courtesy of Dr. R. G. McConnell, Director of the Canadian Geological Survey and Deputy Minister of Mines, I have recently had the opportunity of examining the specimen studied by Billings. The protopodites of the anterior thoracic limbs have a length of 11.5 mm.; they are separated along the median line of the

[1] Quart. Jour. Geol. Soc. London, Vol. XXVI, 1870, p. 480.

ventral surface of the thorax by a space of 4 mm. in width, which with the length of the two protopodites gives a transverse distance of 27 mm. or nearly the width of the axial lobe of the dorsal shield; this indicates that the protopodites were attached to the ventral surface near their distal end and extended well in over the mesosternites of the ventral integument. The original form of the protopodites and following joints of the endopodite has been largely lost through pressure and the deposition of calcareous matter upon them; the distal end of the protopodite is enlarged and all the joints of the endopodite preserved appear to have been filled with sediment before the matrix about them was consolidated. There is nothing to indicate that they differed materially from the limbs of *Isotelus maximus* (pl. 25). Dr. Billings' illustrations give a very fair idea of the appearance of the appendages, although a little diagrammatic.

Formation and locality.—Ordovician: Trenton limestone; Ottawa, Canada.

Family OLENIDÆ Burmeister

Genus TRIARTHRUS Green

TRIARTHRUS BECKI Green

Plate 29, figs. 1-11, Plate 30, figs. 1-20

Triarthrus becki[1] GREEN, 1832, Monogr. Trilobites North America, p. 87, pl. 1, fig. 6. (Original description and illustration.)

Triarthrus becki MATTHEW, 1893, American Jour. Sci., 3d ser., Vol. XLVI, p. 121, pl. 1, figs. 1-7. (Describes and illustrates antennæ, cephalic and thoracic limbs including endopodite and exopodite of limbs.)

Triarthrus becki BEECHER, 1893, American Jour. Sci., Vol. XLVI, p. 361, text fig. 1. (Describes mode of occurrence of trilobites with appendages.) Idem, p. 467, text figs. 1-3. (Describes and illustrates thoracic legs.) Idem, 1894, American Geol., Vol. XIII, pp. 38-43, pl. III, figs. 1-9. (Describes and illustrates antennæ and thoracic limbs, and discusses mode of occurrence.) Idem, 1894, American Jour. Sci., Vol. XLVII, pp. 298-300, text fig. 1, pl. VII, figs. 1-3. (Describes and illustrates appendages found beneath the pygidium.)

Triarthrus becki WALCOTT, 1894, Proc. Biol. Soc. Washington, Vol. IX, pp. 89-97, pl. I, figs. 1-6. (Notes and illustrations of appendages based on new material.) Idem, 1894, Geol. Mag. London, n. ser., Dec. IV, Vol. I, pp. 246-251, pl. VIII. (Reprint of preceding paper.)

Triarthrus becki BERNARD, 1894, Quart. Jour. Geol. Soc. London, Vol. 50, pp. 425, 426, text figs. 11, 12. Idem, 1895, Vol. 51, pp. 352-358. (Reproduces two of Beecher's figures and discusses the structure of the appendages of *Triarthrus becki.*)

[1] In this synonymy the references are only to the original description, and to other papers containing original description or illustration of the interior of the dorsal shield or of the ventral appendages.

Triarthrus becki BEECHER, 1895, American Geol., Vol. XV, pp. 93-98, pl. IV. (Describes and illustrates a unique specimen showing antennæ, cephalic and thoracic limbs.) Idem, 1895, Vol. XVI, p. 172, pl. 8, figs. 12-14, pl. 10, fig. 1. (Describes theoretical larval stage of *Triarthrus becki.*) Idem, 1896, Amer. Jour. Sci., 4th ser., Vol. I, pp. 251-256, pl. VIII, figs. 1, 2. (Describes and illustrates restoration of appendages of *Triarthrus becki* and discusses its morphology.) Also printed in Geol. Mag., London, Dec. IV, Vol. III, 1896, pp. 193-197, pl. IX, figs. 1, 2.

Triarthrus becki OEHLERT, 1896, Bull. Soc. Geol. France, 3d ser., Vol. XXIV, pp. 97-116. Text figs. 1-17, 34. (Summarizes and discusses published data to date on appendages and development.)

Triarthrus becki BEECHER, 1900, Text-book of Pal., Zittel, pp. 615-616, text figs. 1267-1269, 1300, on p. 629. (Resumé of previous papers on appendages.) Idem, The preceding paper of 1900 was again printed in the 1913 edition of Zittel's Paleontology with same illustrations and slight modifications of the text (pp. 700-701, 715, text figs. 1343, 1344, 1345 and 1375). Idem, 1902, American Jour. Sci., 4th ser., Vol. XIII, pp. 167-174, pl. 2, figs. 1-5, pl. 3, fig. 1, pl. 4, fig. 1, pl. 5, figs. 2-4. (Describes and illustrates ventral appendages and integument.) Idem, 1902, Geol. Mag., London, Dec. X, Vol. IX, pp. 152-162, text figs. 1-3, pls. 9, 10, 11. (Reprint of preceding paper.)

Triarthrus becki JAEKEL, 1901, Zeits. deut. geol. Gesellsch., Vol. LIII, p. 161, text fig. 24, p. 162. (Discusses Beecher's conclusions, proposes new interpretation of appendages, and illustrates fragments of an antenna.)

Triarthrus becki VALIANT, 1901, The Mineral Collector, Vol. VIII, pp. 105-112. (Account of discovery of appendages and general remarks.)

Triarthrus becki MOBERG, 1907, Geol. Fören. Forhandl., Bd. 29, Haft 5, pp. 265-272, pl. 4, fig. 2, pl. 5, fig. 1. (Discusses and illustrates appendages in connection with supposed appendages of *Eurycare angustatum.*)

I have long had a sentimental interest in this species largely because my early home was on a knoll formed of the Utica shale in which *Triarthrus becki* occurs, and I collected many specimens of it as a school-boy in and about the city of Utica. In 1879 I published an illustrated paper that described the development of the dorsal shield from the young with one segment to the fully developed individual with sixteen segments.[1] Later Beecher described a younger stage and in several papers discussed and illustrated the ventral surface and appendages. It is unfortunate that he did not live to prepare an extended memoir that he had planned for on its structure. I agree with his interpretations of the appendages of *T. becki* except in some details. His conclusion that the minute elongate lobes beneath the pygidium were endites of a limb similar to that of *Apus*,[2] is not satisfactory in view of the appendages found beneath the pygidium of specimens in the National Museum collections. These are illustrated

[1] Trans. Albany Inst., Vol. X, 1879, pp. 23-33, pl. II, figs. 1-14.

[2] American Jour. Sci., Vol. XLVII, 1894, pl. VII, figs. 1-3.

by figures 4-8, plate 29. Figures 4 and 5 show slender jointed legs (endopodites) similar to those of the thoracic legs, down to the extreme end of the body, a structure similar to that found in *Neolenus* and *Calymene*. The setiferous exopodites are also present to the end of the pygidium. The absence of four expanded subtriangular joints on each leg in figure 4 may be owing to their absence or to the dorsal side of the leg being uppermost and the expanded ventral side of the joints concealed in the rock. This condition of preservation is often met with in the legs of *Marrella*[1] which have expanded joints somewhat similar to those of *T. becki*. The specimen represented by figures 4 and 5 indicates the presence of jointed legs to the end of the pygidium. With this in view, Beecher's conclusion that the limbs beneath the pygidium are similar to those of the young of *Apus* requires further consideration. His diagrammatic sketch (*loc. cit.*, fig. 3) is very much like that of his figure 4 of *Apus*, but his figures 1 and 2 indicate elongate narrow lobes of nearly equal width throughout and similar to those seen in our specimen represented by figures 5, 8, 11. That the legs beneath the pygidium in figures 4 and 5 are typical slender thoracic legs and those beneath the pygidium in figures 8 and 11 are typical branchiopod (*Apus*) limbs is not probable and I am giving in the description of the exopodites a different interpretation to the series of lobes shown in our figures 4, 7, 8 and Beecher's figures 1, 2, 3.

The illustrations of the exterior of the dorsal shield are reproduced on plate 30, but it is unnecessary to reprint the descriptions of the specimens as the figures are sufficient to serve for comparison of the dorsal shield with that of other species which have their ventral appendages described in this paper.

Limbs

We owe to Beecher the working out of the epistoma and cephalic limbs of *T. becki*, although the antennæ found by Valiant had been described by W. D. Matthew.[2] Before considering the true limbs, mention should be made of the metastoma or lower lip discovered and described by Beecher[3] as follows:

> The metastoma is generally clearly shown as a convex arcuate plate just posterior to the extremity of the hypostoma. On each side, at the angles, are two small elevations, or lappets, which suggest similar structures in many

[1] Smithsonian Misc. Coll., Vol. 67, No. 5.

[2] American Jour. Sci., 3d ser., Vol. XLVI, 1893, pl. 1, figs. 1-7.

[3] American Geol., Vol. XV, 1895, p. 97, pl. V, figs. 8-11.

higher Crustacea, and apparently represent the entire metastoma in *Apus* and some other forms. (Pl. 32, fig. 1.)

Beecher worked out the thoracic limbs and found them to be biramous with a strong long proximal joint (protopodite) to which a jointed leg (endopodite) and a jointed setiferous exopodite were attached. Unfortunately most of his illustrations are diagrammatic and give only an approximate idea of the limb. Even the reproduced photographs[1] given an inadequate conception of the true form of the limb, especially of the structure of the exopodite.

Cephalic limbs.—Antennules.—The anterior antennules or antennæ are uniramose, the exopodite of the primitive limb having disappeared. Each one is composed of a strong basal joint (protopodite) attached to the ventral side of the head at the side of the hypostoma about midway of its length. The numerous short joints composing it (pl. 29, fig. 9) each expand slightly at the distal end, giving it a striking appearance quite unlike the smooth, slender antennules of *Neolenus* (pl. 15, fig. 1).

Beecher describes the remaining cephalic appendages as follows:[2]

First pair of biramous appendages, or posterior antennæ.—The second pair of appendages, corresponding to the posterior antennæ, are attached to the head at each side of the glabella, on a line with the extremity of the hypostoma. They are apparently biramous, and thus agree with the second pair of nauplian limbs and with the typical posterior antennæ of many Entomostraca and Malacostraca. They may be compared with the posterior antennæ in *Euphausia pellucida*, one of the schizopods, especially with the *Furcilia* and *Cyrtopia* stages. The details of the endopodite and exopodite are not clearly shown. The former is more commonly preserved, and its distal joint extends just beyond the edge of the carapace. The coxopodite is developed into a triangular plate, the inner angle carrying a masticatory ridge, the whole extending about three-fourths the distance from the side of the glabella to the median line, just below the hypostoma, and directly obliquely backwards (pl. V, figs. 8-11).

Second pair of biramous appendages, or mandibles.—The appendages here correlated with the mandibles are immediately behind the first pair of biramous limbs. The proximal portion, or coxopodite, is similar in form to the preceding, though somewhat smaller, and overlapping its basal part. The palps, or endopodial and exopodial branches, have not been distinctly traced, though their presence is indicated on plate IV, figure 1, where, on the left side, there are endopodites and exopodites in sufficient number for each appendage of the head. That these should be referred to the cephalic limbs is further indicated by their being in advance of the endopodite, which manifestly pertains to the first thoracic segment. The inner edge of the mandibles as well as that of the

[1] The Ventral Integument of Trilobites, American Jour. Sci., 4th ser., Vol. XIII, 1902, pls. II-V.

[2] American Geol., Vol. XV, 1895, pp. 94-95, pls. IV and V.

other gnathobases of the head is apparently finely denticulate, as shown on plate IV, figure 1, and plate V, figure 2.

Third and fourth biramous appendages, or maxillæ.—Following the appendages referred to the mandibles are two pairs of strong limbs, with broad plate-like basal portions, or coxopodites, serving as gnathites (pl. V, figs. 8-11). They resemble each other, and are similar in form to the two preceding limbs, though somewhat larger. They are usually fairly well preserved and their form and structure can be approximately made out. The endopodites are composed of stout joints, and could be extended but a short distance beyond the margin of the head. The exopodites are more slender and carry an abundance of stiff setæ, which often diverge in a fan-like manner from their line of attachment. These brushes of setæ occupying the cavities of the cheeks are often preserved in specimens where the other details of the limbs are obscure or obliterated. In *Triarthrus* they are evidently homologous with similar brushes observed by Walcott in *Calymene.*[1]

This completes the number of paired appendages which can be definitely referred to the head. It is evident they do not differ conspicuously from each other, and, as will be presently shown, they closely resemble the thoracic legs in all essential structural characters [*Loc. cit.*, pp. 94-95].

Beecher describes the protopodite of the limbs as follows:

First it has a slender cylindrical form in the posterior half of the series, then becomes flattened and denticulate, and finally widens, until on the head it forms the triangular plate-like coxopodite, with masticatory ridge and functioning as a gnathite [*Loc. cit.*, p. 96].

The study of the material available of the protopodite of *Neolenus* and other trilobites and of the Branchiopoda (*Apus*) leads me to conclude that it is flattened and plate-like on all the appendages from the head to the end of the series beneath the pygidium. It may be more rounded beneath the pygidium, but the tendency to flat sides is still shown. The positions and form of the appendages in the fossil state is no guarantee that they were the same on the living animal. (See *Restoration of ventral appendages*, p. 165.)

Thoracic limbs.—These consist of an elongate protopodite to which the endopodite (leg) is attached and apparently the exopodite.

The protopodite is described by Beecher[2] as having a slender, cylindrical form in the posterior half of the series, then becoming flattened and denticulate, and finally widened, until on the head it forms the triangular, plate-like protopodite (coxopodite) with masticatory ridge and functioning as a gnathite.

I have not obtained any additional information about the protopodite but from its form in *Isotelus* and *Neolenus* I am inclined to consider that it may have been flattened on all of the limbs and that

[1] Bull. Mus. Comp. Zool., Vol. VIII, No. 10, 1881.

[2] American Geol., Vol. XV, 1895, p. 96.

its position was, as shown by Beecher in 1895,[1] vertical to the plane of the body and not flattened out as shown in his classical restorations of the ventral side of *Triarthrus* in 1896.[2] In this restoration the protopodite and the flat joints of the endopodite are on the same plane which is probably the position they would assume when gradually forced by compression into one plane, but in a natural position the protopodite would arch beneath the ventral surface of the mesosternites (axial lobe) and the flat joints would project downward in the opposite direction as in Beecher's transverse sections of the thorax published in 1895 and referred to above.

Endopodite.—This is formed in the anterior portion of the thorax of four rather long, flattened joints and two relatively short, rounded distal joints. From the distal end of the last joint a strong spine or claw with a short spine on each side gives a trifid termination similar in appearance to that of the leg of *Neolenus* (pl. 16, fig. 3).

Beecher describes the "endites" as follows:[3]

> The whole series of endopodites anterior to the last two or three show modifications from the phyllopodous type, the change involving progressively from one to all of the endites. The endopodites of the pygidium have a true phyllopodiform structure, and are composed of broad leaf-like joints, wider than long. This character is gradually lost in passing anteriorly, the distal endites being the ones first affected. By the time the anterior pygidial limb is reached, the three distal joints are longitudinally cylindrical. The ninth thoracic endopodite shows a fourth endite becoming cylindrical, and on the first and second thoracic legs even the proximal ones are thus modified, making all the endites of these limbs slender in form.

During my study of the specimens in the National Museum collections I found that flattening out and enlargement of the joints (endites) was not always as regular as described by Beecher. Typical anterior endopodites are illustrated by figure 1, plate 29, and typical posterior endopodites by figure 20, plate 30. In two instances I found endopodites that occurred beneath the pygidium with the two distal endites round and slender (figs. 4, 5, pl. 29) and in one example the last three distal joints were cylindrical (fig. 7, pl. 29). The joints (endites) of the endopodite of *Marrella splendens* are similarly enlarged by flattening, and extend downward, but as in *Triarthrus* they are apparently not constant in size in all specimens.[4]

Exopodite.—The exopodite is nearly as long as the endopodite and usually much more in evidence in the fossils. It is formed of a

[1] American Geol., Vol. XV, 1895, pl. V, figs. 1-4.

[2] American Jour. Sci., 4th ser., Vol. I, pl. VIII, fig. 2.

[3] Idem, p. 253.

[4] Smithsonian Misc. Coll., Vol. 67. This paper will be No. 5 of this volume.

strong, many jointed arm (pl. 29, figs. 2, 11) to which is attached a diagonally arranged series of bases or supports for strong setæ, which may be jointed near their base and which are extended into long more or less flattened setæ forming a fringe. The jointed arm appears to be attached to the end of the protopodite beside the proximal joint of the endopodite. Beecher describes and illustrates a long proximal joint with a denticulated lower edge to which setæ are attached and beyond that a many jointed support; the proximal joint is represented to be as long as the first and second proximal joints of the endopodite. In the specimens now available for study I find that the diagonal crenulations extend up to the point of attachment of the arm to the protopodite and that there does not appear to be room for the very long proximal joint illustrated by Beecher (I have not seen the specimens). The structure of the exopodite is fairly well shown by figures 2, 3, 8, 10, 11, plate 29. In figures 2 and 3 the diagonal crenulations outlining the bases of the setæ are shown just beneath the closely jointed supporting arm, also portions of two of the larger endopodites. Figure 10 has the crenulated structure over the entire supporting arm in such a position that it appears that it is the upper and posterior side of the arm to which the crenulations and setæ are attached. In figure 11 the anterior and lower side of the exopodite is shown: it consists of a strong, closely jointed arm with about twenty segments and a flat, slender, lobe-like terminal segment or joint; the distal end of the crenulated margin begins at the proximal end of the terminal section and extends up along the arm past some twenty segments; the setiferous portion or fringe is attached to the crenulated portion. The elongate distal segment of the arm is beautifully shown in figure 8, where numerous minute exopodites are crowded from beneath the pygidium and the transversely lobed joints of the arm of the exopodite appear to rest one on the other. This structure is finely shown on the exopodites of figures 4 and 5.

The flat, narrow terminal joint of the exopodite is a marked character (fig. 11) and when a number are grouped beneath the pygidium (fig. 8, pl. 29) they have the appearance of a series of lobes somewhat similar to the limb of *Apus* as suggested by Beecher,[1] particularly when the minute exopodites beneath the pygidium have their joints flattened and drawn out on the posterior side until they appear like a row of minute, lobe-like exites arranged side by side so as to give the appearance seen in figures 4 and 5.

[1] American Jour. Sci., 3d ser., Vol. XLVII, 1894, p. 300, pl. VII, figs. 1, 2, 3.

Beecher, in describing the appendages of *Trinucleus concentricus,* said:[1]

> The endopodites on the pygidium offer no conspicuous differences from those just described, except that a gradual change in form is manifest as the terminal limbs are reached. The separate endites become more and more transversely cylindrical, until the whole limb appears to be made up of cylindrical segments transverse to its length. A similar condition was observed in the young of *Triarthrus.*[2]

As I interpret the specimens of *T. becki* illustrated on plate 29, figures 4, 5, 8, of this paper, it is the exopodites and not the endopodites that have the transversely elongated endites. This is probably a phyllopod character but not as interpreted by Beecher.

Epipodite.—The presence of a flat epipodite attached to the protopodite of the leg near its proximal end cannot be absolutely proven by the material I have for study but it is quite probable that it existed as there is on three specimens a flat, elongate oval angular disk or lobe that is wider than the joint of the limb; it has a distinct margin on the sides and distal end and in two instances clearly lies above the limb and resting on it. The anterior margin is slightly arched or angular and merges into the distal end and the posterior margin has a slightly angular projection about midway of its length; usually this lobe is so mashed down on either the proximal joint of the endopodite or exopodite that it cannot be clearly separated from the limb. On one specimen preserving several of the probable epipodites (pl. 30, fig. 19) the distal end is bluntly pointed and the margins have very fine, short setæ projecting from them.

Not one specimen in fifty of *Triarthrus becki* shows traces of limbs, and among a hundred or more specimens preserving more or less of the limbs, only four or five specimens show the long protopodite, hence it is not strange that small epipodites, if they existed, have not heretofore been found. In the case of the large epipodites of *Neolenus* it was only by a fortunate splitting of three fragments of shale that they were found at all.

Summary.—The appendages of *Triarthrus becki* are outlined in the restoration of its ventral side (pl. 32) and the cross-sections on plate 34. Comparisons between them and the known appendages of other genera of trilobites may be found under *Observations on the Structure of the Trilobite* (pp. 159-161).

Formation and locality.—Ordovician: Utica shale; three miles (4.8 km.) north of Rome, Oneida County, New York.

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[1] American Jour. Sci., 3d ser., Vol. XLIX, 1895, p. 310.

[2] Idem, Vol. XLVII, pl. VII, fig. 3, April, 1894.

DEVELOPMENT OF *TRIARTHRUS BECKI*[1]

Plate 30, figs. 1-15, 18

"The larval *Triarthrus*[1] in its first known stage is ovate in outline, widest behind, where it also attains its greatest convexity. The frontal margin is marked by a convex fold of the test. The axis is annulated. The anterior six annulations apparently belong to the cephalon, the sixth one being considerably stronger than the others and probably representing the occipital ring. The pygidial portion is defined by a narrow, shallow, transverse furrow; and the axis has two annulations.

"Near the lateral anterior margins are two slight elevations which may represent the palpebral lobes of the eyes, and from them extend two furrows curving inward to the axis and dividing the cephalic region into two portions. The occipital pleura are indicated by slight depressions extending from the occipital ring. The specimen illustrated by figure 15 has a length of .63 mm. and a width of .46 mm."

The second known stage has one thoracic segment; the glabella has broadened in front and the transverse furrows have retreated to its lateral margins; the occipital segment is strong and carries the median node that is characteristic on all later stages of growth; fixed cheeks, narrow and without traces of the palpebral ridge and eye lobe; a node occurs on the thoracic segment and the pygidium is elongate with five fused segments in the axial lobe.

There is a gradual increase in size after the first segment is liberated in the thorax, but not of sufficient importance to indicate distinct periods of development. If any change is to be noted, it is, that, after the development of the twelfth segment, individuals having the same number of thoracic segments vary very much in size, some even being smaller than those having a lesser number of segments; this period of development is a marked one in the history of this trilobite, as an individual of thirteen thoracic segments is larger than one having sixteen. Again we find that an individual of thirteen thoracic segments is more than three times as large as one with fourteen, one being twenty-four and the other seven millimeters in length; that the largest with fourteen segments, thirty millimeters in length, is nearly double the smallest with sixteen segments, and that the adult individual of sixteen thoracic segments is fifty-three millimeters in length. Minor variations have been noticed in individuals having less than thirteen thoracic segments, but in no case has the

[1] Beecher, C. E.: A Larval Form of Trilobite. American Jour. Sci., Vol. XLVI, 1893, pp. 361-362.

size of the one having the lesser number of segments exceeded the next in the series of development. It is not until the twelfth degree of development is passed that this strange anomaly occurs.[1]

The pygidium gradually becomes proportionally shorter after the first stage with one segment and the eye lobe is indicated on individuals with two segments by a minute groove on the outer border of the fixed cheek. When the sixth thoracic segment is developed all parts have attained most of the characters of the adult.[2]

PTYCHOPARIA CORDILLERÆ (Rominger)

Plate 21, figs. 3-5

Conocephalites cordilleræ ROMINGER, 1887, Proc. Acad. Nat. Sci. Phil., p. 17, pl. 1, fig. 7. (Describes and illustrates species.)

Ptychoparia Cordilleræ WALCOTT, 1888, Amer. Jour. Sci., 3d ser., Vol. XXXVI, p. 165. (Refers species to the genus *Ptychoparia*.)

Ptychoparia cordilleræ MATTHEW, 1899, Trans. Royal Soc. Canada, 2d ser., Vol. V, sec. IV, p. 44, pl. 1, fig. 7. (Describes, comments upon, and gives diagrammatic illustration of portion of a specimen.)

Ptychoparia Cordilleræ WOODWARD, 1902, Geol. Mag., new ser., Dec. IV, Vol. IX, p. 536, text fig. 4. (Notes on species with outline figure of a dorsal shield.)

Ptychoparia cordilleræ WALCOTT, 1908, Canadian Alpine Jour., Vol. I, No. 2, pl. 3, fig. 5. (Illustrates nearly entire specimen from Mt. Stephen.) Idem, 1912, Smithsonian Misc. Coll., Vol. 57, p. 190, pl. 24, fig. 2. (Illustrates specimen showing branchiæ (exopodites).)

This species differs from the associated *Ptychoparia palliseri* in having a proportionally shorter frontal limb, narrower fixed cheeks, a less number of thoracic segments, eighteen or nineteen, and absence of a median node on the anterior thoracic segments. From the associated *Ptychoparia permulta* it varies in its broader fixed cheeks and frontal limb, rounded instead of spinous genal angles on the cephalon, more numerous thoracic segments, and in having a nearly smooth surface. *Ptychoparia cordilleræ* is quite abundant on Mount Stephen, and *P. permulta* is abundant at locality **35k**, three miles (4.8 km.) to the north-northeast.

The dorsal shield of this species is well illustrated by figure 4, plate 21. The average number of thoracic segments is eighteen, but one example 23 mm. long has nineteen segments.

Ventral appendages.—Only one specimen has been found showing the thoracic limbs. This indicates very clearly the general character

[1] Walcott, C. D.: Fossils of the Utica Slate. Trans. Albany Inst., Vol. X, 1879, p. 29 (Advance print).

[2] Idem, pp. 26-29.

of the exopodite and that it is situated above the endopodite, although there are only imperfect traces of the latter projecting from beneath the exopodites as shown in figure 5, plate 21.

The exopodites are unlike those of any trilobite now known. They are long, rather broad lobes extending from the line of the union of the mesosternites and the pleurosternites. At the proximal end they appear to be as wide as the axial lobe of each segment, and to increase in width and slightly overlap each other nearly out to the distal extremity. They appear to have extended beyond the dorsal shield, but not as far out as the extremity of the leg (endopodite). They are finely crenulated along both the anterior and dorsal margins which indicates the presence of fine setæ.

Formation and locality.—Middle Cambrian: (**14s**) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad; (**35k**) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field; (**61j**) yellow weathering band of calcareo-argillaceous shale, west slope of Mount Field, near Burgess Pass ridge, about 3,000 feet above Field, and (**58r**) about 2,200 feet (676.9 m.) above the Lower Cambrian, and 3,725 feet (1,146 m.) below the Upper Cambrian, in the limestones forming 2 of the Stephen formation, in the amphitheater between Mounts Stephen and Dennis, above Field, British Columbia, Canada.

PTYCHOPARIA PERMULTA, new species

Plate 21, figs. 1, 2

Dorsal shield.—Dorsal shield rather small and delicate, elongate ovate in outlines, probably quite sharply flexed at the geniculation before being flattened in the shale; its greatest width approximately two-thirds its length.

Cephalon.—Cephalon a little more than one-third as long as the entire shield, semielliptical in outline. Glabella long and slender, moderately elevated along an obtuse medial ridge which is highest a little behind the anterior extremity; dorsal furrows rather broad, not very sharply incised, slightly converging; anterior extremity of the glabella about two-thirds as wide as the base, broadly rounded; anterior furrow much more shallow than the dorsal; glabellar furrows very distinct in the younger forms, the medial and anterior pairs usually obscure in the older; posterior pair strongly oblique, persistent to the occipital ring which they intercept a little to the side of the median line; medial and anterior pairs linear, the medial pair very slightly oblique, the anterior nearly at right angles to the axis; occipital furrow rather broad, uniform in depth; occipital ring rather narrow, not nodulated, similar in character to the anterior segments of the thorax. Fixed cheeks low and wide, the distance from the palpebral lobe to the dorsal furrows about two-thirds the width of the medial portion of the glabella; posterolateral lobe short and broad, obtuse at the distal extremity; posterior groove deep, smoothly concave, in line with the occipital furrow. Palpebral lobe very short, contained more than three times in the length of the glabella, rather narrow and nearly parallel to the dorsal furrow, placed opposite the medial glabellar furrows. Palpebral ridge usually obscure, intercepting the dorsal furrows directly behind the anterior extremities. Frontal limb very narrow in the young, wide and broadly inflated in the adult. Frontal border narrow, upturned, cut off from the limb by a smoothly concave depression. Facial sutures with the posterior and anterior sections oblique and converging toward the short palpebral lobe. Free cheeks usually attached, of approximately the same width as the fixed cheeks. Peripheral border, like the frontal border, elevated and upturned and, like it, cut off from the inner portion by a smoothly rounded groove which intercepts the occipital groove at nearly a right angle; genal angles produced into short but acute spines which terminate opposite the second thoracic segment.

Thorax.—Thoracic segments normally fourteen in number. Axial lobe not very strongly convex, of about the same width as the proximal portion of the pleura; axial annulations narrow and sharply defined, but not nodose. Pleural segments narrow, very compactly arranged, the fourth to the ninth the most produced; pleural furrows almost as wide as the including segment, smoothly rounded; extremities petaloid; posterior inclination very slight.

Pygidium.—Pygidium short, a little more than twice as broad as it is long. Axial lobe relatively broad, truncate at the extremity which falls a little in front of the posterior margin; axial annulations, with the exception of the anterior, obscure, indicating three component segments and a terminal section. Pleural lobes small; pleural furrows distinct anteriorly, obsolete posteriorly, parallel to the anterior margin. Posterior margin an arc of a little less than 180°.

Surface.—Entire external surface finely and closely tuberculated; tubercles most crowded upon the cephalon; venation upon the frontal limb well developed.

Dimensions.—Length of dorsal shield, 25.5 mm.; greatest width of dorsal shield, 17.2 mm.; length of cranidium, 11.0 mm.; length of glabella, 7.0 mm.

Type locality.—(**35k**) One mile northeast of Burgess Pass, British Columbia.

Observations.—This fine species is associated with *Ptychoparia cordilleræ* and *P. palliseri* in the large Burgess shale fauna. It differs from the former in having a tuberculated surface, narrower fixed cheeks, longer frontal limb, spines on genal angles of free cheeks, fewer thoracic segments (four to five less in number), and from *P. palliseri* in the same characters except that the latter has six to seven more thoracic segments, and a somewhat narrower fixed cheek but broader than that of *P. permulta.*

One specimen has two antennules attached, which is the reason for noticing the species in this paper. The antennæ are so flattened in the shale that all traces of the joints are lost. As far as known to me it is the only specimen of the genus *Ptychoparia* preserving even the outline of the anterior antennæ (antennules).

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

Order PROPARIA Beecher

Family CALYMENIDÆ Milne-Edwards

Genus CALYMENE Brongniart

CALYMENE SENARIA Conrad, 1841

Plates 26, 27, 28, 33

Calymene senaria CONRAD, 1841, Fifth Ann. Rept., New York Geol. Surv., pp. 38, 49. (Name proposed with brief description.)

Calymene senaria[1] WALCOTT, 1876, Twenty-eighth Ann. Rept., New York State Mus. Nat. Hist., pp. 89-92. (Notes discovery of natatory and branchial appendages of trilobites in Trenton limestone.) Idem, 1879, Thirty-first Ann. Rept. New York State Mus. Nat. Hist., p. 61, pl. 1,

[1] In the synonymy the references are to the original description and to papers containing description or illustration of the interior of the dorsal shield or of the appendages. No attempt is made to give all references to the species.

figs. 1, 2, 5. (Notes and illustrations of cephalic and thoracic appendages.) Idem, 1881, Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, pp. 198-216, pls. 1-6. (Description and illustrations of cephalic, thoracic and pygidial limbs with restoration of ventral surface of body with legs (endopodites) and a transverse section of the thorax with limbs attached.) Idem, 1884, Science, Vol. III, p. 279, figs. 2, 3. (Refers to *Calymene* in note on appendages of the trilobite.) Idem, 1894, Proceed. Biol. Soc. Washington, Vol. IX, p. 90, pl. 1, fig. 7. (Refers to discovery of an antennule-like appendage in *Calymene senaria.*) Also printed in Geol. Mag., London, n. ser., Dec. IV, Vol. I, p. 246.

As the sections of the appendages of *Calymene senaria* and *Ceraurus pleurexanthemus* have many similar characters the notes on them will be combined under the latter species.

Family CHEIRURIDÆ Salter

Genus CERAURUS Green

CERAURUS PLEUREXANTHEMUS Green

Plates 26, 27, 28

Ceraurus pleurexanthemus Green, 1832, Monogr. Trilobites North America, p. 84, text fig. 10. (Original figure.)

Ceraurus pleurexanthemus Walcott, 1875, Ann. Lyc. Nat. Hist., New York, Vol. XI, pp. 155-162, pl. XI. (Describes and illustrates interior of dorsal shield.) Idem, 1876, Twenty-eighth Ann. Rept. New York State Mus. Nat. Hist., pp. 89-92. (Notes discovery of natatory and branchial appendages of Trilobites in Trenton limestone.) Idem, 1879, Thirty-first Ann. Rept. New York State Mus. Nat. Hist., p. 61, pl. I, fig. 3. (Describes and illustrates thoracic leg of *Ceraurus.*) Idem, 1881, Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, pp. 191-216, pls. 1-4, 6. (Describes and illustrates sections of this species, showing appendages and gives a restoration of thoracic legs.) Idem, 1884, Science, Vol. III, p. 279. (Refers to *Ceraurus* in note on appendages of trilobites.)

The investigation made by me from 1875 to 1880 by cutting thin sections of specimens preserved in a limestone matrix resulted in determining the general character of the appendages of *Calymene senaria* and *Ceraurus pleurexanthemus*.[1] The restorations of 1881 failed, however, to show the presence of antennæ, the form and size of the protopodite or proximal joint of the thoracic and abdominal limbs, and there may have been an error in the restoration of the large distal joints of the fourth or posterior pair of cephalic legs. The antennules and the evidence indicating the larger, more elongate character of the protopodite (proximal joint) of the thoracic and abdominal limbs were not discovered and interpreted until after the publication of my paper of 1881.

[1] Walcott, Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, No. 10, 1881, pp. 198-224, pls. 1-6.

Cephalic Limbs

Antennules.—The occurrence of what might be the longitudinal section or part of an antenna or antennule was known to me in 1882, but it was not until 1894 that reference to[1] it was made as indicating an antennule. The section showing it cut through the head of an enrolled specimen of *Calymene senaria,* and near the cross-section of the hypostoma showed a longitudinal section of a slender jointed antenna-like rod sloping upward while the limbs sloped diagonally outward and downward. With our present information of the antennules of *Triarthrus* and *Neolenus* there is little doubt but that an antennule of *Calymene* is cut across by the section. Attempts to photograph it have been unsatisfactory owing to the density of the section.

Endopodite.—The protopodite of the first, second and third pair of cephalic limbs is smaller and the following joints are more slender than those of the fourth (figs. 6, 9, 11, pl. 26) pair and the limbs of the thorax. Traces of fine spines were seen on the inner end of the protopodite in some of the sections, which indicates that the protopodite functioned more or less as a gnathite. My conception of the relative position and form of the limbs is indicated by the restoration on plate 33.

In the restoration of 1881 of *Calymene* the enlarged distal joints of the posterior pair of cephalic legs (endopodites) were based upon evidence afforded by several slides, four of which are illustrated by figures 9, 10, 12, and 13, plate 26. If such broad joints were present, sections like those in the figures mentioned must result if the section cut through the broader axis of the joint. If it cut through the narrow axis, sections like those represented by figure 11, plate 26, would result. The sections mentioned appear to be best explained by assuming the presence of large, flat distal joints on the posterior cephalic legs, and I am now putting them in the restoration of *Calymene senaria* (pl. 33, fig. 1), although such expanded joints are unknown in *Neolenus* and *Triarthrus*. Probably the broad, flat joints were used in swimming, as the other known appendages are not very well adapted for the purpose.

Exopodite.—Sections cut through the heads of many specimens of both *Calymene* and *Ceraurus* showed more or less of the cephalic legs and the setiferous epipodites, but only rarely was a trace of the spiral exopodite met with. In fact, in only one instance was there

[1] Note on some Appendages of the Trilobites, Proc. Biol. Soc. Washington, Vol. IX, p. 90.

apparently evidence that the spiral belonged to a cephalic limb and in this there was no direct connection shown. There probably was a small exopodite attached to the large protopodite of the posterior cephalic limbs, and a more or less rudimentary one present on the three anterior pairs as short, slender, wire-like or flattened ribbons.

Epipodite.—The presence of flat setiferous lobes beneath the cephalic shield was known in 1881,[1] but the interpretation of their relations to the limbs was not then attempted. Comparing the lobes with those attached to the cephalic limbs of *Neolenus* (pl. 16, figs. 1, 2) we find that the setiferous lobes of *Calymene* and *Ceraurus* are relatively smaller, shorter, and bear stronger setæ. This is shown by figure 2, plate 26, and figure 14, plate 27 (*Ceraurus*), and possibly by figure 11 (*Calymene*). In figure 11, plate 27, the lobe is merged into the mass filling the central part of the space beneath the head, but in figure 12 the lobe is detached on the right side, although it is close to the large protopodite of the posterior cephalic limb to which it was probably attached very much as a similar lobe is attached to the protopodite of the thoracic limbs (pl. 27, fig. 14, left side, and pl. 26, fig. 2, left side).

Thoracic Limbs

The restoration of the thoracic limb of *Calymene* shows a large elongate protopodite, an endopodite, a curious, slender, bifid, spiral exopodite, and a lobe-like setiferous epipodite. The relative positions of the parts are indicated in the restoration, figure 6, plate 35.

Protopodite.—In the case of the proximal joint (protopodite) of the thoracic limbs there is every reason to change my restoration of 1881 and replace the relatively short joint with a long joint that extends inward on each side of the longitudinal axis of the ventral surface about one-third the distance across the axial lobe. This change is based on such sections as those illustrated by figures 1-8, plate 26, and such proximal joints are characteristic of the limbs of *Neolenus, Triarthrus,* and *Isotelus.* Each of these sections represented by figures 1-8 clearly indicates strong, elongate, proximal joints, and those represented by figures 4 and 15 had short, strong spines on the proximal end. It is surprising that such good results were obtained by cutting sections, but these illustrated (figs. 1-8) are selected from among hundreds that did not happen to cut through the limbs at the right angle to show definitely their size and form.

[1] Walcott, Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, No. 10, 1881. pl. 3, figs. 1 and 2.

The proximal joints shown in the restorations of 1881 were correct for transverse and closely associated sections, but not for the longitudinal section of the limb. The form now assumed to be nearly correct for the protopodite is shown by figures 1-8 of plate 26, and by the restoration, figure 1, plate 33.

Endopodite.—The endopodite is formed of six slender joints, the two and it may be three proximal ones being more or less flattened and the distal joints more cylindrical and terminating in a short curved hook or claw and two short spines as in *Neolenus.* The joints of the endopodite of *Ceraurus* appear to have been more expanded at the distal end than those of *Calymene.* This is indicated in the restoration of the cross-section of the dorsal shield and ventral appendages (pl. 34, fig. 1).

Exopodite.—The exopodite is apparently situated between the endopodite and epipodite, but the exact point at which it was attached to the protopodite is unknown, but from comparisons with *Neolenus* and the Anaspids (Malacostraca) the attachment was presumably at the distal end of the protopodite.

The first or proximal portion or base was slender and elongate and from it a bifid, slender, wire-like spiral curved outward and downward so as to be above and free from the leg (endopodite) (pl. 27, figs, 2, 4, and 5). The sections apparently cut across strong, closely coiled spirals that had sufficient rigidity to usually retain their form even when they were crowded together (pl. 27, figs. 4, 6, 8, 9). Occasionally there is a partially drawn-out spiral (fig. 7) or it may have been pulled out into a straight wire or a ribbon (pl. 26, fig. 14).

I was greatly puzzled by the spirals when I began cutting sections of *Calymene* and *Ceraurus* in 1875 and endeavored to find something indicating a long linear support, but in no instance has a trace of such been found or an indication of attached setæ. The latter abound in some sections of *Calymene* and *Ceraurus,* but they belong with the epipodites. When the exopodite of *Triarthrus* was found to have obliquely arranged setæ supported by a jointed arm it seemed as though the problem was solved, but it was soon found (1894) that these were attached to a strong jointed exopodite and did not have a spiral structure. I have more recently worked out and studied several exopodites of *Triarthrus* and have confirmed my former opinion that no sections of them could give the spiral structure shown by the spiral exopodites of both *Calymene* and *Ceraurus.*

Longitudinal and oblique sections of closely coiled spirals of wire set in plaster and cut across are identical in form with the spirals in the trilobite sections (pl. 27, figs. 10, 10*a*). In fact practically every section of the fossil spirals illustrated on plate 27 may be duplicated by making close coils of wire of various sizes and bending them to secure the right longitudinal curvature before embedding in plaster. Elongated or drawn out spirals such as shown in figures 6 and 7 are also easily produced.

Epipodite.—Sections of a setiferous lobe indicate the presence of an epipodite. It appears to have been flat with a fringe of long, strong, simple setæ as shown by figures 12 and 14, plate 27; figure 2, plate 26. In the latter figure and in figure 13, plate 27, the setæ of several epipodites appear to have been cut across so as to give the effect of long rows of setæ. The same condition occurs in specimens of *Marrella* when the setæ of several exopodites are matted against each other.[1]

Two sections show an epipodite near their point of attachment to the protopodite. In figure 12, plate 27, this is shown on both sides not far from the cephalon, and in figure 2, plate 26, on the left side and well back in the thorax.

From these sections I infer that the epipodite was attached to the protopodite well out towards its distal end.

Other sections show the base of the spiral exopodite in the same position, a fact not at all surprising as the exopodite and epipodite may be either accidentally or actually nearly on the same line with relation to the leg (endopodite).

There are two sections (pl. 27, fig. 4) of an enrolled *Calymene* that suggest a small, slender appendage with two long joints, the distal one having a few minute setæ along its outer side. Whether this is a flattened leg (endopodite) cut across on its narrow section or a part of an appendage with which we are not acquainted is difficult to decide with only one indefinite specimen available for study.

Of the appendages beneath the pygidium I wrote in 1881:

> The character of the appendages beneath the pygidium is one of unusual interest, and for a long time was highly problematical, and at present the evidence is not all that could be desired. Four sections, two transverse and two longitudinal, show their presence in *Ceraurus*. That they are jointed is shown by plate II, figure 8, and also in a similar section not illustrated. A transverse section, plate II, figure 4, of the extreme posterior segment of the pygidium also shows the base of the leg and sections of the succeeding anterior legs. The position of the base is the same as that of the posterior leg, plate II, figure 8. That these legs were not foliaceous and branchial is evident, but what their terminal joints were like is yet an unsettled problem of the investigation.[2]

[1] Plate 25, figs. 3, 6, Smithsonian Misc. Coll., Vol. 57.

[2] Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, No. 10, 1881, p. 204.

We have no further information except that from the character of the appendages beneath the pygidium of *Triarthrus* and *Neolenus* it is probable almost to a certainty that the limbs were similar to those of the thoracic region.

Further description and discussion of the appendages and structure of *Calymene* and *Ceraurus* is given in the general discussion, also in the description of illustrations and the restorations.

Formation and locality.—The specimens preserving appendages and illustrated are from the Ordovician: Trenton limestone (upper section): One mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

ODONTOPLEURA TRENTONENSIS (Hall)

Acidaspis trentonensis HALL, 1847, Nat. Hist. Surv. New York, Pal., Vol. I, p. 240, pl. 64, figs. 4*a-f*. (Describes and illustrates species.)

Acidaspis Trentonensis WALCOTT, 1881, Bull. Mus. Comp. Zool., Harvard College, Vol. VIII, p. 206. (Refers to appendages of.)

Odontopleura trentonensis CLARKE, 1892, Forty-fourth Rept. New York State Mus., p. 101. (Changes generic references.)

In this species fragments of both cephalic and thoracic limbs have been observed with the endopodite and exopodite apparently of the same character as those of *Calymene* and *Ceraurus* with which they were associated.

Formation and locality.—The specimens preserving appendages are from the Ordovician: Trenton limestone (upper portion): One mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

Order HYPOPARIA Beecher

Family TRINUCLEIDÆ Emmrich

Genus TRINUCLEUS Murch

TRINUCLEUS CONCENTRICUS Eaton

Dr. C. E. Beecher found traces of the thoracic limbs of this species, which indicate that they were essentially of the same type of those of *Triarthrus becki* with which the specimens of *T. concentricus* were associated[1] at the locality near Rome, New York.

[1] Structure and Appendages of *Trinucleus*. American Jour. Sci., 3d ser., Vol. XLIX, 1895, pp. 307-311, pl. III.

ORDOVICIAN CRUSTACEAN LEG

Plate 36, figs. 1, 2, *2a-d*

A crustacean leg, represented by several specimens, occurs on the surface of a fragment of calcareous shale of Ordovician age from Ohio. It is quite unlike the leg of *Neolenus, Triarthrus,* or *Isotelus.* The proximal joints, coxopodite and basopodite are very short and provided with two sharp processes on the ventral side; the third joint is somewhat similar to the second but is longer; the next four are of nearly equal length and might be compared with second, third, and fourth joints of the leg of *Neolenus;* the distal joint is long, slender, and without a terminal claw. The ventral side of the joints has a fine crenulation indicating the bases of setæ. The unusually fine drawing of a leg made by Mr. Clarence R. Shoemaker shows that the joints were united by a thin membrane that did not resist destruction so well as the thin integument forming the covering of the joints.

The legs are associated with fragments of *Calymene meeki,* but it is not probable they belong to that species; if they did, they are unlike any trilobite leg known to me. The very short coxopodite and basopodite are unknown in the trilobites of which we have the legs, as they are fused into one joint forming the long protopodite in the trilobite. The distal joint is also unlike that of the trilobite legs known to us. The leg (pl. 36, fig. 1) is more like one that we might expect in an Isopod. The legs average about 10 mm. in length. One was illustrated by me in 1881.[1]

Formation and locality.—Ordovician: Cincinnatian, *Cynthiana* limestone. Bank of Ohio River below Covington, Kenton County, Kentucky.

SECTION 2

STRUCTURE OF THE TRILOBITE

Dorsal shield.—The structure of the dorsal shield and hypostoma of the trilobite is so well known that it is unnecessary to discuss it further than to state that the known range of variation in form and segmentation is so great that it undoubtedly has affected the details of the ventral appendages but not their fundamental arrangement and structure.

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[1] Bull. Museum Comp. Zool., Harvard College, Vol. VIII, pp. 204, 224, pl. VI, fig. 5*a*.

The structure of the ventral surface, intestinal canal, and appendages will be considered and incidental reference made to the possible position of the organs within the visceral cavity.

Ventral integument.—Beecher has reviewed the evidence bearing on the structure of the ventral integument [1] briefly and concisely and summed it up as follows:

The ventral integument in trilobites is a thin uncalcified membrane, which may be divided into pleurosternites and mesosternites, corresponding to the mesotergites and pleurotergites of the dorsal test, and like them connected segmentally by an inarticular membrane.

The mesosternites are usually marked by five longitudinal ridges, or buttresses, representing thickenings of the membrane, which may be homologized with apodemal structures in other crustacea, and not with the appendicular system.

These buttresses, or apodemes, include a single median one for each mesosternite, with two others on each side extending forward and obliquely inward, and enclosing subtriangular or rhombic spaces.

The presence and disposition of these buttresses apparently afford information regarding the ventral musculature of the trilobites. A pair of flexors is indicated, together with the lateral strands attached to each mesosternite and extending forward and inward to their union with the main bundles within the cavity of the next anterior somite.[2]

My present review has not led to the discovery of additional evidence, and I agree with Beecher that Jaekel was greatly misled in his interpretation of the cast of the ventral membrane of *Ptychoparia striata*,[3] and that he was led on the evidence furnished by this one specimen of *Ptychoparia* " to reconsider on a false premise the entire question of the anatomy, ontogeny, phylogeny, and affinities of the trilobite." [4]

In connection with my investigation of the structure of ventral integument and appendages of *Calymene* and *Ceraurus* I found [5] that in those longitudinal sections in which the ventral integument is most perfectly preserved it had been a thin, delicate pellicle or membrane, strengthened in each segment by a transverse arch. These arches appear as flat bands separated by a thin connecting membrane, somewhat as the arches in the ventral surface of some of the Macrouran Decapods. The finest illustrations of this structure have been found

[1] American Jour. Sci., 4th ser., Vol. XIII, 1902, pp. 165-174.

[2] Idem, p. 172.

[3] Jaekel, Otto.—Beiträge zur Beurtheilung der Trilobiten. Theil I. Zeits. deut. Geol. Gesells., Bd. LIII, Heft 1, 1901, pp. 133-171, figs. 1-31, pls. IV-VI.

[4] Beecher, C. E., American Jour. Sci., 4th ser., Vol. XIII, 1902, p. 166.

[5] Walcott, C. D.: The Trilobite: New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zool., 1881, Harvard Coll., Vol. VIII, No. 10. pp. 199-200.

in *Calymene,* but several sections of *Ceraurus* show it very well defined. The section represented on plate 28, figure 8, gives a very fine view of the membrane and arches in a longitudinal section. The specimen illustrated on plate 28, figure 7, shows a portion of the dorsal shell of the median lobe broken away so as to exhibit the openings in the ventral surface that gave passage to the muscles, etc., of the legs, the partitions separating the segments of the ventral surface, and the central ridge to which they are attached. This ridge, with the partitions and arches in the membrane beneath, would give the necessary strength and firmness to form the base of attachment of the limbs. The membrane uniting the margins of the dorsal shell and the median lobe of the ventral surface curves upward close to the pleural lobes of the dorsal shell, and leaves but a narrow space between it and the dorsal shell.

In by far the greater number of sections, both transverse and longitudinal, the evidence of the former presence of an exterior membrane protecting the contents of the visceral cavity, rests on the fact that the sections show a definite boundary line between the white calcspar, filling the space formerly occupied by the viscera, and the dark limestone matrix. Even the thickened arches are rarely seen. This is almost universally the case with the legs and attached appendages, as their external membrane is not to be distinguished as such. It would appear that in the process of mineralization the calcspar that replaced the viscera and contents of the appendages also replaced the substance of the membrane, thus forming one continuous mass and effacing all traces of the delicate external test. The nature of this covering is also shown by the present imperfect condition of the appendages. Only in a few rare instances are they found in an approximately perfect state, and the many bizarre forms prove that it was semielastic, and forced into many irregular forms.

On the same small block of limestone with the two jointed legs illustrated on plate 36, figures 2, *2a-d,* occur the remains of the dorsal shell of both *Calymene senaria* and *Trinucleus concentricus.* The contrast in the test of the joints forming the legs and that of the dorsal shell is very striking. The latter is firm, thick, and of a yellow or opalescent color, while the former is of a bronze color, thin and indented with numerous imprints as though it had contracted or shrunk after the decomposition of the muscles of the leg.

The intestinal canal.[1]—Attention was first called to the existence of

[1] Walcott, C. D.: The Trilobite: New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zool., 1881, Harvard Coll., Vol. VIII, No. 10, pp. 200-201.

the intestinal canal in the trilobite by Prof. Beyrich, who discovered it in a specimen of *Trinucleus ornatus*.[1] M. Barrande subsequently gave numerous illustrations of its preservation in *Trinucleus goldfussi,* where, he says, it extended from the middle of the glabella along the interior of the median lobe to the extremity of the pygidium. In some examples it is filled with very fine, soft clay. This substance has, perhaps, largely contributed to preserve the form of the canal, which, once filled and buried in incompressible sand, has undergone no other deformation. There must have been some peculiarity of conformation that preserved the intestinal canal in this species, as in other trilobites from the same quartzites no traces of it are to be seen.[2] M. Barrande mentions that Dr. A. de Volborth discovered in an *Illænus* a lengthened and articulate organ which originated in the glabella and became attenuated toward the pygidium.[3] A cast of the interior, as shown in plate 28, figure 7, might have such an appearance. This, however, is conjectural, as I have not seen an illustration of Dr. Volborth's specimen.

In my cutting of sections of trilobites it was a very rare occurrence to find traces of the intestinal canal. One specimen out of one hundred was a large proportion. The visceral cavity was usually filled with calcspar, and all vestiges of the canal or any other organ obliterated.

In a note taken while cutting sections in December, 1876, it is stated that when grinding down a section from the anterior towards the posterior extremity of the head the cephalic cavity which was filled with calcspar, had a dark, round spot midway between the hypostoma and median lobe of the head. A sketch taken after the grinding had carried the section a short distance back shows the dark spot with the same outline as the opening seen in plate 28, figure 4, that leads into the intestinal canal from the cephalic cavity as exposed in the specimen. That this was the normal form of the intestinal canal is doubtful, but the transverse section, plate 28, figure 5, shows the opening in figure 4 divided into two openings caused in all probability by the ventral integument with its central ridge, having been pressed up against it. In several transverse sections a round, dark spot is seen in the spar a little distance beneath the thoracic segments. This was filled with sediment or food, and thus distinctly outlined.

[1] Ueb. Trilob., II. Stück, p. 30, pl. IV, fig. 1*c*, 1846.
[2] Sys. Sil. Boh., I., p. 229, 1852.
[3] Idem, II, p. 182, 1872.

The position of the opening of the canal in the specimen represented by figure 4, plate 28, and in the section ground away, would indicate that it passed beneath the cephalic shield into the cephalic cavity, and then recurved to the opening of the mouth. Posteriorly it extended to the extremity of the pygidium, as described by M. Barrande.

The space occupied by the canal and other internal organs is not large, as it is contained mostly between the arched median lobe of the dorsal shell and the ventral membrane, as shown in the restorations of the cross-sections of the thorax (plate 34).

Appendages

limbs

The hypostoma, metastoma, and caudal rami are not treated as true limbs.

The limbs are essentially the same for all of the trilobites of which we now know them (pl. 35, figs. 4-7). They have with the exception of the antennæ a protopodite bearing two rami, the endopodite and the exopodite. The coxopodite and basopodite of the theoretical primitive crustacean limb is fused into one large joint which in this paper will be designated as the proximal joint or protopodite. To this stem or base there is attached a strong jointed endopodite or walking leg and an exopodite varying greatly in form and structure, but always present in those trilobites of which we have the limbs well preserved, except possibly on some of the cephalic limbs. The protopodite may also bear one or more appendages known as the epipodite and possibly another lobe or exite. In the antennæ the exopodite has disappeared, leaving only the simple jointed endopodite. The various joints of the limb were probably connected by a thin flexible membrane protecting the muscles as with recent crustaceans. Some of the details of the limbs will be found in the description of the appendages of the several species.

Antennules.—The antennule of the trilobite is formed of a simple, jointed endopodite, the exopodite of the primitive limb having disappeared. In *Triarthrus* the long, slender antennules are composed of a strong, elongate basal joint (protopodite) attached to the ventral side of the head beside the hypostoma; the remaining joints are short and expand slightly at the distal end (pl. 32, fig. 1). In *Neolenus* (pl. 31) the joints of the antennules are much like those of *Triarthrus,* but there is less expansion at the distal end of each joint which results in a smoother, more cylindrical surface. The antennules of *Ptychoparia* are too imperfect to obtain details, but they appear to be similar to those of *Neolenus*.

Protopodite.—The protopodite is now fairly well known for the limb of the Ordovician species, *Calymene senaria, Ceraurus pleurexanthemus, Triarthrus becki, Isotelus maximus,* and particularly well for the Cambrian species *Neolenus serratus*. In all, it is large, elongate, and presumably formed of two fused joints, the coxopodite and basopodite. No traces have been seen of a precoxal joint. In all but *Triarthrus* the point of attachment to the ventral surface of the body appears to have been about midway and in *Triarthrus* nearer the distal end. The exact form of attachment to the ventral integument is unknown, but as stated under *Neolenus* it was probably narrow and long and connected the dorsal side of the protopodite with the ventral integument and interior supports somewhat as the limbs of *Apus* and *Limulus* are attached to the body. The original form of the protopodite is not fully preserved in any specimen known to me, but from Beecher's specimens a fairly accurate idea may be obtained for *Triarthrus* and from the flattened specimens found in *Neolenus* it appears that the cross-section is much like that of the protopodite of *Apus* (pl. 36, fig. 4), and another suggestion is obtained by comparing it with the leg of *Limulus*. In *Apus* and *Limulus* the protopodite is flat with the nearly vertical sides, and the proximal margin thin with rows of fine spines that continue more or less along the ventral margin towards its distal end. A longitudinal outline of the protopodite of *Neolenus* as restored is shown by figure 4, plate 35, and this may have been the section of the protopodite of nearly all trilobite limbs as they appear to have had the same function in all the genera in which they are now known.

Endopodite.—The endopodite or leg extends outward from the distal end of the protopodite. It is composed of six joints and a short curved terminal claw with two short spines projecting from near the base of the claw. The joints vary in length and relative size in the several species now known. They appear to be essentially the same in form for *Calymene* and *Triarthrus,* but in *Triarthrus* they extend further beyond the edge of the dorsal shield as the pleural lobes of the latter are proportionally narrower. In *Neolenus* the legs extend beyond the dorsal shield very much as in *Triarthrus,* but not quite as far. *Calymene, Ceraurus,* and *Isotelus* are often found enrolled, which indicates that the legs could be drawn within the margin of the shield.

Exopodite.—The exopodite appears to spring from or near the distal end of the protopodite. It varies from the bifid spiral of *Calymene* and *Ceraurus* to the simple, two-jointed, broad, flat, setiferous lobe of *Neolenus* and the many jointed, complicated, setiferous exopodite of *Triarthrus.* A setiferous exopodite is indicated for *Ptychoparia, Isotelus,* and *Trinucleus,* but the structure is unknown.

Epipodite.—The large epipodite of *Neolenus* (pl. 20, figs. 3, 4) is a flat, two-jointed elongate lobe attached to the protopodite and reaching out to the edge of the carapace. A second and much smaller elongate lobe is indicated on one specimen that was attached near the larger lobe (pl. 18, fig. 2). A small setiferous epipodite is attached to the protopodite of *Calymene* (pl. 35, fig. 6) and *Triarthrus* seems to have a small, flat, oval, finely setiferous lobe in about the same place (pl. 30, fig. 19).

Exite.—What may be an exite on the protopodite of *Neolenus* is shown on figures 3 and 4, plate 20. Its assumed position is indicated on the restoration of this species (pl. 18, fig. 2, and pl. 31).

Cephalic limbs.—The cephalic limbs of *Calymene* except the antennules were determined in 1881,[1] and those of *Triarthrus* in 1895,[2] and *Neolenus* including antennules in 1918 (pl. 31). In the three genera the protopodites of four pairs of limbs form gnathobases to which are attached the endopodite or jointed leg as the main stem of the limb and an exopodite that is fairly well known for *Triarthrus* and *Neolenus* and less so for *Calymene.* The character of the limbs and their position indicate that the trilobite lived on soft food that was pushed along to the mouth by the protopodites. No evidence has been discovered of the existence of specialized gnathobases capable of crushing or triturating hard food.

Thoracic limbs.—The thoracic limbs of the species of trilobite with which they have been found have a large protopodite and a strong, relatively large and long endopodite that formed a powerful walking leg of six joints and a short terminal claw; the legs vary somewhat in size in the several species, but all were adapted to the needs of the animal both when walking and when forcing its way through soft mud and sand in search of food. In addition to the endopodite an exopodite is known to have been present in the thoracic limbs of *Calymene, Ceraurus, Neolenus, Kootenia, Triarthrus, Trinucleus,* and *Odontopleura.* The spiral exopodites are found in *Calymene,*

[1] Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, 1881, pl. VI, fig. 1.

[2] American Geol., Vol. XV, 1895 (February), pl. V, figs. 8-11.

Ceraurus, and *Odontopleura;* the flabelliform types in *Neolenus* and *Kootenia;* the setiferous plumes of *Triarthrus* appear to have been capable of service as swimming organs, also of functioning as branchiæ.

It is probable that flat, more or less setiferous epipodites occurred on the protopodites of the limbs of most if not all trilobites, but we know them with certainty only on *Neolenus, Calymene,* and *Ceraurus,* and somewhat doubtfully in *Triarthrus.* They attain their greatest development in *Neolenus,* and the same is true of the small, flat lobes tentatively referred to as exites. The several types of thoracic limbs as now known are illustrated by diagrammatic drawings which are reproduced by figures 4-7, plate 35.

Pygidial limbs.—The limbs beneath the pygidium appear to be essentially the same as those of the thoracic region as far as the endopodite is concerned and usually the same is true of the exopodite, the known exception being in *Triarthrus* where the many jointed setiferous arm of the exopodite appears to resolve itself into a series of minute lobes that are transverse to the axis of the limb and look like the exites of a phyllopod limb.

Summary.—The appendages may be summarized as follows:

Cephalic:

1. *Antennules.*—Uniramose, slender, many jointed, and attached to the ventral integument of the cephalon about midway of the glabella.
2. *Antennæ.*—Represented by the anterior pair of cephalic limbs which are posterior to the opening of the mouth.
3. *Mandibles.*—Represented by the second pair of cephalic limbs.
4. *Maxillula.*—Represented by the third pair of cephalic limbs.
5. *Maxilla.*—Represented by the fourth pair of cephalic limbs.

Thoracic: A pair of biramous limbs to each segment or somite of the thorax, each limb consisting of a fused coxopodite and basopodite forming a protopodite; an attached, six-jointed endopodite or leg with a terminal spine or spines, one of which is usually in the form of a slightly curved claw; an exopodite that may or may not be jointed and which is attached to the distal end of the protopodite; one or more flabelliform epipodites attached to the distal part of the endopodite and in one instance (*Neolenus*) one or more exites (attached to the anterior side of the protopodite?).

Abdominal: No abdominal appendages are differentiated from those of the thorax by their structure. Those referred to as such are the limbs beneath the pygidium which are similar in structure to those beneath the thorax. A pair of pygidial limbs occur for each segment of the pygidium and the posterior ones may show traces of a more primitive structure.

Caudal rami: Known only for *Neolenus.* Long, slender, many jointed, uniramous and attached to the ventral integument at the posterior end of the pygidium. The caudal rami are not considered to represent true limbs, although in *Neolenus* they are quite similar in appearance to the antennules and are attached to the ventral integument. They may represent the appendages of the anal segment.

Position of the Limbs

When I took up the question of the restoration of the ventral appendages of *Neolenus* I decided to study first the form and arrangement of the appendages of the Branchiopoda, and following that the Malacostraca, as I considered the trilobite to be a form intermediate in its development between the Branchiopoda and the lower Malacostraca, as represented by the Phyllocarida, Syncarida, and Mysidacea. The appendages of the trilobite genera *Triarthrus, Calymene, Ceraurus,* and *Isotelus* were then examined with a view of ascertaining if possible their form and arrangement when the animal was living. These studies and comparisons led me to the conclusion that the limbs of the trilobites had essentially a similar arrangement as those of the Branchiopoda, that the cephalic appendages were less specialized, and that the form of the protopodite was that of a flattened joint projecting inward and forward toward the median line and providing at its distal end support for the endopodite or jointed leg and a varying form of exopodite, and epipodites if present.

I then examined some large specimens of *Apus lucasanus* Packard in which, looking on the ventral surface, the protopodites of the thoracic limbs extend obliquely forward from each side towards the median line at an average angle of 30°, and present the narrow ventral surface of the protopodite and its anteriorly sloping surface which almost passes beneath the next anterior limb when viewed from above as the animal is lying on its back. This gives the effect of broad, closely arranged thoracic limbs when actually they are narrow and deep. I next gradually pressed a specimen out flat between strong glass plates, so that it was possible to see just what happened to it from the beginning of the application of the flattening process until it was completely flattened out. The result was that the protopodite and connecting joints of the limbs were seen to change from pointing forward with the narrow ventral edge uppermost to a position where they were directly transverse or pointing backward and with the flat side of the joints pushed over so as to lie on the plane of the dorsal shield, a position usually found in the limbs of the fossil trilobite.

This experiment was repeated many times with the same result. If we now consider that the larger number of trilobites which have been found with the appendages attached were lying on their backs and that the silt settled down directly on the appendages and as the weight increased the appendages were pressed down on the dorsal shield and flattened out very much in the same manner as *Apus* with the glass plates, it is extremely probable that the limbs were pressed out of position and often pushed out beyond the edges of the dorsal shield. I also submitted a number of small specimens of *Limulus polyphemus* to pressure between glass plates and found that the flat proximal joints of their cephalic legs assumed nearly the same position as the legs of the fossil trilobite and pointed more or less backward.

The position of the limbs in the fossil specimens is clearly indicated for *Neolenus* on plates 15, 17-19, where the protopodite and endopodite (leg) extend outward and backward from the median axis of the dorsal shield; the exopodites extend outward and forward, plates 21-23; the cephalic limbs extend outward and forward as in plate 16. Although pressed flat on the shale and more or less forced away from their original position in relation to their points of attachment to the ventral integument, the limbs are probably in a more natural position than those of *Isotelus* and *Triarthrus*.

The limbs of *Isotelus* (pl. 25) slope forward in such a manner as to indicate that the protopodites have all been forced over and swung around so as to point backward towards the central axis and forward and outward or almost the reverse of their position when living; the endopodites are nearer their probable normal position, but still slope too much forward.

The limbs of *Triarthrus* have the axis of their protopodites sloping inward and backward as in *Isotelus,* with the endopodite and exopodite extending forward in a natural position.

The conclusion drawn from the study of the limbs of the fossils and recent crustaceans is that the normal position of the protopodites of the trilobite was that indicated in the restorations of *Neolenus* (pl. 31), *Triarthrus* (pl. 32), *Calymene* (pl. 33), also that the flat protopodites and adjoining joints of the endopodite (leg) were vertical or nearly so to the plane of the ventral surface and dorsal shield, and when viewed from directly above when the animal was lying on its dorsal surface would show only the thin edge of the joints as shown in the restorations, plates 31-33. The deep or broad side of the limbs is seen only on a side view as shown by the transverse sections on plate 34. It is probable that Beecher was misled by the appearance of the appendages of *Triarthrus* in the fossil state in making his restoration of the ventral surface and appendages of *T. becki* as he represents the limbs from the proximal end of the protopodite to the distal joint of the endopodite as lying on their side, and also has the protopodite pointing obliquely backward.

Respiration of the trilobite.—Walcott assumed that the function of respiration in *Calymene* and *Ceraurus* was performed by the spiral exopodites and setiferous epipodites.[1] Beecher wrote of the probable respiratory apparatus of *Triarthrus* and *Trinucleus:*[2]

> No traces of any special organs for this purpose have been found in this genus, and their former existence is very doubtful, especially in view of the perfection of details preserved in various parts of the animal.
>
> The fringes on the exopodites in *Triarthrus* and *Trinucleus* are made up of narrow, oblique, lamellar elements becoming filiform at the ends. Thus, they presented a large surface to the external medium, and partook of the nature of gills.

Beecher quotes Gegenbaur as follows:[3]

> The functions of respiration and of locomotion are often so closely united that it is difficult to say whether certain forms of these appendages should be regarded as gills, or feet, or both combined. [Elements of Comparative Anatomy, English edition (Bell and Lankester), p. 241.]

If the flat, epipodite-like lobes illustrated in figure 19, plate 30, are what they appear to be they would have served as gills.

Neolenus has an elaborate respiratory system if we consider the exopodite and the epipodites (pl. 35, fig. 4) as gills. In this species the protopodite and endopodite of the limbs were so strong that it is not probable that the test covering them functioned in respiration.

There is no doubt of the presence in the trilobite of well-developed and specialized organs of respiration comparable with those of the Malacostraca, such as the Nebaliacea, Anaspidacea, and Mysidacea.

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[1] Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, 1881, pp. 207, 208.

[2] American Jour. Sci., 4th ser., Vol. I, 1896, p. 255.

[3] Idem.

Restoration of ventral appendages.—The restorations of the ventral surface and appendages of *Neolenus, Triarthrus,* and *Calymene* are undertaken in order to present in graphic form these crustaceans as I conceive they appeared when living. It was with great hesitancy that the broad, short protopodite as I drew it in 1881 [1] was abandoned and the narrow, deep, elongate protopodite substituted. The limbs of *Neolenus,* however, clearly had a deep, narrow protopodite and a similar form evidently prevailed in the first three joints of the endopodite. A study of specimens of the limbs of *Triarthrus* led to the same result and with these two in mind the sections of the limbs of *Calymene* and *Ceraurus* were found to be capable of a similar interpretation as far as the protopodites and to a limited extent the proximal joints of the endopodite were concerned. Another line of supporting evidence is given by the tracks, trails, and burrows made by trilobites on and in the muds and sands of Cambrian time. The sharp, deep, clearly lined imprints (pls. 38-40) could only have been made by a strong limb with a narrow and deep protopodite and endopodite. With this form of limb in mind the restorations are made as though looking directly down on the ventral surface, so as to show the narrow side of the limbs and a little of their sides for *Neolenus,* plate 31, *Triarthrus,* plate 32, and *Calymene,* plate 33. The exopodites of the three species were quite unlike and they have been represented so as to give some conception of their form by turning them partially over on their side. Their position in the transverse sections (pl. 34) is more nearly natural than as they are represented on plates 31-33.

I have planned for twenty years to redraw my restoration of *Calymene* of 1881,[2] but it was not until the material representing *Neolenus* was studied that I felt that the restoration could be undertaken with a prospect of improving on the first attempt. After working out *Neolenus* and *Calymene* I studied Beecher's restoration of *Triarthrus* and a number of original specimens and made a sketch from which the restoration on plate 32 was drawn. Sketches of the transverse sections were also made with a view of obtaining side views of the limbs; a third sketch is a diagrammatic outline of the limb of each species with all known appendages attached to the protopodite so as to clearly distinguish them.

[1] Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII, 1881, pl. VI, fig. 1.

[2] Idem, pl. VI, fig. 1. Smithsonian Misc. Coll., Vol. 57, 1912, p. 192.

The sketches were turned over to Mr. Clarence R. Shoemaker, of the U. S. National Museum, as the base for the drawings reproduced on plates 31-34, with the request that he would, from his knowledge of the appendages of the Crustacea, give the restorations as natural an appearance as possible.

The restorations may be of service to the student of recent and fossil crustacea and also serve as a stimulus to further research in order that with new material and a different point of view more satisfactory results may be obtained by the future student. The restorations of the thoracic limbs are so fundamental I will mention them more fully.

Restoration of thoracic limbs.—As far as known the thoracic limb of *Neolenus, Isotelus, Triarthrus, Ceraurus,* and *Calymene* has a large protopodite to which the leg (endopodite), exopodite, and when present the epipodite or epipodites are attached. This large protopodite is presumably formed of a basopodite and coxopodite so closely fused that the line of jointing has disappeared.

Neolenus.—Represented by *Neolenus serratus* (Rominger), from the Middle Cambrian. This is the most complex limb thus far known among the trilobites. It has (pl. 35, fig. 4) a true ambulatory leg (endopodite) attached to a large protopodite that served also as a gnathobase and as the base for a large setiferous exopodite and large and small lobe-shaped epipodites, and on the anterior series of limbs at least one or two small, flat endites. This limb is much like the anterior thoracic limb of *Anaspides tasmaniæ* (pl. 35, fig. 1) and has the same elements in it as the first thoracic limb of *Paranaspides* (pl. 35, fig. 3). The exopodite in the first thoracic limb of *Anaspides* is a simple unjointed rod, but on the second limb it is jointed, somewhat setiferous, and antennæ-like in the outer portion. The endites on the inner side of the coxopodite of the first thoracic limb serve as gnathobases, but they are not present on the posterior limbs. The flat, lobe-like epipodites are essentially similar in all the genera of the Anaspidacea. Their position is shown on plate 35.

Calymene (pl. 35, fig. 6).—Represented by *C. senaria* Conrad of the Trenton formation of the Ordovician. This limb is nearly as complex as that of *Neolenus* as it has an endopodite, exopodite, and an epipodite, but in its simple bispiral exopodite and small epipodite it does not appear to be as highly developed a limb.

Ceraurus (pl. 35, fig. 7).—Represented by *Ceraurus pleurexanthemus* Green of the Ordovician. As far as known the limb of this species is essentially similar to that of *Calymene.*

Triarthrus (pl. 35, fig. 5).—Represented by *Triarthrus becki* Green of the Utica shale of the Ordovician. The anterior thoracic limbs of *Triarthrus* have the elements of the limb of *Neolenus, Calymene,* and *Ceraurus,* and may be compared with them except as to the details of the exopodite and epipodite. The more posterior limbs show flattened and transversely elongate joints (pl. 34, figs. 6 and 7) which Beecher compares with the large endites of the phyllopodan limb. In the restorations, plate 32, I have given the limb from beneath the pygidium nearly the same form as the thoracic limb, basing it on the specimens available for study in the collections of the National Museum. The transverse phyllopodan-like joints of the exopodite of the limbs of the posterior portions of the animal beneath the pygidium are not represented in the diagrammatic sections (See pl. 29, figs. 4, 5, 8, 11).

The longitudinal restorations of the thoracic limbs (pl. 35) were drawn in order to clearly indicate the various elements entering into the structure of the limb. These should be compared with the side views of the limbs in the transverse sections (pl. 34) and those of the restorations of the ventral side of *Neolenus, Triarthrus,* and *Calymene* (pls. 31-33).

Comparison with crustaceans.—Early authors (1750-1843) compared the dorsal shield of the trilobite with various crustaceans, especially *Apus* and *Limulus,*[1] and when traces of appendages began to be discovered these comparisons were continued[2] (1870-1881). Bernard, as the result of a very comprehensive study, felt confident that the trilobites may take a firm place at the root of the crustacean system with the existing *Apus* as their nearest ally.[3]

He concluded[4] that—

> *Apus,* on account of its richer segmentation, the absence of pleurae on the trunk-segments, and its more membraneous parapodia-like limbs, must be assumed to lie in the direct line upwards from the original annelidian ancestor toward the modern crustacea. The trilobites then must have branched off laterally from this line either once or more than once, in times anterior to the primitive *Apus,* as forms specialized for creeping under the protection of a hard imbricated carapace.

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[1] See Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, 1881, pp. 193-195.

[2] Idem, pp. 195-197.

[3] Nature, Vol. 48, 1893, p. 582. Quart. Jour. Geol. Soc. London, Vol. 50, 1894, pp. 411-432, and Vol. 51, 1895, pp. 352-359.

[4] The Systematic Position of the Trilobites, Idem, 1894, Pt. I, pp. 429-430.

In 1895, with the new evidence afforded by the trilobite *Triarthrus becki,* he concluded[1] that—

The trilobites, therefore (as exemplified by *Triarthrus*), in spite of their extremely primitive mouth-formula, do not stand in the direct line of descent of the Crustacea, but are lateral offshoots, specialized for a creeping manner of life.

The discovery of the limbs of *Triarthrus* led Walcott to abandon the view (held in 1881) that the trilobite was closely allied to *Limulus*[2] in favor of its being a crustacean that was neither a "true Entomostracan or Malacostracan nor was it a lineal descendant from either, but was probably a descendant from a common ancestral type"[3] of all three.

Two general facts led me in 1894 to think that the modern crustacean is descendant from the Phyllopod branch of the Branchiopoda and the Trilobita from a distinct branch.[4] 1st. The Trilobita branch exhausted its vital energy in Paleozoic time and disappeared. 2d. The Phyllopod branch developed slowly until after the Trilobita passed its maximum and then began its great differentiation that in its descendants approaches culmination in recent times.

When the trilobite and phyllopod diverged from their common crustacean ancestor, the trilobite began to differentiate and to use its initial vital energy in developing new species, genera and families. Probably two thousand species and one hundred or more genera are known from Paleozoic strata. With this great differentiation the initial vital energy was exhausted and the Trilobita disappeared at the close of Paleozoic time without leaving direct descendants.

The Branchiopoda, including the Ostracoda, Copepoda, and Cirripedia developed steadily during Paleozoic and subsequent geologic time until to-day their descendants form the subclasses Branchiopoda and Malacostraca, each of which is equivalent to the subclass Trilobita of Paleozoic time. Springing from a common crustacean base the three groups have many features in common, and in details of structure of the limbs many striking resemblances occur. It does not impress me that trilobites were true Branchiopodans or Malacostracans; they have certain characteristics in common, but these are not necessarily the result of lineal descent one from the other, but are the result of descent from a common ancestral crustacean type of

[1] Quart. Jour. Geol. Soc. London, Vol. 51, 1895, Pt. 2, p. 356.

[2] Bull. Mus. Comp. Zool., Harvard Coll., Vol. VIII, 1881, pp. 209-211.

[3] Proc. Biol. Soc. Washington, Vol. IX, 1894, p. 94.

[4] This view is only confirmatory of the result of the profound study of the Apodidæ by Bernard (The Apodidæ, Nature Series, 1892).

pre-Cambrian time that lived in the pelagic fauna in which all the earlier types of life were probably developed[1] and from which, as time passed on, additions were made to the paleontologic record of the geologic series of formations. We know that Phyllopods, Ostracods and Trilobites were clearly differentiated in lower Cambrian time.

Beecher compared the trilobite with the phyllopods and concludes that points of likeness may be established with almost every order of Crustacea, showing chiefly the relationship between the trilobite and the ancestors of modern Crustacea.[2] He has well summed up the evidence in favor of the trilobites being considered true crustaceans rather than allied with the Arachnids.[3] Also in his classical memoir on the " Natural Classification of the Trilobites " he states the claim of the trilobite to a position as a subclass of the Crustacea equivalent to the subclass Entomostraca and the third subclass Malacostraca. He concludes:[4]

> In nearly every particular the trilobite is very primitive, and closely agrees with the theoretical crustacean ancestor. Its affinities are with both the other subclasses, especially their lower orders, but its position is not intermediate.

I have neither the time nor space in which to review further the literature on the trilobites. It is too voluminous; the student will find the list of works given in the Zittel-Eastman Text-book of Paleontology, 1913, Vol. I, pp. 692-694, to be very helpful, and there is also there a valuable discussion of the trilobite by Beecher as revised by Raymond.

In connection with the study of *Neolenus* I have had occasion to compare the general arrangement of trilobite limbs with those of the order Notostraca (*Apus,* etc.) and to compare its limbs with those of the Malacostracan order Anaspidacea.

Apus.—The trilobite is clearly not a Branchiopod. Beecher considered that the supposed phyllopod-like legs (endopodites) beneath the pygidium of *Triarthrus* brought the trilobites close to *Apus,* but if my view is correct, that the endopodites are normal beneath the pygidium and that it is the exopodite that has the primitive lobe-like

[1] See Brooks' beautiful memoir on Salpa, with its suggestive theory of the origin of the bottom faunas of the ocean and the early geologic faunas. The Genus Salpa, Memoirs from the Biological Laboratory of The Johns Hopkins University, II, 1893, pp. 140-177.

[2] American Geol., Vol. XV, 1895, p. 99.

[3] Text-Book of Palaeontology, Zittel-Eastman, 1900, p. 622.

[4] American Jour. Sci., 4th ser., Vol. III, 1897, p. 93.

joints, the relation to *Apus* is weakened as the exopodite is very much more variable in the trilobite than the endopodite.

The more simple oral appendages of the trilobite compared with those of *Apus* (Branchiopoda), which has reduced and considerably specialized mouth parts, indicates that they are more primitive than those of *Apus,* but the highly developed thoracic limbs of the trilobite and its dorsal shield point to *Apus* as somewhat nearer the primitive crustacean type.

The typical trunk limb of the branchiopod includes the primary elements of the limb of the trilobite, but while the trilobite limb undoubtedly passed through the branchiopod stage it was long before Cambrian time and before the life of the oldest trilobite we now know. Beecher thought that he had found evidence of a branchiopod limb in the limbs beneath the pygidium in *Triarthrus,* but as mentioned above the evidence for this view may be otherwise interpreted. The series of setiferous lobes on the proximal joint (protopodite) of the limbs of *Apus,* extending inward toward the median line of the ventral surface of the body and which function as gnathobases, is represented in the trilobite by the long protopodite of the limbs with its setiferous proximal end and ventral margin.

Marrella.—With the Middle Cambrian *Marrella splendens* Walcott[1] the trilobite has several characters in common. These include (*a*) sessile eyes, (*b*) a large hypostoma with the proximal joints of the cephalic limbs assembled at its posterior end or beneath it, (*c*) a pair of biramose limbs for each trunk segment, and (*d*) expansion of the joints of the posterior thoracic legs (endopodites).

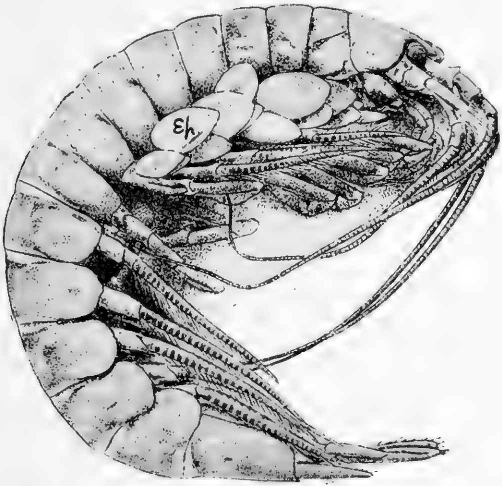
Its more specialized mouth parts, and absence of gnathobases on the thoracic limbs, indicate less primitive characters, while its carapace and an almost total absence of an abdominal section or pygidium points to it as a primitive form possibly ranking in development between *Apus* and the trilobite.

Anaspidacea.—The most striking instance of similarity of the thoracic limbs of a trilobite and those of a recent crustacean is that of the thoracic limbs of *Neolenus* which strongly suggest those of the Malacostracan genus *Anaspides,*[1] a crustacean of the order Syncarida, found in a fresh-water pool in Tasmania, New Zealand. The resemblance is shown by the presence in both of a strong ambulatory jointed leg (endopodite), a jointed setiferous exopodite, and two

[1] Smithsonian Misc. Coll., Vol. 57, 1910, p. 193, pls. 25, 26.

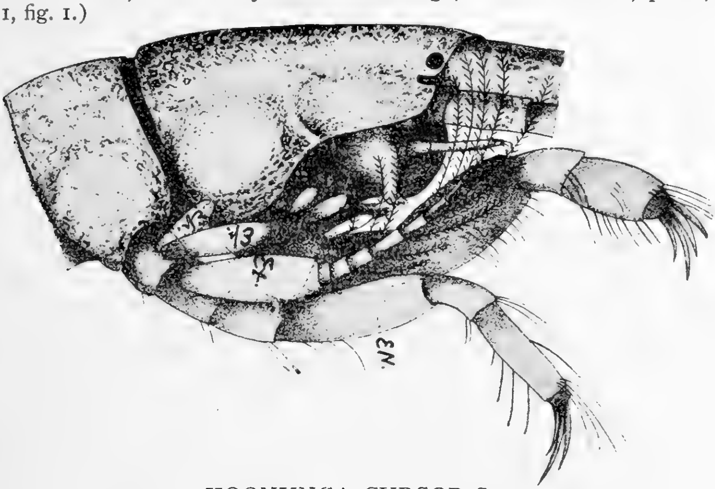
[1] On the genus *Anaspides,* W. T. Calman, Trans. Royal Soc. Edinburgh, Vol. 38, Pt. 4, 1896, p. 791, pl. 2, fig. 12.

jointed flabelliform epipodites attached to the proximal joints (coxopodite and basopodite) of the limb. Whether or not the plate-like lobes shown beside the median lobe of the dorsal shield in figures 3 and 4, plate 20, of *Neolenus* can be compared with the internal lobes



ANASPIDES TASMANIÆ G. M. Thomson

Fig. 1 (× 3.5).—Side view of male illustrated here to show thoracic legs with exopodites and epipodial lamellæ. This species is without dorsal shield. (After Calman, Trans. Royal Soc. Edinburgh, Vol. XXXVIII, pt. iv, 1896, pl. 1, fig. 1.)

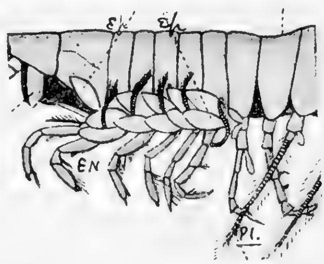


KOONUNGA CURSOR Sayce

Fig. 2 (× 37).—Anterior part of the animal, showing character of first thoracic limb with its leg (endopodite), exopodite (*ex*), and epipodites (*ep*). (After Sayce, Trans. Linnean Soc. London, 2d ser., Zool., Vol. XI, pt. 1, 1908, pl. 1. fig. 3.)

of the coxa of the maxilliped of *Anaspides*[1] is not readily determined, but it is very suggestive and not improbable (pl. 35, figs. 1-3). The exopodite of the thoracic limb of *Anaspides* (text fig. 1) recalls in its jointed structure the exopodite of *Triarthrus,* but the exopodite of *Koonunga* (text fig. 2), although jointed is quite unlike it, and the exopodite of *Paranaspides* (text fig. 3) is slender, closely jointed and setiferous, and much like that of *Anaspides.*

Another form closely allied to *Anaspides* is *Koonunga* Sayce.[2] It differs from *Anaspides* in having a sessile eye as in all trilobites with eyes, in details of several of the appendages, the mouth parts, and in having the anterior thoracic segment fused to the cephalon. The thoracic leg is essentially the same as that of *Anaspides* (pl. 35, fig. 2). Mr. Sayce considers *Koonunga* the most primitive Edriophthalmatan known.



PARANASPIDES LACUSTRIS Smith
FIG. 3 (× 4).—Thoracic limbs with leg, epipodites and exopodite. (After Smith.)

The first thoracic limb of *Paranaspides* Smith[3] has a jointed leg (endopodite), a simple unjointed exopodite, two epipodites, and two simple flat lobes (exites) attached to the coxopodite (See pl. 35, fig. 3). The latter are of interest to us as they correspond in form and probably position to the flat, plate-like lobes (exites) found in connection with the thoracic limb of *Neolenus.* A feature to be considered is that these flat lobes occur only on the anterior or first thoracic pair of legs in the *Anaspides* while they are known to be

[1] On the genus *Anaspides,* W. T. Calman, Trans. Royal Soc. Edinburgh, Vol. 38, Pt. 4, 1896, p. 791, pl. 2, fig. 12.

[2] Trans. Linnean Soc. London, 2d ser., Zool., Vol. 11, Pt. 1, 1908, pp. 1-16, pls. 1, 2.

[3] Proc. Royal Soc. London, Ser. B, Vol. 80, 1908, p. 470, text fig. No. 6, p. 171.

present in a position to indicate that they were associated with several of the anterior thoracic legs of *Neolenus*.

The thoracic limbs of the trilobite differ from those of the Anaspidacea by having the coxopodite and basopodite of the latter fused in a strong protopodite, but it is quite evident that the latter have characters in their thoracic limbs that were present in the trilobite. In other respects the species of the Anaspidacea are quite unlike the trilobite as now known to us.

Nebaliacea.—The thoracic limb of *Nebalia* with its jointed leg-like endopodite, lobe-like exopodite and epipodite is much like that of *Neolenus* except in the development of the basopodite. In its more specialized cephalic limbs and separation of the thoracic limbs into two distinct tagmata of eight pairs of thoracic limbs and the abdominal section of seven somites, *Nebalia* is less primitive than the trilobite.

Cyamus.—An examination of the spiral branchiæ of the parasitic crustacean *Cyamus scammoni* Dall shows them to be formed of a slender, strong, tapering tube that may be a complete spiral as shown by figure 9, plate 28, or it may be straightened out near the base and irregularly coiled towards the distal end. If the spiral of an alcoholic specimen is bent over or pulled out of shape without breaking, it at once springs back to its original form when released. The spirals of *Cyamus* are apparently attached to the ventral surface directly, but not on the same segment with the jointed leg. As *Cyamus* is a highly modified parasitic crustacean it is probable (as suggested by Mr. C. R. Shoemaker) that the coxopodite of the leg that has been lost in the changes incident to a parasitic life has become fused with the segment and thus the spiral branchiæ have become apparently attached to the ventral surface of the segment. They are attached at the same point of the pleural part of the segment as the legs on the adjoining segments. The spiral branchiæ are introduced as they serve to explain the spirals of the exopodites of *Calymene* and *Ceraurus,* also as an illustration of the survival of an unusual character of the trilobite or a recurrence of the same form in a modern crustacean.

Conclusion.—Many further comparisons of parts might be made with other modern crustaceans (*e. g.,* the Mysidacea, Euphausiacea, some of the " Schizopods "), but they would only go to prove that the trilobite is a primitive crustacean far back on the line of descent from the original crustacean type which existed in pre-Cambrian or Lipalian time.[1]

Tracks of Trilobites

When writing of the tracks occurring on the Upper Cambrian Potsdam sandstone of Canada and New York in 1912, I said:[2]

> If we picture in our imagination a trilobite with a series of twelve pairs of legs posterior to the cephalon (figs. 1 and 2), and five pairs of cephalic legs, walking on the smooth or rippled surface of fine wet sand exposed at low tide, I think we can readily explain the *Protichnites* tracks on the Potsdam sandstone. Such a series of feet would make varied and complex series of tracks that would differ in depth, definition and details of grouping with the varying degree of consistency and hardness of the surface over which the animal was traveling and its method of moving. I have fine trilobite trails made on the surface of sandy mud that show the imprint of a considerable portion of the legs. On a hard surface the animal touched only the extremities of the legs, but on a muddy surface the terminal joint would sink in and other joints would leave an impression.
>
> The trifid imprint resulted from the impress of the end of the terminal joint of the trilobite's leg with its three movable spines.[3]

Some of the tracks referred to above are illustrated on plate 42, and on plates 37, 38, 41, a series of trilobite tracks and trails from the Middle Cambrian sandstones of the Grand Canyon of the Colorado River. The latter show the impression of the distal joints and some the entire length of the leg as the surface in places was less resistant and the leg sank deeper into it. The series of tracks and burrows also clearly indicate that the trilobite was the animal that made the trails, burrows, and wallows that gave rise to the casts that have been largely described by authors under the generic term *Cruziana* d'Orbigny.[3]

The size and depth of the trails left by the trilobite prove that their legs were long, strong, and attached to a large protopodite. When the animal was pushing its way through a soft surface of sand or fine muddy sediment in search of food (Annelids, etc.), the legs appear to have bunched together in groups of two, three or more, and slowly crowded the animal forward (pl. 38, figs. 3, 4; pl. 39, pl. 40). That it was annelids the trilobite was seeking is indicated by the presence in the sandstone or shale of large numbers of annelid borings and casts of trails, some of which follow along the furrow made by the

[1] Smithsonian Misc. Coll., Vol. 57, 1910, p. 14 (footnote).

[2] Idem, 1912, No. 9, p. 278.

[3] See Delgado for description and illustrations. Estudo Sobre os Bilobites de Portugal, Acad. Sci. Lisbon, 4to, 1886.

trilobite (pl. 37, fig. 3), while others are beneath it or cross at various angles. One of the small slabs of annelid trails and casts of borings is illustrated on plate 42, and there is a large series of them in the collections of the United States National Museum.

I will not give a detailed description of the tracks and trails as the illustrations tell the story of the almost endless variation caused by the varying conditions under which they were made. We know something now of the variation in size, form, and length of trilobites' limbs, and it is evident from the tracks and trails that there were many other variations of which nothing is known. When experimenting with the common rock crab of the New England coast, I found that by causing the same crab to creep, run, or wallow on and in sediments of varying material, hardness, and consistency, many kinds of tracks and trails could be produced, and the same was true with the common "Horse Shoe" crab (*Limulus*) of the Florida shore. If we had a living crustacean with the same type of protopodite, endopodite and exopodites, and dorsal shield that the trilobite has, it would be quite possible to largely reproduce the trails and tracks illustrated on plates 37-42.

Just how the trilobite used its numerous limbs when pushing through the mud or sand it is difficult to imagine. The motion must have been very slow and probably there was a general irregularity of movement of the limbs when the more complicated trails were made. This is indicated by figure 6, plate 37; figure 3, plate 38; figures 1-4, plate 39; figures 1-5, plate 40. Such trails as that of figure 2, plate 41, are less complicated than the trail represented by figure 1, plate 39. There is no animal known from the rocks on which the tracks and trails occur but the trilobite that could have made them.

The trilobites that may have made the trails on the sands and muds of Middle Cambrian time include species of the genera *Agnostus, Eodiscus, Ptychoparia, Dolichometopus, Bathyuriscus, Asaphiscus, Neolenus,* etc. These give a wide variation in size, and undoubtedly in ventral appendages and the same is true of the trilobites of the Lower and Upper Cambrian, Ordovician, Silurian, and Devonian time. Some future student of the trails and tracks found on Paleozoic rocks should make great collections and also conduct many experiments with recent crustaceans in the making of trails and tracks under all possible conditions. Most interesting results will be secured by a careful, patient, thorough worker.

General Summary

At the risk of repetition of statements made in this paper and by authors I will give a brief summary of the structure of the trilobite that may possibly be of service to the teacher, and student, of recent and fossil crustacea.

Dorsal shield.—All known trilobites had a more or less chitinous shield or carapace which was thick and strong in the Illænidæ, etc., or thin and delicate in the Mesonacidæ, *Olenellus,* etc. As yet no forms have been found that were without a complete dorsal shield, but it is probable that such existed in pre-Cambrian time when the trilobite was diverging from its primitive crustacean ancestor. Naked phyllopod crustaceans lived in Middle Cambrian time and left their record on the Burgess shale,[1] so it is possible that such can be preserved. One trilobitic-like form, *Nathorstia,*[2] had a very delicate dorsal shield, and possibly others existed in earlier Cambrian time that will add to the story of the evolution of the carapace and structure of the ventral surface and appendages.

The subclass Trilobita may be defined, after Raymond in Zittel's Text-book,[3] modified to meet data afforded by *Neolenus,* as follows:

Marine Crustacea, with a variable number of metameres (segments); body covered with a hard dorsal shield or crust, longitudinally trilobate into the defined axis and pleura; cephalon, thorax and abdomen distinct. Cephalon covered with a shield composed of a primitively pentamerous middle piece, the cranidium, and two side pieces, or free cheeks, which may be separate or united in front, and carry the compound sessile eyes when present; cephalic appendages pediform, consisting of five pairs of limbs, all biramous, and functioning as ambulatory and oral organs, except the simple antennules, which are purely sensory. Upper lip forming a well-developed hypostoma; under lip (epistoma) present. Segments of the thorax movable upon one another, varying in number from two to twenty-nine. Abdominal segments variable in number, and fused to form a caudal shield. Ventral integument a thin uncalcified membrane, divided into pleurosternites and mesosternites connected segmentally by an interarticulate membrane. Mesosternites usually with five longitudinal ridges, a median one with two oblique extending obliquely forward on each side (the spaces thus formed indicate attachment of ventral muscles). All segments, thoracic and abdominal, carry a pair of jointed biramous limbs. All limbs have their proximal elements forming gnathobases, which become organs of manducation on the head. Respiration integumental and by bran-

[1] Smithsonian Misc. Coll., Vol. 57, 1912, pp. 157-170, pl. 27, fig. 6; pl. 28, fig. 1. *Opabinia.*

[2] Idem, pp. 194-195, pl. 28, fig. 2.

[3] Zittel-Eastman, Paleontology, 1913, Revised by Raymond, pp. 692-694.

chial fringes on the exopodites, epipodites, and exites. Development proceeding from a protonauplius form, the protaspis, by the progressive addition of segments at successive moults.

Intestinal canal.—Of the internal organs only the intestinal canal is known. This, starting at the mouth, curves upward, and extends beneath the median lobe of the dorsal shield the entire length of the body, terminating at the anal opening beneath the last segment of the pygidium. There were probably hepatic cæca opening into the anterior end, but as yet none have been seen, although they are present in the Branchiopod genus *Burgessia,* which is associated with *Neolenus* in the Burgess shale.[1]

The appendages may be summarized as follows:

Cephalic:

1. *Antennules.*—Uniramose, slender, many jointed, and attached to the ventral integument of the cephalon about midway of the glabella.
2. *Antennæ.*—Represented by the anterior pair of cephalic limbs which are posterior to the opening of the mouth.
3. *Mandibles.*—Represented by the second pair of cephalic limbs.
4. *Maxillula.*—Represented by the third pair of cephalic limbs.
5. *Maxilla.*—Represented by the fourth pair of cephalic limbs.

Thoracic: A pair of biramous limbs to each segment or somite of the thorax, each limb consisting of a fused coxopodite and basopodite forming a protopodite; an attached six-jointed endopodite or leg with terminal spines, one of which is usually in the form of a slightly curved claw; an exopodite that may or may not be jointed and which is attached to the distal end of the protopodite; one or more flabelliform epipodites attached to the distal part of the endopodite and in one instance (*Neolenus*) one or more exites (attached to the anterior side of the endopodite?).

Abdominal: No abdominal appendages are differentiated from those of the thorax by their structure. Those referred to as such are the limbs beneath the pygidium which are similar in structure to those beneath the thorax. A pair of pygidial limbs occur for each segment of the pygidium and the posterior ones may show traces of a more primitive structure.

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[1] Smithsonian Misc. Coll., Vol. 57, 1912, pp. 177-180, pl. 27, figs. 1-3; pl. 30, figs. 3, 4.

Caudal rami: Known only for *Neolenus.* Long, slender, many jointed, uniramous and attached to the ventral integument at the posterior end of the pygidium. The caudal rami are not considered to represent true limbs, although in *Neolenus* they are quite similar in appearance and seem to be attached to the ventral integument as though they represented the appendages of the anal segment.

Manner of life.—The trilobite was a marine crustacean that lived in shallow seas, bays, sounds and inlets, and sometimes deeper waters. In its younger stages of growth a free moving and swimming animal, it later became a half-burrowing, crawling, and sometimes swimming animal and moving at times with the flow of the tides and prevailing currents. Much of its life must have been spent searching for food in the mud and silt after its younger free swimming days had passed.

Its spawning habit was presumably much like that of *Limulus.* Eggs have been found both within and free from the body, and a younger stage of growth (protonauplius) occurs in the fossil state. It was at home on many kinds of sea-bottom and was able to accommodate itself to muddy as well as clear water.

It was intensely gregarious in some localities and widely scattered in others, depending upon local conditions, and habits of the various species.

Respiration.—Trilobites had an ample system of respiration by setiferous exopodites, epipodites, and exites attached to the cephalic, thoracic, and abdominal limbs. These may be seen in the restoration of the limbs on plates 34 and 35.

Food.—The structure of the gnathobases of the cephalic limbs indicates soft food such as worms, minute animal life, and decomposed algæ.

Persistence in time.—Without means of offence, and of defense only by covering itself closely by its dorsal shield or hiding in the mud, the trilobite persisted from far back in pre-Cambrian time to the close of Carboniferous time. This was owing largely to its being able to adapt itself to a varied and changing environment, and to its great reproductive powers. Its eggs must have been brought forth in immense numbers and in favorable localities for development.

Extinction.—The trilobite slowly developed in pre-Cambrian time, reached its maximum in the Cambrian period, and continued on in full tide until well into Ordovician time when the sea bottoms became crowded with a large and varied fauna, and numerous enemies, some small and insidious, parasitic in nature, others large and powerful, appeared, together with various types which, while not physically antagonistic, were economically so in being better adapted to live in the same manner under the same conditions. It kept up the struggle but, already an ancient type, it had lost its juvenile race plasticity and ability to modify itself to meet the new conditions, and it was therefore unable to adapt itself to its new environment. Never having penetrated into fresh or other non-marine waters, or into the deep sea, those havens of refuge where the relics of many ancient types may still be found, the trilobite, unable to cope with the new world in which it found itself, was consumed as food by its new enemies, both internal and external, and at the same time subjected to overwhelming competition, so that the individuals died off more rapidly than they could reproduce, and the race disappeared with the close of Paleozoic time. It persisted for many million years and left its remains more or less abundantly through about 75,000 feet of stratified rocks.

DESCRIPTION OF PLATE 14

PAGE

Neolenus serratus (Rominger) 126

Fig. 1. (× 1.5.) A nearly perfect dorsal shield flattened in the shale. It has one antennule, two caudal rami and a few legs (endopodites) extending out from beneath it. The glabella of the cephalon is crushed in as it is in all but one specimen of the species I have seen. The median spine on each segment of the thorax and pygidium is broken off close to its base, and usually the base and a piece of the test are broken off with it. U. S. National Museum, Catalogue No. 65510.

The specimens illustrating *Neolenus serratus* (pls. 14-23) are from locality **35k**, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia, Canada.

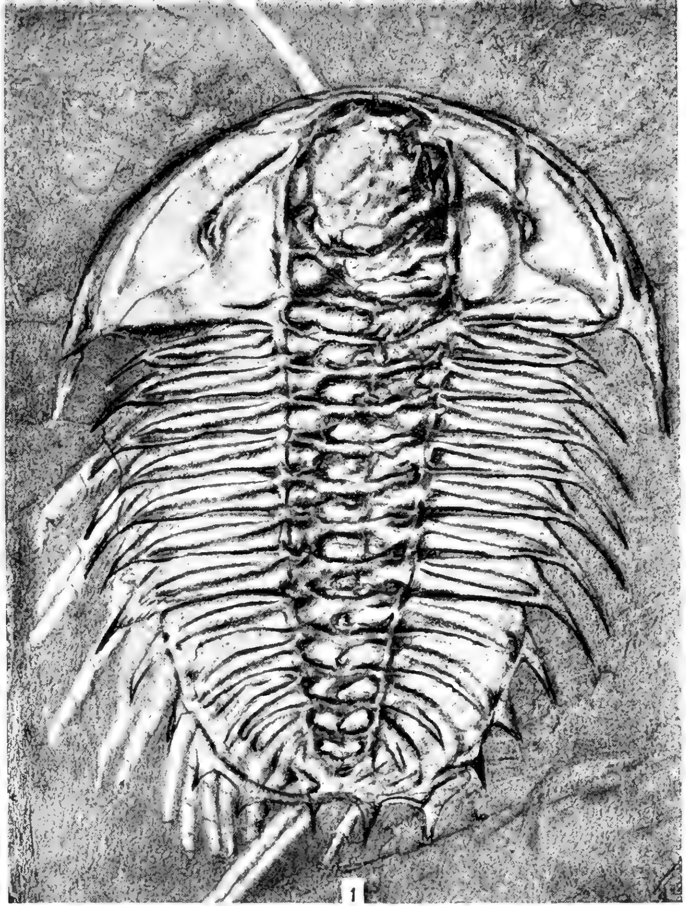
Kootenia dawsoni Walcott 131

Fig. 2. (× 2.) A somewhat broken and crushed dorsal shield that illustrates the general character of the species. U. S. National Museum, Catalogue No. 65511.

3. (× 2.) Right side of a crushed and exfoliated dorsal shield with portions of the thoracic legs (endopodites) and exopodites fringed with long setæ. U. S. National Museum, Catalogue No. 65512.

This is the only specimen known to me of this species that shows remains of the ventral appendages.

The specimens represented by figs. 2 and 3 are from locality **35k**, as given above.



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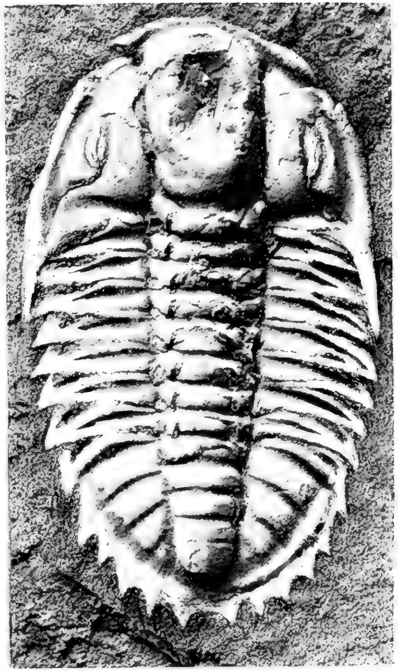

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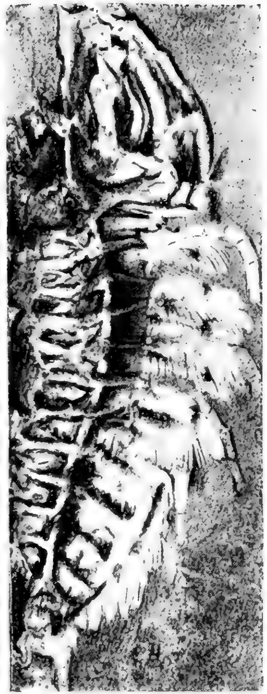

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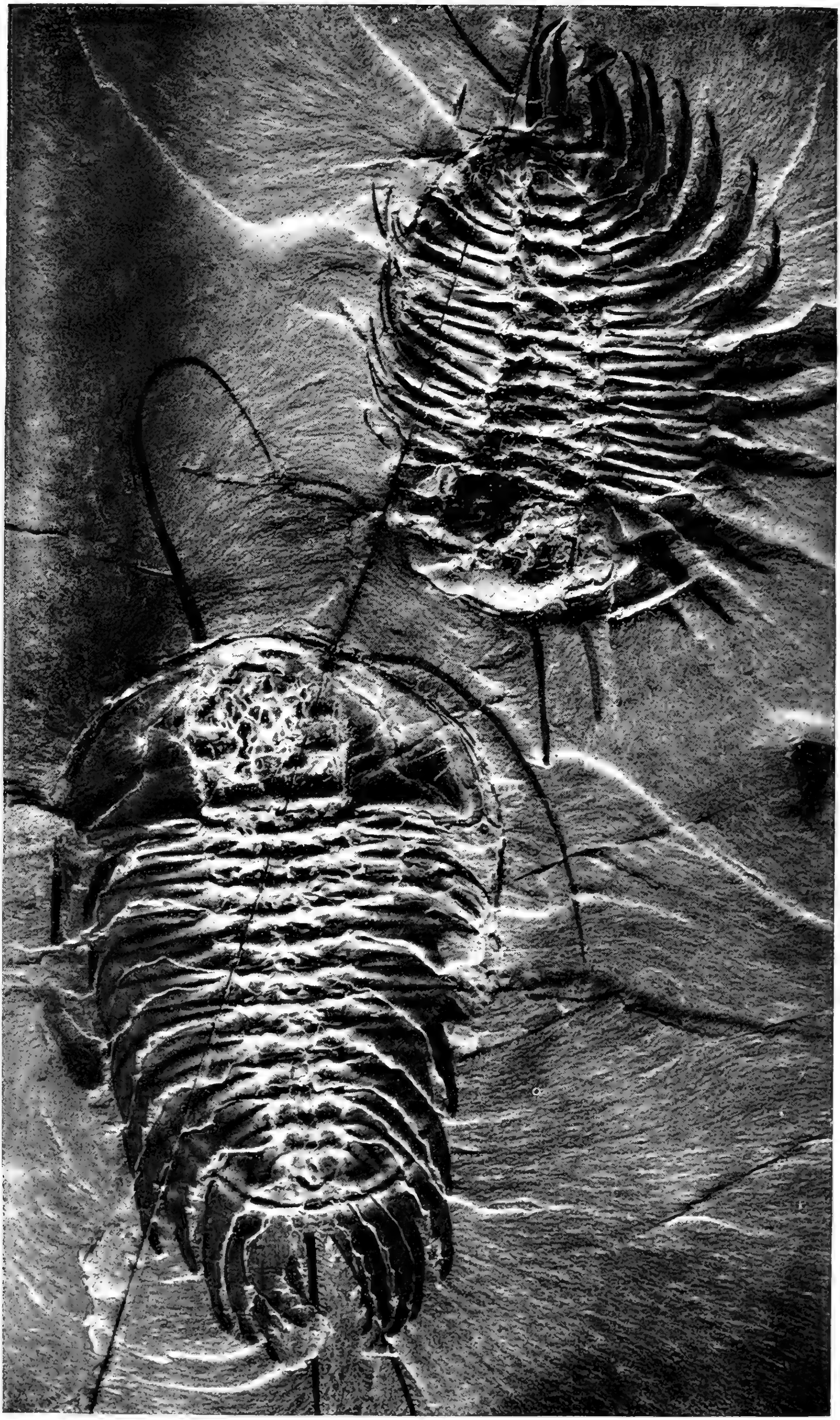
NEOLENUS AND KOOTENIA



NEOLENUS SERRATUS (Rominger)

DESCRIPTION OF PLATE 15

PAGE

Neolenus serratus (Rominger) 126

FIG. 1. (Natural size.) Photograph of a large, partially exfoliated dorsal shield with the antennules projecting from beneath the cephalon, the caudal rami slightly pushed backward from their normal position, and a fine series of the thoracic and abdominal legs (endopodites). Some of the legs preserve the large proximal joint (protopodite). The posterior portion of this specimen is illustrated by an enlarged figure on pl. 17, fig. 3.

The matrix at the top of the plate preserves the impression of 15 endopodites of the same character as those with the dorsal shield. The photograph of this was reproduced by me in 1912 (Smithsonian Misc. Coll., Vol. 57, pl. 45, fig. 1).

U. S. National Museum, Catalogue No. 58588.

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

DESCRIPTION OF PLATE 16

PAGE

Neolenus serratus (Rominger) 126

FIG. 1. (× 2.) Cephalic legs (endopodites) with one plate-like exopodite that probably was attached to the protopodite of the fourth cephalic leg. The protopodite of the third leg has numerous short spines on its inner margin that indicate that it served as a gnathobase. U. S. National Museum, Catalogue No. 65513.

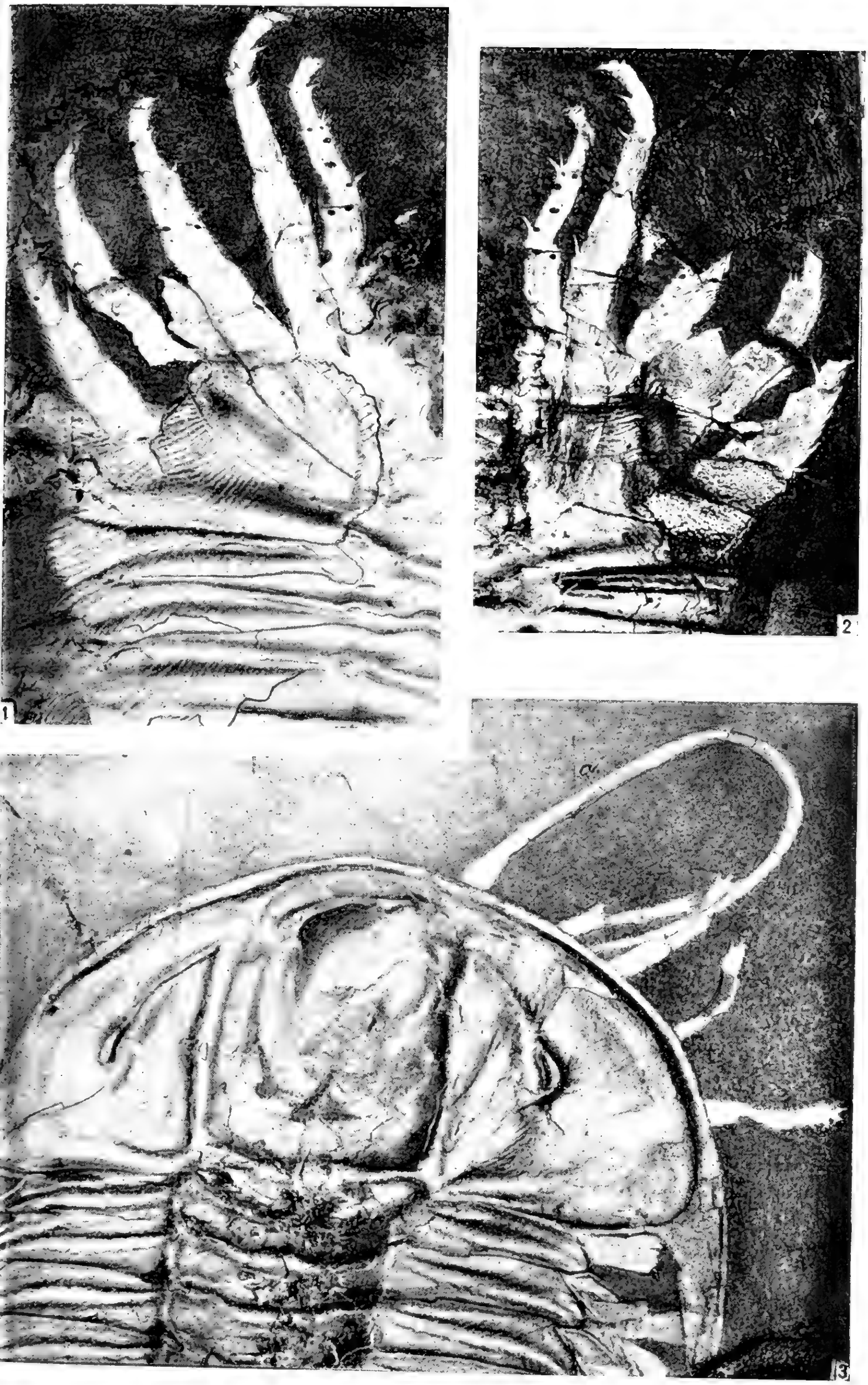
2. (× 2.) The matrix of the specimen represented by fig. 1. Fragments of the legs, etc., have exfoliated, so that the details of the specimen and the matrix differ, and a portion of the test of the dorsal shield is also shown on the right, lower side. The exopodite of fig. 2 is not shown at all on fig. 1, as its impression was removed in clearing the film of shale over the protopodite of the third cephalic leg. U. S. National Museum, Catalogue No. 58590.

This specimen was illustrated in 1912 (Smithsonian Misc. Coll., Vol. 57, pl. 45, fig. 3).

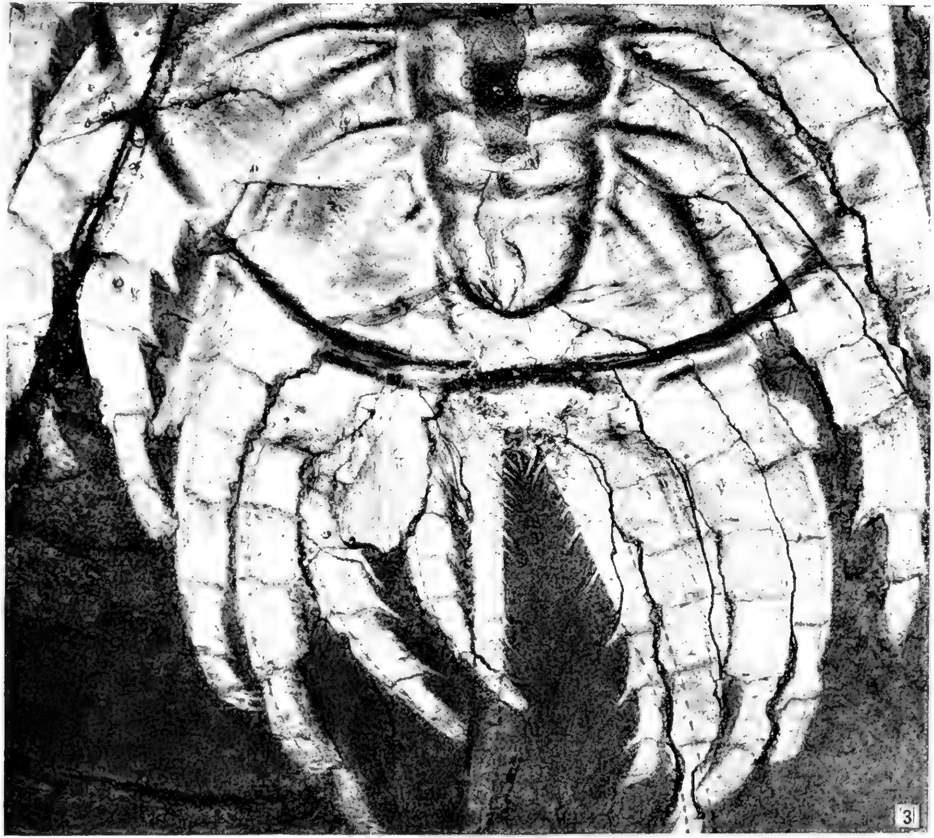
3. (× 2.) Anterior portion of a dorsal shield with an antennule and cephalic legs (endopodites). The distal joints of the legs show the terminal claw and two strong, short spines. Faint traces of the long setæ attached to an exopodite are shown near the right eye and also beside the right pleuræ of the thorax. U. S. National Museum, Catalogue No. 58591.

The right side of this figure was published in 1912 (Smithsonian Misc. Coll., Vol. 57, pl. 45, fig. 4).

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



Cephalic appendages of
NEOLENUS SERRATUS (Rominger)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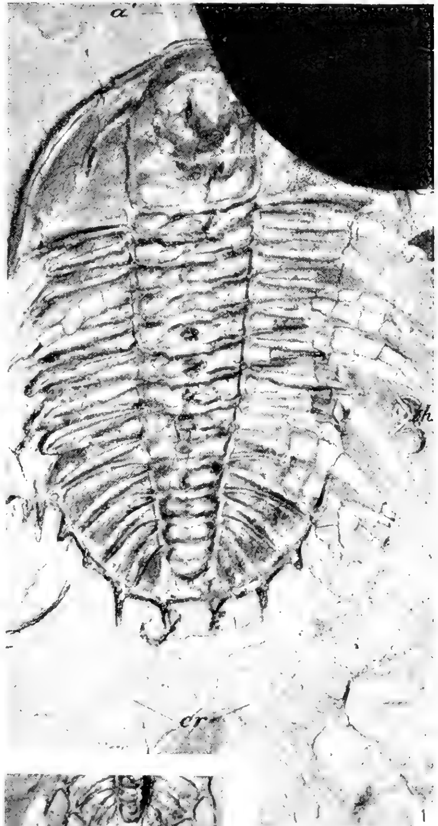
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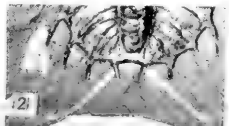
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DESCRIPTION OF PLATE 17

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Neolenus serratus (Rominger) 126

FIG. 1. (Natural size.) A partly exfoliated specimen, showing (*a*) an antennule, numerous thoracic legs (*thl*), and jointed caudal rami (*cr*). The caudal rami have been dragged backward, pulling with them a portion of the under edge of the ventral lining of the body cavity. U. S. National Museum, Catalogue No. 57656.

2. (Natural size.) Pygidium with the caudal rami extending out from beneath it in their probable natural position. U. S. National Museum, Catalogue No. 57657.

The above described figures were published in 1912 (Smithsonian Misc. Coll., Vol. 57, pl. 24, figs. 1, 1*a*).

3. (× 3.) Enlargement of the posterior portion of the dorsal shield and appendages illustrated by fig. 1, pl. 15. U. S. National Museum, Catalogue No. 58588.

The basal joints (protopodites) of the limbs are not well defined as they have been so flattened and crushed against the inside of the dorsal shield that they have the relief of the fused segments of the pygidium. Between the caudal rami there are two elongate oval spots that probably represent the anal opening which was forced out of shape and divided by pressure when the animal was buried in the fine sediment. It looks as though the limbs and caudal rami had been forced out from beneath the pygidium.

This figure was first published in 1913 (Text-book of Pal., Eastman ed. of Zittel, Vol. I, fig. 1376, p. 716).

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

DESCRIPTION OF PLATE 18

PAGE

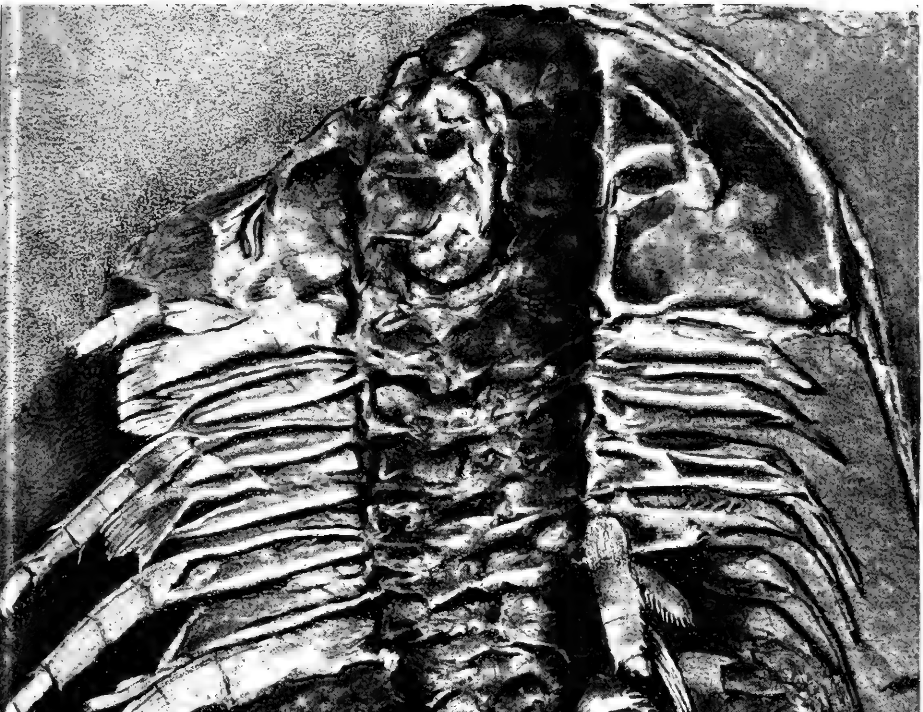
Neolenus serratus (Rominger) (See pl. 20, fig. 1) 126

FIG. 1. (×2.) Enlargement of the specimen illustrated by fig. 1, pl. 20. The two anterior legs on the left side and details of the legs showing the protopodite were worked out of the shale after the photograph reproduced on plate 20 was taken. On the right side back of the fourth thoracic segment, a small lobe (epipodite) is seen with its proximal portion resting against the protopodite of a thoracic leg. On the left side long setæ of the exopodites appear from beneath the lateral margin of the thoracic pleura. A portion of the caudal rami projects from beneath the pygidium. The joint lines of the legs have been darkened and the spines on the protopodites lightened so as to bring them out in stronger relief. See description of this specimen on pl. 20, fig. 1, for catalogue number.

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

2. Diagrammatic transverse section at about the fourth thoracic segment. This is based on the restoration illustrated on plate 31. The lettering is as follows:

d. s. = dorsal shield.	exi. = exite.
en. = endopodite.	int. = intestinal canal.
ep. = epipodite.	pr. = protopodite.
ex. = exopodite.	v. i. = ventral integument.



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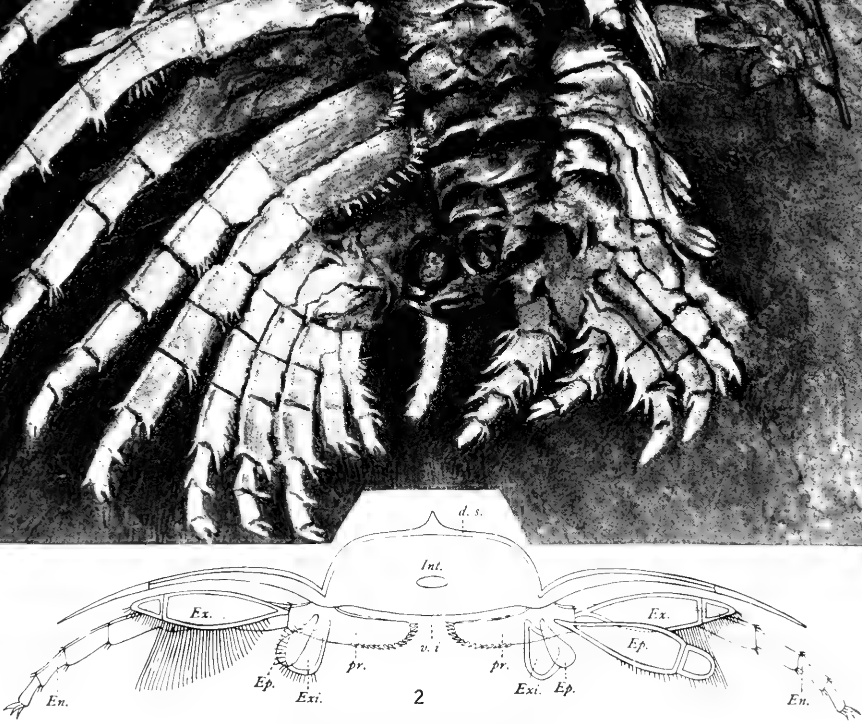

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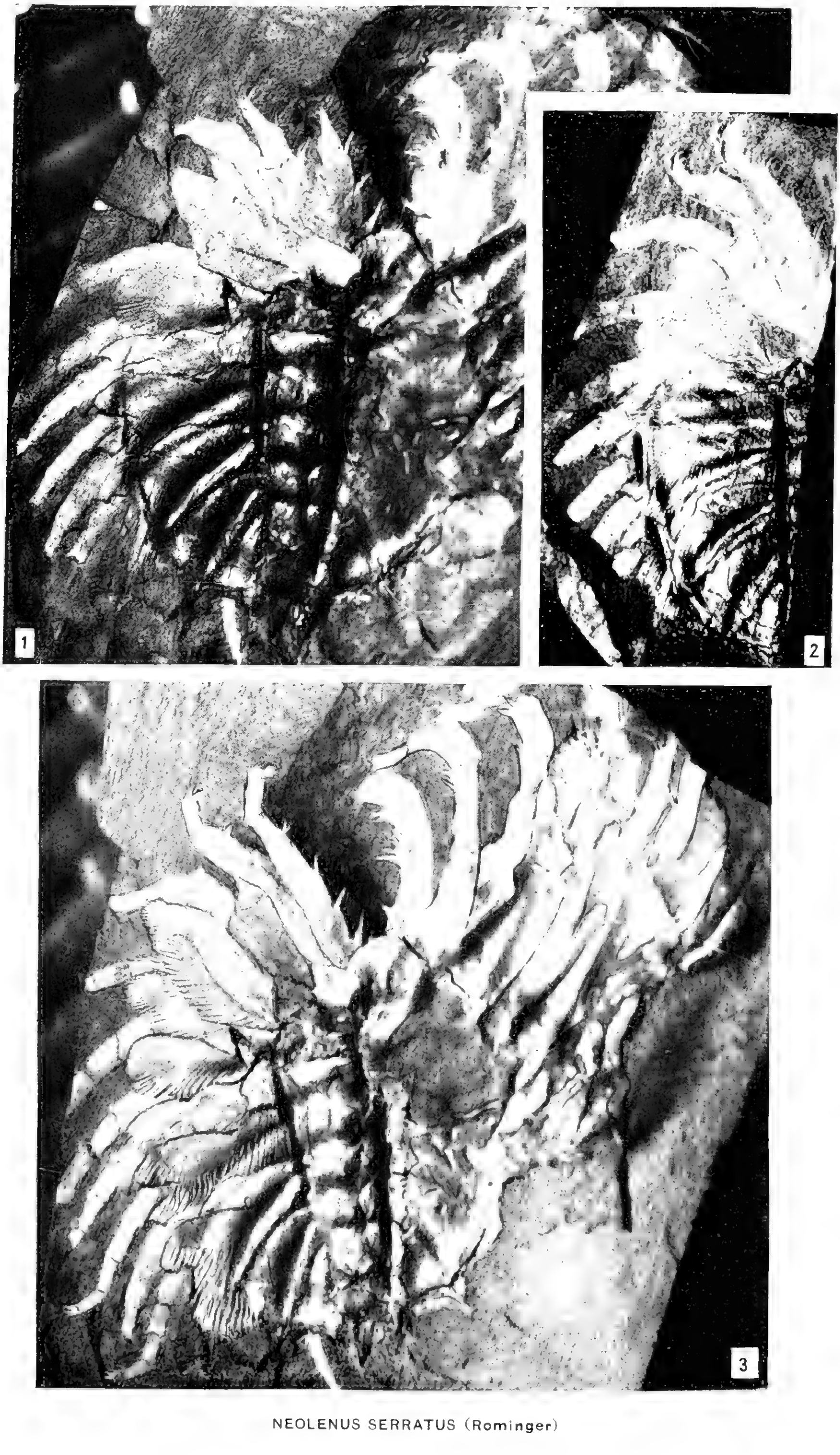
NEOLENUS SERRATUS (Rominger)



NEOLENUS SERRATUS (Rominger)

DESCRIPTION OF PLATE 19

PAGE

Neolenus serratus (Rominger) 126

FIG. 1. (× 2.) The specimen illustrated by this reproduction of an untouched photograph shows a pygidium to which the ventral surface and appendages adhered when the thorax and cephalon were broken up and pushed to the right side, dragging the legs out in a fan-shaped manner. A further description is given under fig. 3. U. S. National Museum, Catalogue No. 65514.

2. (× 2.) Photograph of the matrix of the left side of figs. 1 and 3, reversed so as to show the appendages adhering to it in a natural position. These have been drawn in on fig. 3 in order to restore some of the finer parts that were lost by exfoliation when the shale was split open at the quarry.

3. (× 2.) This distorted and crushed specimen has 17 legs (endopodites), several exopodites, and the ends of two of the large epipodites projecting from beneath the exopodites. The most important evidence given by it is that the exopodite and large epipodite are the same for the abdominal limbs as for those of the thorax. The epipodites occur between the leg (endopodite) and the exopodite. The characters seen on the specimen illustrated by fig. 1 and by the matrix, fig. 2, are combined in fig. 3.

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

DESCRIPTION OF PLATE 20

PAGE

Neolenus serratus (Rominger) (See pl. 18) 126

FIG. 1. (Natural size.) A partially exfoliated dorsal shield with finely preserved thoracic and abdominal legs (endopodites); three of these have the proximal joint (protopodite) one of which has spines on its proximal end, and another has fine spines along its posterior margin as well as on its proximal end. U. S. National Museum, Catalogue No. 58589.

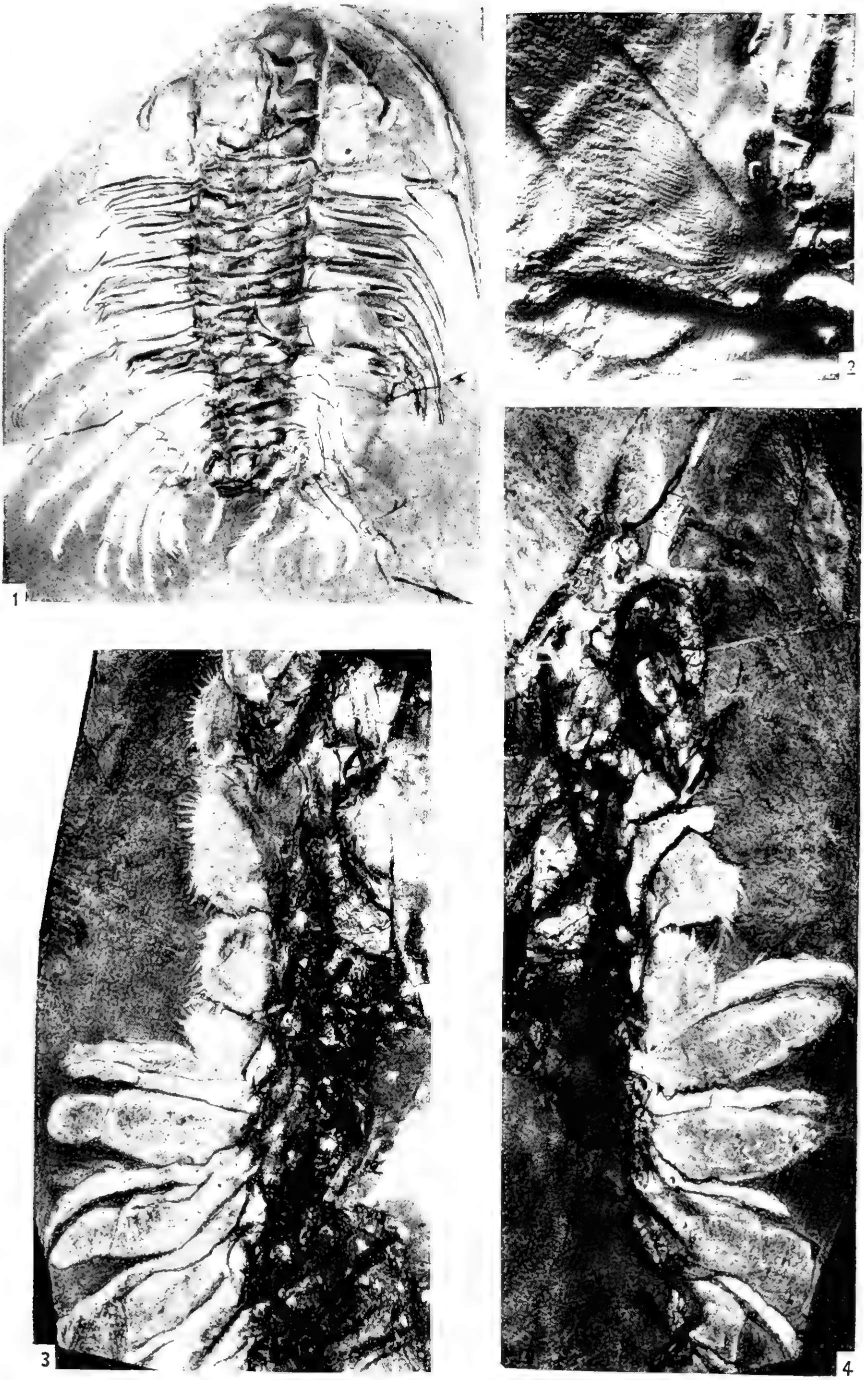
This figure has been published but at the time the proximal joints of the endopodites had not been uncovered. (See Smithsonian Misc. Coll., Vol. 57, 1912, pl. 45, fig. 2.) It was used again in 1913 (Text-book Pal., Eastman ed. of Zittel, Vol. 1, fig. 1377, p. 716).

2. (× 2.) An exopodite of one of the cephalic appendages with its long slender setæ. The thin, plate-like lobe was pushed up into the eye and molded by it. U. S. National Museum, Catalogue No. 65520.

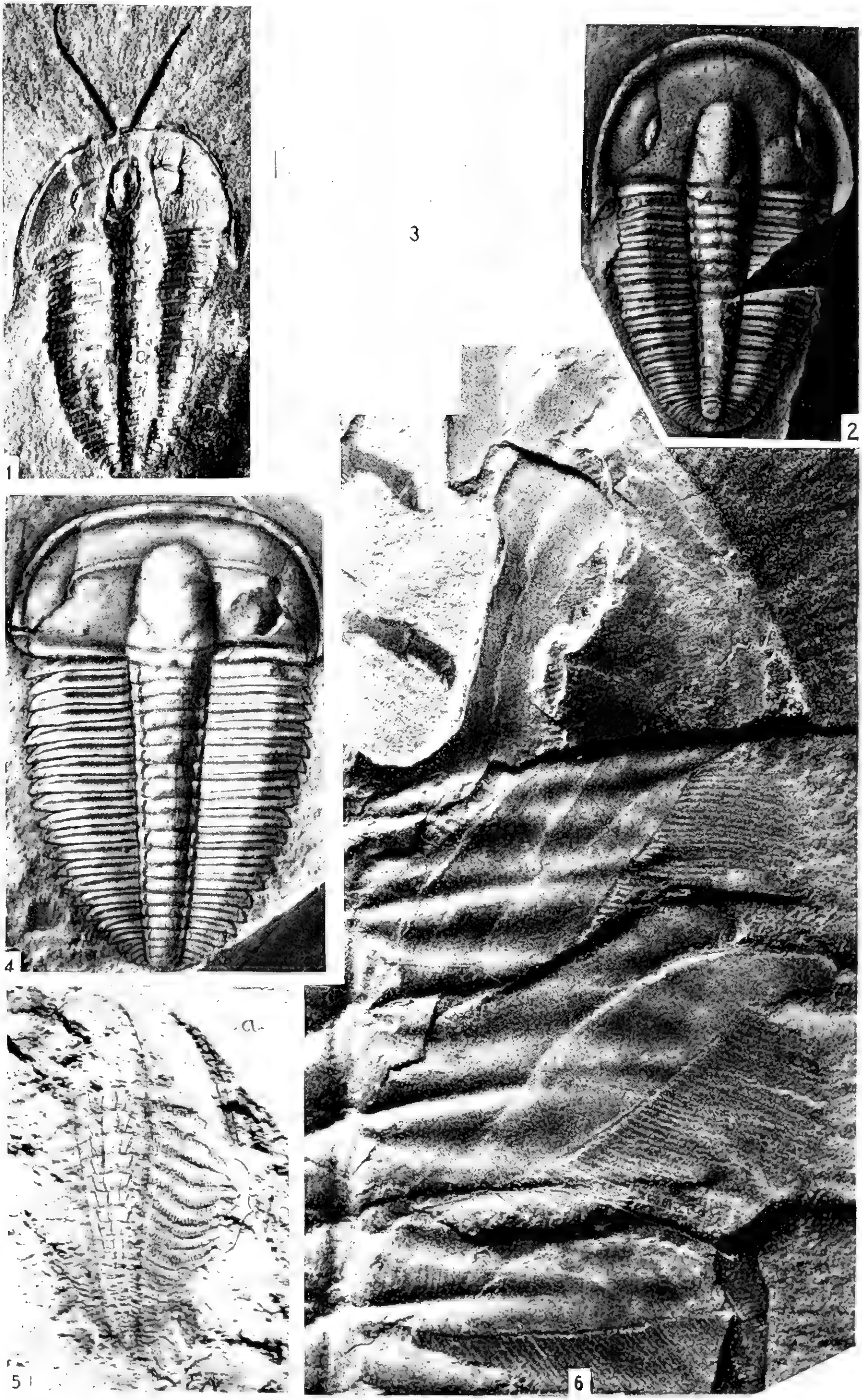
3. (× 2.) Jointed epipodites flattened on the surface of the shale. The legs (endopodites) are beneath the epipodites. Thin, flat lobes occur beside the axial lobe toward the upper end of the figure, that were probably attached to the inner side of the protopodite of the cephalic legs as an endite or epipodite. They have fine, short spines along the outer margin that are somewhat stronger than those of the epipodites of the thoracic appendages. It is barely possible that these plates were attached to the ventral integument just under the protopodite joint of the leg. U. S. National Museum, Catalogue No. 65515.

4. (× 2.) Matrix of the specimen represented by fig. 3.

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



Branchiæ—NEOLENUS SERRATUS (Rominger)



PTYCHOPARIA AND NEOLENUS

DESCRIPTION OF PLATE 21

PAGE

Ptychoparia permulta Walcott 145

FIG. 1. (× 2.) A laterally compressed and partially exfoliated dorsal shield with two flattened antennules projecting from beneath the cephalon in front of the glabella. U. S. National Museum Catalogue No. 65516.

2. (× 2.) A broken dorsal shield preserving surface granulation and form except as changed by flattening in the shale. This is the type specimen of the species. U. S. National Museum, Catalogue No. 65517.

Ptychoparia cordilleræ (Rominger) 144

FIG. 3. Outline of one of the exopodites shown on the right side of fig. 5. The broad proximal end and crenulate margins are two prominent features. The general outline suggests the exopodite of *Neolenus*, fig. 6.

4. (× 3.) A nearly entire dorsal shield with 18 thoracic segments. U. S. National Museum, Catalogue No. 65518. The specimen represented by fig. 4 is from locality **14s**, Middle Cambrian: Stephen formation; *Ogygopsis* shale on Mount Stephen, British Columbia, Canada.

5. (× 6.) A small specimen with the dorsal shield exfoliated so as to expose the ventral integument of the axial lobe with the thickened ridges crossing the mesosternites; also obscure endopodites of the thoracic limbs and clearly defined crenulated exopodites. U. S. National Museum, Catalogue No. 57658. This specimen was poorly illustrated by Walcott, 1912, Smithsonian Misc. Coll., Vol. 57, pl. 24, fig. 2.

Neolenus serratus (Rominger) 126

FIG. 6. (× 3.) Exopodites fringed with flattened setæ, exposed by the removal of the dorsal test. The position of the endopodite or leg beneath the exopodite is shown on the right lower part of the figure. U. S. National Museum, Catalogue No. 65519.

A drawing of a portion of this specimen was published in 1913 (Text-book Pal., Eastman ed. of Zittel, Vol. 1, fig. 1343, p. 701).

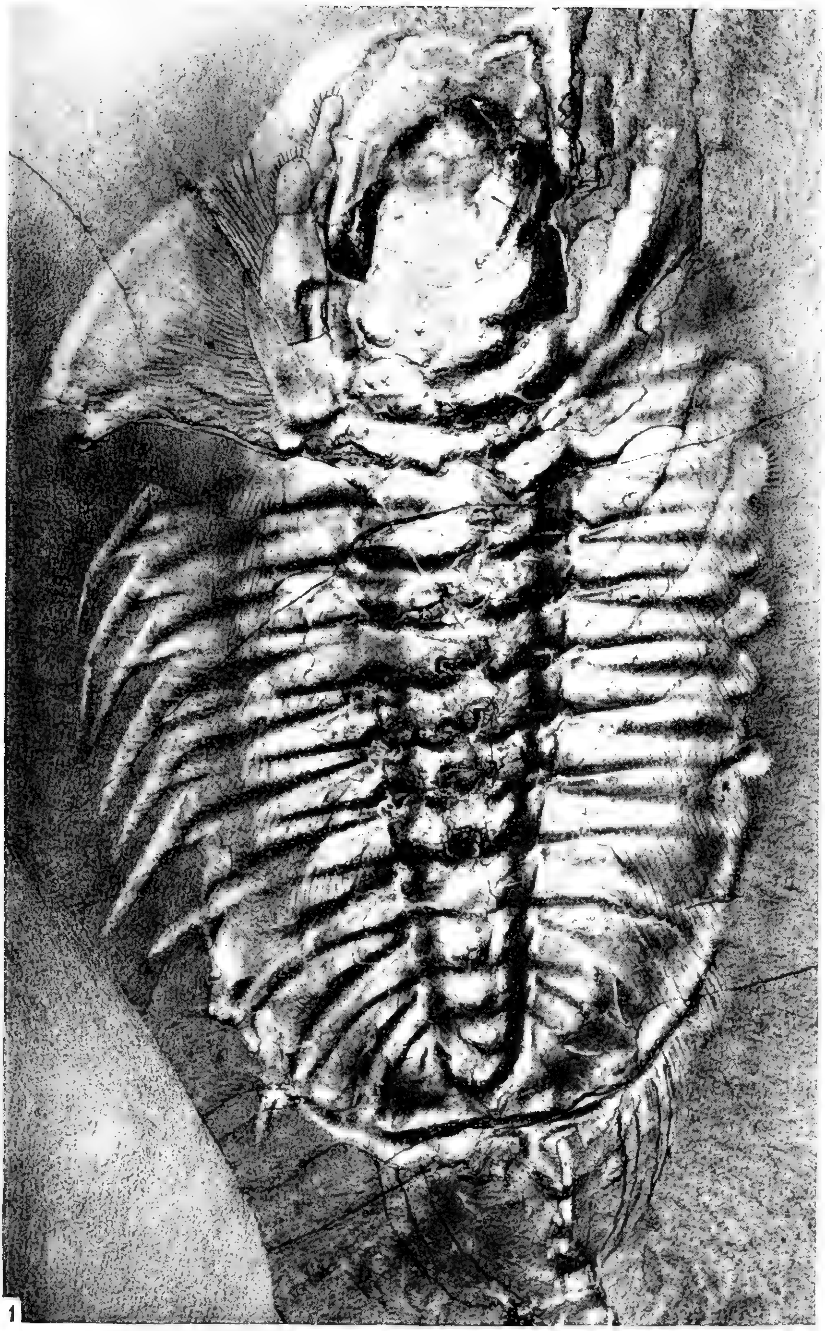
The specimens illustrated by figs. 1, 2, 5, and 6 are from locality **35k**, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia, Canada.

DESCRIPTION OF PLATE 22

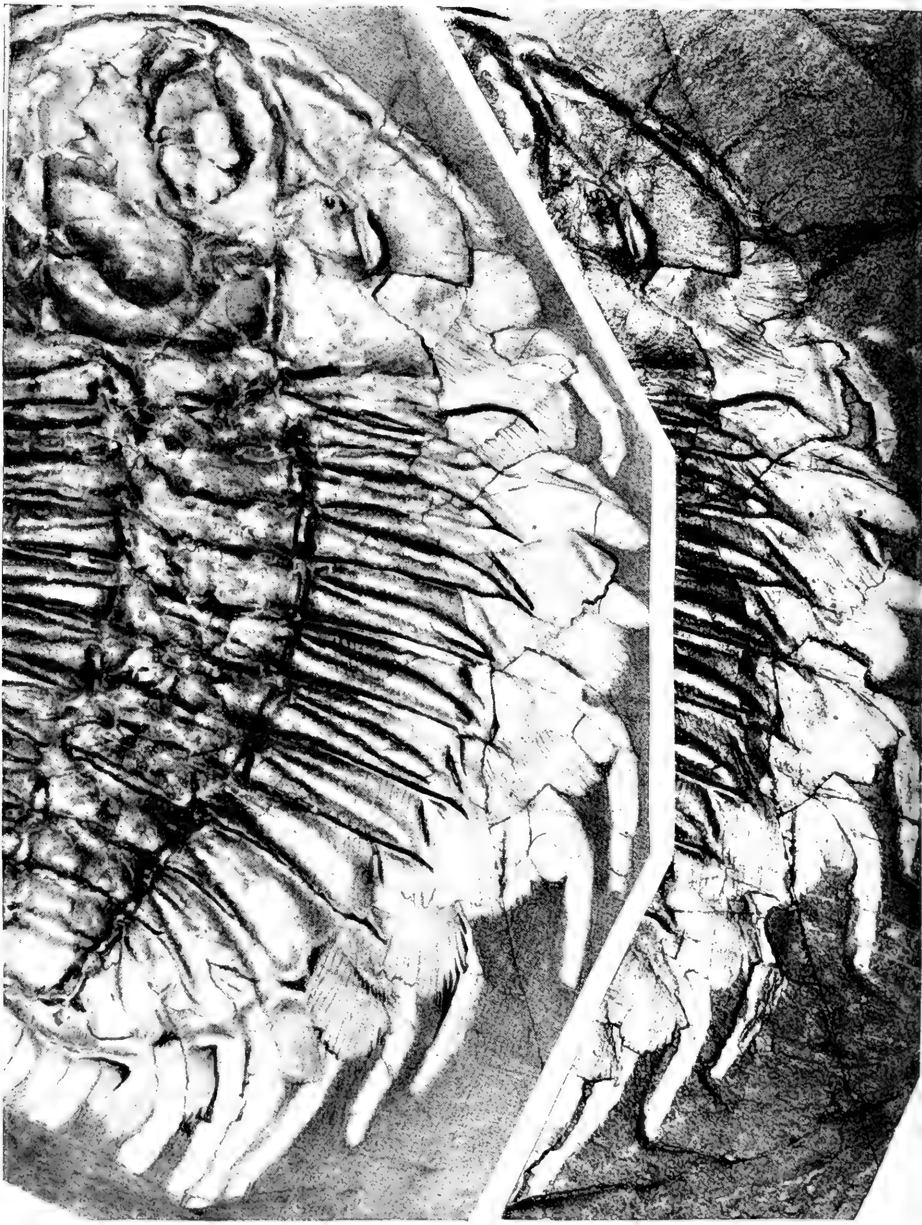
FIG. 1. (× 2.) In the specimen represented by this figure the large, flattened exopodites (*ex*) have been bent forward and also pushed more or less to the right of their original position. The distal end of three of the epipodites (*ep*) projects slightly from beneath the thin fringed exopodites on the right side. The caudal rami and some of the posterior legs (endopodites) project backward from beneath the pygidium. Fig. 3, pl. 20, shows the epipodites more distinctly, also that their position is above that of the endopodite. U. S. National Museum, Catalogue No. 65520.

The exopodites of *Ptychoparia* (pl. 21, fig. 5) are similar in general form to those of *Neolenus*, and the same is true of the exopodites of *Kootenia dawsoni* (pl. 14, fig. 3).

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



NEOLENUS SERRATUS (Rominger)
Illustrating exopodites



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NEOLENUS SERRATUS (Rominger)

DESCRIPTION OF PLATE 23

PAGE

Neolenus serratus (Rominger) 126

FIG. 1. (× 2.) Partially exfoliated interior of a specimen where the appendages on the right side have to a considerable extent clung to the specimen. These show the leg (endopodite), the end of the larger epipodite, also the outer portions of the large setiferous exopodite. U. S. National Museum, Catalogue No. 65521.

2. (× 2.) Untouched photograph of the right side of the specimen represented by fig. 1. Inserted here in order to show to what extent fig. 1 has been retouched. It is impossible in photographing specimens of this character to so reflect the light that it records all the details.

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

DESCRIPTION OF PLATE 24

PAGE

Isotelus walcotti Ulrich.. 134

FIG. 1. (× 3.5.) A very perfect dorsal shield retaining traces of the fused segments of the cephalon and pygidium and the points of attachment of the muscles of the median lobe of the cephalon and thorax. This illustration should be carefully studied in connection with pl. 25. U. S. National Museum, Catalogue No. 61261.

The specimen illustrated is from the Ordovician: Trenton limestone; 1 mile (1.6 km.) east of the Trenton Falls, in town of Russia, Herkimer County, New York.

Isotelus gigas var. *insignis* Ulrich 134

FIG. 2. (Natural size.) Natural cast of the interior surface of the test of a pygidium on which 14 fused segments are clearly outlined. U. S. National Museum, Catalogue No. 61255.

The specimen illustrated is from the Ordovician: Trenton limestone; Covington, Kentucky.

Isotelus maximus Locke (See pl. 25, fig. 1)........................... 133

FIG. 3. (About one-half natural size.) Matrix of the specimen represented by fig. 3*a*, showing the impression made by the thoracic legs, and traces of the legs to the extremity of the pygidium. U. S. National Museum, Catalogue No. 33458.

3*a*. (About one-half natural size.) Ventral surface of a specimen preserving more or less of the thoracic legs. The matrix of this specimen is shown by fig. 3.

These two figures are from untouched photographs, and are inserted for the purpose of showing the data upon which the appendages shown by fig. 1, pl. 25, are based.

The specimen illustrated by figs. 3, 3*a*, is from the Ordovician: Cincinnatian (Richmond); Oxford, Ohio. U. S. National Museum, Catalogue No. 33458.

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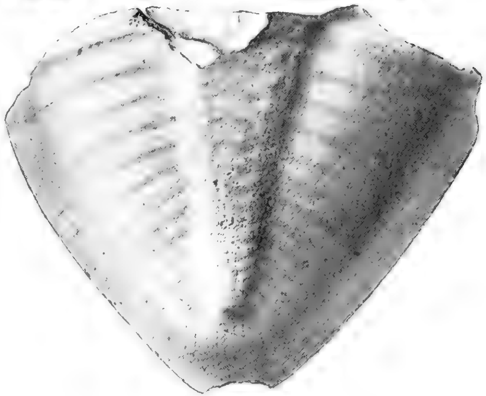

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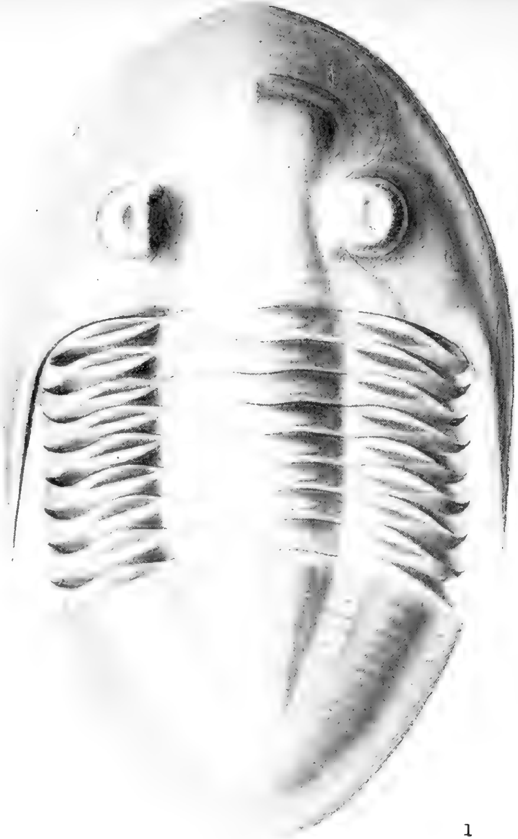

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ISOTELUS

ISOTELUS MAXIMUS Locke

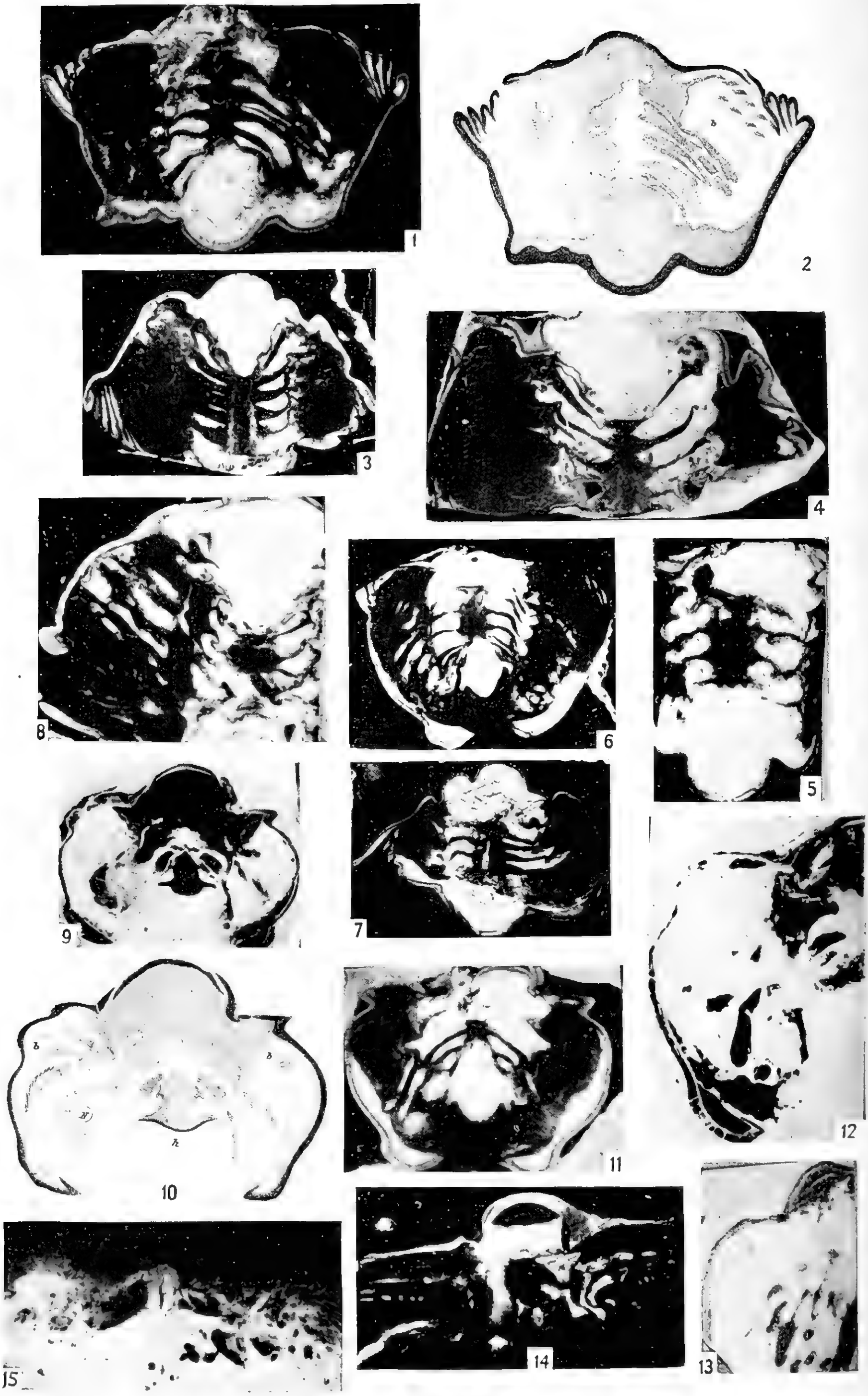
DESCRIPTION OF PLATE 25

PAGE

Isotelus maximus Locke (See pl. 24, figs. 3, 3*a*) 133

FIG. 1. (Natural size.) Illustration of the under side of the original specimen with the shaded outlines of an entire interior of a dorsal shield projecting beyond the broken specimen on all sides. The 26 pairs of appendages preserved include the legs (endopodites) and traces of the setæ of an exopodite on the right side. The joints of the legs represent all that is shown in the matrix and relief. The most prominent character is the very large proximal joints (protopodites) of the legs, which correspond to the large protopodites of *Neolenus* (pl. 18) and *Triarthrus* (pl. 32). U. S. National Museum, Catalogue No. 33458.

The specimen illustrated is from the Ordovician: Cincinnatian (Richmond); Oxford, Ohio.



SECTIONS OF TRILOBITES

CALYMENE AND CERAURUS

DETAILED DESCRIPTION OF PLATE 26

PAGE

Calymene senaria Conrad 147

FIG. 1. (× 3. Untouched photograph.) Transverse section through the head from the anterior side back to the lower posterior margins and thence across five segments of the thorax of an enrolled specimen. The large basal joints (protopodite) on five pairs of legs are shown. The four lower pairs on the right hand side of the figure are cut nearly on the longitudinal axis of the joint, while those on the left are cut across diagonally, which makes their sections much shorter. The two joints at the top which correspond to the fourth or fifth thoracic segment give the characteristic section where the joint is cut across obliquely (See also pl. 26, fig. 14; pl. 27, figs. 1, 2, 4).

Several joints of the leg are attached to the upper right hand basal joint, also a short section of the coiled portion of an exopodite. On the left side a section is shown of the epipodite with its attached setæ. Both the exopodite and epipodite are so delicate in the slide that the camera failed to reproduce them. They are restored in fig. 2.

The filling of the cephalic cavity is shown in the lower portion of the figure, also the outline of the eye on the left side, and the basal joint of one of the cephalic legs. The next pair of joints above presumably belonged to the cephalic region.

2. A drawing made from the section represented by fig. 1, and published by me in 1881 (Bull. Museum Comp. Zool., Harvard Coll., Vol. 8, pl. 3, fig. 3).

3. (× 3. Untouched photograph.) This section is essentially the same as that represented by fig. 1, but varies in details. It illustrates the tapering out of the proximal end of the basal joints (protopodites), a character that is also indicated in figs. 1 and 4.

4. (× 4. Untouched photograph.) Another section similar to that represented by figs. 1 and 3, in which the two pairs of large upper protopodites approach closely and they are also provided with minute spines on their proximal end.

Traces of the spiral portion of the exopodites are faintly shown on the left side. These are very clear in the section but do not photograph well. The same is true of the same appendage in the enclosed space on the left side of fig. 3.

5. (× 4. Untouched photograph.) Central portion of a section, showing the basal joints of the leg cut across obliquely, also the filling of the visceral cavity beneath the thorax.

6. (× 4. Untouched photograph.) Section cutting through the head in nearly the same direction as that represented by fig. 1. It shows, however, the hypostoma, the basal joints of the legs, and some of the following joints. One of the most interesting features is the presence of the basal joints of two of the anterior slender cephalic limbs that in the section are between the large joints and the hypostoma. This section also shows traces of the exopodites.

7. (× 3. Untouched photograph.) Section through the thoracic portion of an enrolled specimen, showing large protopodites.

PAGE

Ceraurus pleurexanthemus Green 148

FIG. 8. (× 4. Untouched photograph.) Section approximately the same as fig. 1, showing the proximal joints of the legs and some of the distal joints, also traces of the spiral portion of the exopodites.

The enlarged basal joint shown on the left side near the outer edge may have been one of the enlarged joints of the posterior cephalic leg.

Figs. 1 to 8 are given for the purpose of illustrating the large elongate proximal joints (protopodites) and to show that their inner ends are drawn in toward the median line of the longitudinal axis of the ventral surface and that from their form and position they undoubtedly were closely allied both in shape and function to the proximal joints of the limbs of *Neolenus* and *Triarthrus*.

Calymene senaria Conrad 147

FIG. 9. (× 3. Untouched photograph.) Transverse section through the head, which cuts across the proximal joints of some of the cephalic legs, the hypostoma, and the enlarged basal joints of the posterior pair of cephalic legs. Other portions of various legs are cut across, which are outlined in the drawing (fig. 10).

10. (× 4.) Drawing based on the section represented by fig. 9. This was published as fig. 1, pl. 6, in 1881 (Bull. Mus. Comp. Zool., Harvard College, Vol. 8).

11. (× 3. Untouched photograph.) One of the best sections illustrating the cephalic legs. This shows the large proximal joints of the posterior pair and the relatively small joints of the second and third pair of legs.

This section was used as the base for a drawing published in 1881 (Bull. Museum Comp. Zool., Harvard Coll., Vol. 8, pl. 1, fig. 6).

12. (× 5. Untouched photograph.) This section is nearly on the same line as that of fig. 11. It is given to show the supposedly enlarged distal joints of the posterior pair of the cephalic legs.

13. (× 3. Untouched photograph.) Another section showing the enlarged joint similar to that of figs. 9 and 12.

Ceraurus pleurexanthemus Green 148

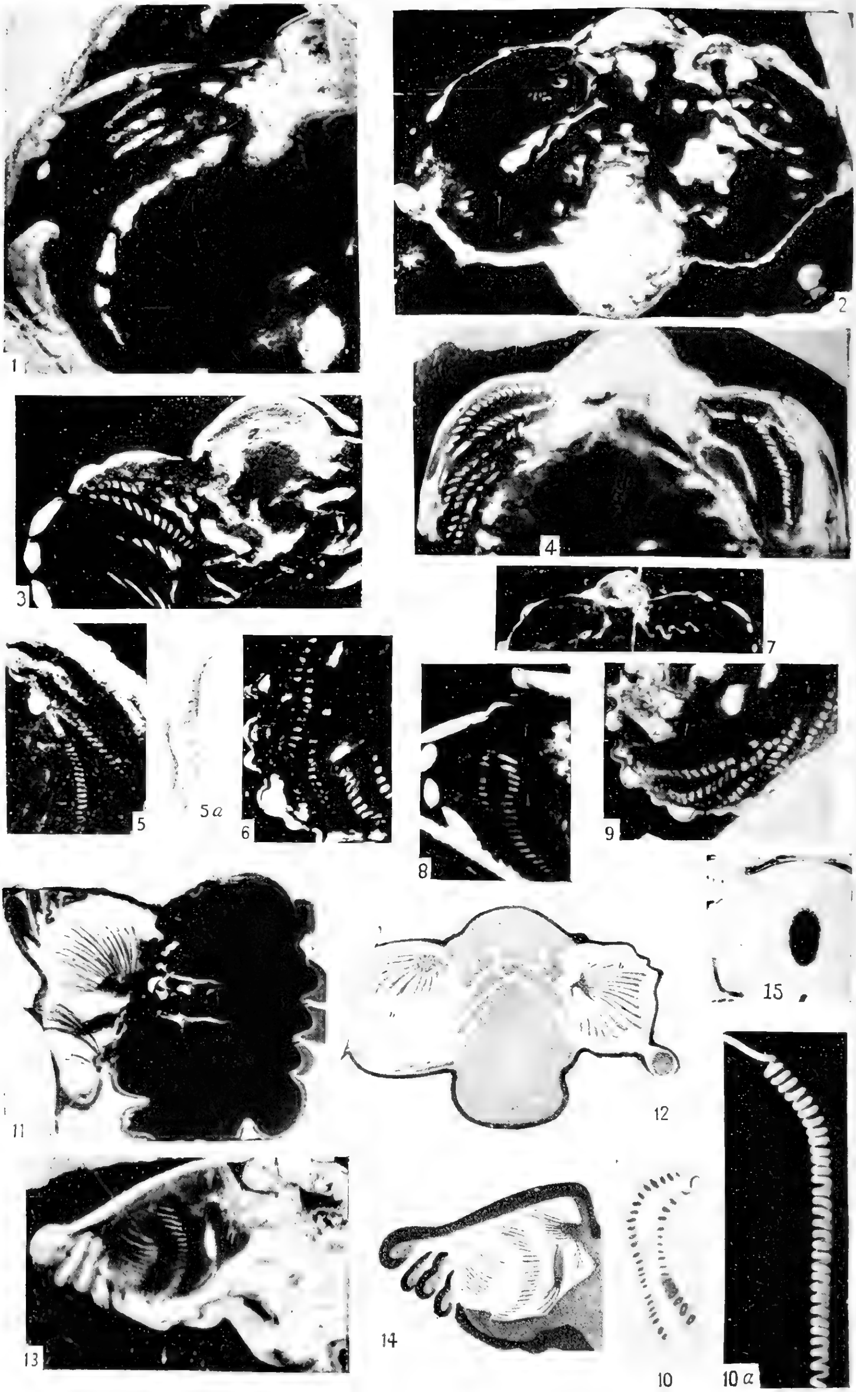
FIG. 14. (× 3. Untouched photograph.) Transverse section of the thorax of a specimen showing on the right side an oblique section of the proximal joint of the limb, sections of a crushed and broken leg on the left side, and sections of the support and the drawn-out, ribbon-like, more or less coiled exopodites.

This section was illustrated by a drawing in 1881 (pl. 2, fig. 3, Bull. Museum Comp. Zool., Harvard Coll., Vol. 8).

15. (× 3.) Photograph of a thin section cutting across on the left side a protopodite which has some of the fine spines attached to its ventral and inner margins.

All of the sections illustrated on this plate were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The specimens illustrated are from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES

CERAURUS, CALYMENE, WIRE SPIRALS

DETAILED DESCRIPTION OF PLATE 27

PAGE

Ceraurus pleurexanthemus Green.. 148

FIG. 1. (× 5. Untouched photograph.) Section of an enrolled specimen, showing one-half of a transverse section through the thorax. The jointed limb is broken across the proximal joint and slightly pulled to the left. It shows six joints in addition to the protopodite and above the latter traces of the exopodites. This is the best example of a leg obtained in sectioning several hundred trilobites. A drawing based on this section was illustrated by me in 1881 (pl. 2, fig. 2, Bull. Museum Comp. Zool., Harvard College, Vol. 8).

2. (× 3. Untouched photograph.) Transverse section of an enrolled specimen which cuts through several joints of a pair of thoracic limbs. These corroborate the form of the joints shown in fig. 1. A drawing based on this section was illustrated by me in 1881 (pl. 2, fig. 1, Bull. Museum Comp. Zool., Harvard College, Vol. 8).

3. (× 4. Untouched photograph.) Transverse section through the thoracic portion of an enrolled specimen, showing traces of the proximal joints, thoracic legs, and particularly the spiral structure of the exopodites.

6. (× 4. Untouched photograph.) Longitudinal section of the thorax, cutting across displaced branches of the exopodite. One of these shows the spiral character very clearly.

7. (× 3. Untouched photograph.) Transverse section of the thorax of a small specimen in which the section is cut across a pulled out spiral of the exopodite.

8. (× 5. Untouched photograph.) Portion of a section in which the section of an unusually long, curved, and somewhat distorted spiral is preserved.

9. (× 4. Untouched photograph.) A section somewhat similar to that represented by fig. 6 where the spiral exopodites were closely coiled to form a relatively stronger structure. In figs. 6, 8, and 9 it appears as though the ventral appendages had been displaced and pushed against the interior of the dorsal shield. These sections are instructive in showing the strength of the spirals and also of the vicissitude to which the appendages were subjected antecedent to their mineralization.

15. (× 4.) Portion of a section cutting through the head and showing five segments of a slender appendage that may have been an antennule.

Calymene senaria Conrad.. 147

FIG. 4. (× 4. Untouched photograph.) Transverse section of the thorax of an enrolled specimen, in which the proximal joints of the legs are preserved, also the bifurcating spiral exopodites. This section is one of the best illustrating the exopodites of this species. Another section cut through the same trilobite a short distance from this one shows the bifid exopodite more clearly. In a drawing made from this section and published by me in 1881 (pl. 3, fig. 9, Bull. Museum Comp. Zool., Harvard College, Vol. 8) the narrow arm extending down from the protopodite on the right hand side was considered to represent the epipodite as it was thought that there were traces of setæ on the lower portion. I now doubt the correctness of this interpretation, as it is more probably a cross-section of a flattened leg (endopodite). At the time of writing I do not have available for

Calymene senaria Conrad—Continued. PAGE

examination either of the sections cut through this trilobite, therefore cannot give as conclusive an interpretation of the section as otherwise would be possible.

A drawing based on this section was illustrated by me in 1881 (fig. 9, pl. 3, Bull. Museum Comp. Zool., Harvard College, Vol. 8).

FIG. 5. (× 4. Untouched photograph.) Section of an exopodite, showing its bifid character and the short, arm-like support. A drawing based on this section was illustrated by me in 1881 (pl. 4, fig. 3, Bull. Museum Comp. Zool., Harvard College, Vol. 8).

5*a*. (× 4.) Exopodites from *Ceraurus* showing the attachment of the spiral to the supporting basal joint or arm. The sections used in these drawings are in the Museum of Comparative Zoology, Harvard College. The drawings were first used in 1881, on pl. 4, fig. 4 (Bull. Museum Comp. Zool., Harvard College, Vol. 8).

11. (× 5. Untouched photograph.) Transverse section cutting across the upper posterior margin of the head and the anterior upper side of the thorax in such a manner as to show the filled-in visceral cavity and the basal portion of several setiferous, presumably thoracic appendages, which are interpreted as epipodites (See fig. 2, pl. 26; fig. 12, pl. 27).

A drawing based on this section was published by me in 1881 in which the right side was restored (fig. 1, pl. 3, Bull. Museum Comp. Zool., Harvard Coll., Vol. 8).

12. (× 4. Untouched photograph.) A drawing based upon a section which is now not available for making a photograph. This shows an epipodite on each side, also the proximal joint of some of the cephalic legs. The presence of a metastoma is suggested by the small triangular section which occurs between the proximal ends of the two large protopodites.

This figure was reproduced in 1881 (pl. 3, fig. 2, Bull. Museum Comp. Zool., Harvard Coll., Vol. 8).

13. (× 5. Untouched photograph.) Oblique transverse section of several epipodites, displaced and more or less crowded together. A drawing (fig. 14) based on this section was published in 1881 (fig. 8, pl. 3, Bull. Museum Comp. Zool., Harvard College, Vol. 8).

14. A drawing based on the section represented by fig. 13.

The specimens illustrated by figs. 1-14 are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

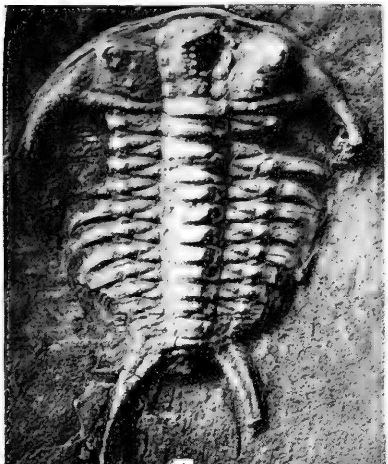
They are from the upper portion of the Trenton limestone, Ordovician; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

Wire spirals 152

FIG. 10. Untouched photograph of wire spirals which have been set in plaster and filed across so as to obtain sections corresponding to those found in enrolled specimens of *Calymene* and *Ceraurus*.

10*a*. Photograph of a white wire spiral against a dark background, illustrating a closely coiled spiral such as those cut across in the sections represented by figs. 3-6 and 9.

7



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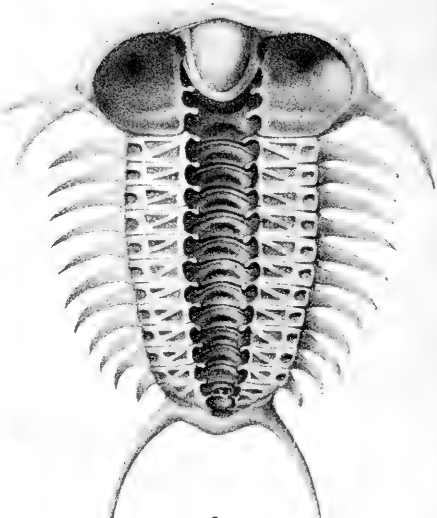

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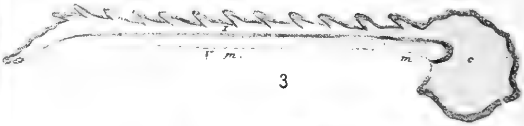

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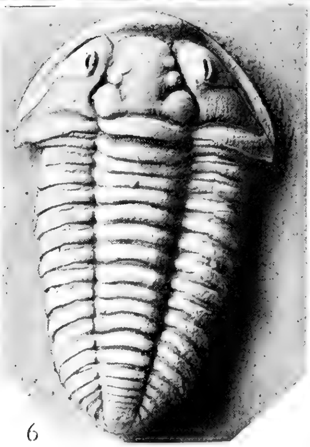

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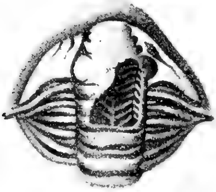

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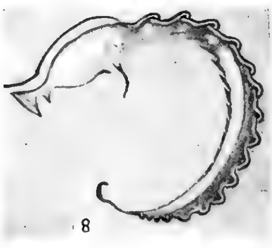

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ORDOVICIAN TRILOBITES

DESCRIPTION OF PLATE 28

PAGE

Ceraurus pleurexanthemus Green 148

FIG. 1. (× 2.) Untouched photograph of the dorsal shield of a specimen from the thin layer of limestone from which all of the specimens showing appendages of this species and *Ceraurus pleurexanthemus* were obtained. U. S. National Museum, Catalogue No. 18038.

2. Restoration of the interior of the dorsal shield drawn from specimens associated with that represented by fig. 1. (After Walcott, Ann. Lyceum Nat. Hist., Albany, N. Y., Vol. XI, 1875, pl. XI. Idem, Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII, 1881, pl. IV, fig. 5.)

3. Diagrammatic median longitudinal section showing dorsal shield, hypostoma, and outline of ventral membrane (*vm*), and position of intestinal canal, based on data obtained from thin sections and the specimen represented by fig. 4. (After Walcott, 1881, pl. IV, fig. 6, Bull. Museum Comp. Zool., Vol. VIII.)

4. (× 2.) Cephalon with the dorsal test broken away over the cephalic cavity so as to show the inner side of the hypostoma and the enlarged opening of the intestinal canal. Museum Comparative Zoology, Harvard College.

5. (× 2.) A transverse section of fig. 4 across the third thoracic segment. The section of visceral cavity and intestinal canal are the only traces of parts other than the dorsal shell. The light spot in the center of each dark spot represents the light shining through from the front. The division of the intestinal canal into two parts is undoubtedly of accidental occurrence.

(Figs. 4 and 5 are after Walcott, 1881, pl. IV, figs. 1 and 2, Bull. Museum Comp. Zool., Vol. VIII.)

Calymene meeki Foerste 197

FIG. 6. (× 1.5.) Exterior of dorsal shield of the Cincinnati variety of *Calymene senaria,* introduced to illustrate the dorsal shield of *Calymene.* U. S. National Museum, Catalogue No. 65522.

Locality: Ordovician: Maysville formation; Cincinnati, Ohio.

Calymene senaria Conrad 147

FIG. 7. (× 1.5.) Enrolled specimen showing the cast of a portion of the ventral integument. This appears to show the cast of the mesosternites, and the openings that led into the base of the limbs. A median ventral ridge is also indicated.

Calymene senaria Conrad—Continued. PAGE

FIG. 8. (× 3.) Section cutting longitudinally through the axial lobe of a partially enrolled specimen. This shows a section of the dorsal shield for its entire length, the hypostoma and filling of the cephalic cavity, portion of a distorted cephalic leg and the ventral integument with its thickened, transverse mesosternites—of the latter only seven of the twenty present are clearly shown in the figure. (After Walcott, fig. 2, pl. V, Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII, 1881.)

Cyamus scammoni Dall.. 173

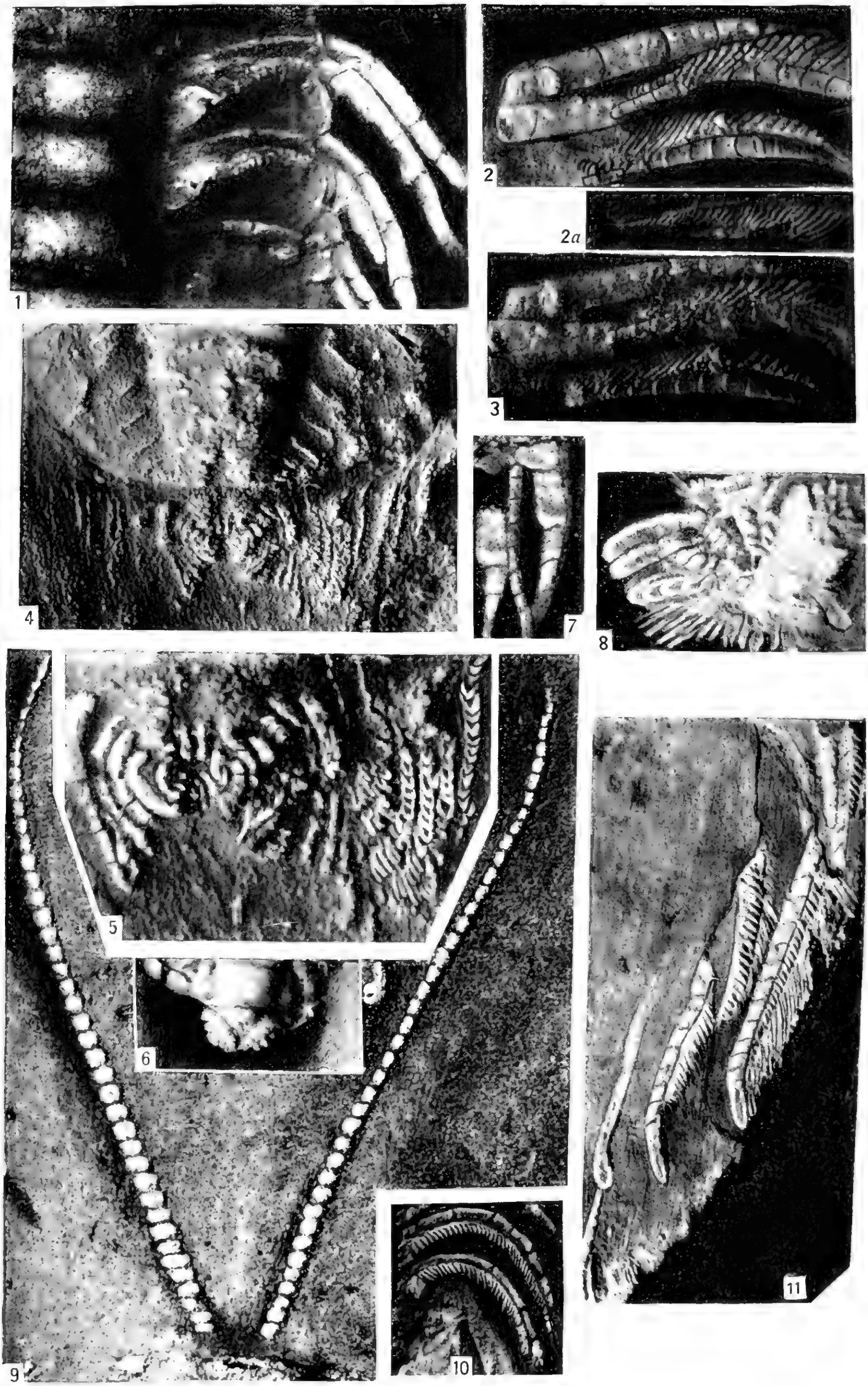
FIG. 9. (About × 8.) Spiral branchia attached to the third and fourth thoracic segments. (After Dall.)

Cyamus diffusus Dall.. 173

FIG. 10. (About × 8.) Ribbon-like branchiæ attached to thoracic segments. (After Dall.)

The two species of *Cyamus* are described by Dr. W. H. Dall (Proc. California Acad. Sci., Vol. IV, 1872, pp. 281-283) and illustrated (Marine Animals and the American Whale Fishing, Chas. C. Scammon, 1874). Of the branchiæ of *Cyamus scammoni* (fig. 9) Dr. Dall wrote, "The third and fourth segments each have a branchia attached on each side. This, near the base, divides into two cylindrical filaments spirally coiled from right to left." The branchiæ of *Cyamus diffusus* Dall, fig. 10, are described as "single, cylindrical, slender, with a very short papilliform appendage before and behind each branchia." They are attached to the segments as shown in fig. 10.

Figs. 9 and 10 are reproduced from Walcott, 1881, pl. IV, figs. 9, 10, Bull. Museum Comp. Zool., Harvard Coll., Vol. VIII. The specimens on which figs. 4 and 7 are based are in the Museum of Comparative Zoology, Cambridge, Massachusetts.



APPENDAGES OF TRIARTHRUS BECKI Green

DESCRIPTION OF PLATE 29

PAGE

Triarthrus becki Green.. 135

FIG. 1. (× 6. Untouched photograph.) Two thoracic limbs, showing the endopodite and the setiferous exopodite. (Collection, Peabody Museum, Yale University.)

2 and 3. (× 8. Fig. 3, untouched photograph. Fig. 2, endopodites and exopodites outlined.) The setæ of the upper exopodite are jointed as indicated in fig. 2. U. S. National Museum, Catalogue No. 65523.

2a. (× 6.) An exopodite illustrating the crowding of the setæ on the jointed arm. This occurs on the same specimen as the parts represented by fig. 8.

4. (× 12.) Untouched photograph of endopodites and exopodites that were forced from beneath the pygidium. The endopodites are attached to the protopodites and appear to have the same structure as those beneath the thorax. The exopodites, however, show the joints of the supporting arm as overlapping lobes (See fig. 8). A further enlargement is made in fig. 5 (× 20).

5. (× 20.) Enlargement of the posterior portion of fig. 4 to bring out the minute, overlapping, lobe-like joints of the arm of the exopodite.

These photographs illustrate the appendages that have been crowded out posteriorly from beneath the pygidium, and show the strong proximal joints of the legs and the setiferous exopodites. U. S. National Museum, Catalogue No. 65524.

6. (× 8. Untouched photograph.) Another specimen showing the ventral membrane and the bases of the limbs that have been crowded out from beneath the pygidium. U. S. National Museum, Catalogue No. 65525.

7. (× 8.) Ends of legs (endopodites) from beneath a pygidium. U. S. National Museum, Catalogue No. 65526.

8. (× 18. Untouched photograph.) Minute exopodites crowded from beneath the pygidium. See text for discussion of these interesting appendages. U. S. National Museum, Catalogue No. 65527.

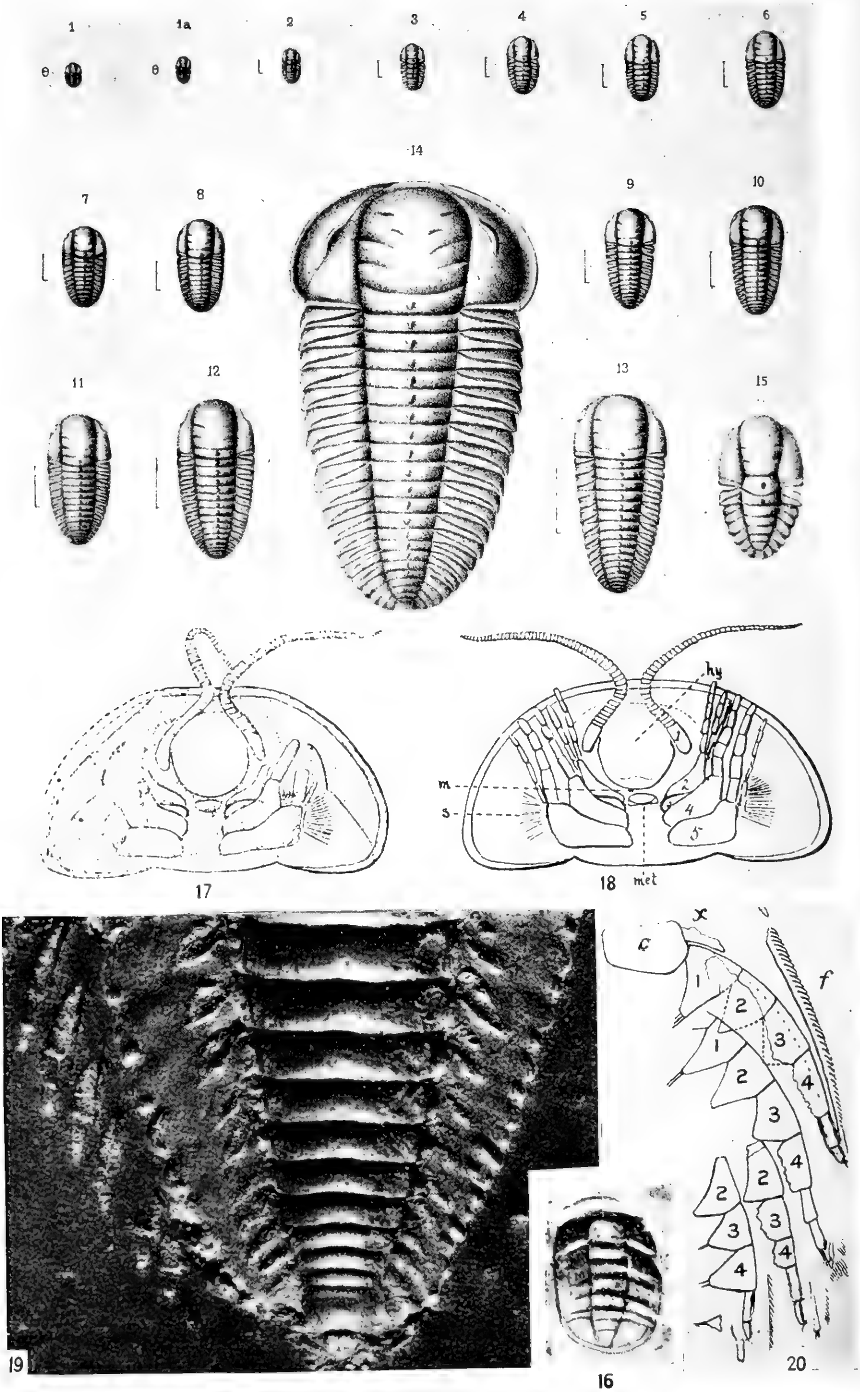
9. (× 6. Untouched photograph.) Illustration of a very fine pair of antennules, projecting from beneath the anterior margin of the head. (Specimen in the Collection of Peabody Museum, Yale University.)

10. (× 6.) Outer portion of thoracic limb of anterior portion of right side of thorax, showing the jointed endopodite and setiferous exopodite. The lower endopodite has a trifid spinous termination. The joints of the endopodite and the separation of the base of the setæ on the exopodite have been outlined on the photograph. U. S. National Museum, Catalogue No. 65528.

Triarthrus becki Green—Continued.

FIG. 11. (× 15.) This figure illustrates the structure of the exopodite of the thoracic limb more clearly than any other specimen I have seen. The supporting jointed portion terminates in a flattened elongate narrow lobe or section similar to that shown in fig. 8, where several of the terminal sections of exopodites projected from beneath the pygidium. U. S. National Museum, Catalogue No. 65529.

The specimens illustrated by figs. 1-11 are from locality **373**, Ordovician: Utica shale; 3 miles (4.8 km.) north of Rome, Oneida County, New York.



TRIARTHRUS BECKI Green

DESCRIPTION OF PLATE 30

PAGE

Triarthrus becki Green 135

FIG. 1. Natural size and enlargement of an individual having one thoracic segment.

1*a*. A narrow and more elongate individual having one segment in the thorax.

15. Natural size, and enlargement of 1*a*, to fifteen diameters to show the character of the head and pygidium and their relative proportions and size.

1-13. A series of individuals illustrating the gradual development of the head and thorax on the addition of each thoracic segment. The pygidium diminishing in size as compared with the other parts of the body. The numbers 1-13 also indicate the number of segments in the thorax of each individual to which they refer. All enlarged to three diameters.

13. Enlargement to three diameters of an individual having fourteen thoracic segments.

14. Fully developed individual of sixteen thoracic segments, natural size. All the larger specimens have been flattened by compression. The convexity in the figure is the same as in an individual of sixteen segments, 33 mm. in length.

The free cheeks are also pressed out so as to show their margins.

All of the specimens illustrated by figs. 1-14, 15, are from a locality northwest of Holland Patent, Oneida County, New York. They occur in the Utica shale of the Ordovician and are now in the collection of the Museum of Comparative Zoology, Harvard College.

Figs. 1-14, 15, are after Walcott, 1879, Trans. Albany Inst., Vol. X, pl. II, figs. 1-15.

16. (× 20.) Outline of an embryonic specimen that preceded fig. 1 in development. This shows the cephalon and pygidium well outlined, and the thorax undeveloped. U. S. National Museum, Catalogue No. 65530.

The two specimens that were used in sketching this figure are from locality **373**, Ordovician: Utica shale; 3 miles (4.8 km.) north of Rome, Oneida County, New York.

17. (× 4.) Diagrammatic sketch of a specimen preserving the hypostoma, epistoma, and cephalic appendages. After Beecher, American Geologist, Vol. XV, 1895, pl. 5, fig. 10.

The specimen is in the collection of the Peabody Museum, Yale University, from the same locality as that represented by fig. 16.

18. Diagrammatic restoration of the cephalic appendages: *hy* = hypostoma; *m* = metastoma; 1 = antennæ; 2 = first pair biramous appendages, or posterior antennæ; 3 = mandibles; 4, 5 = maxillæ. (After Beecher.)

Triarthrus becki Green—Continued.

FIG. 19. (× 15.) Photograph of a specimen that appears to indicate the presence of epipodites. The flat, rounded, diamond-shaped lobes originate along the line between the mesosternites and pleurosternites of the ventral integument, and extend obliquely backward in the direction in which the limbs are usually found. The dorsal shield was removed from over them, and in one example nearer the cephalon, the limb is clearly situated beneath the lobe. U. S. National Museum, Catalogue No. 65525.

The specimen is from the same locality as the specimen represented by fig. 16.

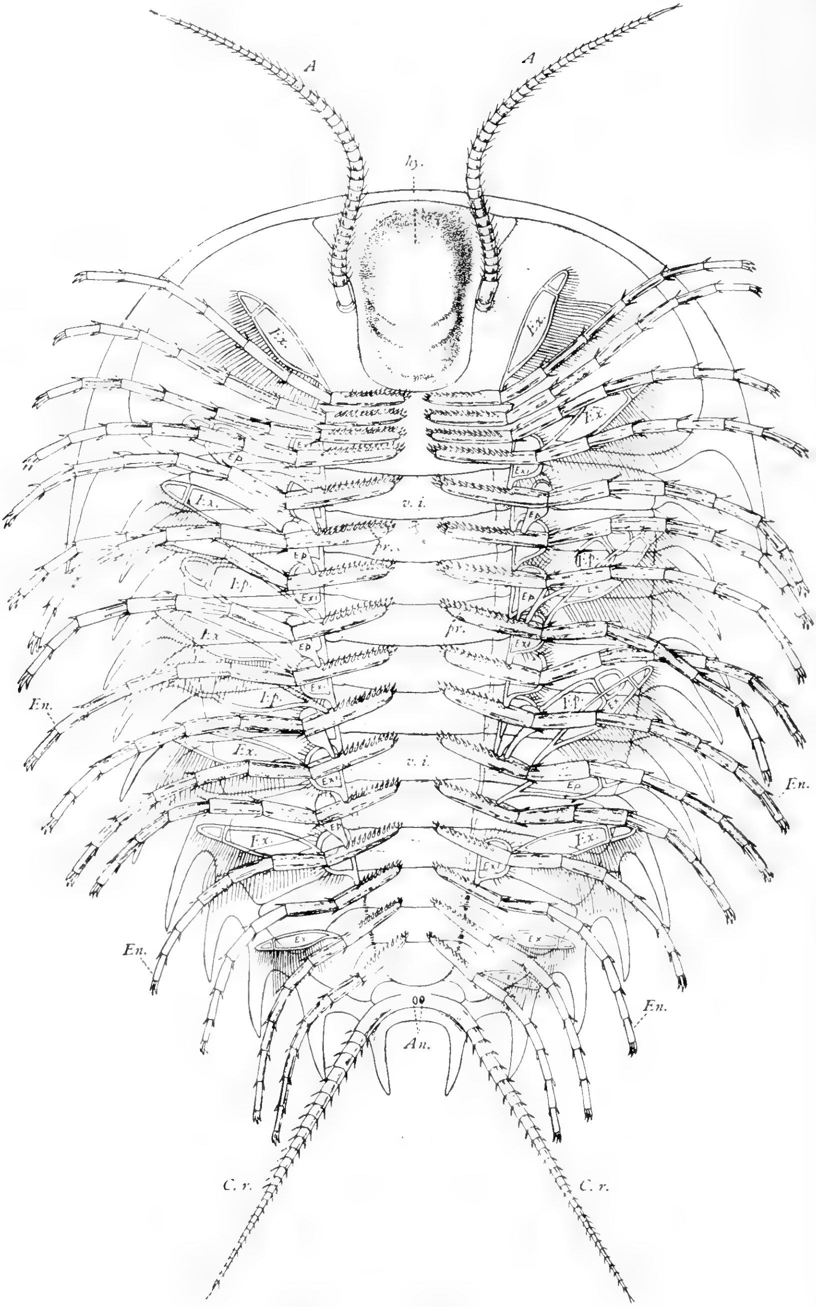
20. (× about 6.) Limbs occurring on the under side of an individual of 14 thoracic segments. Limbs with flattened, enlarged proximal joints and slender distal joints.

c. Limb preserving large joint of protopodite, four enlarged proximal joints and three slender distal joints. At *x* the point of attachment of an exopodite is shown, and in the specimen it looks as though *f* had been broken away from *x*.

The above appendages lie so irregularly on the inner side of the segments of the thorax and pygidium that it is not practicable to make a satisfactory photograph. U. S. National Museum, Catalogue No. 65531.

An outline drawing based on this specimen was published by me in 1894 (Proceed. Biol. Soc. Washington, Vol. IX, pl. 1, fig. 3).

The specimens illustrated by figs. 16-20 are from locality **373**, Ordovician: Utica shale; 3 miles (4.8 km.) north of Rome, Oneida County, New York.



Restoration of ventral surface of
NEOLENUS SERRATUS (Rominger)

DESCRIPTION OF PLATE 31

Legend

d. s. = dorsal shield.	ep. = epipodite.
hy. = hypostoma.	ex. = exopodite.
a. = antennules.	exi. = exite.
an. = anal aperture.	pr. = protopodite.
c. r. = caudal rami.	v. i. = ventral integument.
en. = endopodite.	

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Neolenus serratus (Rominger) 126

FIG. 1. (About two times the average size of the species.) This restoration is based on study of all available specimens of the species that show any of the ventral appendages. Reference will be made to the specimens illustrated on plates 14-23 in describing the restoration as they show more or less of every appendage represented.

(1) Antennules (a). Shown by figs. 1, pl. 14, 1, pl. 15, 3, pl. 16.

(2) Cephalic limbs: Figs. 1, 2, 3, pl. 16, 2, pl. 20, 6, pl. 21, 1, pl. 22. The endopodites are best shown by figs. 1, 2, pl. 16, and the exopodites by fig. 1, pl. 16, and fig. 1, pl. 22. Whether the exites, figs. 3 and 4, pl. 20, are present beneath the cephalon, is not determined. No traces of epipodites were observed.

(3) Thoracic limbs: Figs. 1, pl. 14, 1, pl. 15, 1 and 3, pl. 17, 1, pl. 18 (the best one), 1, 2, 3, pl. 19, 1, 2, 4, pl. 20, 6, pl. 21, 1, pl. 22, 1, pl. 23. The endopodite is best shown by fig. 3, pl. 17, and fig. 1, pl. 18. The exopodite by figs. 3, pl. 19, 6, pl. 21, 1, pl. 22, 1, pl. 23. The large epipodite by figs. 3 and 4, pl. 20, and the small epipodite by fig. 1, pl. 18.

(4) The abdominal limbs or those beneath the pygidium are not differentiated from those of the thoracic region. They are well shown by figs. 1, pl. 15, 3, pl. 17, 1, pl. 18, 1, pl. 20.

(5) Caudal rami (c. r.). These are best shown by figs. 1, pl. 15, 1, 2, 3, pl. 17.

(6) Anal aperture or genital openings (an.): indicated only on fig. 3, pl. 17.

Observations.—In the restoration all the endopodites are essentially the same, decreasing only in length and size from the cephalon to the end of the body. The exopodites, epipodites, and exites are represented on only a few of the limbs as otherwise they would be so crowded together that it would be difficult to distinguish the various members of the limbs.

In looking at the restoration the observer must recall that the limbs are seen from their narrow lower side and that they are quite deep in the vertical section as shown in the transverse view, fig. 2, pl. 18. The latter view also shows the protopodites, endopodites, exopodites, epipodites, and exites in position.

This restoration should be compared with the restoration of *Triarthrus* on pl. 32 and of *Calymene*, pl. 33.

DESCRIPTION OF PLATE 32

Legend

d. s. = dorsal shield.	ep. = epipodite.
hy. = hypostoma.	ex. = exopodite.
a. = antennules.	pr. = protopodite.
en. = endopodite.	v. i. = ventral integument.

PAGE

Triarthrus becki Green 135

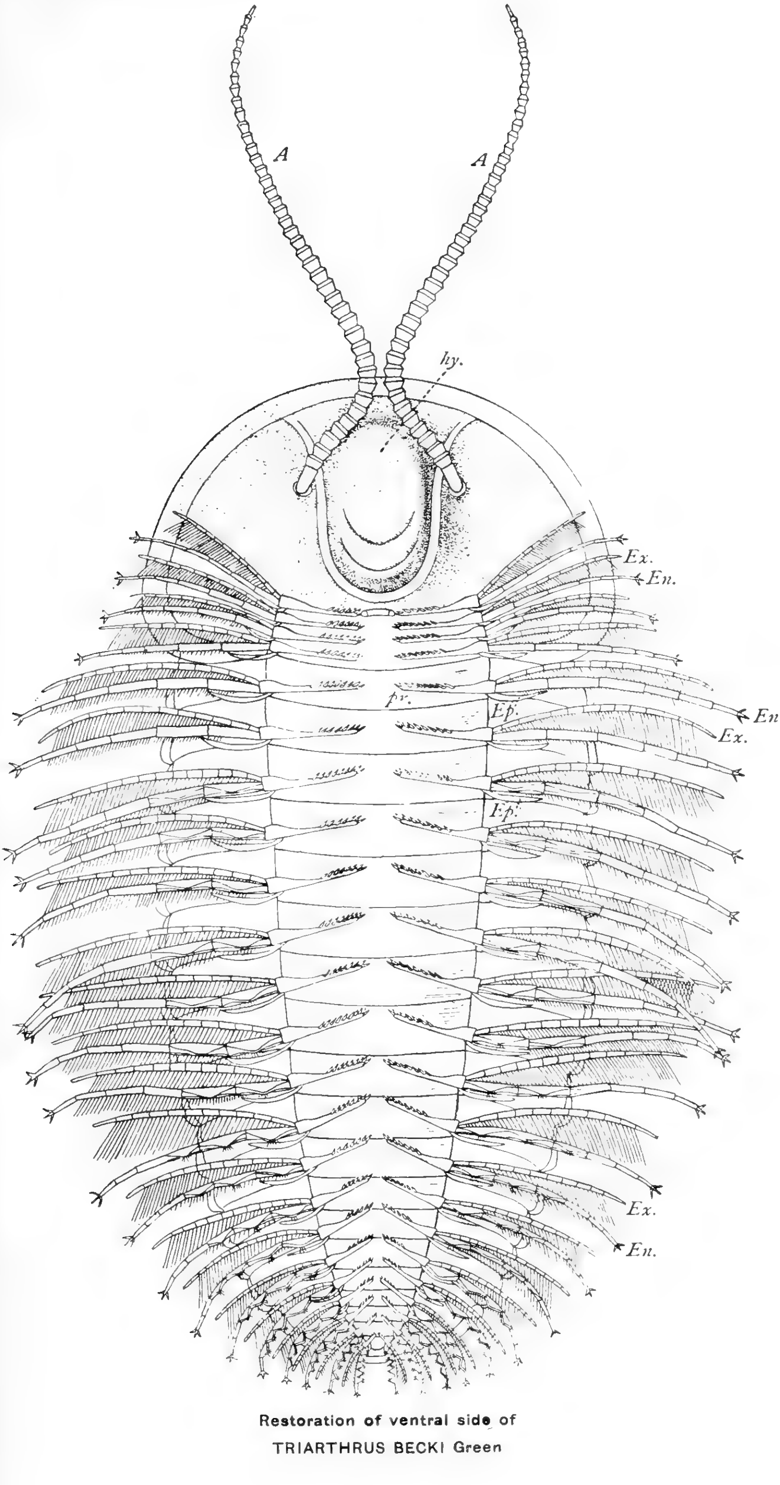
FIG. 1. (About 3 times the size of the average adult specimen of the species.) This restoration of the ventral surface and limbs is based on study of all specimens available at this time and old notes on some of those in the collection at Peabody Museum, Yale University, a few of which were illustrated by Beecher.

The specimens illustrated on plates 29 and 30 were studied with others when making the restorations of this species. From the one represented by fig. 19, pl. 30, I first gained the impression that there was a small epipodite attached to the proximal joint of the leg. From figs. 2-5, 8-11, pl. 29, the conception of the structure of the exopodite, especially the transverse, lamellated joints suggesting the endites of the limb of *Apus* was obtained. Fig. 4 led me to consider that the leg (endopodite) beneath the pygidium was similar to that of the thorax and that the phyllopod-like endites were part of the exopodite and not of the endopodite as tentatively interpreted by Beecher. Fig. 7, pl. 29, and fig. 20, pl. 30, illustrate the expanded joints of the endopodites.

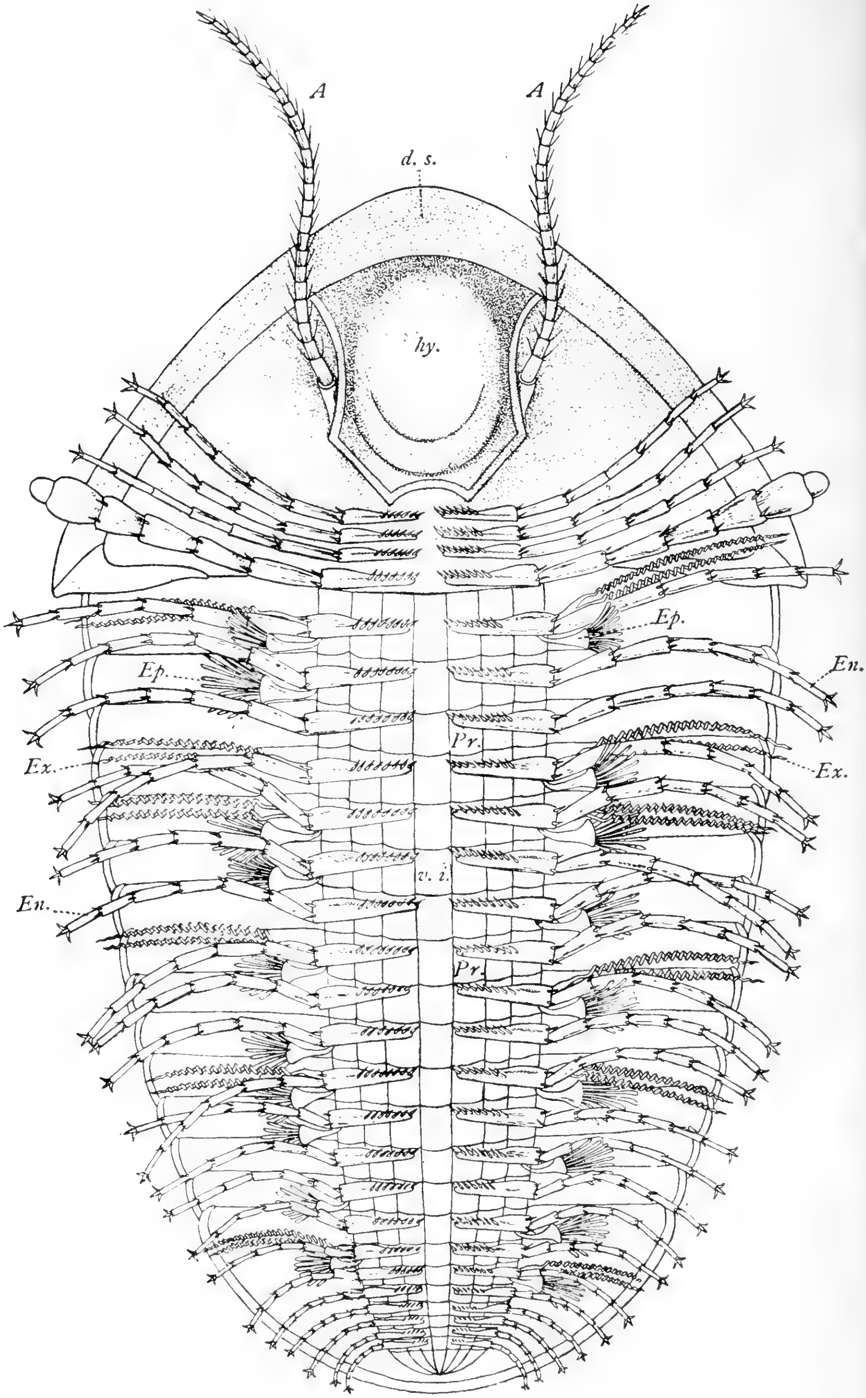
The restoration has quite a different aspect from that made by Beecher although the essential elements of structure are the same. The protopodites are placed in what is considered to be their normal position and the flattened joints of the endopodite are given as nearly vertical instead of being on the plane of the ventral surface of the body of the trilobite. Beecher shows the protopodite, endopodite, and exopodite in their approximately natural position in his restored transverse sections of the thorax and appendages.

Observation.—In looking at the restoration the observer must recall that the limbs are seen from their narrow lower (ventral) side and that they are quite deep in their vertical section as shown by the transverse views (pl. 34, figs. 4-6) of the thorax.

This restoration should be compared with the restoration of the ventral side of *Neolenus* (pl. 31) and *Calymene* (pl. 33).



Restoration of ventral side of
TRIARTHRUS BECKI Green



Restoration of ventral side of
CALYMENE SENARIA Conrad

DESCRIPTION OF PLATE 33

Legend

d. s. = dorsal shield.	ep. = epipodite.
hy. = hypostoma.	ex. = exopodite.
a. = antennule.	pr. = protopodite.
en. = endopodite.	v. i. = ventral integument.

PAGE

Calymene senaria Conrad 147

FIG. 1. (About two and a half times the average size of the species.) This restoration is based on my studies of the ventral appendages of *Calymene senaria* from 1875-1880, and published in 1881. The restoration of 1881 is taken as the base and such changes made in it as the discoveries of antennules and long protopodites necessitate. Only a fragment of an antennule has been seen, but with fine antennules of *Neolenus* and *Triarthrus* for study I do not hesitate to put them in the restoration of this species. Through the kindness of Dr. Alexander Agassiz I had the opportunity of making a photograph of the original thin sections which I made 1875-1880. Some of these are reproduced on plate 29.

Observations.—In looking at the restoration the observer must recall that the limbs are seen from their narrow lower (ventral) side and that they are quite deep in the vertical section as shown in the view of the transverse section of the thorax, fig. 2, pl. 34. The latter view gives a side view of the entire limb.

This restoration should be compared with the restoration of the ventral side of *Neolenus* (pl. 31) and *Triarthrus* (pl. 32).

DESCRIPTION OF PLATE 34

Legend

d. s. = dorsal shield.	exi. = exite.
en. = endopodite.	int. = intestinal canal.
ex. = exopodite.	pr. = protopodite.
ep. = epipodite.	v. i. = ventral integument.

PAGE

Ceraurus pleurexanthemus Green 148

FIG. 1. (× about 5.) Transverse diagrammatic sketch of one of the anterior thoracic segments presenting a side view of the ventral appendages as far as known. Some of the sections affording data on the limbs of *Ceraurus* are illustrated on pls. 26, 27.

Calymene senaria Conrad (See pl. 33) 147

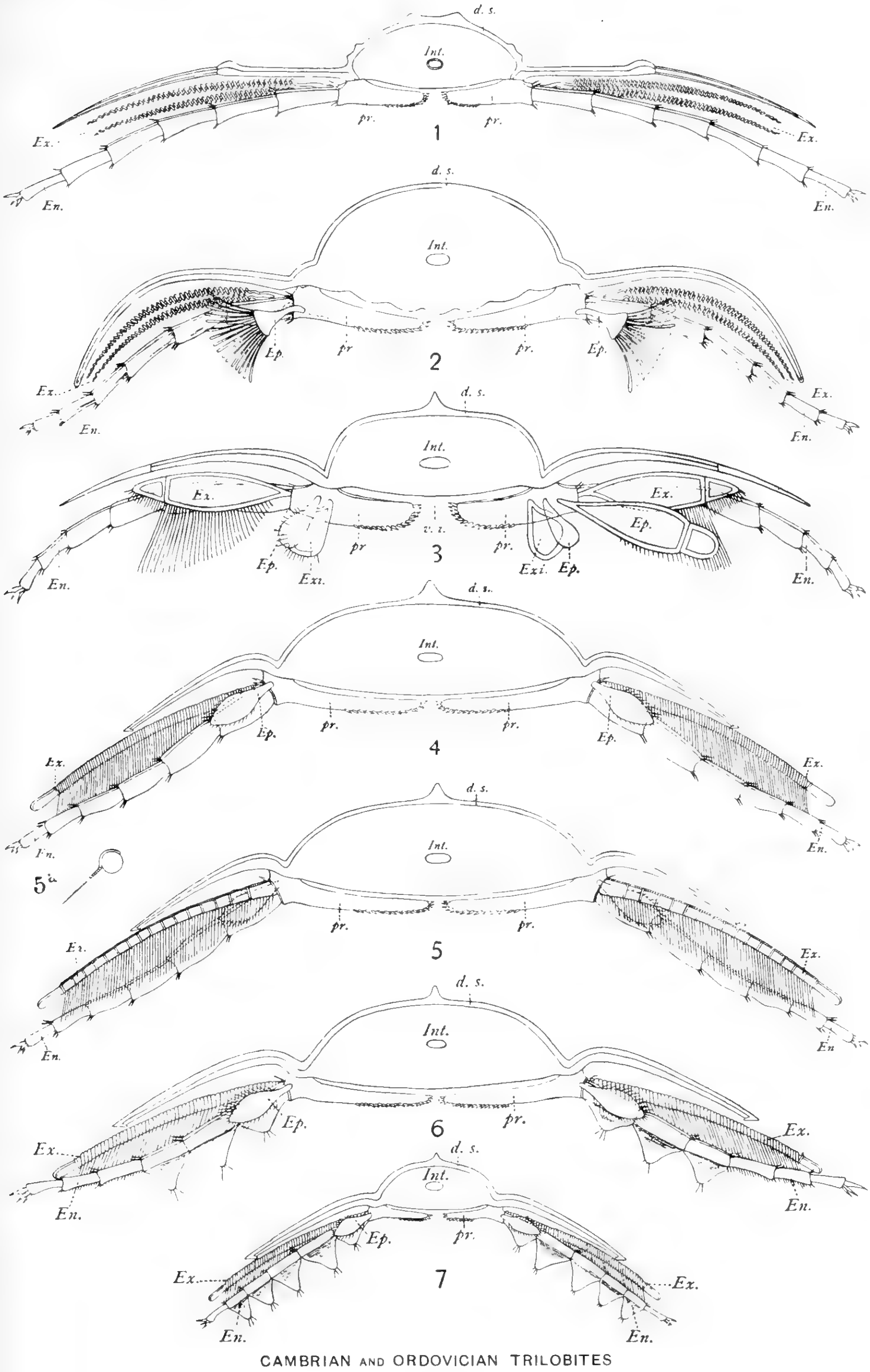
FIG. 2. (× about 5.) Transverse diagrammatic sketch of one of the anterior thoracic segments presenting a side view of the ventral appendages as far as known. Some of the sections affording data on the limbs of *Calymene* are illustrated on pls. 26, 27.

Neolenus serratus (Rominger) (See pl. 31) 126

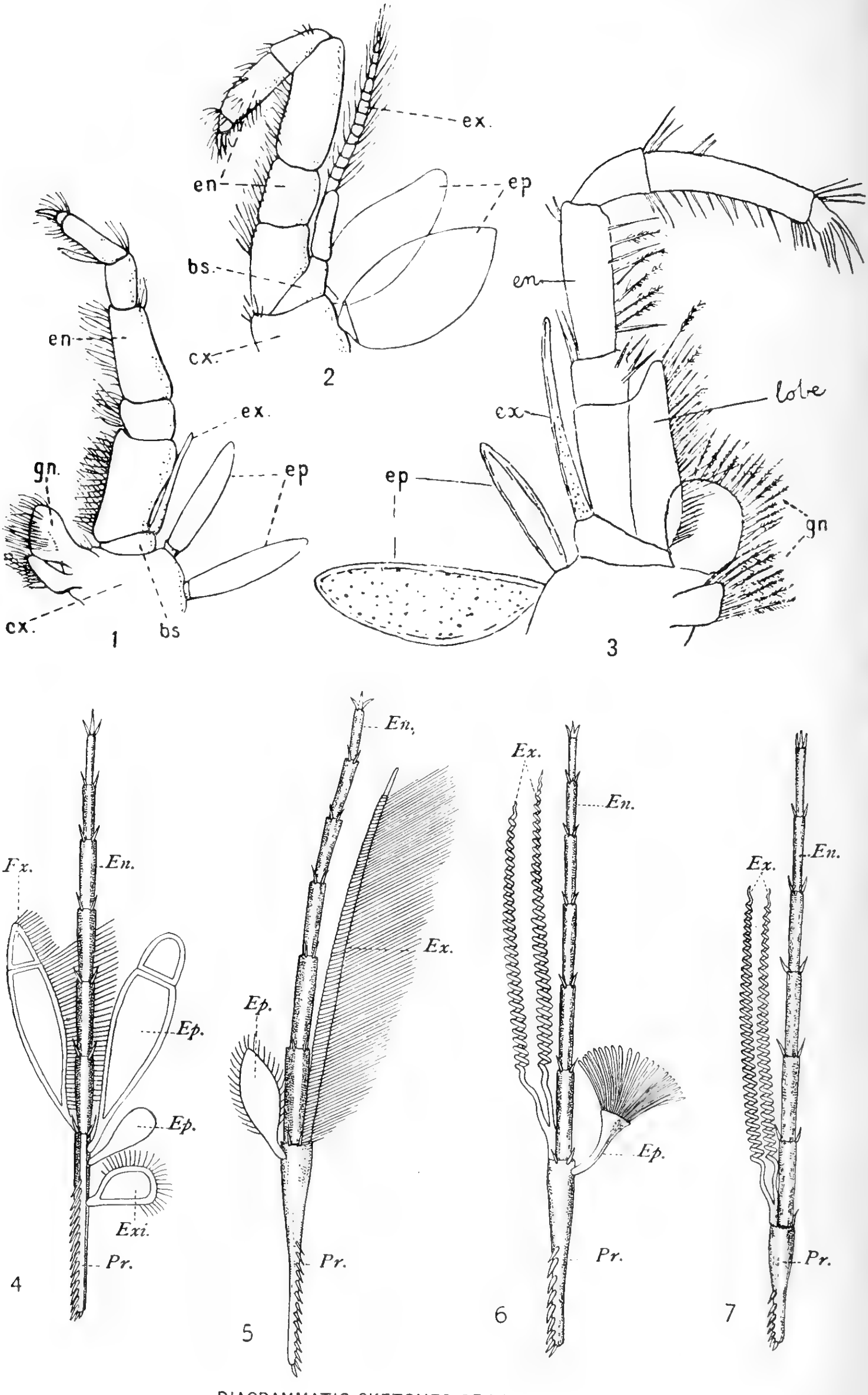
FIG. 3. (× about 3.) Transverse diagrammatic sketch of an anterior thoracic segment presenting a side view of the ventral integument and the limbs.

Triarthrus becki Green (See pl. 32) 135

FIGS. 4-7. (× about 5.) Transverse diagrammatic sections of thoracic segments and appendages. Fig. 4 = posterior side of third segment, showing the strong, jointed arm of the exopodite and its attachment to the distal end of the protopodite; 5 = anterior side of the third thoracic segment and limbs, showing the setiferous exopodite, the endopodite, and the small epipodite; 5*a* = section of the arm of the exopodite, showing the manner in which the setæ are attached to it; 6 = anterior side of the eighth thoracic segment with three enlarged joints on the leg (endopodite); 7 = posterior view at the third segment of limbs of pygidium; the endopodite has five expanded joints and a slender distal joint.



CAMBRIAN AND ORDOVICIAN TRILOBITES
with ventral appendages
Transverse diagrammatic sections



DIAGRAMMATIC SKETCHES OF THORACIC LIMBS
TRILOBITES AND RECENT CRUSTACEANS

DESCRIPTION OF PLATE 35

Legend

en. = endopodite. bs. = basopodite.
ex. = exopodite. exi. = exite.
ep. = epipodite. gn. = gnathobase.
cx. = coxopodite.

PAGE

Anaspides tasmaniæ G. M. Thomson (See text fig. 1, p. 171) 170

FIG. 1. Enlarged diagrammatic outline of second thoracic limb. (After Calman.)

2. Enlarged diagrammatic outline of first thoracic limb. (After Calman.)

Paranaspides lacustris Smith (See text fig. 3, p. 172) 170

FIG. 3. Enlarged diagrammatic outline of first thoracic limb. (After Smith, Proc. Royal Soc. London, Ser. B, Vol. 80, 1908, p. 471, fig. 6.)

Neolenus serratus (Rominger) 126

FIG. 4. Diagrammatic sketch of a thoracic limb to illustrate the several parts and their supposed position in relation to the protopodite.

Triarthrus becki Green 135

FIG. 5. Diagrammatic sketch of a thoracic limb showing the protopodite, exopodite, and supposed epipodite.

Calymene senaria Conrad 147

FIG. 6. Diagrammatic sketch of thoracic limb, showing the protopodite, endopodite, spirals of exopodite, and setiferous epipodite.

Ceraurus pleurexanthemus Green 148

FIG. 7. Diagrammatic sketch of thoracic limb, showing the protopodite, endopodite, and spirals of exopodite.

The diagrammatic sketches of the thoracic limbs of the four genera were prepared for the purpose of comparing them with each other, and also to form the basis of comparison of the limb of *Neolenus* with that of *Anaspides,* text fig. 1, p. 171, and *Koonunga,* text fig. 2, p. 171, *Paranaspides,* text fig. 3, p. 172.

DESCRIPTION OF PLATE 36

PAGE

Crustacean limb, genus and species undetermined........................ 154

FIG. 1. (× 20.) Drawing based on photographs of several jointed legs which are preserved on the surface of a small slab of shaly limestone. They are light brown in color and have a polished surface similar to the chitinous legs of recent crustaceans.

1*a*. (× 20.) Transverse section of a third joint that has been worked out of the rock.

2, 2*a-d*. (× about 8.) Reproduction of photographs of several of the legs on the slab of limestone. Fig. 2 has eight joints, fig. 2*a* six, figs. 2*b* and 2*c* eight; fig. 2*d* is a fragment preserving four joints. The distal joint has been outlined in fig. 2*c*. U. S. National Museum, Catalogue No. 65532.

Formation and locality.—Ordovician: (Trenton) *Cynthiana* limestone. Bank of Ohio River below Covington, Kenton County, Kentucky.

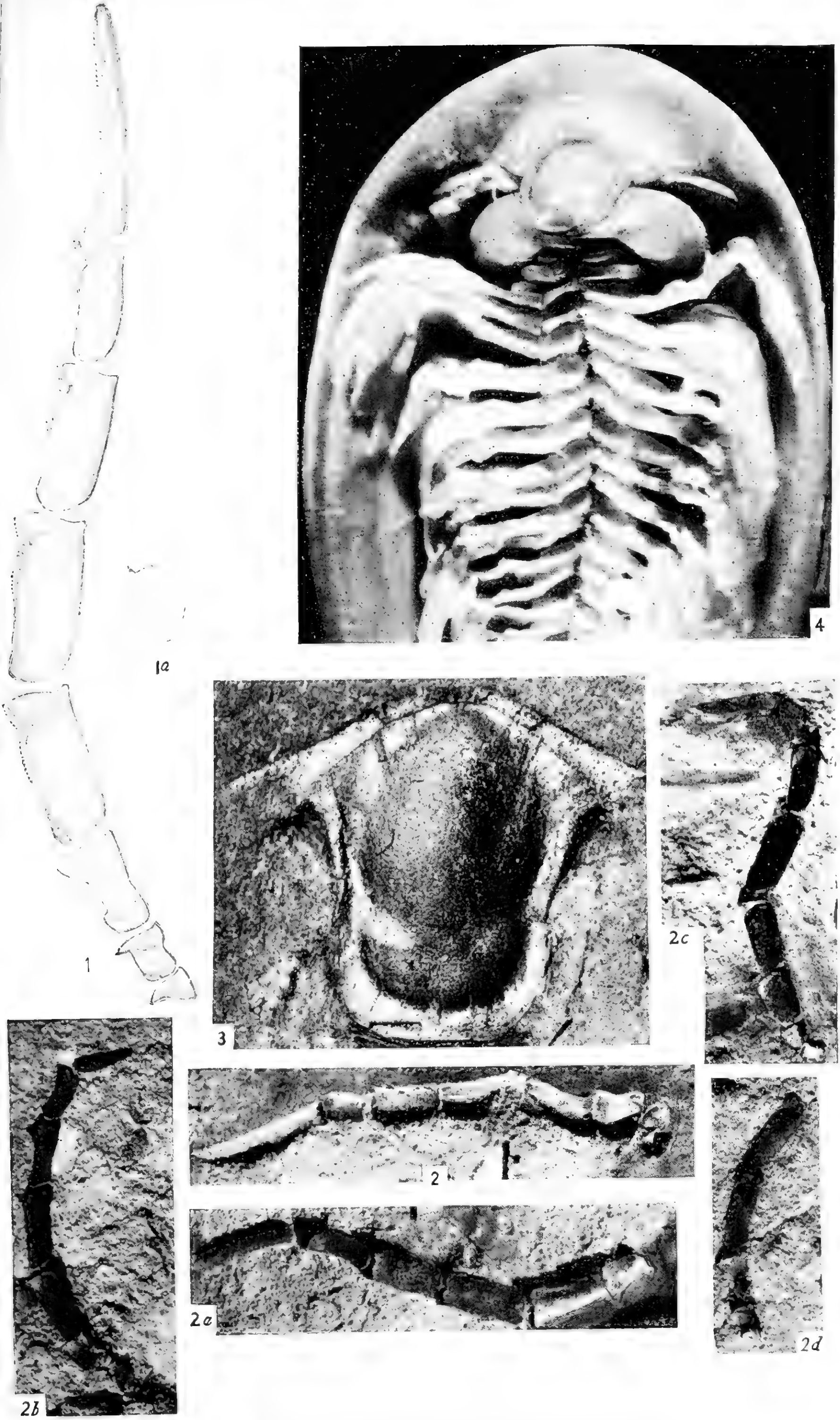
Neolenus serratus (Rominger).. 126

FIG. 3. (× 8.) A small, nearly entire hypostoma enlarged. U. S. National Museum, Catalogue No. 65533.

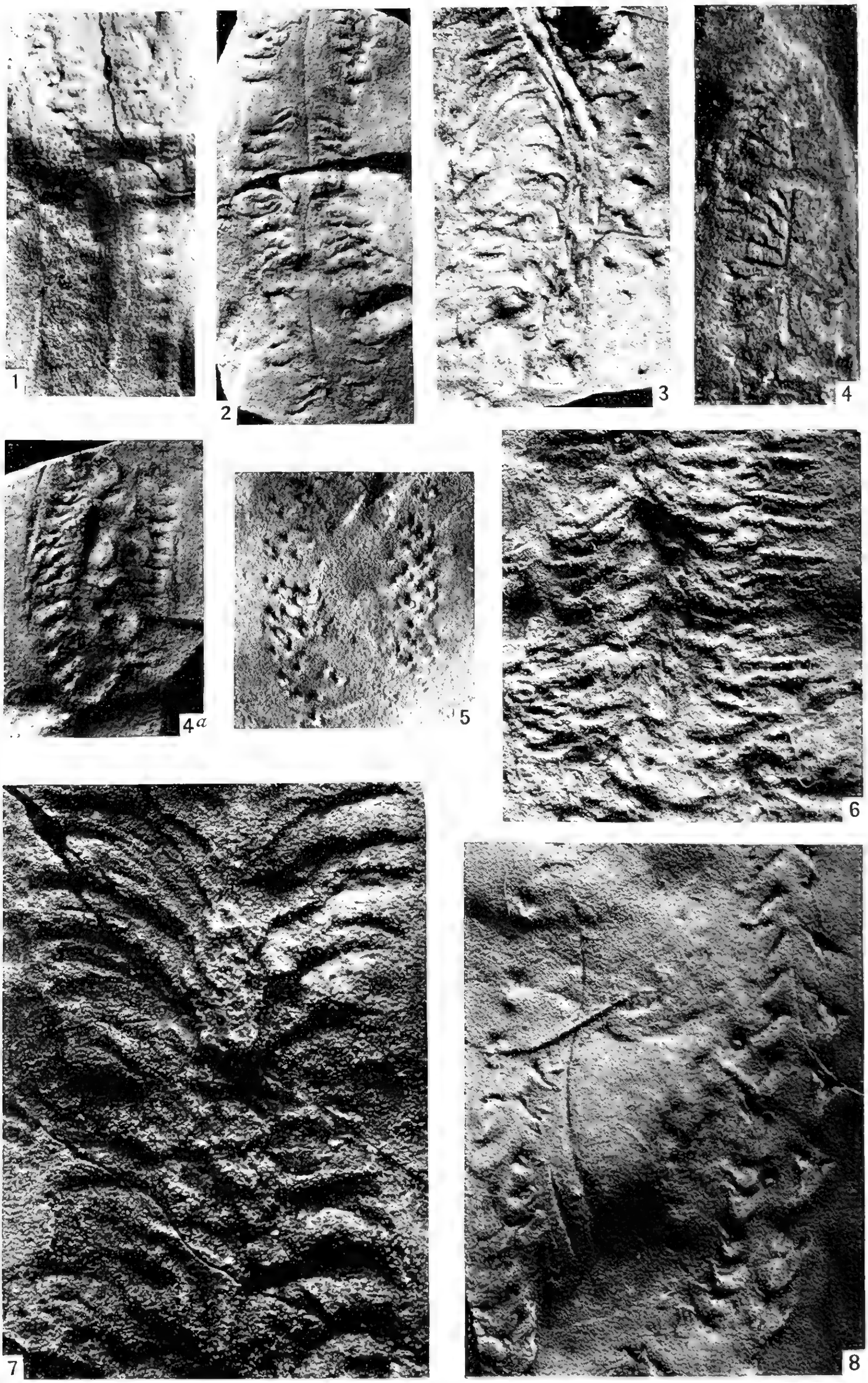
Formation and locality.—**35k,** Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia, Canada.

Apus lucasana Packard.. 169

FIG. 4. (× 6.) Ventral view of carapace with hypostoma, cephalic and 12 pairs of the trunk limbs slightly pushed over so as to show their form and arrangement. The *Apus* is from a pond near Aurora, New York.



CRUSTACEAN LIMB, NEOLENUS AND APUS



TRILOBITE TRACKS AND TRAILS

DESCRIPTION OF PLATE 37

PAGE

Trilobite tracks and trails 174

FIG. 1. (Natural size.) Trail on surface of fine compact sand where the legs were used to push the dorsal shield along while the edges of it were resting on the sand, thus leaving a slight marginal groove and a central groove made probably by the median projection at the end of the pygidium. U. S. National Museum, Catalogue No. 66136.

2. (Natural size.) Imprint of short strong legs with an apparent bifurcation at the outer end. Some of them are tripartite which indicates a central claw with the two spines. U. S. National Museum, Catalogue No. 66137.

3. (Natural size.) Trail where the legs on the left side left their imprint for nearly their entire length, and on the right side only the distal joint and terminal claw touched the sand. After the trilobite had made the trail a worm came up through the sand and followed along in the center of the trail for some distance. U. S. National Museum, Catalogue No. 66138.

4. (Natural size.) A trail essentially similar to that of fig. 2, but with the imprint of the leg from the median line out to its distal extremity. The division of the impression near the outer end may have been caused by one of the other legs leaving its impression at a different angle, or it may have been that the exopodite had a sufficiently strong supporting arm to make an impression. U. S. National Museum, Catalogue No. 66139.

4*a*. (Natural size.) Trail cut deeper into the sand than those represented by figs. 1-4. U. S. National Museum, Catalogue No. 66140.

The specimens illustrated by figs. 1-4, 4*a*, are from locality **73**, Middle Cambrian: Tapeats sandstone; Tonto group; Quagunt Valley, Grand Canyon of the Colorado River, Arizona.

5. (Natural size.) This track was made by the claw and end of the distal joint of the legs when the animal was ascending a slight muddy slope. U. S. National Museum, Catalogue No. 66142.

The specimen represented by fig. 5 is from locality **8u**, Middle Cambrian: Flathead sandstone and shales; 4 miles (6.4 km.) above Walker's ranch in canyon, North Fork of Dearborn River, Lewis and Clark National Forest, Montana.

5. (Natural size.) Cast of a trail made by the protopodites and legs, the latter showing to the right beyond the cast of the deep, narrow impressions made by the protopodites. U. S. National Museum, Catalogue No. 66141.

From locality **3j**, Middle Cambrian: Wolsey ? shale; about 6 miles (9.6 km.) west-northwest of Scapegoat Mountain on the Continental Divide between Bar Creek and the headwaters of the south fork of the North Fork of Sun River, Powell County, Montana.

Trilobite tracks and trails—Continued.

FIG. 7. (Natural size.) Trail over relatively soft surface of sand where the protopodites have sunk into the sand, crowding it up along the median line. There are a few traces of the leg beyond portion of the trail illustrated. U. S. National Museum, Catalogue No. 66143.

The specimen illustrated is from the Middle Cambrian: Tapeats sandstone, on Shinimo Creek, below Powell's Plateau, Grand Canyon of the Colorado River, Arizona.

8. (Natural size.) Trail made on surface of ripplemarked, very fine sand, where only the ends of the legs touched the sand. U. S. National Museum, Catalogue No. 66144.

From locality **73a**, Middle Cambrian: Tapeats sandstone; in Chuar Valley, Grand Canyon of the Colorado River, Arizona.

DESCRIPTION OF PLATE 38

FIGS. 1 and 2. (× 3.) Track where the legs appear to have burrowed down into the sand so as to leave a relatively deep impression. U. S. National Museum, Catalogue No. 8616.

The specimen illustrated is from the Tonto shale, above the Tapeats sandstone; Grand Canyon of the Colorado River, Arizona.

This specimen was illustrated by Dr. C. A. White in Palæontology, Geog. and Geol. Expl. and Surv. west 100th Merid., Pt. 1, Vol. IV, 1878, pl. 1, figs. 6*a-b*.

3. (Natural size.) Trail in which the impressions made by the protopodites are preserved, also the edge of the dorsal shield. There are no traces of the imprints of the legs beyond the dorsal shield. U. S. National Museum, Catalogue No. 66145.

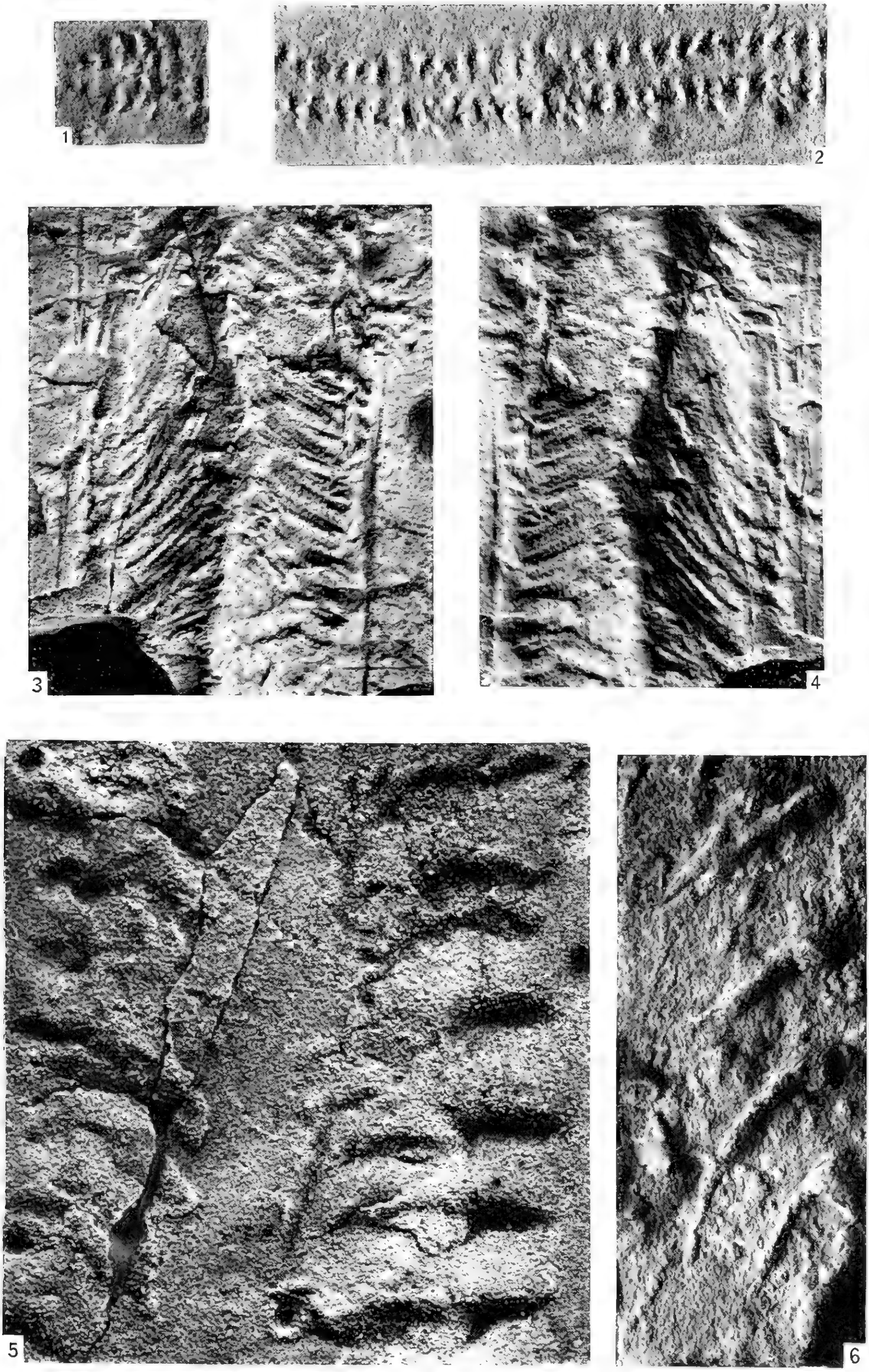
The specimen illustrated is from locality **115**, Upper Cambrian: Lower beds at L'Anse Cove, east side of Great Belle Isle, Conception Bay, Newfoundland.

4. (Natural size.) Photograph of the cast of the trail represented by fig. 3.

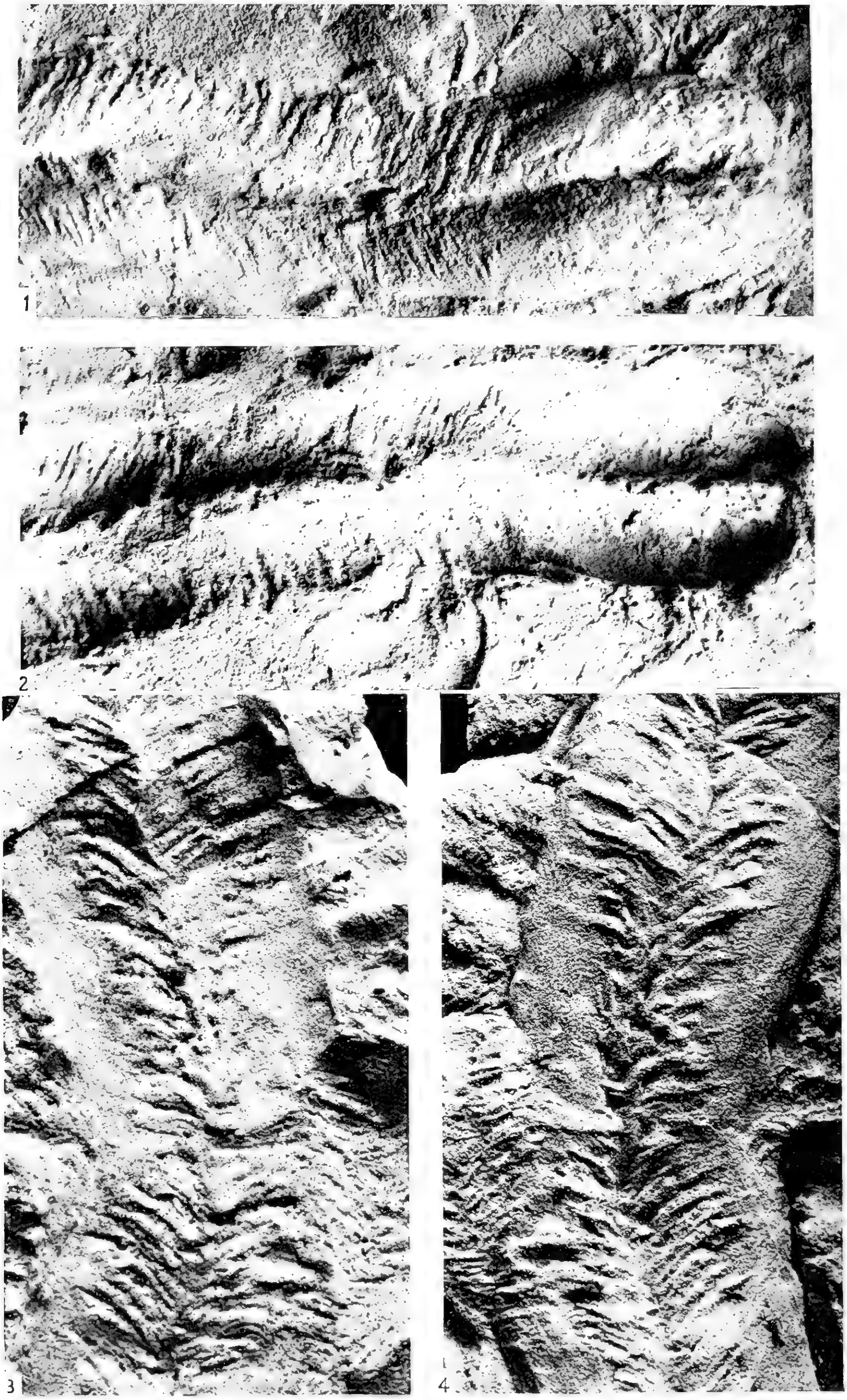
5. (Natural size.) Portion of a trail in which the imprints of the protopodites and part of the inner joints of the leg are preserved. U. S. National Museum, Catalogue No. 66146.

6. (× 2.) Fragment of a trail preserving the cast of the impression of the end of the protopodite and portions of the legs. U. S. National Museum, Catalogue No. 66147.

The specimens represented by figs. 5 and 6 are from the Middle Cambrian: Tapeats sandstone, on Shinimo Creek, below Powell's Plateau, Grand Canyon of the Colorado River, Arizona.



TRILOBITE TRACKS AND TRAILS



TRILOBITE TRACKS AND TRAILS

DESCRIPTION OF PLATE 39

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FIG. 1. (Natural size.) Natural cast of a trail in which at the right of the figure the trilobite evidently burrowed deeper into the sandy mud. It then moved a short distance and again went deeper into the mud. This is better shown by the fig. 2, which is of a cast made of the specimen represented by fig. 1, and which represents the actual trail made by the animal. U. S. National Museum, Catalogue No. 66148.

2. (Natural size.) Plaster cast made of the natural cast illustrated by fig. 1. This shows the original trail of the animal made on the surface of the muddy sand.

The specimen represented by figs. 1 and 2 is from locality **73a**, Middle Cambrian: Tapeats sandstone; in Chuar Valley, Grand Canyon of the Colorado River, Arizona.

3 and 4. (Natural size.) Trail made on the surface of the sand and natural cast of it represented by fig. 4, which shows the form of the endopodites that made the impressions shown by fig. 3. Fig. 3 is made from a cast made of the natural cast represented by fig. 4. U. S. National Museum, Catalogue No. 66149.

From locality **8u**, Middle Cambrian: Flathead sandstone and shales; 4 miles (6.4 km.) above Walker's ranch in canyon, North Fork of Dearborn River, Lewis and Clark National Forest, Montana.

DESCRIPTION OF PLATE 40

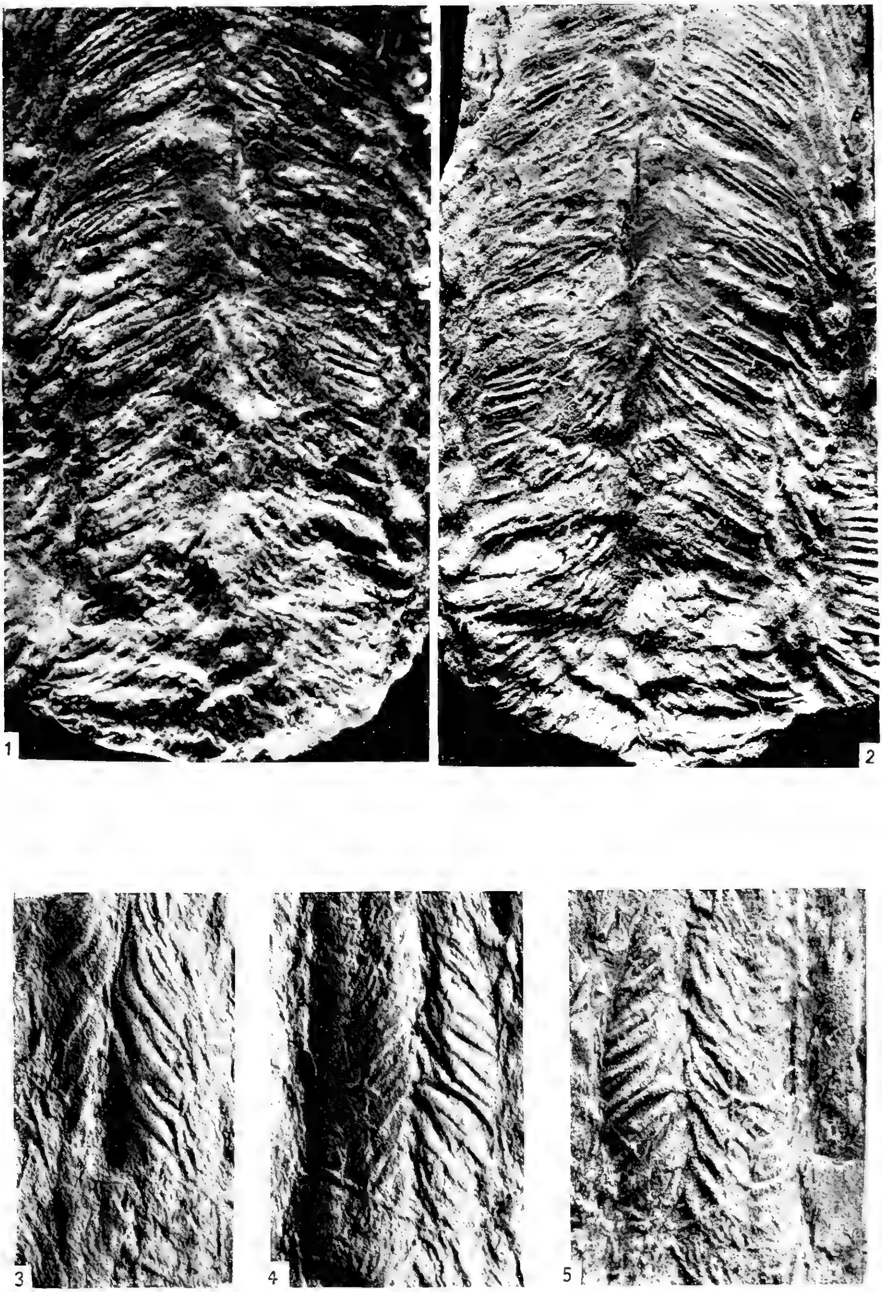
FIGS. 1 and 2. (Natural size.) Fig. 1 is from a photograph of a cast made of the natural cast represented by fig. 2 of a trail in which the protopodites have left their impressions; also on the left side there are traces of the legs (endopodites). Fig. 2 reproduces the ventral side of the appendages making the impressions. U. S. National Museum, Catalogue No. 66150.

From locality **114b**, Lower Ordovician: sandstone 1 mile (1.6 km.) north of L'Anse Cove, Great Belle Isle, conception Bay, Newfoundland.

3, 4, and 5. (Natural size.) Figs. 3 and 4 represent portions of the natural cast of a trail which is unlike any of the other trails illustrated. The natural trail is shown by fig. 5. U. S. National Museum, Catalogue No. 66151.

From locality **366n**, Upper Cambrian: Lower *Lingula* flags at Portmadoc, Merionethshire, North Wales.

This track is described as *Cruziana semiplicata* by Salter.



TRILOBITE TRACKS AND TRAILS

TRILOBITE TRACKS AND TRAILS

DESCRIPTION OF PLATE 41

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FIGS. 1 and 2. (Natural size.) Fig. 1 is a natural cast of a large trail crossed by a smaller one where the animal was half burrowing along in relatively soft sediment, stopping frequently and leaving a trail such as that shown by fig. 2.

It must be recalled that frequently trails were made in semiplastic mud and that later on sand was washed into the trails, thus making casts, in which when the subsequently formed rock is exposed to weathering the shale formed by the mud dissolves and disappears, leaving the cast of the trail as shown in this instance by fig. 1. U. S. National Museum, Catalogue No. 66152.

From locality **73a,** Middle Cambrian: Tapeats sandstone; in Chuar Valley, Grand Canyon of the Colorado River, Arizona.

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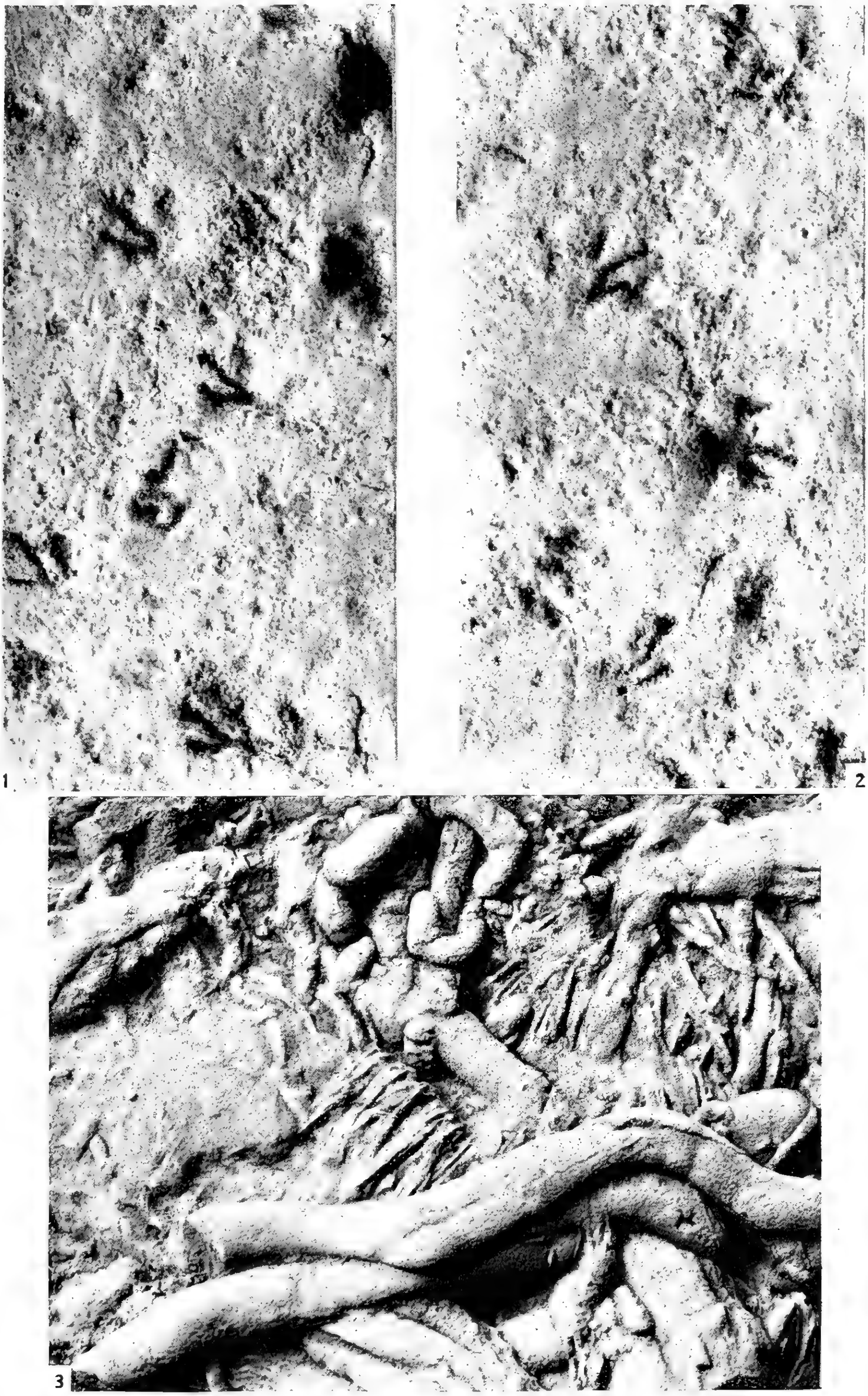
FIGS. 1 and 2. (Natural size.) Right and left side of a portion of a broad track (13 to 15 cm.) showing trifid termination of the individual imprints formed probably by the claw and spines of the distal extremity of the leg. The central portion of the track has been cut out in order to bring the imprints of the two sides within the limits of the plate. U. S. National Museum, Catalogue No. 58593.

The specimen represented is from locality **220b**, Upper Cambrian: Potsdam sandstone; near Beauharnois, Province of Quebec, Canada.

These tracks were illustrated on pl. 47, Vol. 57, Smithsonian Miscellaneous Collections, 1912.

3. (Natural size.) Photograph of a natural cast of annelid trails, trilobite trails, etc., which illustrate the abundance of annelids in and on the muddy surface of the bottom over which the trilobite was foraging for food. U. S. National Museum, Catalogue No. 66153.

From locality **8u**, Middle Cambrian: Flathead sandstone and shales; 4 miles (6.4 km.) above Walker's ranch in canyon, North Fork of Dearborn River, Lewis and Clark National Forest, Montana.



TRILOBITE TRACKS AND ANNELID TRAILS

INDEX

The references in **heavy-face** type refer to the pages upon which the genera and species are described and figured.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 5

CAMBRIAN
GEOLOGY AND PALEONTOLOGY
IV

No. 5.—MIDDLE CAMBRIAN ALGAE

(With Plates 43 to 59)

BY
CHARLES D. WALCOTT

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No. 5.—MIDDLE CAMBRIAN ALGAE

By CHARLES D. WALCOTT

(With Plates 43 to 59)

CONTENTS

DESCRIPTION OF PLATES

INTRODUCTION

The presence of an algal flora in connection with a large invertebrate fauna of Middle Cambrian age in the Burgess shale has been known to me for several years, but I delayed studying it in order to obtain all the material possible from the Burgess Pass quarry of British Columbia.

Through the kindness of Dr. Charles A. Davis of the United States Bureau of Mines in 1913 a number of thin sections were made of the algal remains in which occur what appear to be chains of cells of blue-green algae (Cyanophyceae) (see pl. 43), and later a series of slides were cut through the courtesy of Director George Otis Smith by Mr. Frank S. Reed of the petrological laboratory of the United States Geological Survey.

All of the type and study series of specimens are deposited in the United States National Museum where they may be examined by students.

Habitat.—The study of the shales and the invertebrate remains of the Middle Cambrian Burgess shale in which the algae are found leads to the following conclusions in regard to their habitat:

The compact, smooth, exceedingly fine-grained siliceous Burgess shale was deposited from relatively quiet, muddy water. At intervals this condition must have been continuous for some time as layers of the shale several inches in thickness have the crustaceans distributed irregularly through them. Where the shale is in thin layers with distinct lamination and bedding surfaces the fossils are more abundant but less perfectly preserved.

The presence of carbonic acid gas has been mentioned as follows:[1] That carbonic acid gas was present in the mud and immediately adjoining water is suggested by the very perfect state of preservation of the numerous and varied forms of life. These certainly would have been destroyed by worms and predatory crustaceans that were associated with them if the algal plant life and animals that dropped to the bottom on the mud or that crawled or were drifted onto it were not at once killed and preserved with little or no decomposition or mechanical destruction. This conclusion applies to nearly all parts of a limited deposit about six feet in thickness, and especially to the lower two feet of it.

Owing to faulting and alteration of most of the shales by shearing the area available for collecting is limited to about 120 feet (36.6 m.) of outcrop on a steep slope of the mountain. This condition limits our information as to the original extent of this remarkable deposit. It was probably laid down in a small bay or lagoon in close connection with the shallow Middle Cambrian sea.

It is evident that the algae, sponges, annelids, crustaceans, etc., now found in the shale lived in quiet, relatively shallow waters swarming with life and readily accessible to the waters of the open sea. In the preliminary study of the fauna I have distinguished 94 genera in collections from a block of shale not over 15 (4.5 m.) by 100 feet (29.7 m.) in area and 7 feet (2.13 m.) in thickness. Individuals of several species of crustaceans occur in large numbers at three horizons, notably *Marrella splendens* and *Hymenocaris perfecta*. Trilobites, with the exception of the genera *Agnostus* and *Pagetia*, are not abundant, although their tests almost make up massive beds of calcareous shales a few feet below the base of the Burgess shale.

Mode of growth of the Algae.—The absence of evidence of the existence of a point of attachment on any of the forms referred to

[1] Smithsonian Misc. Coll., Vol. 57, 1912, p. 42.

Morania (pls. 44, 45) except as the colonies were held together in a mucous or gelatinous matrix leads to the conclusion that they floated freely in the water and sank to the bottom along with the crustaceans, annelids, etc., that lived among and fed more or less on them. Small shells (*Lingulella*), ostracods (*Aluta*), and trilobites are found attached to membranous expansions of the plant mass as though the shells had been lying on the bottom and the algae settled down over them, and in other examples the algae were on the bottom and the shells or trilobites became attached to the upper surface of the algae (pl. 58, fig. 4). Where the algal remains form a layer of appreciable thickness in the shale numerous small annelids (*Canadia setigera* Walcott[1]) are almost always present, but it is rarely that the larger annelids and crustaceans are associated with them; this indicates that the algae covered sufficiently large areas on or near the surface of the water to afford a favorable habitat for *Canadia setigera* and other small invertebrates. The species of algae forming small colonies floated in the water free from those forming large masses and they were frequently associated with them.

When we conclude that many of the forms of algae now found in the Burgess shale grew as free colonies it must be remembered that most, if not all, of the algal material was carried into the area by currents and deposited on the muddy bottom of the pool, lagoon or bay, and that probably none of it grew *in situ*. The floating species (*Morania confluens*, etc.) were drifted by prevailing currents or winds and the sessile species (*Donaldella insolens, D. mimica, D. virgata, Waputikia ramosa*, etc.) were readily detached by animals feeding among them or torn loose by currents or waves and drifted to their final resting place.

Manner of preservation.—The algal remains usually occur as shiny black films on the surface of the hard dark siliceous shale; this form of preservation is the same as for the medusae, sponges, annelids, crustaceans, etc., except that the algae were evidently more gelatinous and membranous; it appears to have made little difference whether the fossil was a flat, thin frond, a sphere, or a thick-bodied crustacean; all alike have been reduced to films of varying thickness without greatly distorting the original outline and arrangement of parts. The mucous or gelatinous mass of algae; the spongin and spicules of sponges; the flesh of annelids; the test and body of crustaceans, have all been replaced by a shiny black

[1] Smithsonian Misc. Coll., Vol. 57, No. 5, 1911, p. 119, pl. 23, figs. 1-3.

carbonaceous-appearing siliceous film containing pyrite in varying proportions. It is evident that the original organic and inorganic matter was removed by solution and replaced by the black film, the original convexity and relief being lost in the process and by subsequent compression.

The presence of spherical, barrel-shaped and broadly cylindrical cell-like bodies singly and in chains (pl. 43) of varying length in association with the fronds of *Morania confluens* at once raises the question as to their organic and inorganic origin. Rauff contends that such bodies are simple balls, cylinders, etc., of pyrite (FeS_2) and are of inorganic origin.[1] He states that such black pyrite balls and strings of balls occur not only in association with sponges and other organic remains, but also in limestones where there is no evidence of organisms, all of which I freely admit. In the case of the strings of balls and barrel-shaped cylinders associated with *Morania confluens,* there are the remains of an alga closely allied in appearance to the Blue-Greens (Cyanophyceae) which have cells similar in appearance and arrangement to the fossil forms; that they are preserved in pyrite is to be expected from the fact that the animal matter of the sponges and crustaceans is replaced by pyrite in the Burgess shale but in the form of microscopic cubes with glistening faces; such cubes occur in association with the spheres, cylinders, etc., found with *Morania.* I think we have here an illustration of organic and crystalline (inorganic) phenomena. It is difficult for me to conceive of strings of pyrite balls being assembled in curved lines of varying configuration unless there were organic structures that gave them form and direction.

Genera and species.—The following genera and species of algae have been identified:

CYANOPHYCEAE (MYXOPHYCEAE) (BLUE-GREEN ALGAE)
  Order HORMOGONEAE
    Family NOSTOCACEAE
      Morania confluens, new species
      Morania costellifera, new species
      Morania elongata, new species
      Morania fragmenta, new species
      Morania frondosa, new species
      Morania ? globosa, new species
      Morania parasitica, new species
      Morania ? reticulata, new species
      Marpolia spissa, new species
      Marpolia aequalis, new species

[1] Palaeontographica, Vol. 40, pp. 328-330, pl. 17, figs. 2, 3.

Chlorophyceae (green algae)
Yuknessia simplex, new species

Rhodophyceae (red algae)
Waputikia ramosa, new species
Dalyia nitens, new species
Dalyia racemata, new species
Wahpia insolens, new species
Wahpia mimica, new species
Wahpia virgata, new species
Bosworthia radians, new species
Bosworthia gyges, new species

Comparison with recent Algae.—All comparisons of the fossil Cambrian algae with living algae with exception of the genus *Morania* are based on similarity of outward macroscopic characters and form of growth. Anyone possessing a slight acquaintance with living algae, knows that this is a very uncertain standard as essentially the same outward form may occur in different genera and even orders. We have in the fossil species only the pressed and flattened remains of fragments of the original plant and in one instance possible evidence of the microscopic structure; in their pressed condition, however, they may be compared with dried herbarium specimens with a prospect of at least pointing out resemblances that indicate that some of the algae of lower Middle Cambrian time closely resemble those of the present day.

Cyanophyceae.—The Cambrian genus attaining the greatest development in species and abundance of specimens is *Morania*, a form that is so closely allied to the living Blue-Green algae that I have ventured on both macroscopic and microscopic characters to refer it to the Order Hormogoneae and with some uncertainty to the Family Nostocaceae. *Marpolia* also may be tentatively placed with the Blue-Green algae, although it could quite as well be grouped under the Chlorophyceae.

Comparisons.—*Nostoc commune* Vaucher (pl. 46, figs. 1, 1*a*) has many points of exterior resemblance, also *Nostoc verrucosum* (Linn.) Vaucher (pl. 46, fig. 2), with *Morania confluens* (pls. 44, 45). Comparison should also be made with *Anabaena variabilis* Kützing (pl. 46, figs 4, 4*a*). The surface of *Morania confluens* (pl. 44, fig. 11) is sometimes wrinkled as it is in *Nostoc verrucosum* (pl. 46, fig. 2).

Morania ? costellifera (pl. 47, figs. 1, 2) may be compared with *Nostoc parmeloides* Kützing (pl. 46, figs. 3, 3*a-d*) and somewhat in surface characters to *Nostoc verrucosum* (pl. 46, fig. 2). In external appearance the small masses of *Morania fragmenta* (pl. 48, fig. 1) resemble those of *Nostoc sphaericum* Vaucher (pl. 53, fig. 1). The large perforated frond of *Morania ? frondosa* (pl. 49, fig. 1) and *M. reticulata* (pl. 52, fig. 2*a*) may be compared with that of *Anabaena variabilis* Kützing (pl. 46, fig. 4). The delicate disks of *Morania globosa* (pl. 48, figs. 2, 2*a-c*) resemble those of the living *Nostoc pruniforme* Agardh (pl. 53, fig. 2).

Marpolia spissa (pl. 52, figs. 1, 1*a-b*) had a form of growth apparently similar to that of *Cladophora arcta* (Dillw.) Kützing and *C. gracilis* (Griffiths) Kützing (pl. 51, fig. 1), and the transverse walls of the filaments are much like those of *C. fracta* (Vahl) Kützing and some species of *Chaetomorpha, C. clavata* (Agardh) Kützing, *C. aerea* (Dillw.) Kützing. Comparison should also be made for form of growth with *Ectocarpus mitchellae* Harvey, *E. elegans* Thuret, and *Pylaiella littoralis* (L.) Kjellman.

Chlorophyceae (Green Algae).—The genus and species included under the Chlorophyceae is *Yuknessia simplex* (pl. 54, fig. 1), which is a very doubtful reference.

Rhodophyceae (Red Algae).—This group is represented by a number of species that indicate that the algae of Middle Cambrian time had attained a development that included the highly organized Rhodophyceae, a conclusion that might be anticipated from the advanced stage of evolution of the associated sponges, holothurians, annelids and crustaceans.

The fossil forms may be compared with living species on the basis of external appearance and form.

Waputikia ramosa (pl. 54, fig. 2) has a somewhat similar mode of branching as *Dasya gibbesii* Harvey (pl. 53, fig. 3) and the form of stem and main branches is not unlike those of *Euthora cristata* (Linn.) J. Agardh. *Dalyia racemata* (pl. 56, figs. 1, 1*a-c*) has transverse lines on its branches that suggest those of *Halurus equisetifolius* (Lightf.) Kützing, and its branches suggest *Carpomitra cabrerae* (Clem.) Kützing, and its terminal branches *Griffithsia opuntioides* J. Agardh. *Wahpia insolens* (pl. 57, figs. 1, 1*a*) branches in similar manner to *Ahnfeldtia plicata* (Huds.) Fries and *Cystoclonium purpurascens* (Huds.) Kützing. Comparison should also be made with *Ahnfeldtia concinna* J. Agardh and *Gymnogongrus leptophyllus* J. Agardh. *Wahpia mimica* (pl. 55, fig. 2) with its round stem and manner of branching recalls *Ahnfeldtia plicata* (Huds.) Fries and *Ceramium rubrum* (Huds.) Agardh. *Wahpia virgata* (pl. 57, fig. 2) suggests *Ceramium nitens* (Agardh) J. Agardh.

Bosworthia simulans (pl. 57, fig. 3) probably had a form of growth not unlike that of *Dumontia filiformis* (Huds.) Greville (pl. 51, fig. 2) and possibly *Dictyota ciliata* J. Agardh and *D. fasciola* (Roth) Lamour.

We have also to consider that in this Burgess shale flora there is only a portion of the marine algal flora of Cambrian time, and this is represented by fragments of plants that grew in a very limited area tributary to the small basin into which they were drifted and deposited; the marvelous part is that we have anything preserved as fossils of such delicate and evanescent plants; what the larger algal flora of the great Cambrian seas of North America, Europe and Asia may have been we do not know, but from this one rich spot in the Burgess shale, and the great extent and advanced development of the invertebrate Cambrian faunas in many areas it is probable almost to a certainty there was an algal flora present in Cambrian time along all shore lines and in all bays, inlets and small bodies of water very much as at the present time. That fresh-water algae also flourished is indicated by its presence in the pre-Cambrian Algonkian rocks of the Cordilleran region of western America.[1]

Dr. G. F. Matthew has named and described several species of supposed algae from the Cambrian formations of Acadia, none of which appears to me to be sufficiently well defined to satisfactorily prove that they were of undoubted algal origin.

I have examined the type specimens of *Palaeochorda setacea*,[2] which appear to be the casts of trails of annelids that were moving over and through the sand and mud; the surface characters described by Matthew are such as occur on casts of trails in a fine-grained sandstone matrix.

Phycoidella stichidifera[3] is represented by a specimen that is in poor condition and also obscure. I doubt if it is of algal origin.

The types of the remaining species I have not seen and cannot express an opinion on them; they are microscopic in size, and the illustrations are more or less diagrammatic.

During the forty years in which I have been collecting and examining other collections except those from the Burgess shale, I have seen a few fragments that indicated the existence of algae in

[1] See Smithsonian Misc. Coll., Vol. 64, No. 2, 1914, Pre-Cambrian Algonkian Algal Flora, pp. 77-156, pls. 4-23.

[2] Trans. Royal Soc. Canada, Vol. 7, Sec. 4, 1890, p. 145, pl. 6.

[3] Idem, p. 144, pl. 5, figs. 5*a*-*d*.

the Cambrian strata, but none of the specimens gave satisfactory evidence of their undoubted algal origin. Many annelid trails, tidal water markings, trails of crustaceans and drifting medusae had been referred to as of algal origin but all were susceptible of some other interpretation.

Acknowledgments.—I wish to express my gratitude to the late Dr. Charles A. Davis for cutting thin sections and photographing them. The photographs of specimens were made by Mr. L. W. Beeson of the U. S. National Museum, and the necessary retouching of the background by Mrs. Mary Vaux Walcott. Mr. William R. Maxon, U. S. National Herbarium, has been most helpful in calling attention to sources of information in the collections of the National Herbarium and in botanic literature. Dr. Marshall A. Howe, New York Botanical Garden, kindly read the proof to verify the nomenclature of the recent algae.

CALCAREOUS ALGAE

Two species of calcareous algae have been found in thin sections of the Burgess shale from which most of the algal remains described in this paper have been obtained. Other genera and species have been described from various Cambrian formations, but as this is a preliminary study of the forms from the Burgess shale they will not be considered at this time.

DESCRIPTION OF SPECIES

CYANOPHYCEAE (MYXOPHYCEAE) (BLUE-GREEN ALGAE)

Order HORMOGONEAE[1]

" Plants multicellular, filamentous, attached to a substratum or free-floating; filaments simple or branched, usually consisting of one or more rows of cells within a sheath; reproduction occurs by means of hormogones or resting gonidia."[1]

Family NOSTOCACEAE[2]

" Sheaths forming a more or less distinct mucous, gelatinous or membranaceous tegument, mostly confluent, often not present; trichomes consisting of a single row of uniform cells, with heterocysts, usually twisting and entangled, not branched, showing no differentiation of base and apex, reproduction by means of vegetative division, hormogones and gonidia."[2]

Genus MORANIA, new genus

Plant mass (colony) at first small, irregularly globose or spheroidal with surface raised in low rounded bosses that give the flattened

[1] Tilden, J.: Minnesota Algae, Vol. 1, 1910, Minn., p. 56.

[2] Idem, p. 160.

mass an irregularly circular outline. As the mass expanded it assumed various forms, bullose, filiform, globose, and spread out in perforated or non-perforated membranous sheets; solid or hollow; mucous, gelatinous or leathery;[1] made up of tangled trichomes often torulose (chain-like); cells irregularly spherical, barrel-shaped or broadly cylindrical, larger heterocysts, cells intercalary; gonidia undetermined. (The cell description is tentative as it is based on such material as is illustrated on pl. 43.)

Genotype.—Morania confluens Walcott.

Stratigraphic range.—Middle Cambrian, lower 10 feet (3.05 m.) of the Burgess shale member of the Stephen formation.

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

Observations.—The above generic outline follows that of *Nostoc* Vaucher, as defined by Josephine Tilden.[2] It is based on the study of a large series of specimens and many thin slides. The question may arise as to why not place the Middle Cambrian species under *Nostoc* as they so closely resemble species of that genus. I would do so were it probable that a genus of the Nostocaceae had persisted from early Middle Cambrian time to the present. Representatives of the family might persist for millions of years, but we hesitate to conclude that the genus has not changed and therefore prefer to use a new generic term to include the Cambrian forms.

The species referred to *Morania* are:

Morania confluens Walcott
Morania costellifera Walcott
Morania elongata Walcott
Morania fragmenta Walcott
Morania frondosa Walcott
Morania ? globosa Walcott
Morania parasitica Walcott
Morania ? reticulata Walcott

MORANIA CONFLUENS, new species

Plate 43, figs. 1-6; plate 44, figs. 1-11; plate 45, figs. 1, 1*a*; plate 58, fig. 3

Plant mass (colony) free as far as known, gelatinous, more or less firm in early stages and irregularly spheroidal in form but quickly spreading out in very irregular flat or convex forms or in

[1] See second paragraph under "Manner of Preservation," p. 221.

[2] Minnesota Algae, 1910, p. 161.

membranous perforated sheets that are torn and broken into large and small fragments. The lacunae or perforations vary greatly in size, number, and arrangement. Often a group of small colonies are held together by the gelatinous-appearing base which forms a film on the surface of the shale; color unknown; strands flexuous and more or less entangled; no sheaths or distinct entire trichomes observed; cells [1] spherical, barrel-shaped; heterocysts irregularly spherical and larger than the cells. (See pl. 43, figs. 2, 4.) Gonidia unknown.

Observations.—There is no uniform outline or base, or point of attachment of any portion of the fragments of this perforated membranous frond-like alga. No two pieces agree in size and outline or in the size and form of the openings through the dark glistening surface of the frond. With a magnification of 20 times, long, fine, irregular, more or less interlacing, flattened, branching strands or fibers may be seen which run in the general direction of the longitudinal axis of the fragment of alga in which they occur. The interlacing effect may have been produced by the matting down of several layers of irregular strands upon each other. The general appearance of the alga on the surface of the shale is shown by figures 1-6, plate 43. From the study of these and several hundred additional specimens I conclude the alga was in the form of a mucous, gelatinous mass that formed a plant colony which assumed an irregular frond-like shape when pressed flat in the shale; it was built up of flexuous, curved, more or less tangled strands embedded in a gelatinous matrix. We do not know the original form of the plant mass further than it must have been elongate and presumably frond-shaped with numerous perforations through it of various size. It was recumbent and was deposited from the water in great profusion on the firm surface of the mud.

Microscopic structure.[2]—Through the courtesy of the late Dr. Charles A. Davis of the United States Bureau of Mines I obtained a series of thin slides made from the membranous fossil remains of this species. With great skill he cut sections parallel to the flattened surface which showed in a remarkable manner chains of cells, some of which are illustrated on plate 43, figures 1-4.

The cells appear to have been spherical, elongate oval, barrel-shaped and cylindrical; the sections include long chains of cells that curve

[1] See second paragraph under "Manner of Preservation," p. 221.

[2] Idem.

and bend (figs. 2-4) very much as in the recent Nostocaceae, or the cells may be in groups or single (fig. 1). The sections illustrated were cut parallel to the surface of the alga and to the lamination of the shale which accounts for the success in getting long chains of cells. No traces of body sheaths have been observed.

Mode of occurrence.—This species occurs abundantly in several layers of the siliceous Burgess shale and also less frequently throughout the band of shale which carries a large crustacean fauna; over 1,500 specimens were collected and many more might have been brought in.

The plant mass may be represented by (*a*) a small, delicate, irregularly circular film on the shale (pl. 44, figs. 3, 4) which is the remains of a flattened spheroidal mass; (*b*) a grouping of the bodies (*a*) pressed together on the shale (figs. 6, 7); (*c*) the beginning of a flattened membranous sheet (fig. 10); (*d*) irregularly strung out group in a gelatinous base (figs. 8, 9); (*e*) small membranous fragments (figs. 5, 11); (*f*) large, irregular, perforated membranous fragments in one thickness on the shale (pl. 45, figs. 1, 1*a*) or (*g*) lying in layers forming beds several millimeters in thickness. The largest fragment in the collection is 15 cm. in width and 20 cm. in length.

Comparison with recent algae.—Of recent forms, *Nostoc commune* Vaucher (pl. 46, figs. 1, 1*a*) has many points of resemblance. These include the small spherical-shaped colonies that form irregular disks when flattened; the highly irregular, torn and perforated sheets; also essentially the same form of chains of cells. It may also be compared with *Nostoc verrucosum* (Linn.) Vaucher (pl. 46, fig. 2) as the latter has a similar habit of growth in outward form and the surface of *M. confluens* is sometimes wrinkled as in *N. verrucosum,* but it does not have the same characteristic surface.

Comparison should also be made with *Anabaena variabilis* Kützing (pl. 46, figs. 4, 4*a*) which occurs as floating masses on the surface of the water and in many other forms but these are not as close to *Morania confluens* as *Nostoc commune.* Torn fragments of the red alga *Kallymenia perforata* J. Agardh resemble the larger perforated fragments of *M. confluens* as do those of *Ulva reticulata* Forsk.

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

MORANIA COSTELLIFERA, new species

Plate 47, figs. 1, 2

Plant mass (colony) free as far as known; irregularly circular or elongate oval as they occur flattened on the surface of the shale; probably discoid or semiglobose when uncompressed; gelatinous or leathery, strong and not readily torn or broken; surface with more or less irregular costae or wrinkles that vary in strength on different specimens, the costae may be the result of the shrinkage of globose hollow colonies. No traces of strands have been observed; microscopic characters unknown.

Plant masses referred to this species have a diameter of from 3 mm. to 20 mm.

Observations.—This species differs from *Morania globosa* and the round form of *M. confluens* in its more leathery appearance, wrinkled surface and firm outline. In exterior outlines the flattened colonies of this species resemble the recent *Nostoc parmeloides* Vaucher (pl. 46, fig. 3) and somewhat in surface *Nostoc verrucosum* (Linn.) Vaucher.

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

MORANIA ELONGATA, new species

Plate 47, figs. 3, 3*a*

Plant mass (colony) free as far as known with an irregular circular outline as though spheroidal bodies 1 to 2 mm. in diameter had been flattened to a film on the shale while held together in a gelatinous matrix; some of them appear to have split up so as to give a ragged and sharp outline to the thin films as they occur singly and in groups in association with the more circular bodies. The colonies were held together in long strings of gelatinous matter that trailed in narrow masses in the water; these elongate masses are usually 2 to 3 cm. broad and 10 cm. or more in length and with indefinite outlines; some examples appear as if they had been smeared over the mud as a thin film, while others show laminations caused by the crushing down of several thicknesses on each other.

Observations.—The form of the colonies of this species seems to be similar to those of *Morania fragmenta* (pl. 48) but their grouping is quite different as they string out into long irregular masses while

M. fragmenta forms masses of definite outline; many of these resemble long slender worms broken up and flattened out and smeared over the shale, while others are definite in outline; the irregular appearance is also increased by the presence of trails of small annelids that evidently sought the floating algae and went to the bottom with it.

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

MORANIA FRAGMENTA, new species

Plate 48, figs. 1, 1*a*

Plant mass (colony) free as far as known, irregularly circular, oval or elongate, and from 0.75 to 2 mm. in diameter when flattened on the surface of the shale; these smaller bodies are grouped in circular, elongate, and variously outlined clusters that were apparently held together in a mucous or gelatinous matrix. The clusters average about 3 to 5 mm. in diameter and occur widely scattered over the surface of the shale or they may form relatively thick masses about the carapace of a crustacean [1] as though they had been gathered on the bottom by an eddy in the water; these circular groups vary in size from 5 to 20 cm. and may include torn fragments of *Morania confluens.* The impression made by the examination of a large number of specimens is that the small colonies formed balls or globose masses of varying shape held together by a mucous or gelatinous matrix and that when flattened out they formed disks, circular, oval, elongate or broken and irregular in outline; the larger number of specimens represent broken masses, hence the specific name *fragmenta.*

Observations.—This species differs from others referred to *Morania* by having the small colonies united in groups to form irregular masses that average 3 to 5 mm. in diameter.

In external form the colonies of *M. fragmenta* resemble the living *Nostoc sphaericum* Vaucher (pl. 53, fig. 1); they appear to have floated free in the water both singly and in groups held together by a mucous or gelatinous matrix.

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

[1] Usually *Hymenocaris* or *Hurdia.*

between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

MORANIA ? FRONDOSA, new species

Plate 49, figs. 1, 1*a*

Only one specimen of this species has been found in the collections; this is a portion of a large frond-like mass on the surface of the shale that appears to have formed a thin membranous film perforated by numerous more or less oval openings, lacunae, varying from 1 to 3 mm. in greatest diameter. It looks similar to the thin gelatinous masses of *Anabaena variabilis* Kützing (pl. 46, fig. 4) as they appear when dried out on blotting paper. The latter species often forms gelatinous scums floating on the surface of the water, and it is very easy to imagine that a similar condition existed in the case of *M. frondosa.*

The type and only specimen of this species is 11 cm. in length by 6 cm. in width up to where a break in the shale cuts it off.

Observations.—The only other form known to me from the Burgess shale that in any way may be compared with *M. frondosa* is *M. reticulata,* and only to the extent that both appear to have been thin floating masses that dropped to the muddy bottom and left a trace of their general form on its surface.

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

MORANIA ? GLOBOSA, new species

Plate 48, figs. 2, 2*a-d*

Plant masses (colonies) free as far as known, disk-shaped as they occur flattened out on the shale but probably spheroidal or elongate-globose before compression. The plant masses now appear as dark, thin shiny membranous films, circular, oval or elongate-oval in outline, with their surface mottled by irregular patterns of bright silvery material. The specimens in the collection vary in size from 13 mm. to 90 mm., and all appear to have been very delicate gelatinous or mucous-like bodies with sufficient firmness of structure to preserve their outline when compressed in the thin layers of mud and to also wrinkle slightly by lateral compression; no traces of strands comparable with those of *Morania confluens* (pl. 44, fig. 11) have been observed or lacunae perforating the frond; color and microscopic structure unknown.

Observations.—This species is readily distinguished from the globular or disk-shaped forms of *M. confluens* by regularity of outline, more delicate and thinner film on the shale and absence of strands and lacunae; from *M. costellifera* it differs in its thin delicate film, smooth surface and outline on the shale.

Among recent species, herbarium specimens of *Nostoc pruniforme* Agardh (pl. 53, fig. 2) resemble the delicate membranous disks of *M. globosa* both in outline and smooth surface.

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

MORANIA PARASITICA, new species

Plate 50, figs. 1, *1a*, 2

Plant mass (colony) free as such but in groups lying on and attached to the smooth surface of the carapace of crustaceans and that of the membranous film of *Morania globosa*. The individual masses are about 1 mm. in diameter; they occur singly and in irregular clusters or they may be so pressed together as to form a continuous surface; they were probably held together by a gelatinous exudation from the colonies.

Observations.—The first impression of this incrusting form was that it represented masses of *Morania fragmenta* (pl. 48) that had become attached to, and spread irregularly over, the surface of smooth objects; the small round disk-like masses are similar in shape but after examining a large number of specimens I think we may tentatively separate them as distinct from *M. fragmenta.*

The incrusting alga may occur scattered thinly over the surface or cover it entirely; in no instance has it been seen to extend beyond the edge of the crustacean carapace or membranous alga on which it occurs. I thought that perhaps the incrusting form might be a secondary deposit of mineral origin and asked Dr. George P. Merrill of the United States National Museum to examine and test it with this in view. He very kindly did so and reported as follows: "The material giving the sheen to these fossil impressions is not, as I had been inclined at first to think, of a metallic-sulphide nature but is wholly untouched by acids, even aqua regia.

I am, therefore, inclined to regard it as of a carbonaceous or graphitic nature. It cannot be due to an impregnation of liquid hydrocarbon but rather to vegetable or animal growth and contemporaneous with the shale."

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

MORANIA ? RETICULATA, new species

Plate 52, figs. 2, *2a*

This species, like *M. frondosa,* appears to have been in the form of a gelatinous floating film that when pressed flat on the muddy bottom left only a trace of its form; this indicates that the mass was perforated by numerous small openings, which give the surface the appearance of an irregularly reticulated, slightly roughened, more or less torn membrane that may be compared with herbarium specimens of *Anabaena variabilis* Kützing (pl. 46, fig. 4).

Observations.—The specimen illustrated has an irregular mass of *M. confluens* attached to it.

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

MARPOLIA, new genus

All that is known of this genus is described under the type species.

Genotype.—*Marpolia spissa* Walcott.

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

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

Observations.—The second species, *M. aequalis,* apparently has a definite axis and branches, which probably arises from the twisting together of the filaments and their imperfect preservation; fragments of *M. spissa* occur in the same beds which have the characteristic shiny silvery appearance of *M. aequalis.*

MARPOLIA SPISSA, new species

Plate 52, figs. 1, 1*a-b*

Thallus formed of slender, flexuous branched filaments that, twisted together, form an irregular axis from which the filaments extend in tufts or dense masses in the same general direction as they branch at narrow angles; the form of the thallus appears to depend upon how the floating mass of algae happened to settle on the surface of the muddy bottom; often the cæspitose tufts have been so completely torn apart that the shiny, silvery filaments nearly cover the surface of the shale (fig. 1*b*); the filaments are marked by transverse lines into sections a little longer than wide as in the living *Cladophora fracta* (Vahl) Kützing; the outer walls are slightly indented opposite the transverse lines, but I have not been able to discover further details of structures.

The larger tufts average from 3 to 5 cm. in length, and may spread out to 4 or 5 cm. at the top.

Microscopic structure unknown.

Observations.—This species is very abundant on several layers of the shale either as tufts (figs. 1, 1*a*) or scattered filaments. The plants were probably epiphytic, growing in tufts attached to any object and from which they were readily detached by currents or annelids and crustaceans moving about among them. The form of growth is somewhat similar to that of the living *Cladophora arcta* (Dillw.) Kützing, and *C. gracilis* (Griffiths) Kützing (pl. 51, fig. 1), and the transverse walls of the filaments are macroscopically much like those of *Cladophora fracta* (Vahl) Kützing and some species of *Chaetomorpha, C. clavata* (Agardh) Kützing, *C. aerea* (Dillw.) Kützing; comparison should also be made for form with *Ectocarpus mitchellae* Harvey, *E. elegans* Thuret, and *Pylaiella littoralis* (L.) Kjellman.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass; and (14s) *Ogygopsis* zone of the Stephen formation, at the great " fossil bed " on the northwest slope of Mount Stephen, both above Field on the Canadian Pacific Railroad, British Columbia, Canada.

MARPOLIA AEQUALIS, new species

Plate 55, fig. 1

Thallus a tuft of fine branching filaments that when twisted together give the appearance of a central stem and strong branches; the filaments appear to be a little larger than those of *M. spissa,* and they are not as much flattened on the shale; traces of transverse lines are clearly shown on some of the filaments. The one specimen referred to this species has a length of about 4 cm.

Microscopic structure unknown.

Observations.—This form is closely related to *M. spissa* (pl. 52); it differs in being somewhat more robust and in its larger filaments. It may be compared with the living *Cladophora scopaeformis* (Ruprecht) Harvey in its robust habit of growth.

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

CHLOROPHYCEAE (GREEN ALGAE)

Genus YUKNESSIA, new genus

The description of the type species includes what is known of the genus.

Genotype.—*Yuknessia simplex* Walcott.

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

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

YUKNESSIA SIMPLEX, new species

Plate 54, figs. 1, 1*a*-*c*

Thallus small, 2 to 3 mm. in diameter; main stem large, hollow, and covered with closely arranged conical plates, each plate probably forming the base of a long flexuous stipe that shows no evidence of jointing, bifurcating or carrying branches; the stipes are slender and form a thin shiny film on the shale; there does not appear to be any terminal bifurcation, although on one specimen it is suggested by the presence of two whorls of terminal branchlets of *Dalyia racemata* (pl. 56).

Microscopic structure unknown.

Observations.—I placed this form as a possible sertularian when making a preliminary examination of the collection, but it shows no structure warranting it nor is it closely allied to any recent algae; some of the Codiaceae have a strong stem supporting a mass of bifurcating branches, *Penicillus* and *Rhipocephalus,* but here the resemblance ceases as the stipes of *Yuknessia* are unbranched and the stem is covered with plates. Dr. Rudolph Ruedemann describes a somewhat similar form from Ordovician, Trenton, limestone of New York[1] which he placed tentatively with the algae; this has a large plated stem, but the stipes are branched as in *Penicillus.*

There are three well-defined specimens in the collection; one shows a portion of the side of the main stem and the other two the rounded top of the main stem with a number of stipes radiating from it.

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

RHODOPHYCEAE (RED ALGAE)

Family RHODOMELACEAE

Genus WAPUTIKIA, new genus

All that is known of this genus is described under the type species. Its geographic distribution and stratigraphic range are the same as for the genus *Morania* (p. 225).

Genotype.—*Waputikia ramosa* Walcott.

WAPUTIKIA RAMOSA, new species

Plate 54, figs. 2, *2a-b*

Thallus consisting of a rather strong, somewhat flexuous central stem or stipe with relatively strong branches springing from it at irregular intervals; the primary branches give off short secondary

[1] New York State Museum Bull. 133, 1908, pp. 206-207, pl. 3, figs. 1-5.

branches, which give rise to minor branches, and these again divide into branches each having several slender filamentous branchlets attached apparently to the outer side of the branch.

The largest specimen in the collection, which is probably a fragment broken off from a large frond, has a length of 6 cm. with a width of 3 cm.

The central stem and all branches have a black, smooth shiny surface without traces of linear or transverse lines or markings and resemble thin carbonaceous films.

Microscopic structure unknown.

Observations.—The mode of branching of this species recalls the genus *Dasya* of the Rhodophyceae, notably *D. gibbesii* Harvey (pl. 53, fig. 3), which has a more slender stem and branches, but its terminal filaments form foliage-like clusters that resemble those of *Waputikia ramosa* to a surprising degree. The form of the stem and main branches is somewhat similar to those of *Euthora cristata* (Linn.) J. Agardh as shown by herbarium specimens.

When stripped of the terminal filaments the branches resemble those of a branch of a deciduous bush without leaves.

This form is rare as only five specimens were met with in the six years' collecting at the Burgess Pass quarry.

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

DALYIA, new genus

The description of the type species includes practically all that is known of the genus.

Genotype.—*Dalyia racemata* Walcott.

The other species referred to the genus is *D. nitens,* which occurs in the same layer of shale with *D. racemata.*

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

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

DALYIA RACEMATA, new species

Plate 55, figs. 4, *4a-b;* plate 56, figs. 1, *1a-c*

Thallus formed of narrow slender stems or stipes 0.4 to 0.6 mm. in diameter, branching from a simple central stem; the stems are usually pressed flat and show only a smooth surface, but there are a few that have traces of transverse lines, and one fragment of a thallus has distinct transverse lines about a diameter of the stem apart, giving it a jointed appearance, in this respect resembling the stems of the living *Halurus equisetifolius* (Lightf.) Kützing; a single branch may extend out at nearly a right angle to the central stem, as one on each side, or there may be a grouping of three or four radiating from the distal end of the central stem; the plain, straight branches support at their distal end a whorl of stipes or branchlets that vary in length from 3 to 10 mm., and these may also have one or more short branchlets in a whorl of not to exceed five short stipes, as now known. The largest thallus has a length of about 4 cm. Microscopic characters unknown.

Observations.—This species is moderately abundant in a more or less broken up state in one layer of shale along with drifted fragments of crustaceans; it probably flourished in the waters near by and was drifted along by gentle currents until the fragments found a resting place on the muddy bottom.

Among fossil forms *Callithamnopsis fructiosa* (Hall) Whitfield[1] has simple branches bearing terminal whorls of branchlets very similar to those of *D. racemata,* but the general arrangement of the branching is quite dissimilar.

Among living algae fragments of *Griffithsia opuntioides* J. Agardh suggest the terminal branchlets of *Dalyia racemata,* but the branching from the central stem is more like that of *Carpomitra cabrerae* (Clem.) Kützing.

D. racemata differs from *D. nitens* in the attachment of the branches to the central stem and in the form of the whorls at the end of the branches.

Formation and locality.—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, on the west slope of the ridge betwen Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, also (14s) *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3,540 feet (1,089 m.) below the Upper Cambrian, at the great

[1] Bull. American Museum Nat. Hist., Vol. 6, 1894, p. 354, pl. 11, figs. 4-8.

" fossil bed " on the northwest slope of Mount Stephen, both above Field on the Canadian Pacific Railroad, British Columbia.

DALYIA NITENS, new species

Plate 55, fig. 3

Thallus known only by a single specimen, consisting of a fragment of the central stem, with two branches that are attached to globose or pyriform enlargements of the main stem; the straight, slender branches have a pyriform enlargement at the distal end that supports a whorl of at least five slender branchlets or pinnules that do not show in the specimen evidence of further division; the appearance of the flattened stem suggests that it was hollow and of a carbonaceous nature. The fragment of the thallus preserved has a length of 15 mm.

Microscopic characters unknown.

Observations.—Among fossil forms this species may be compared with the Ordovician species *Callithamnopsis fructiosa* Whitfield,[1] with respect to its slender branches with enlarged distal end and whorl of branchlets; the latter species does not have the enlargement of the main stem where the branches arise, and its general aspect is dissimilar. There does not appear to be any recent alga that resembles this species in external appearance.

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

Genus WAHPIA, new genus

The description of the type species includes all that is known of the genus.

Genotype.—Wahpia insolens Walcott.

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

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

[1] Bull. American Museum Nat. Hist., Vol. 6, 1894, p. 354, pl. 11, figs. 4-8.

WAHPIA INSOLENS, new species

Plate 57, figs. 1, 1*a*

Thallus consisting of a long central stem with long slender branches that spring from it at an angle of about 45°; these give rise to a few minor branches of the same character. A second specimen has four successive branchings with possibly a very delicate branching at the end of the fourth member. The surface of the stem and larger branches is marked by a strong median line with clearly defined edges, which indicates that they represent hollow stems flattened on the shale. Microscopic structure unknown.

The largest specimen has a total length of 8 cm.

Observations.—Both of the two specimens found of this species appear to be drift fragments from which most of the finer branches have been broken off. *W. insolens* branches in a similar manner to the recent marine algae *Ahnfeldtia plicata* (Huds.) Fries and *Cystoclonium purpurascens* (Huds.) Kützing. A stem of the latter with extensions of the branches broken off, resembles closely *W. insolens.* Comparison should also be made with *Ahnfeldtia concinna* J. Agardh and *Gymnogongrus leptophyllus* J. Agardh, which have a somewhat similar form of branching.

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

WAHPIA MIMICA, new species

Plate 55, fig. 2

Of this species only one broken specimen of the thallus has been found. The stem and branches are narrow, rigid, and have left a strong impression on the shale; the primary branches are numerous and alternate on opposite sides of the stem in their flattened condition; the secondary branchlets are also numerous and have the same arrangement as the main branches; some of the long secondary branches appear to bifurcate towards their distal end.

Microscopic structure unknown.

Observations.—This form has several of the characters of *Wahpia insolens,* but it differs in its more numerous branches and branchlets. Its round stem and manner of branching strongly suggest the recent

Ahnfeldtia plicata (Huds.) Fries or *Ceramium rubrum* (Huds.) Agardh.

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

WAHPIA VIRGATA, new species

Plate 57, fig. 2

This species differs from *W. insolens* and *W. mimica* in having a larger proportional central stem and more flexuous branches and branchlets. The mode of branching and flexuous branches and branchlets may be compared with the recent species *Ceramium nitens* J. Agardh.

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

BOSWORTHIA, new genus

All that is known of this genus is described under the type species. Its geographic distribution and stratigraphic range are the same as the genus *Morania* (p. 225).

Genotype.—Bosworthia simulans Walcott.

BOSWORTHIA SIMULANS, new species

Plate 57, fig. 3; plate 58, figs. 1, 1*a*

Thallus formed of flexuous, membranous branches decompoundly branched to a limited degree and with two or three narrow branchlets near the extremities of the larger branches; as flattened out on the shale the stipes vary from 2.5 mm. in width to 0.5 mm. at the outer ends; the thin membranous ribbon-like stipes were evidently easily folded, twisted and sprawled on the surface of the mud, or the thallus may have been compact and when pressed flat in the laminations of the muddy sediment the stipes were matted down on each other; only traces of the carbonaceous matter remain on the specimens.

The thallus known to us has a length of 8 cm. and a width of 3.5 cm.; it narrows at the base as though attached to a central stem at the base, and also narrows slightly towards the top.

Observations.—Of this form only two specimens have been found; one of them (pl. 58, fig. 1) shows the branches grouped closely and matted down on each other, and in the other (pl. 57, fig. 3) they have been spread out and more or less displaced as though a portion of the thallus had been torn off and drifted along by the current.

Among living algae *Dumontia filiformis* (Huds.) Greville (Rhodophycea) has a somewhat similar form of growth, and possibly some species of the Phaeophyceae, *Dictyota ciliata* J. Agardh and *D. fasciola* (Roth) Lamour. may be compared with *B. simulans*. The recent species have similar flexuous, membranous stipes that branch in nearly the same manner. Among fossil forms *Polyaedictyota ramulosa* (Spencer)[1] of the Silurian has a somewhat similar form of growth and appearance.

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

BOSWORTHIA GYGES, new species

Plate 58, fig. 2

Thallus formed of delicate ribbon-like branches rising from a central base and forming a compact frond-like mass on the shale; the branches as flattened on the shale are about 1 mm. in width and the branching is obscured by their close grouping; the one specimen known of the species has a length of about 3.25 cm.

Microscopic structure unknown.

Observations.—This species differs from *B. simulans* in its compact thallus and less flexuous branches. It adds one more species to the relatively rich plant life of the Burgess shale and seems to be worthy of recognition.

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

CALCAREOUS ALGAE

Genus SPHAEROCODIUM Rothpletz

Sphaerocodium Rothpletz, 1890, Bot. Centralbl., vol. 41, p. 9.

[1] See Whitfield, Bull. American Mus. Nat. Hist., Vol. 16, 1902, p. 399, pl. 53, figs. 1, 2.

SPHAEROCODIUM ? PRAECURSOR, new species

Plate 59, figs. 1, 1*a-c*

This species occurs as a very small free thallus as shown by transverse sections found in thin sections cut from the Burgess shale. The exterior walls have been destroyed by solution and replaced by a mass of fine calcite crystals (figs. 1, 1*a-b*). The interior of the mass is filled with sections of what were probably irregular tubes that have been obscured and often destroyed by the recrystallization of the mineral matter of the original structure. The convolutions of the tubes appear to have been short and without any recognizable arrangement in the sections available for study.

Measurements.—The larger masses are from 0.6 mm. to 1.75 mm in diameter with tubes about 0.01 to 0.015 mm. across.

Observations.—This species is represented by larger specimens than *Sphaerocodium ? cambria* and its tubular structure is also coarser and less definitely arranged; its structure may be compared with that of *S. munthei* Rothpletz[1] (pl. IV, fig. 4) but owing to its imperfect condition none of the finer details can be determined.

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

SPHAEROCODIUM ? CAMBRIA, new species

Plate 59, fig. 2

This is a microscopic form the thin sections of which show numerous fine, irregularly arranged tubes that resemble those of *S. gothlandicum* Rothpletz.[1] The thallus and tubes are much more minute than those of *S. praecursor.*

Dimensions.—The type specimen is broken off along the margins—it is approximately 0.0255 mm. across; the tubes are about 0.0006 to 0.0008 mm. in diameter.

Observations.—Only one specimen of this species has been located in the slides although several were seen in a preliminary examination of slides when a locating and measuring stage was not available.

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

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[1] Sveriges Geol. Unders., Ser. Ca, No. 10, 1913, p. 19, pl. 4, figs. 1, 2.

DESCRIPTION OF PLATE 43

PAGE

Morania confluens Walcott (See pls. 44, 45 and 58) 226

Fig. 1. (× 90.) Strings of round, cell-like bodies formed of pyrite and broken strings of smaller and similar bodies; cubes of pyrite are scattered in the thin rock slide, which is photographed by transmitted light. (Slide No. 25.)

2. (× 200.) Still further enlargement of strings of cell-like bodies formed of pyrite. (Slide No. 81.)

3, 3*a*. (× 1,000.) A few scattered balls of pyrite, some of which show in outline a botryoidal appearance. (Slide No. 81.)

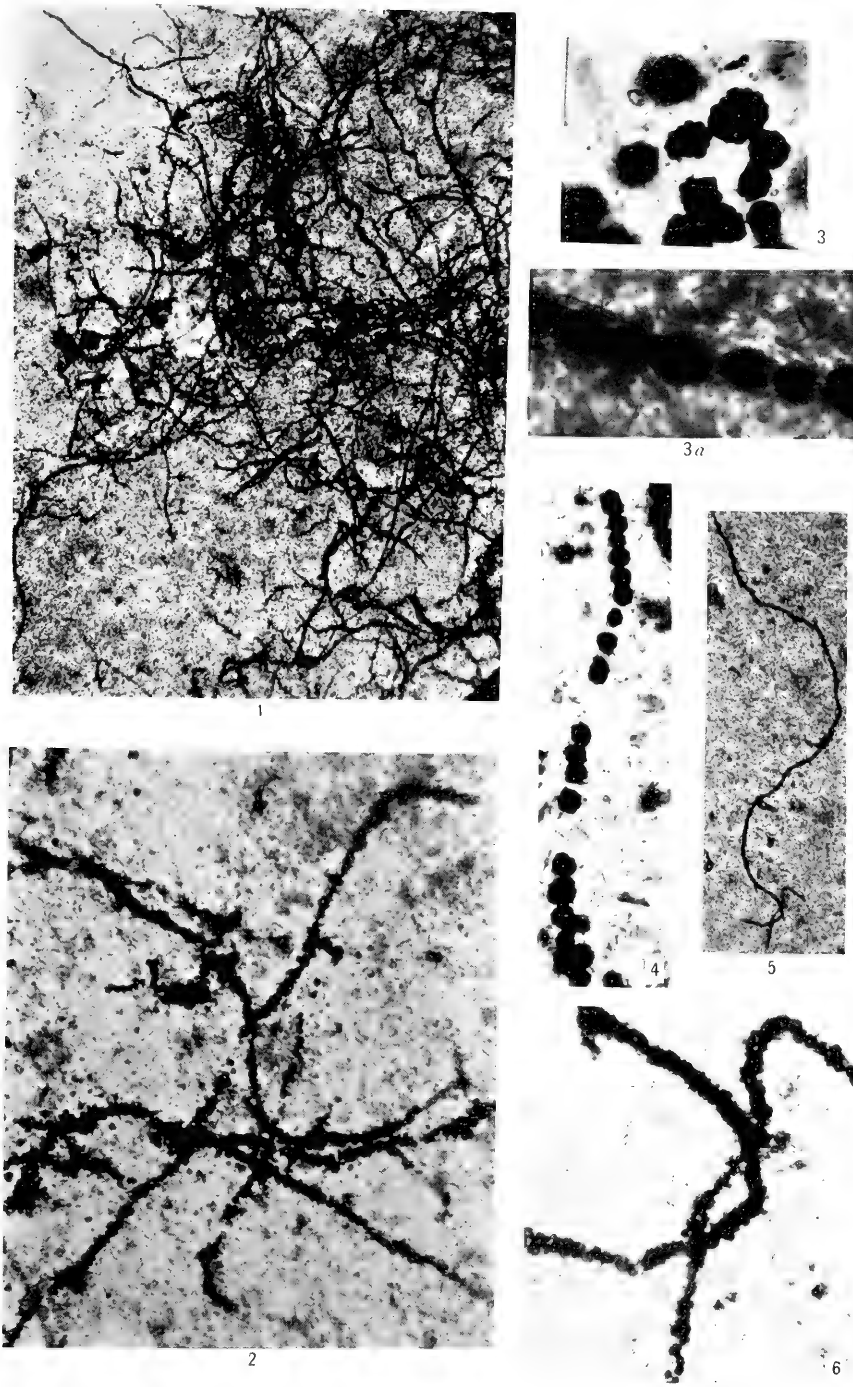
4. (× 400.) A broken chain of round cell-like bodies. (Slide No. 81.)

5. (× 60.) A flexuous chain crossed at the lower end by a fragment of a chain. (Slide No. 96.)

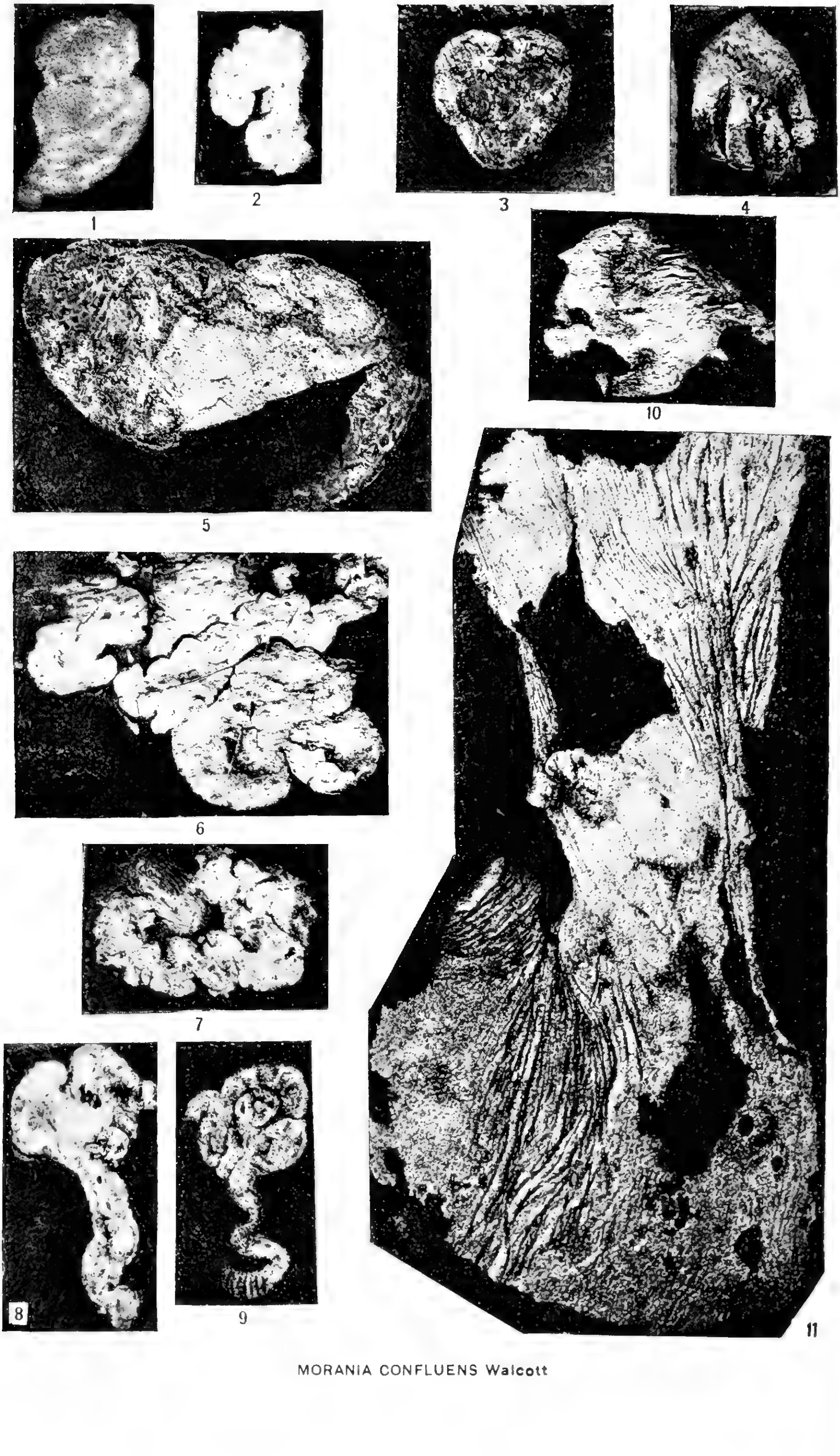
6. (× 250.) Enlargement of the lower end of the chain represented by fig. 5.

The chains and balls represented by the above-described figures occur in thin rock sections cut on the plane of flattened specimens of the alga *Morania confluens* (See pls. 44, 45) as it occurs on the surface of the shale.

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



CHAINS AND BALLS ASSOCIATED WITH MORANIA CONFLUENS Walcott



MORANIA CONFLUENS Walcott

DESCRIPTION OF PLATE 44

PAGE

MORANIA CONFLUENS Walcott (See pls. 43, 45, and 58) 226

FIGS. 1 and 2. (Natural size.) Two small groups or colonies that were held together by a gelatinous mass which now forms a film on the surface of the shale. U. S. National Museum, Catalogue Nos. 35378 and 35379.

3 and 4. (× 2.) Small, irregular and somewhat thicker films than those represented by figs. 1 and 2. U. S. National Museum, Catalogue Nos. 35380 and 35381.

5. (× 2.) Portion of a membranous frond that has been distorted and torn. U. S. National Museum, Catalogue No. 35382.

6. (Natural size.) Several small plant masses that have been flattened down together on the shale, some of which have the outlines shown by figs. 1 and 2. U. S. National Museum, Catalogue No. 35383.

7. (Natural size.) Another group of small plant masses with one on the upper side that appears to be *Morania ? costellifera*. (See pl. 47, figs. 1, 2.) U. S. National Museum, Catalogue No. 35384.

8. (Natural size.) An irregular plant mass with part extended on the shale. U. S. National Museum, Catalogue No. 35385.

9. (× 2.) A small plant mass similar to that represented by fig. 8, with what may have been an annelid trail extending down from it. U. S. National Museum, Catalogue No. 35386.

10. (× 2.) Fragment of a plant mass with lacunae extending through it. U. S. National Museum, Catalogue No. 35387.

11. (× 3.) Portion of a large plant mass that has been laterally compressed so as to give it an irregularly finely wrinkled surface. U. S. National Museum, Catalogue No. 35388.

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

DESCRIPTION OF PLATE 45

PAGE

MORANIA CONFLUENS Walcott (See pls. 43, 44, and 58) 226

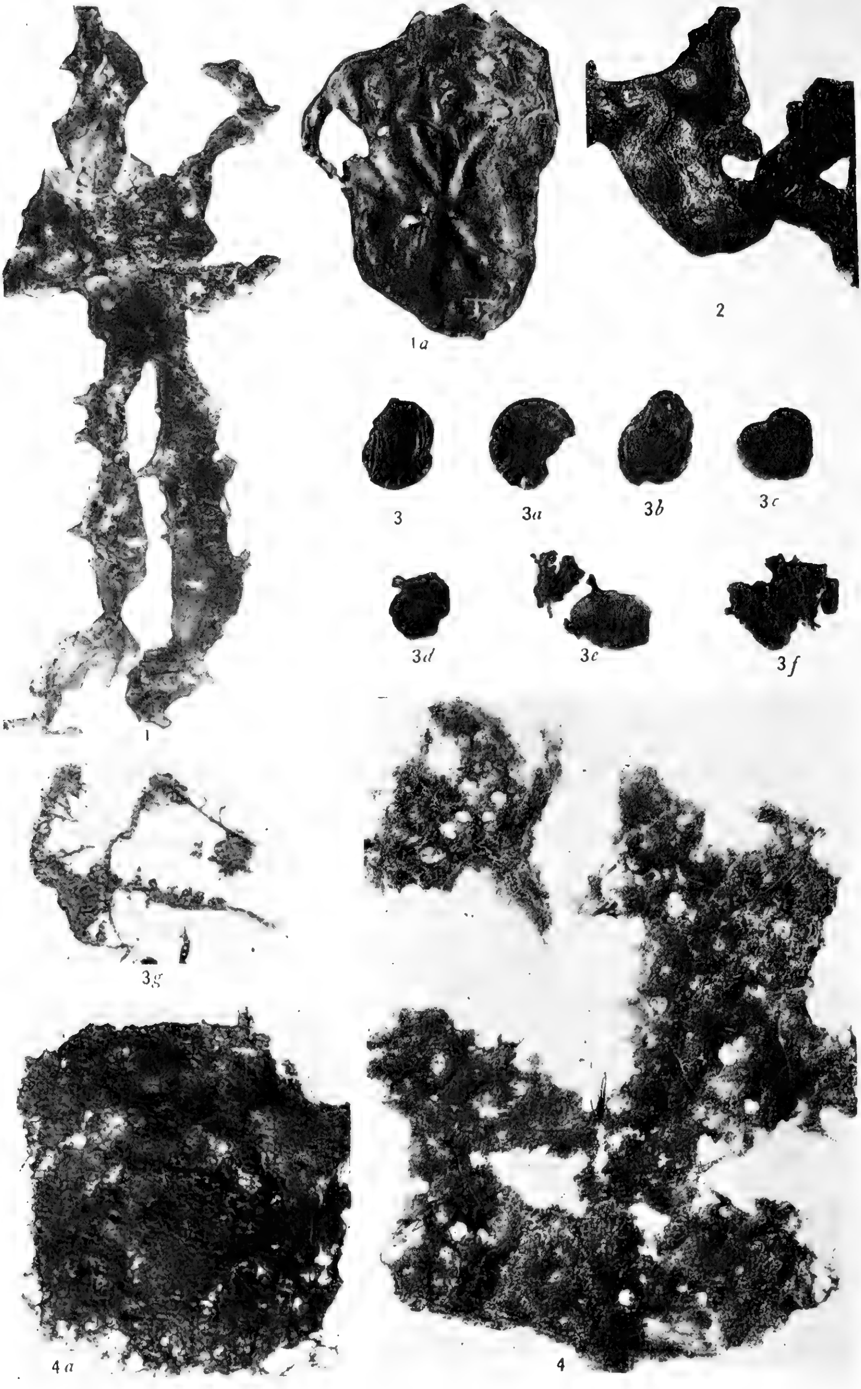
FIG. 1. (× 4.) A torn, irregular fragment of a large plant mass with numerous lacunae. The surface is striated or finely wrinkled longitudinally by lateral compression. U. S. National Museum, Catalogue No. 35389.

1*a*. (Natural size.) A fragment of a gelatinous-appearing plant mass with numerous lacunae. U. S. National Museum, Catalogue No. 35390.

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

MORANIA CONFLUENS Walcott

3



RECENT ALGAE

1. Nostoc commune Vaucher
2. Nostoc verrucosum (Linn.) Vaucher
3. Nostoc parmeloides Vaucher
4. Anabaena variabilis Kützing

DESCRIPTION OF PLATE 46

PAGE

NOSTOC COMMUNE Vaucher 228

FIG. 1. (Natural size.) Fragment of a plant mass flattened by pressure, for comparison with the fossil form *Morania confluens* (fig. 1, pl. 45).

1a. (Natural size.) A plant mass with unbroken outline, flattened by pressure, for comparison with the fossil forms of *Morania confluens* (figs. 1-5, pl. 44) and *M. ? globosa* (figs. 2, 2a-c, pl. 48).

NOSTOC VERRUCOSUM (Linn.) Vaucher 228, 229

FIG. 2. (Natural size.) Portion of a plant mass, flattened by pressure, that has a finely wrinkled surface similar to that of some fossil specimens of *Morania confluens* (fig. 11, pl. 44).

NOSTOC PARMELIOIDES Kützing 229

FIGS. 3, 3a-d. (Natural size.) More or less circular plant masses, flattened by pressure, that suggest the fossil form *Morania costellifera* (figs. 1, 2, pl. 47).

3e-g. (Natural size.) Broken and irregular plant masses that may be compared in form with the fossil *Morania fragmenta* (fig. 1, pl. 48).

ANABAENA VARIABILIS Kützing 228, 231

FIG. 4. (Natural size.) Plant mass flattened on paper. The lacunae and mode of spreading out suggest the fossil forms, *Morania confluens* (fig. 1, pl. 45), *M. frondosa* (fig. 1, pl. 49), and *M. reticulata* (fig. 2a, pl. 52).

4a. (Natural size.) A more dense mass of this species.

All of the figures on this plate are reproductions of photographs of specimens of recent algae in the National Herbarium at the Smithsonian Institution.

DESCRIPTION OF PLATE 47

PAGE

MORANIA COSTELLIFERA Walcott.. 229

FIGS. 1 and 2. (× 3.) Two specimens showing sharp wrinkles of costae which have given the name to the species. U. S. National Museum, Catalogue Nos. 35391 and 35392.

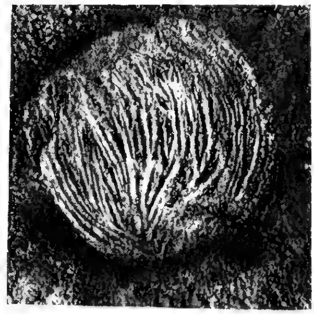
MORANIA ELONGATA Walcott.. 229

FIG. 3. (Natural size.) Portion of a specimen as it appears on the shale. U. S. National Museum, Catalogue No. 35393.

3a. (× 4.) Enlargement of the central portion of the specimen represented by fig. 3, illustrating the general appearance of the species.

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

3a



1

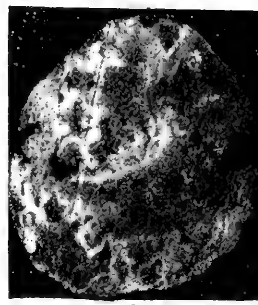
2

3

1, 2. Morania ? costellifera Walcott
3, 3a. Morania elongata Walcott

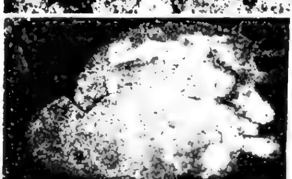
1a

1

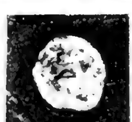


2

2a



2d



2b

2c

1. Morania fragmenta Walcott
2. Morania ? globosa Walcott

DESCRIPTION OF PLATE 48

PAGE

MORANIA FRAGMENTA Walcott 230

FIG. 1. (Natural size.) A typical illustration of this species as it occurs on the surface of the shale. U. S. National Museum, Catalogue No. 35394.

1*a*. (× 4.) A portion of the specimen represented by fig. 1, enlarged to show the character of the fragments.

MORANIA ? GLOBOSA Walcott 231

FIG. 2. (Natural size.) A specimen flattened on the shale and showing only a thin gelatinous appearing film. U. S. National Museum, Catalogue No. 35395.

2*a*. (× 2.) A still more gelatinous appearing specimen than that represented by fig. 2. U. S. National Museum, Catalogue No. 35396.

2*b*. (Natural size.) A small round specimen resembling that illustrated by fig. 2. U. S. National Museum, Catalogue No. 35397.

2*c*. (× 3.) Enlargement of the specimen represented by figure 2*b*.

2*d*. (× 2.) A distorted specimen which may be one of the smaller plant masses of *Morania confluens*. U. S. National Museum, Catalogue No. 35398.

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

DESCRIPTION OF PLATE 49

PAGE

MORANIA ? FRONDOSA Walcott.. 231

FIG. 1. (Natural size.) Portion of the frond described in the text. U. S. National Museum, Catalogue No. 35399.

1a. (× 2.) Enlargement of a portion of the specimen represented by fig. 1, to illustrate the lacunae.

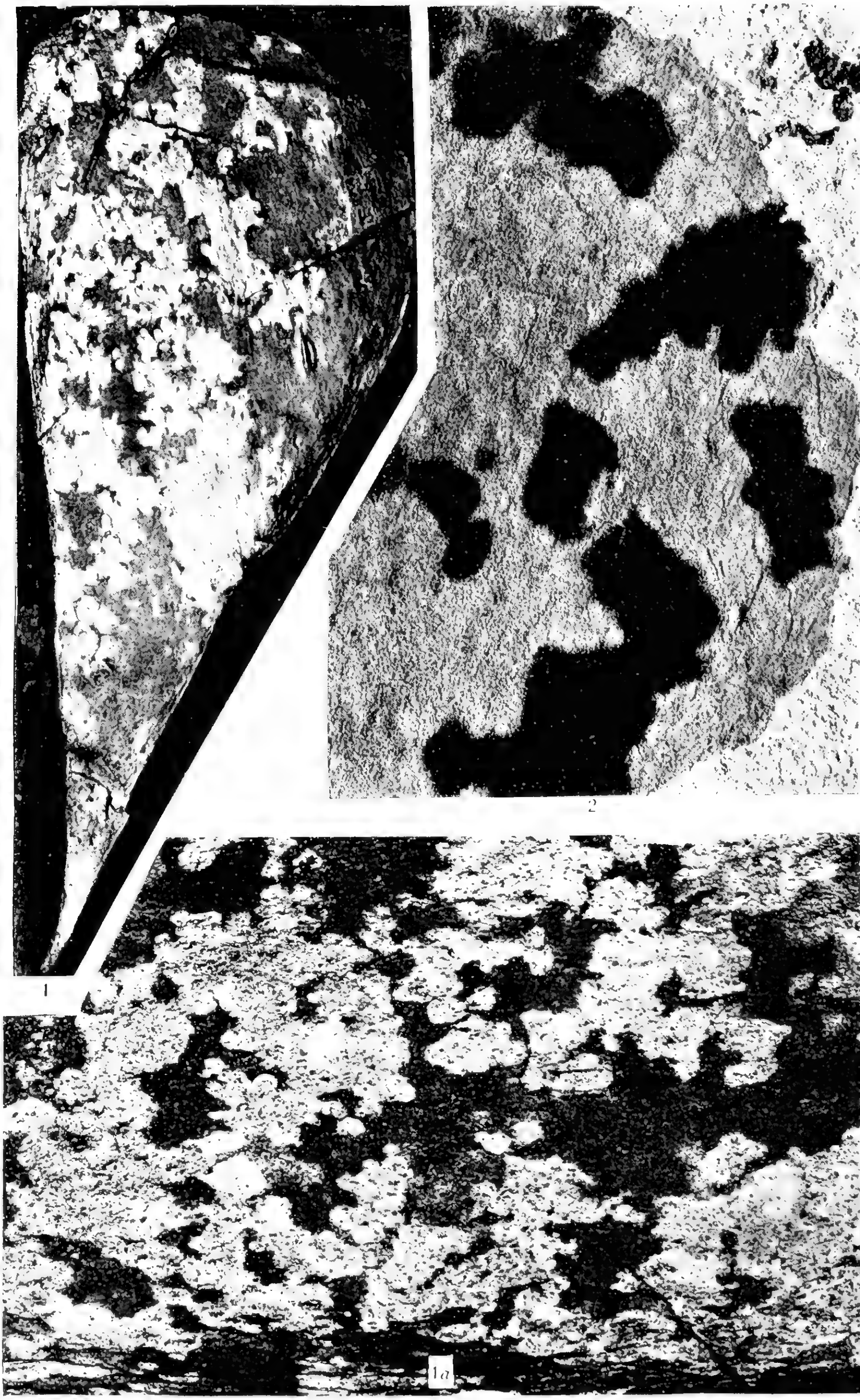
MORANIA species undetermined..

FIG. 2. (Natural size.) Fragment of what may have been an undetermined species of *Morania*. U. S. National Museum, Catalogue No. 35400.

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

1a

1. Morania frondosa Walcott
2. Morania sp. undt.



MORANIA PARASITICA Walcott

DESCRIPTION OF PLATE 50

PAGE

MORANIA PARASITICA Walcott 232

FIG. 1. (Natural size.) A specimen of *Hurdia victoria*[1] more or less encrusted with this species. U. S. National Museum, Catalogue No. 57718.

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

2. (× 3.) Portion of a specimen of *Morania ? globosa* encrusted with this species. U. S. National Museum, Catalogue No. 35401.

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

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[1] Smithsonian Misc. Coll., Vol. 57, 1912, p. 186, pl. 32, fig. 9.

DESCRIPTION OF PLATE 51

PAGE

CLADOPHORA GRACILIS (Griffiths) Kützing.................................. 234

FIG. 1. (× 2.) Portion of a plant mass spread and flattened on a card, for comparison with the fossil form, *Marpolia spissa* (figs. 1, 1*a-b*, pl. 52).

DUMONTIA FILIFORMIS (Huds.) Greville.................................. 242

FIG. 2. (Natural size.) Portion of a plant opened and pressed flat on a card for comparison with the fossil form *Bosworthia simulans* (fig. 1*a*, pl. 58).

All of the figures on this plate are reproductions of photographs of specimens of recent algae in the National Herbarium at the Smithsonian Institution.

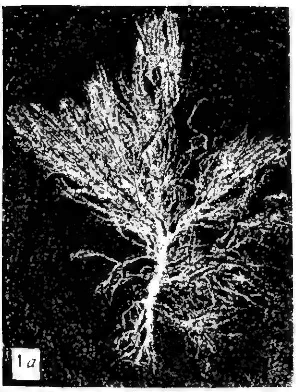
1

2

RECENT ALGAE

1. Cladophora gracilis (Griffith) Kützing
2. Dumontia filiformis (Huds.) Greville

1



1b

2

1. Marpolia spissa Walcott
2. Morania reticulata Walcott

DESCRIPTION OF PLATE 52

PAGE

MARPOLIA SPISSA Walcott 234

FIG. 1. (× 2.) Portions of a thallus with the filaments twisted into stems and extending as tufts as they branch at narrow angles. U. S. National Museum, Catalogue No. 35403.

1a. (× 2.) A specimen with the filaments more loosely arranged than in fig. 1. U. S. National Museum, Catalogue No. 35404.

1b. (× 4.) Enlargement of a portion of the surface of a fragment of shale that is thickly strewn with broken filaments of this species. U. S. National Museum, Catalogue No. 35405.

MORANIA ? RETICULATA Walcott 233

FIG. 2. (Natural size.) A frondlike mass of this species partly covered by *Morania confluens.* U. S. National Museum, Catalogue No. 35402.

2a. (× 4.) Enlargement of a portion of specimen represented by fig. 2, to illustrate the lacunae of the frond.

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

DESCRIPTION OF PLATE 53

PAGE

NOSTOC SPHAERICUM Vaucher 231

FIG. 1. (Natural size.) A group of plant masses, flattened on a card, for comparison with the smaller specimens of the fossil species of *Morania ? globosa* (fig. 2*b*, pl. 48), and when broken, with *Morania fragmenta* (figs. 1, 1*a*, pl. 48).

NOSTOC PRUNIFORME (Linn.) Agardh 232

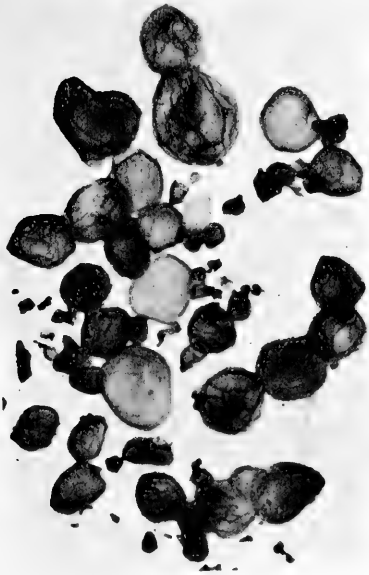
FIG. 2. (Natural size.) Two plant masses flattened on a card that resemble very closely similar circular films of the fossil species *Morania globosa* (figs. 2, 2*a*, 2*c*, pl. 48).

DASYA GIBBESII Harvey 237

FIG. 3. (× 2.) Portion of a plant flattened on a card, for comparison with the fossil species *Waputikia ramosa* (fig. 2, pl. 54).

3*a*. (× 2.) Portion of a stem for comparison with the stem of the fossil species *Waputikia ramosa* (fig. 2*b*, pl. 54).

All of the figures on this plate are reproductions of photographs of specimens of recent algae in the National Herbarium at the Smithsonian Institution.



1

2

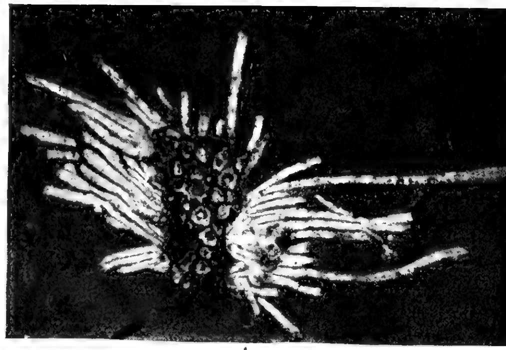
3

3a

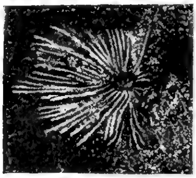
RECENT ALGAE

1. Nostoc sphaericum Vaucher
2. Nostoc pruniforme (Linn.) Agardh
3. Dasya gibbesii Harvey

1

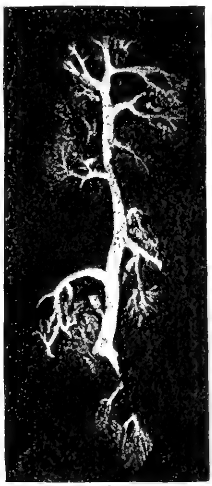


1*a*

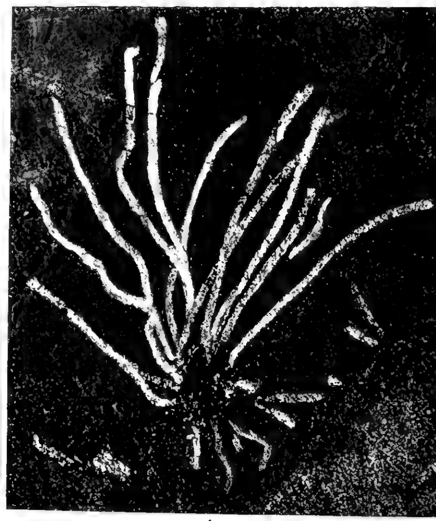


1*b*

2*a*



2*b*



1*c*

2

1. Yuknessia simplex Walcott
2. Waputikia ramosa Walcott

DESCRIPTION OF PLATE 54

PAGE

YUKNESSIA SIMPLEX Walcott 235

FIG. 1. (× 2.) Type specimen flattened on the shale. U. S. National Museum, Catalogue No. 35406.

1a. (× 3.) Sketch of specimen illustrated by fig. 1.

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

1b. (× 3.) The upper portion of a small specimen showing the radiating stipes. U. S. National Museum, Catalogue No. 35407.

1c. (× 4.) Stipes radiating from the summit of the central body of a relatively large specimen. U. S. National Museum, Catalogue No. 35408.

WAPUTIKIA RAMOSA Walcott 236

FIG. 2. (× 2.) A flexuous stem with branches illustrating the appearance of the plant when pressed flat on the shale. U. S. National Museum, Catalogue No. 35409.

2a. (× 3.) Fragment of a small stem and main branches that have been stripped of the secondary branches and branchlets. U. S. National Museum, Catalogue No. 35410.

2b. (× 2.) A central stem with branches partly stripped of the secondary branches and branchlets. U. S. National Museum, Catalogue No. 35411.

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

DESCRIPTION OF PLATE 55

PAGE

MARPOLIA AEQUALIS Walcott 235

FIG. 1. (× 2.) An elongated tuft of branching filaments, portions of which twisted together give the appearance of a central stem and branches. U. S. National Museum, Catalogue No. 35412.

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

WAHPIA MIMICA Walcott 240

FIG. 2. (× 2.) Type specimen illustrating stem and form of branches. U. S. National Museum, Catalogue No. 35413.

DALYIA NITENS Walcott 239

FIG. 3. (× 3.) Central stem with branches and whorl of branchlets at the end of each. U. S. National Museum, Catalogue No. 35414.

DALYIA RACEMATA Walcott (See pl. 56) 238

FIG. 4. (× 4.) Whorl of branchlets that may belong to this species. U. S. National Museum, Catalogue No. 35415.

4*a*. (× 3.) Branches and whorls of branchlets that may belong to this species, but more probably indicate a distinct form. U. S. National Museum, Catalogue No. 35416.

4*b*. (× 3.) A fine branch showing variation in form from those represented on plate 56, U. S. National Museum, Catalogue No. 35417.

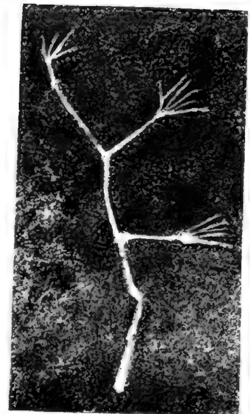
The specimens represented by figs. 2-4, 4*a* are from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railroad, British Columbia.

4*c*. (× 3.) A specimen of this species occurring in the Mount Stephen fossil bed, 3 miles (4.8 km.) in an air line from the Burgess Pass quarry. U. S. National Museum, Catalogue No. 35418.

From locality 14s, as given above under fig. 1.


1


2


3


4a

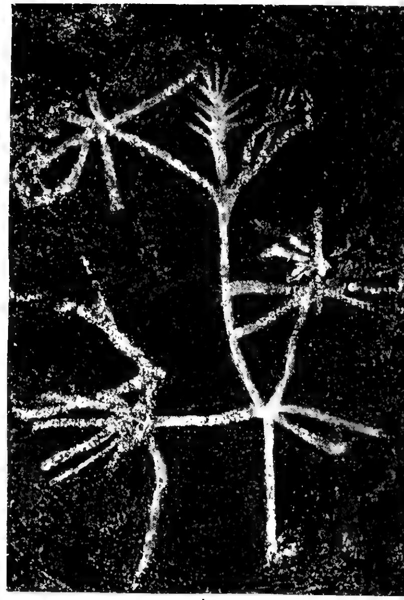

4


4c


4b

1. Marpolia aequalis Walcott
2. Wahpia mimica Walcott
3. Dalyia nitens Walcott
4. Dalyia racemata Walcott

1



1a

1b

1c

DALYIA RACEMATA Walcott

DESCRIPTION OF PLATE 56

PAGE

DALYIA RACEMATA Walcott (See pl. 55) 238

FIG. 1. (× 2.) A group of stems with branches and whorls enlarged on a smaller scale than the specimens represented by figs. *1a*, *1b*, and *1c*. U. S. National Museum, Catalogue No. 35419.

1a, *1b*. (× 3.) Specimens illustrating variation in the mode of branching. The center upper stipe of fig. *1a* results, I think, from the pressing together of a number of short branchlets. This tendency is shown in fig. *1c*. U. S. National Museum, Catalogue Nos. 35420, 35421.

1c. (× 4.) Specimen with closely grouped branchlets on the terminal whorls which suggest the specimen illustrated by fig. 4, pl. 55. U. S. National Museum, Catalogue No. 35422.

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

DESCRIPTION OF PLATE 57

PAGE

WAHPIA INSOLENS Walcott.. 240

FIGS. 1, 1*a*. (Natural size.) Two specimens flattened on the shale, illustrating the mode of branching. U. S. National Museum, Catalogue Nos. 35423, 35424.

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

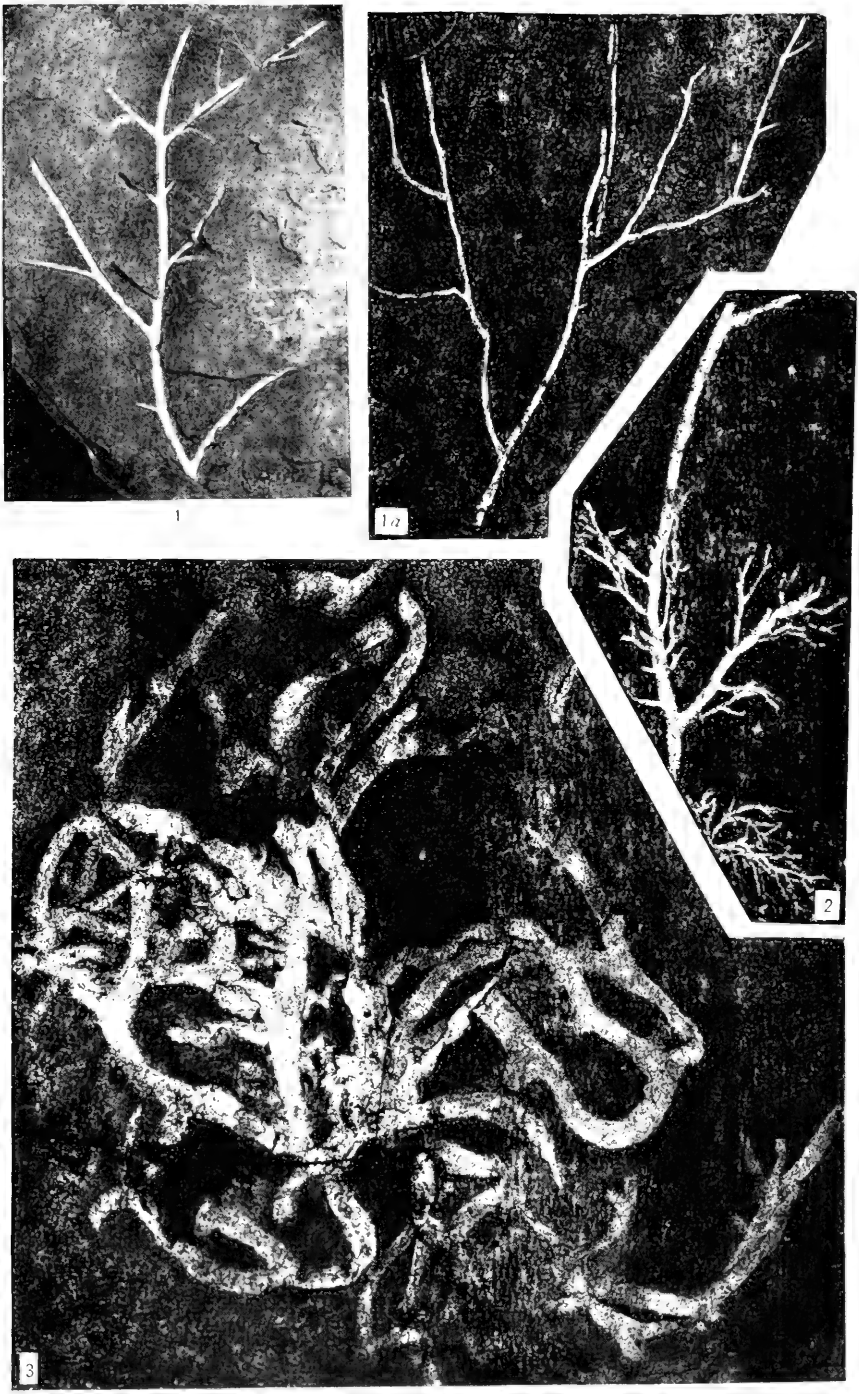
WAHPIA VIRGATA Walcott.. 241

FIG. 2. (× 3.) Type specimen of the species. U. S. National Museum, Catalogue No. 35425.

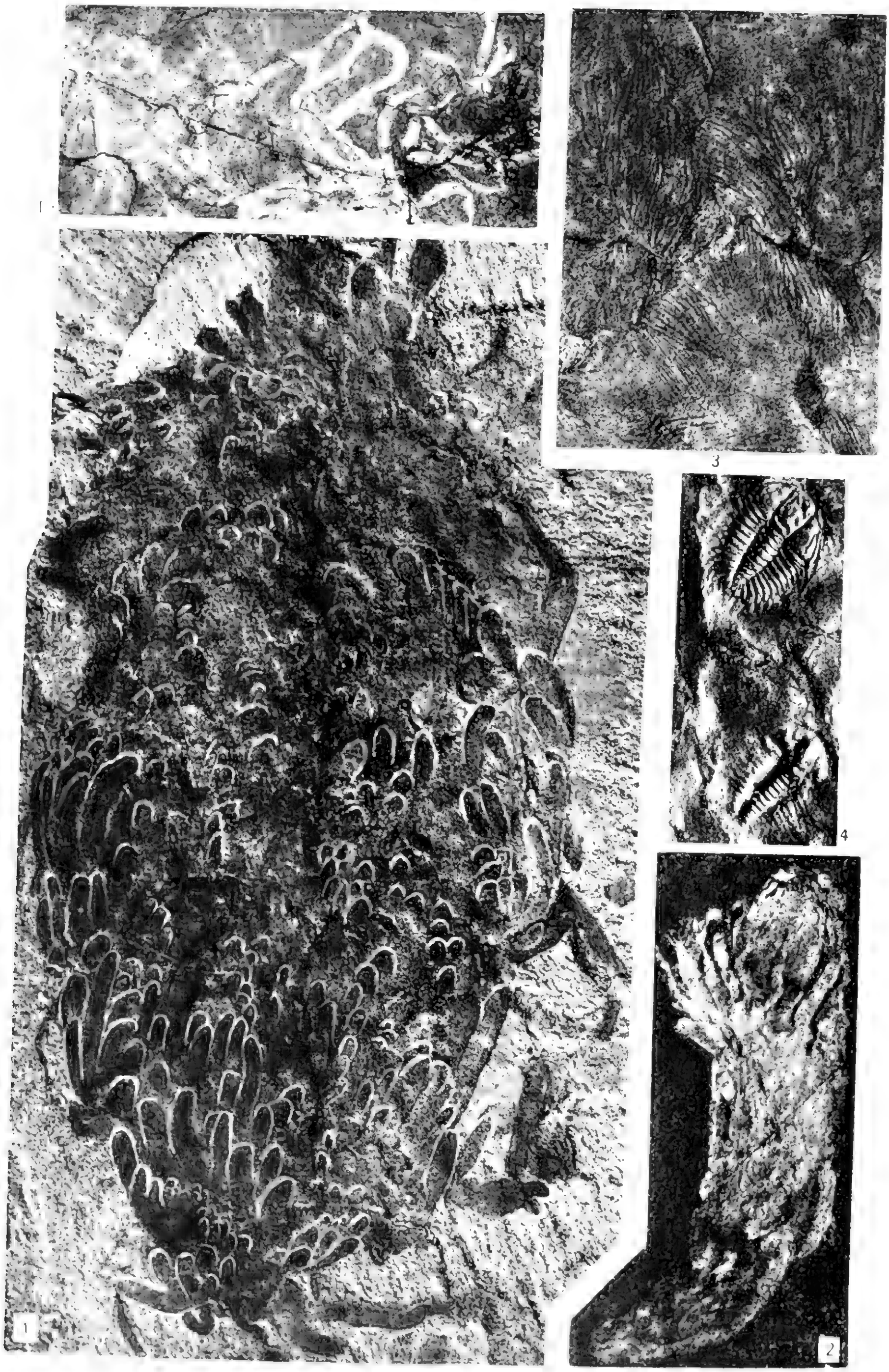
BOSWORTHIA SIMULANS Walcott (See pl. 58, fig. 1)..................... 241

FIG. 3. (× 2.) Illustration of the flexuous branches pulled apart and pressed flat on the surface of the shale. U. S. National Museum, Catalogue No. 35426.

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



1. Wahpia insolens Walcott
2. Wahpia virgata Walcott
3. Bosworthia simulans Walcott



1. Bosworthia simulans Walcott
2. Bosworthia gyges Walcott
3. Morania confluens Walcott
4. Morania with trilobites

DESCRIPTION OF PLATE 58

PAGE

BOSWORTHIA SIMULANS Walcott (See pl. 57, fig. 3) 241

FIG. 1. (× 2.) A specimen illustrating the probable outline of the thallus when occurring in a compact form. U. S. National Museum, Catalogue No. 35427.

1*a*. (Natural size.) Specimen illustrated by enlarged figure on pl. 57, fig. 3. U. S. National Museum, Catalogue No. 35426.

BOSWORTHIA GYGES Walcott 242

FIG. 2. (× 2.) Type specimen illustrating the form and mode of growth of this species. U. S. National Museum, Catalogue No. 35428.

MORANIA CONFLUENS Walcott (See pls. 43, 44, 45, and 58) 226

FIG. 3. (× 3.) Portion of the surface of a frond showing fine strands and wrinkles. U. S. National Museum, Catalogue No. 35429.

MORANIA and Trilobites 220

FIG. 4. (× 2.) The upper trilobite (*Oryctocephalus reynoldsi* Reed) is resting on a piece of *Morania,* and the lower trilobite (*Ptychoparia*) is covered with a thin layer of it as described in the text. U. S. National Museum, Catalogue No. 35430.

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

DESCRIPTION OF PLATE 59

PAGE

SPHAEROCODIUM ? PRAECURSOR Walcott 243

FIGS. 1 (× 73) and 1*a*. (× 85.) Thin sections across the thallus of two small specimens. The outer wall is replaced by a narrow band of calcite crystals that extend somewhat irregularly into the sponge and the irregular tubular structure fills in the entire central space. Slide No. 79. 1 is located on stage at 101.5 + 43; 1*a* on stage at 102 + 48.2. U. S. National Museum, Catalogue No. 35431.

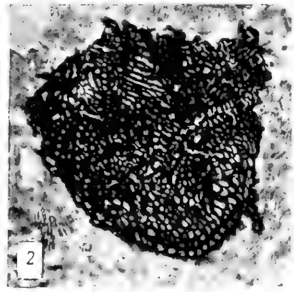
1*b*. (× 365.) Further enlargement of a portion of the thallus on the left side of the specimen represented by fig. 1.

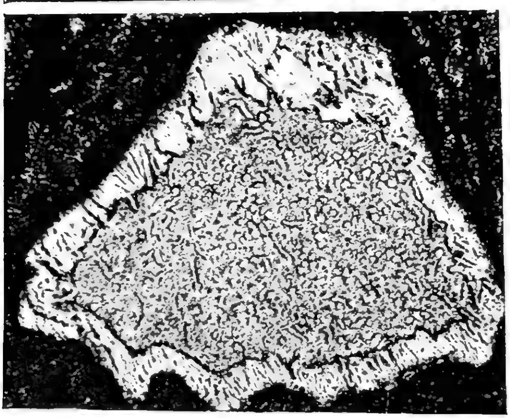
1*c*. (× 500.) Enlargement of a portion of specimen in slide No. 78, located on stage at 109 + 43. U. S. National Museum, Catalogue No. 35431.

SPHAEROCODIUM CAMBRIA Walcott 243

FIG. 2. (× 1200.) A minute thallus showing the ends and oblique sections of the twisting, irregularly distributed tubes. Thin rock slide No. 45, located on stage at 105.5 + 39. U. S. National Museum, Catalogue No. 35432.

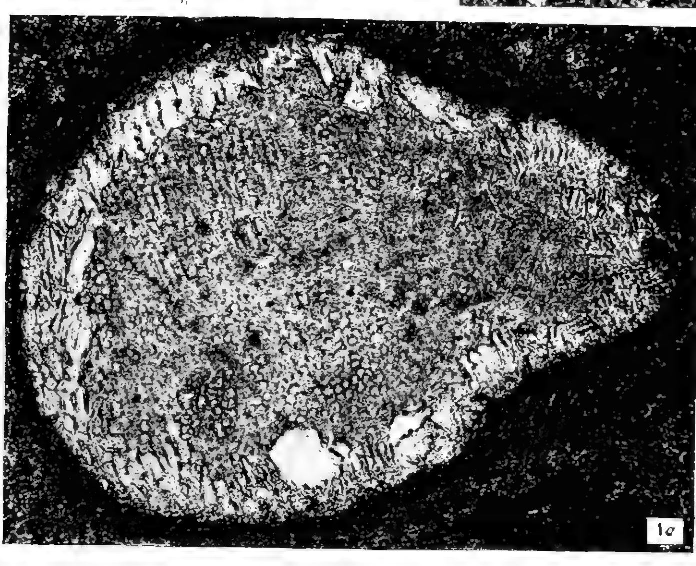
The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.





1.

1c



1. Sphaerocodium ? praecursor Walcott
2. Sphaerocodium ? cambria Walcott

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 6

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 6.—MIDDLE CAMBRIAN SPONGIAE

(With Plates 60 to 90)

BY
CHARLES D. WALCOTT

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No. 6.—MIDDLE CAMBRIAN SPONGIAE

By CHARLES D. WALCOTT

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ILLUSTRATIONS

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INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Sub-Class Silicispongiae

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

[1] Trans. Royal Soc. Canada, 2d ser., Vol. 2, Sec. IV, 1896, p. 99.

[2] Text Book of Pal., Eastman, 2d ed., 1913.

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

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

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

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

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

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

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

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

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

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. XX, 1887, pp. 19-25, 151-155, pls. 4, 5, 6, 28, 29, and 46.

[2] Idem, p. 218, pl. XLIII, figs. 1-4.

[3] Idem, Vol. XXI, 1887, pls. 93, 94.

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

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

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

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

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

[4] Idem, p. 97.

[5] Idem, p. 121.

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

[7] Idem, p. 119.

[8] Idem, p. 705.

DESCRIPTION OF SPECIES

Sub-Class SILICISPONGIAE

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

Order MONACTINELLIDA Zittel

(MONAXONIDAE Sollas)

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

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

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

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

Sub-Order HALICHONDRINA Vosmaer

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

HALICHONDRITES Dawson

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

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

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

[2] Idem, p. 1.

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

Genotype.—*Halichondrites elissa* Walcott.

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

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

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

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

HALICHONDRITES ELISSA, new species

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

Sponge elongate, tubular in form.

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

The best preserved specimen of this sponge is broken off 12 cm. from what appears to have been the summit of the body, which as flattened has a diameter of 5.5 cm.; from the upper rim the long rods project directly upward from 3 to 5 cm.; at the upper border of the body the minute acerate spicules appear to be embedded in a membrane; most of them cross each other obliquely to form a dense mass and they extend upward beyond the rim, while others are transverse or else more or less oblique to the vertical; over the surface of the body of the sponge there is the same fine spicular membrane which completely covers the large rods towards the top of the body and appears to have covered them everywhere before the membrane was removed by the splitting of the matrix from the surface of the sponge.

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

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

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

TUPONIA, new genus

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

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

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

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

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

Genotype.—*Tuponia lineata* Walcott.

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

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

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

The identified species are:

Tuponia bellilineata Walcott
Tuponia flexilis Walcott
Tuponia lineata Walcott

TUPONIA LINEATA, new species

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

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

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

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

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

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

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

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

Dimensions.—A specimen 36.4 cm. in length has a width as flattened on the surface of the shale of 6 mm. at the upper end, 14 mm. half way of its length, and 5 mm. near its base; it is contracted for a short distance to 6 mm. in width 14 cm. from its base. The probable diameter of this specimen when uncompressed was 4 mm. at the top, 9 mm. midway, and 3.5 mm. at the base. That this species grew to considerable size is proven by the presence of a portion of a large sponge 18 cm. in length and 3 cm. in width as flattened on the shale, or about 2 cm. in diameter in a natural condition; it probably had a total length of from 70 to 80 cm. when entire.

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

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

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

TUPONIA BELLILINEATA, new species

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

General form elongate, expanding very gradually upward.

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

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

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

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

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

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

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

TUPONIA FLEXILIS, new species

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

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

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

Dimensions.—The largest specimen is a fragment 15 mm. across at right angles to the vertical spicules; all the rope-like specimens decrease very slightly in diameter; one 4 mm. in diameter decreases to 1.5 mm. in a distance of 14 cm., and another 35 mm. in length has an almost uniform width of 1.5 mm.; a rope-like strand curved in a narrow U and with both ends broken off has a length of 21 cm. with a width of 6 mm. at the large end and 2.5 mm. at the smaller end; a number of the smaller specimens are shown by figures 1a, 1d, plate 65, which is a very good illustration of size and form.

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

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

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

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

TUPONIA FLEXILIS var. INTERMEDIA, new variety

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

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

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

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

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

Genus TAKAKKAWIA, new genus

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

Genotype.—*Takakkawia lineata* Walcott.

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

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

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

TAKAKKAWIA LINEATA, new species

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

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

Reticulum.—The main skeletal elements are formed of long, simple, slender spicules that are gathered into vertical strands continuous from their inception to the upper rim of the body; these strands may be formed of two or three main spicules with several very fine ones that may continue as part of the main strand or curve out and terminate in the space between the strands; short spicules also start in the strand and project beyond it so as to give a frazzled appearance to parts of the strands; at the base there are several of the long spicules closely pressed together into a rounded point that is surrounded by a mat of extremely fine vertical spicules; the main spicules diverge and quickly gather as strands with spaces between them; at about midway of the type specimen (fig. 4) there are eight strands; three of these merge into the adjoining strands as they near the top; in some specimens the strands appear as though they had been twisted so as to contract and expand several times in the course of their length; where the strands broaden out between the contracted zones the enclosed space between the spicules is filled with a shiny film similar to that of the narrow elongate bodies toward the summit of the sponge; towards the summit of the body the main spicules are merged into and obscured in a dense mat of fine vertical spicules forming the vertical bands.

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

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

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

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

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

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

WAPKIA, new genus

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

Genotype.—*Wapkia grandis* Walcott.

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

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

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

WAPKIA GRANDIS, new species

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

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

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

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

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

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

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

HAZELIA, new genus

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

Genotype.—*Hazelia palmata* Walcott.

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

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

Observations.—The strands of the skeleton of *Hazelia* are similar to those of *Halichondrites elissa* in being formed of very slender threadlike spicules that presumably depended upon a fibrous connective tissue to bind them together, but here the resemblance ends as the strands of *Hazelia* are undulating, more or less inosculating where they come in contact with each other and they also radiate upward and outward from whatever may have been their basal point of growth.

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

The species now referred to the genus are:

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

HAZELIA PALMATA, new species

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

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

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

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

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

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

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

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

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

HAZELIA CONFERTA, new species

Plate 72, fig. 3

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

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

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

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

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

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

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

HAZELIA DELICATULA, new species

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

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

Reticulum.—The surface is slightly roughened by vertical, closely undulating strands of very slender elongate spicules and similar but small, short, transverse strands that cross the interspaces between the vertical strands in an irregular manner, their ends being fastened into the vertical strands, which gives a roughly irregular quadrangular mesh; on some portions of the surface the main strands have so divided as to inosculate with the adjoining strands to form oval or elongate oval spaces, the transverse strands not being present; both features, quadrangular and oval species, may be present on the same frond. Numerous delicate acerate spicules extend into the open space of the mesh from the strands or they may lie across it without any apparent relation to any other spicules or aggregated in minute tufts; these fine short spicules often form a spicular fringe about the irregular spaces of the mesh (fig. 1*c*, pl. 70). The strand spicules vary from 0.08 to 0.16 mm. in diameter, and the strands are about 0.8 to 1 mm. across.

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

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

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

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

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

HAZELIA ? GRANDIS, new species

Plate 71, fig. 2

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

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

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

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

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

HAZELIA MAMMILLATA, new species

Plate 90, figs. 3, 3*a*

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

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

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

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

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

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

HAZELIA NODULIFERA, new species

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

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

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

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

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

HAZELIA OBSCURA, new species

Plate 71, figs. 1, *1a*

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

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

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

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

CORRALIA, new genus

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

Genotype.—*Corralia undulata* Walcott.

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

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

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

CORRALIA UNDULATA, new species

Plate 72, figs. 2, 2*a*

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

Reticulum.—The skeletal strands are about 1 mm. across near the upper end where the specimen is 20 mm. in width; they are separated by very narrow spaces or else touch each other; some of the strands look as though they were made of a bundle of smaller parallel strands; spicules obscure owing to covering by dermal layer, but where visible they are delicate, threadlike and appear to be parallel with the strand; by reflected light a series of minute transverse strands may be seen crossing some of the spaces between the vertical strands in such manner as to divide the space into minute rectangles. The dermal layer has been so largely replaced by microscopic crystals of pyrite (FeS_2) that its spicules are rarely seen, a few minute monacts are visible towards the lower end of the specimen represented by figure 2.

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

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

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

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

SENTINELIA, new genus

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

Genotype.—*Sentinelia draco* Walcott.

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

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

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

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

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

SENTINELIA DRACO, new species

Plate 72, figs. 1, 1*a*

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

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

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

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

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

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

Family SUBERITIDAE

CHOIA, new genus

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

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

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

Genotype.—*Choia carteri* Walcott.

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

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

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

The species now referred to *Choia* are:

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

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

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

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

CHOIA CARTERI, new species

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

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

[1] Rept. Voyage H. M. S. Challenger, Zool., Vol. 20, p. 218, pl. XLIII, figs. 1-4.

[2] Geol. Mag. London, N. Ser., Dec. III, Vol. VIII, 1891, pp. 22-24. Text fig. unnumbered.

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

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

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

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

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

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

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

CHOIA RIDLEYI, new species

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

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

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

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

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

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

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

CHOIA UTAHENSIS, new species

Plate 75, fig. 1

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

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

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

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

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

CHOIA HINDEI (Dawson)

Plate 76, figs. 1, 1*a*

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

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

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

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

[2] Idem, pl. 13.

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

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

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

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

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

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

HAMPTONIA, new genus

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

Genotype.—*Hamptonia bowerbanki* Walcott.

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

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

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

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

HAMPTONIA BOWERBANKI, new species

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

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

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

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

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

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

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

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

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

PIRANIA, new genus

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

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

Genotype.—*Pirania muricata* Walcott.

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

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

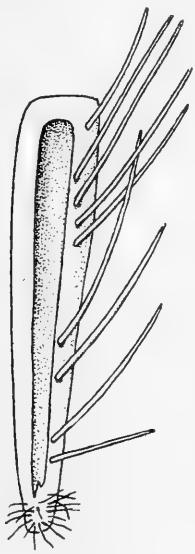
Observations.—The details of form and structure are given under the description of the type species.

PIRANIA MURICATA, new species

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

Numerous specimens more or less crushed and flattened in the shale prove that the body of the sponge was in the form of a rather small, round, hollow stem, with one offshoot, as far as known, which branched from the main stem at an acute angle. The body is formed of an outer plated wall, an interior wall (as yet of unknown structure), and an intervening space filled up with spicules and spongin that in the fossil condition is a mass of microscopic pyrite crystals which have replaced the organic matter, which is a common form of replacement among the fossils of the Burgess shale. The top of the tube is closed by a transverse layer of about the same depth as the thickness of the side walls.

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



4.

4*a*.

Pirania muricata Walcott

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

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

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

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

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

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

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

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

Order HEXACTINELLIDA O. Schmidt

(*Triaxonia* F. E. Schulze)

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

Sub-Order LYSSACINA Zittel

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

Family PROTOSPONGIDAE Hinde

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

Genus PROTOSPONGIA Salter[2]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

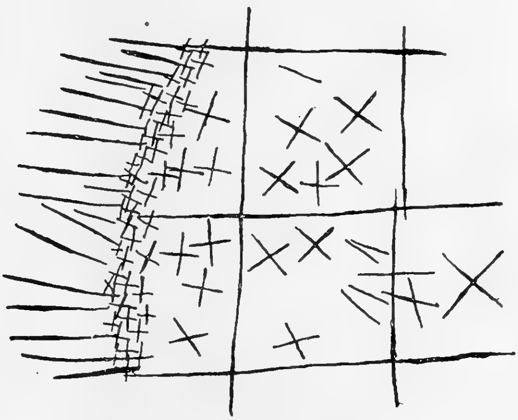

FIG. 6.—*Protospongia mononema.* Cruciform and protective spicules, × 5.

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

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

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

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

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

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

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

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

The species now recognized from undoubted Cambrian strata are:

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

PROTOSPONGIA FENESTRATA Salter

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[5] Idem, p. 236.

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

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

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

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

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

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

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

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

PROTOSPONGIA HICKSI Hinde

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DIAGONIELLA Rauff

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

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

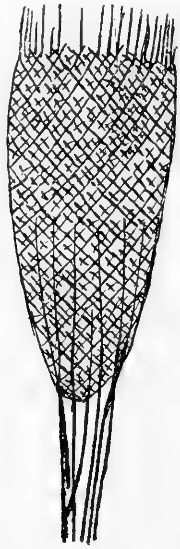


FIG. 7.—*Diagoniella cyathiformis* (after Dawson, fig. 13).

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

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

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

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

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

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

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

Genotype.—Protospongia coronata Dawson.

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

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

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

DIAGONIELLA HINDEI, new species

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

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

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

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

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

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

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

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

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

Genus KIWETINOKIA, new genus

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

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

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

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

Genotype.—*Kiwetinokia utahensis* Walcott.

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

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

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

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

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

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

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

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

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

KIWETINOKIA UTAHENSIS, new species

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

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

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

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

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

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

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

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

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

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

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

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

KIWETINOKIA SPIRALIS, new species

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

This species is represented by a few scattered cruciform spicules associated with a number of fragments of long, slender rope-like rods formed of closely twisted strands that appear to have been very slender spicules etched by transverse raised bands dividing them into sections slightly longer than wide; whether these bands formed the base of minute spines as in the rods associated with *Hyalostelia* *gracilis* Hinde[1] is not determinable from the specimens. No triradiate spicules have been found in association with the rods or cruciform spicules.

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

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

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

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

KIWETINOKIA METISSICA (Dawson)

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

Sir William Dawson described the species as follows:

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

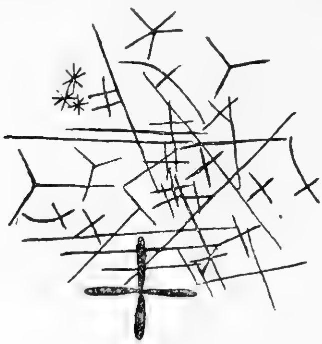
[1] British Fossil Sponges, Pal. Soc., 1887, p. 129, pl. 1, figs. 5, 5*a-f*.

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

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

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

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



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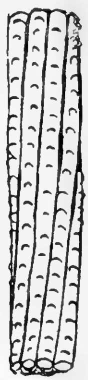

8*a*.

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

Sub-Order DICTYONINA Zittel

Family VAUXININAE, new family

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

Observations.—The Vauxininae are probably the Cambrian ancestors of the Dictyonina of the Trias, Jurassic and Cretaceous periods, although they differ in their thin walls and the four-rayed spicules of the skeletal framework, three of which are on one plane and one axial ray penetrating inward at right angles to the surface of the sponge. These sponges have in common with the Dictyonina a continuous spicular skeletal framework formed by cementing together the points of the rays, and their growth results in cylindric, branching or flattened sponges.

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

VAUXIA, new genus

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

Genotype.—*Vauxia gracilenta* Walcott.

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

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

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

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

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

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

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

The species referred to the genus are:

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

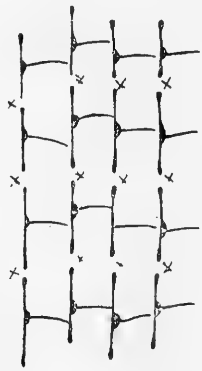
VAUXIA GRACILENTA, new species

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

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

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

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



Vauxia gracilenta Walcott.

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

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

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

Observations.—The occurrence of hundreds of almost unbroken specimens results from the strong spicular skeleton as a direct fracture was necessary to break even a slender tube, but many of the branches were more readily broken from the main branch; many surfaces of shale are almost covered with the flattened branches and single tubes especially in the layers 20 feet (6.1 m.) to 50 feet (15.25 m.) above the lower portion of the Burgess shale.

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

VAUXIA BELLULA, new species

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

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

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

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

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

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

VAUXIA DENSA, new species

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

Sponges either simple or branched; tubes transversely corrugated by slight undulations or nearly smooth; dermal layer dense and usually preserved as a dull black film that suggests a carbonaceous mineral, but as that is the general appearance of nearly all the fossils in the Burgess shale it has little significance; where the dermal surface is slightly oxidized and of a brownish color it is covered with very minute crystals of pyrite and they are also very abundant on the black specimens.

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

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

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

VAUXIA DIGNATA, new species

Plate 81, figs. 2, *2a-c*

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

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

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

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

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

VAUXIA (?) VENATA, new species

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

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

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

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

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

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

Family OCTACTINELLIDAE Hinde

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

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

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

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

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

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

Genus EIFFELIA, new genus

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

Genotype.—Eiffelia globosa Walcott.

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

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

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

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

[1] Palaeontographica, Vol. 40, 1893, p. 171.
[2] Sil. Fauna des West. Tennessee, 1860, pp. 13, 14.
[3] Rept. H. M. S. Challenger, Zool., Vol. XXI, 1887, pl. 54, fig. 1.

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

EIFFELIA GLOBOSA, new species

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

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

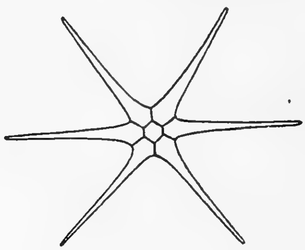


FIG. 10 (× 6).—A spicule with central node and six rays.

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

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

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

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

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

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

Sub-Order HETERACTINELLIDA Hinde

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

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

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

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

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

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

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

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

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

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

[1] Text-book Pal. Eastman Ed., 1913, p. 62.

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

[3] Text-Book Pal. Eastman Ed., 1913, p. 63.

Family CHANCELLORIDAE new family

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

Genus *Chancelloria* Walcott.

CHANCELLORIA, new genus

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

Genotype.—*Chancelloria èros* Walcott.

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

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

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

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

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

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

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

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

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

The species referred to the genus are:

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

CHANCELLORIA EROS, new species

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

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

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

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

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

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

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

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

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

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

CHANCELLORIA DRUSILLA, new species

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

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

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

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

There are many rectangular spicules of varying size with four slender rays associated with the spicules of this species which I have referred to *Protospongia fenestrata* Salter ? as it is not probable that they belonged to the same type of sponge as *Chancelloria drusilla.*

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

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

CHANCELLORIA LIBO, new species

Plate 87, figs. 1, 1*a*

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

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

CHANCELLORIA YORKENSIS, new species

Plate 87, fig. 3

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

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

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

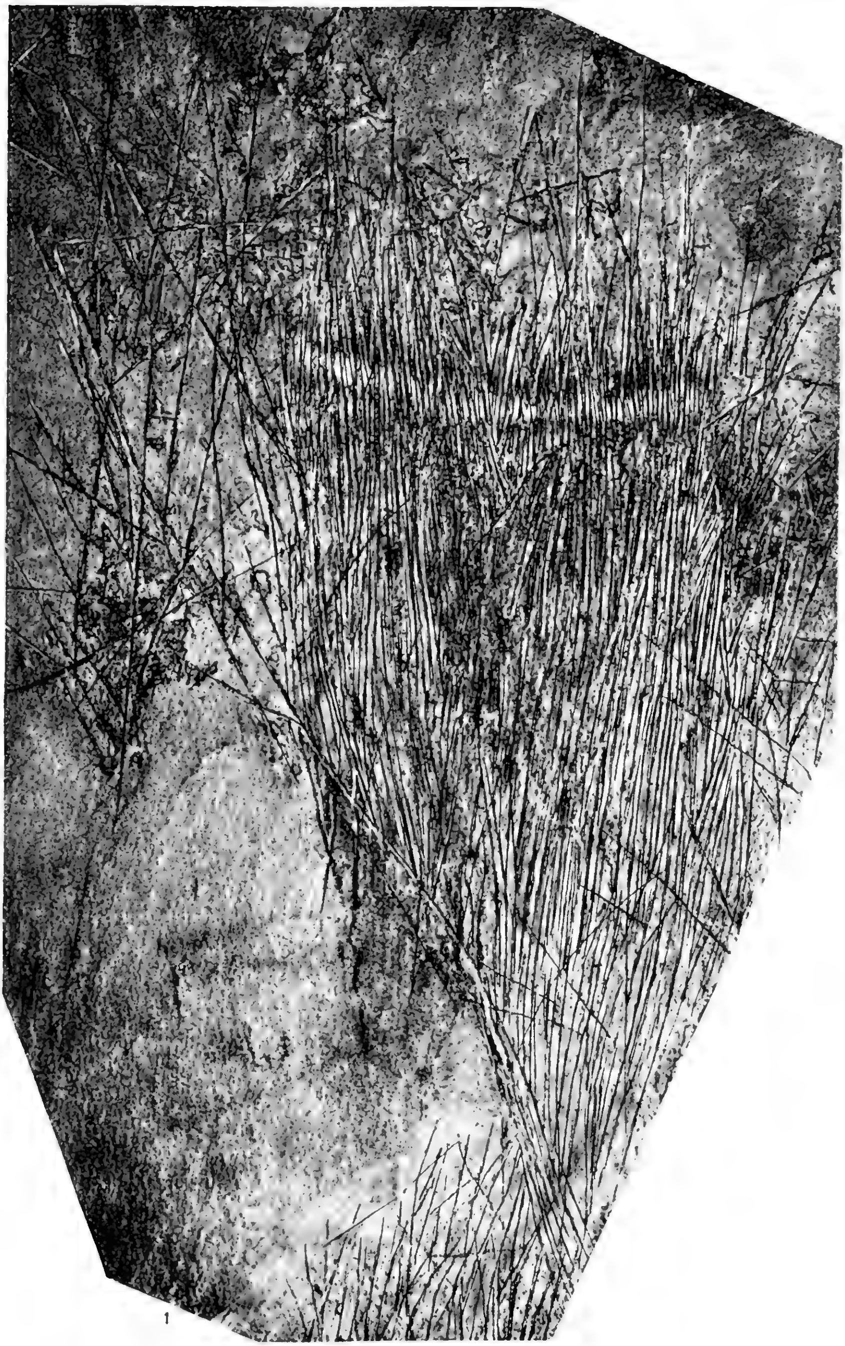
DESCRIPTION OF PLATE 60

PAGE

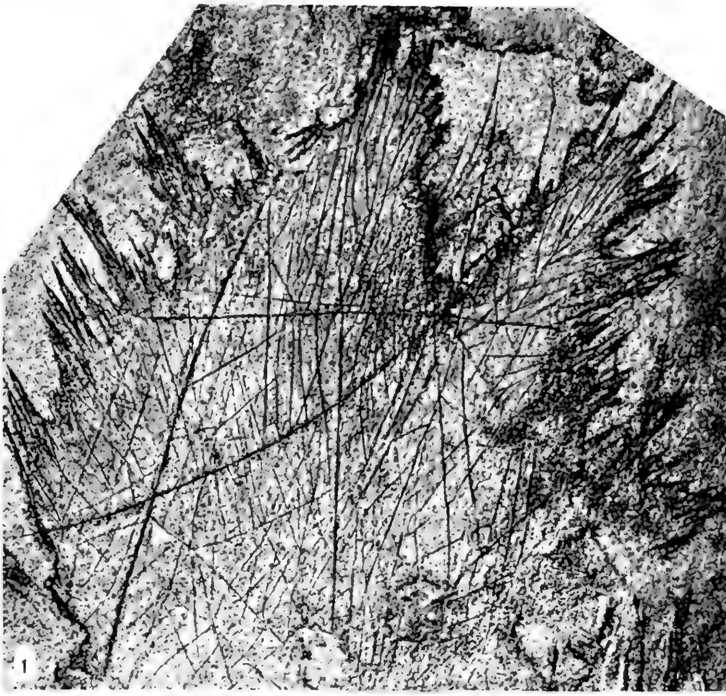
Halichondrites elissa Walcott (see pl. 61) 270

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

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



HALICHONDRITES ELISSA Walcott



HALICHONDRITES ELISSA Walcott

DESCRIPTION OF PLATE 61

PAGE

Halichondrites elissa Walcott (see pl. 60) 270

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

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

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

DESCRIPTION OF PLATE 62

PAGE

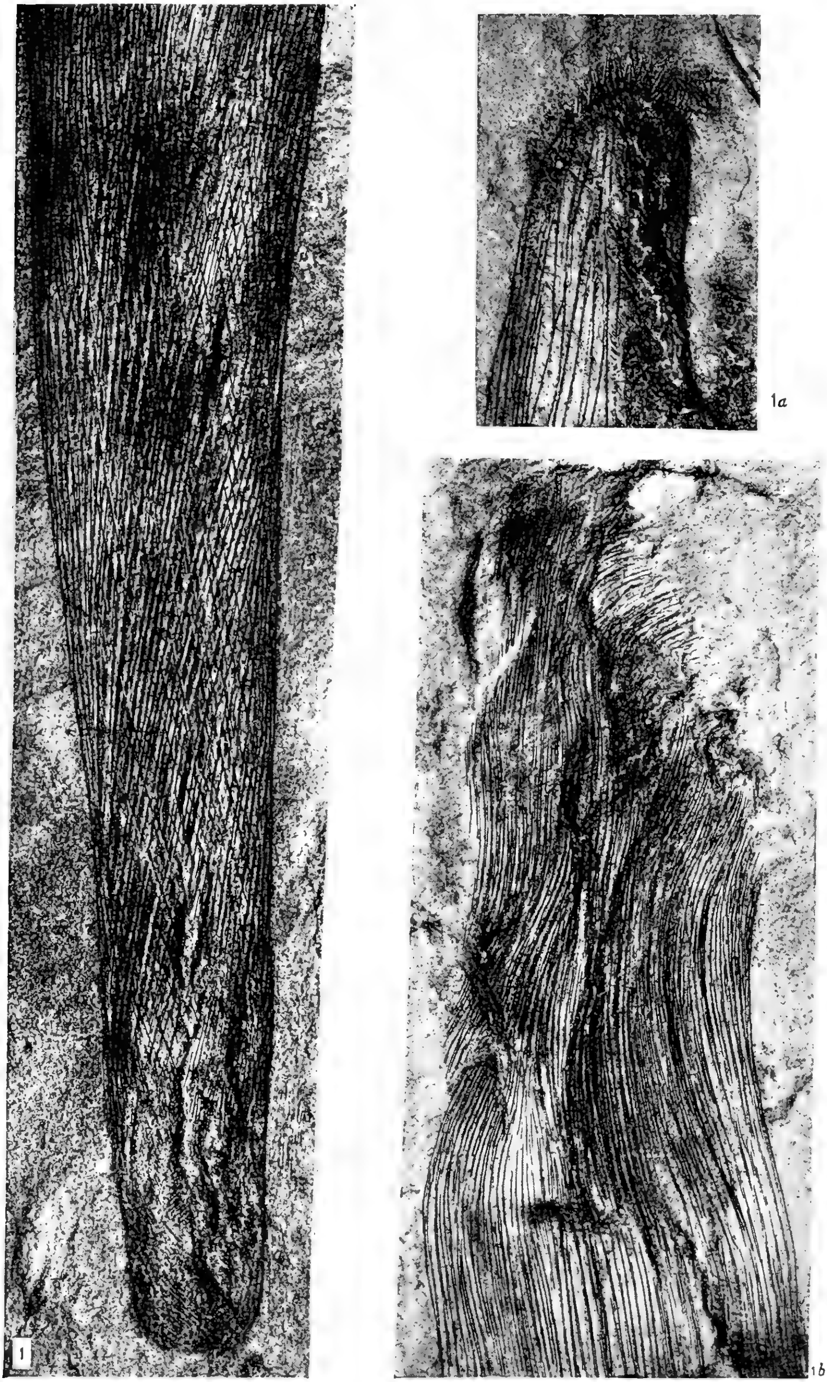
Tuponia lineata Walcott (see pls. 63 and 90) 272

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

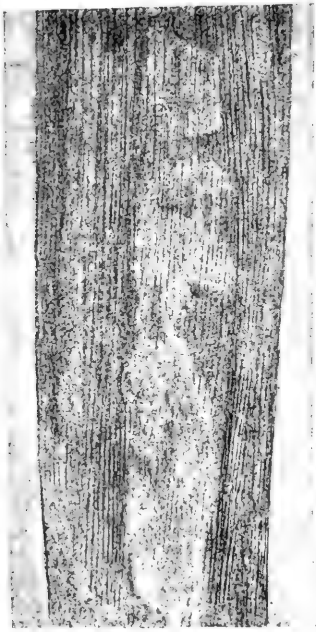
1*a*. (×4.) Upper end of fig. 1*b*, pl. 63, enlarged to illustrate the fine waving spicules about the margin. U. S. National Museum, Catalogue No. 66448.

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

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



TUPONIA LINEATA Walcott



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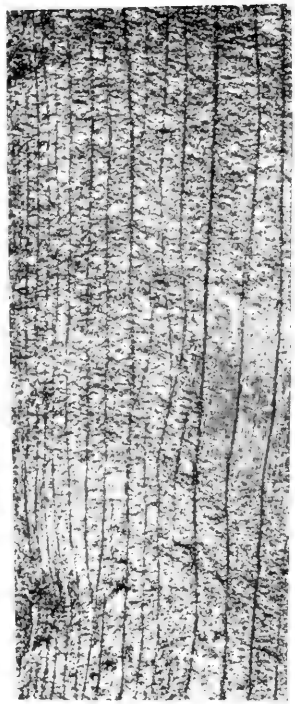
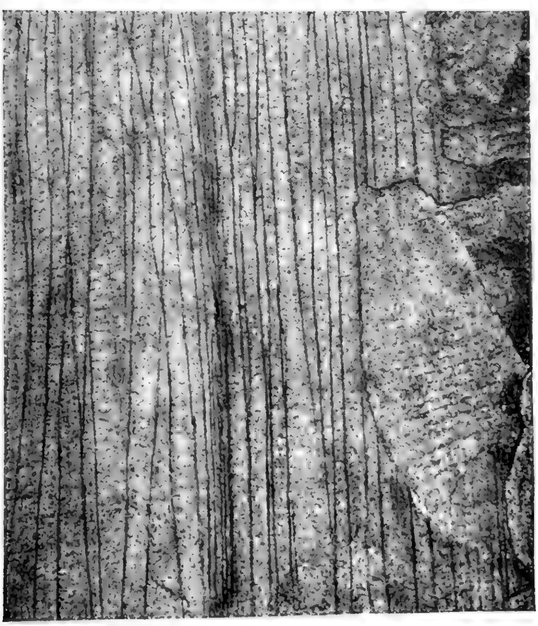


1*c*

1*b*



1*a*

TUPONIA LINEATA Walcott

DESCRIPTION OF PLATE 63

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

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

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

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

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

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

DESCRIPTION OF PLATE 64

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Tuponia flexilis intermedia Walcott.................................... 276

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

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

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

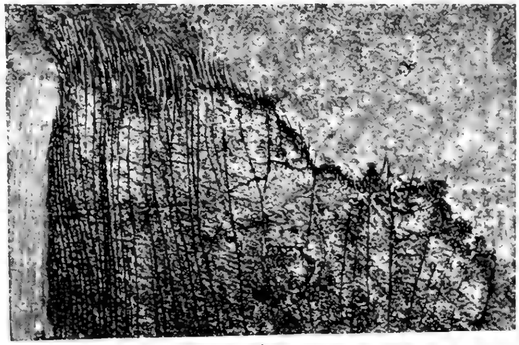
Tuponia bellilineata Walcott.. 274

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

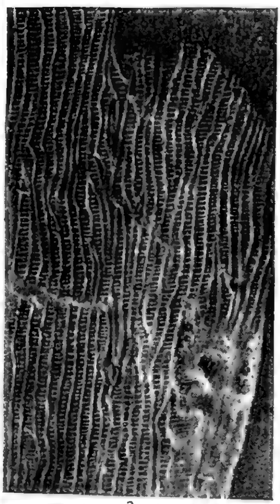
2*a*. (× 6.) Vertical strands.

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

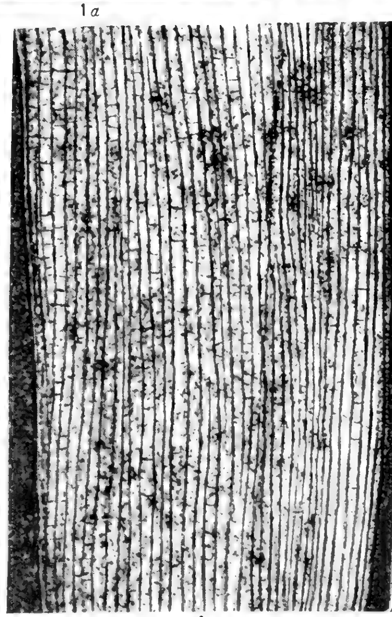
The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation, on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



1a



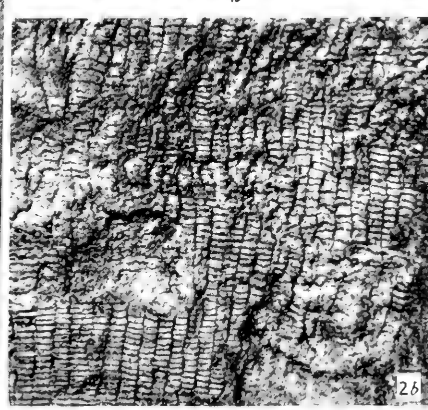
2a



1b

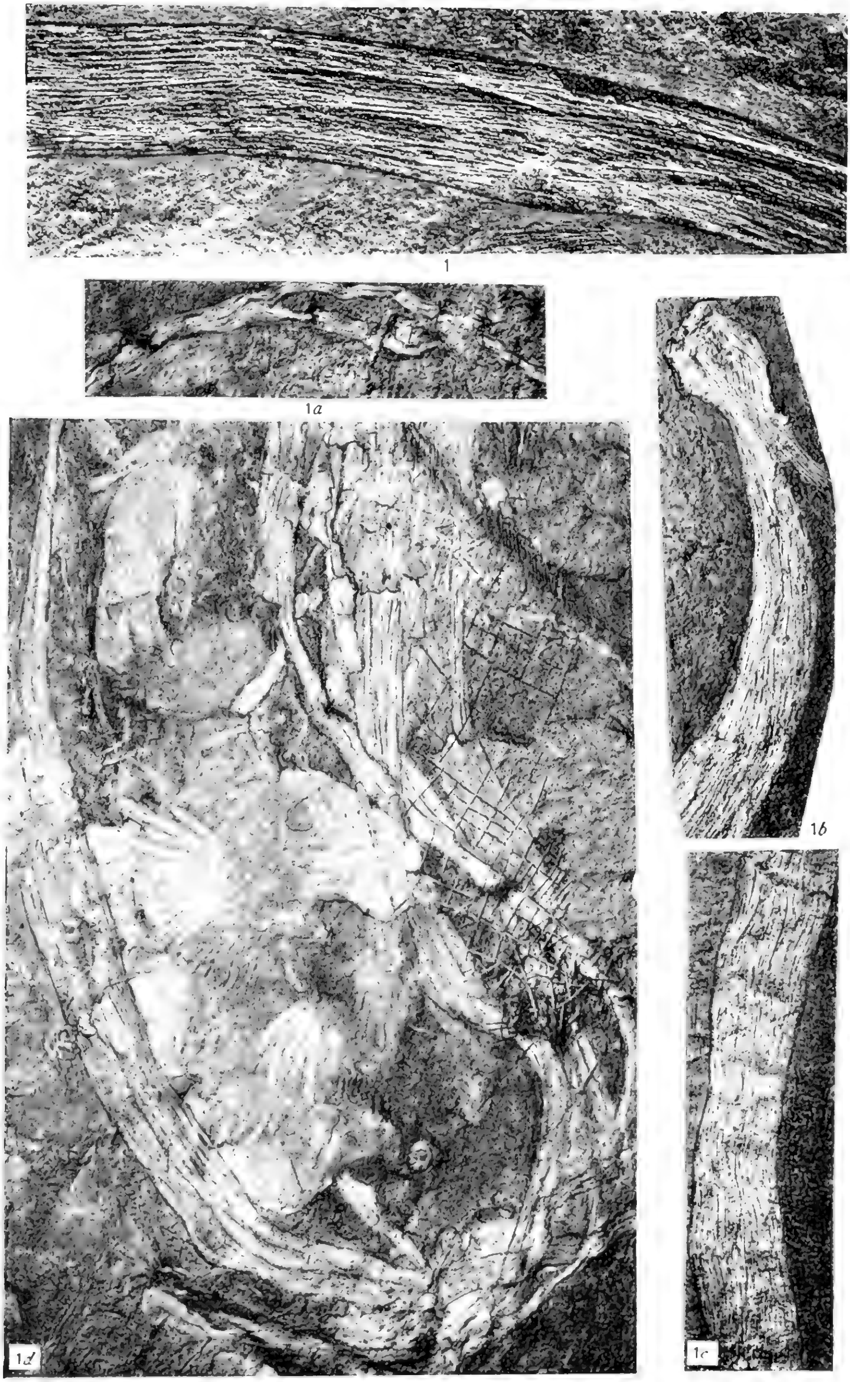
1

2



2b

1. Tuponia flexilis intermedia Walcott
2. Tuponia bellilineata Walcott



TUPCNIA FLEXILIS Walcott

DESCRIPTION OF PLATE 65

PAGE

Tuponia flexilis Walcott 275

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

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

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

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

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

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

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

DESCRIPTION OF PLATE 66

PAGE

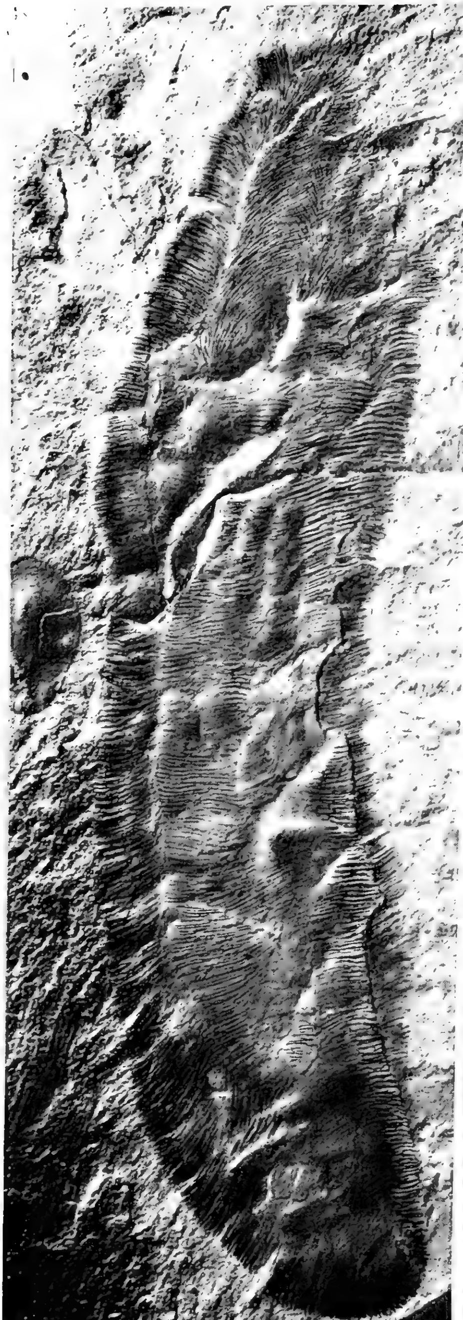
Wapkia grandis Walcott (see pls. 67 and 68) 279

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

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

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

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



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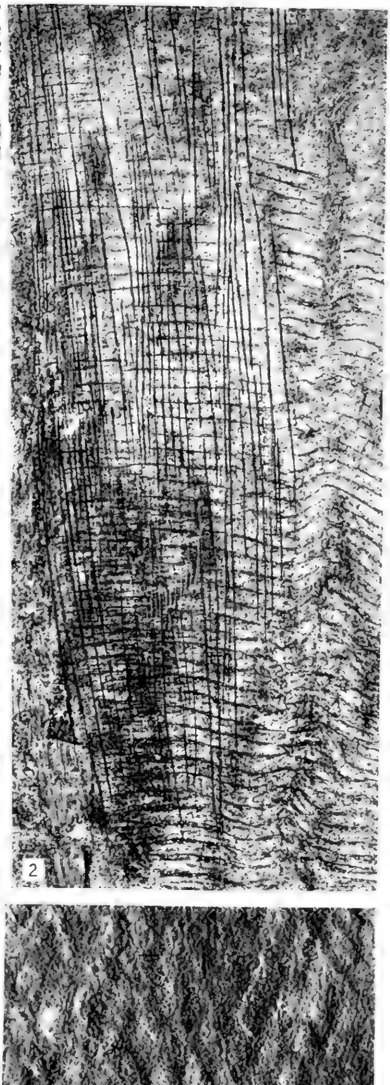


2

3

WAPKIA GRANDIS Walcott

WAPKIA GRANDIS Walcott

DESCRIPTION OF PLATE 67

PAGE

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

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

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

DESCRIPTION OF PLATE 68

PAGE

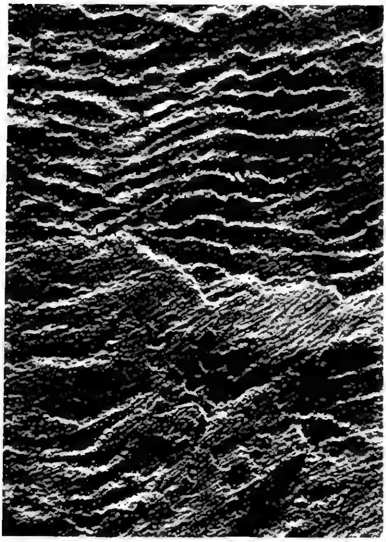
Wapkia grandis Walcott (see pls. 66, 67) 279

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

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

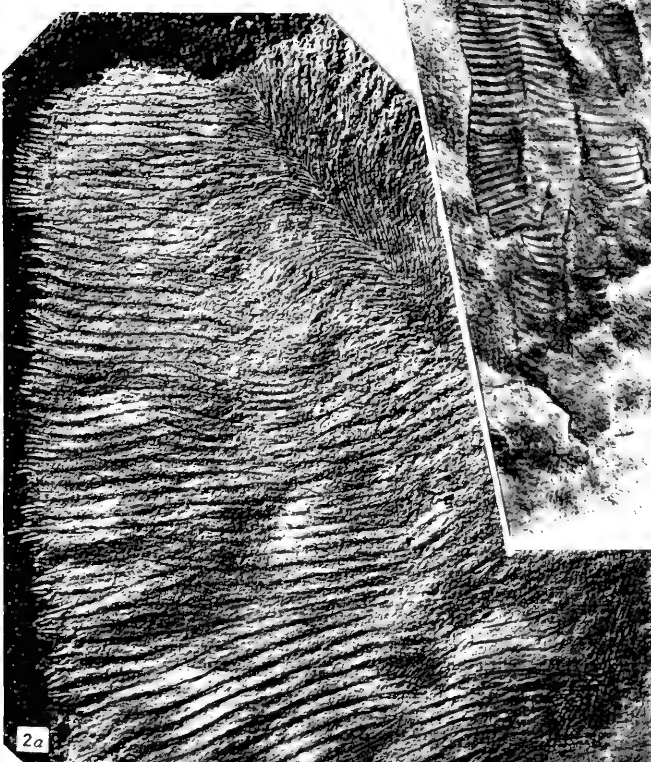
2*a*. (× 2.) Enlargement of the upper right-hand section of the specimen illustrated by fig. 2, to exhibit the transverse strands and mat of fine transverse spicules.

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



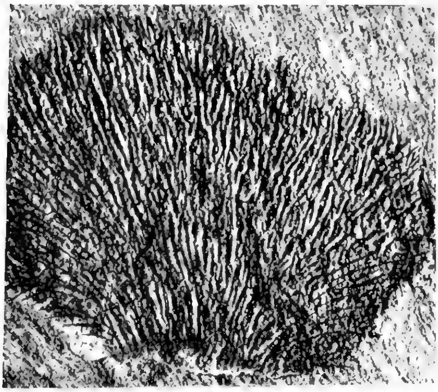
1

2



2a

WAPKIA GRANDIS Walcott



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1a

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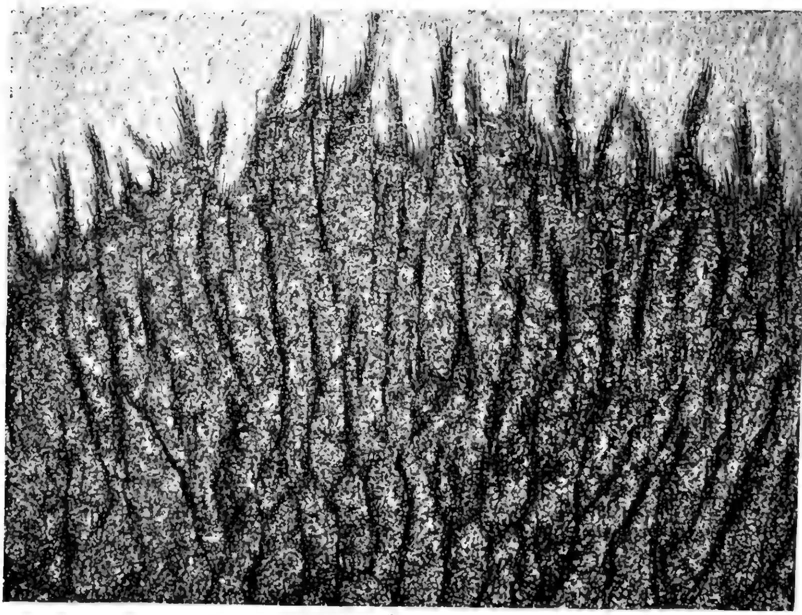


1c

HAZELIA PALMATA Walcott

DESCRIPTION OF PLATE 69

PAGE

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

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

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

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

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

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

DESCRIPTION OF PLATE 70

PAGE

Hazelia delicatula Walcott (see pl. 90) 284

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

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

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

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

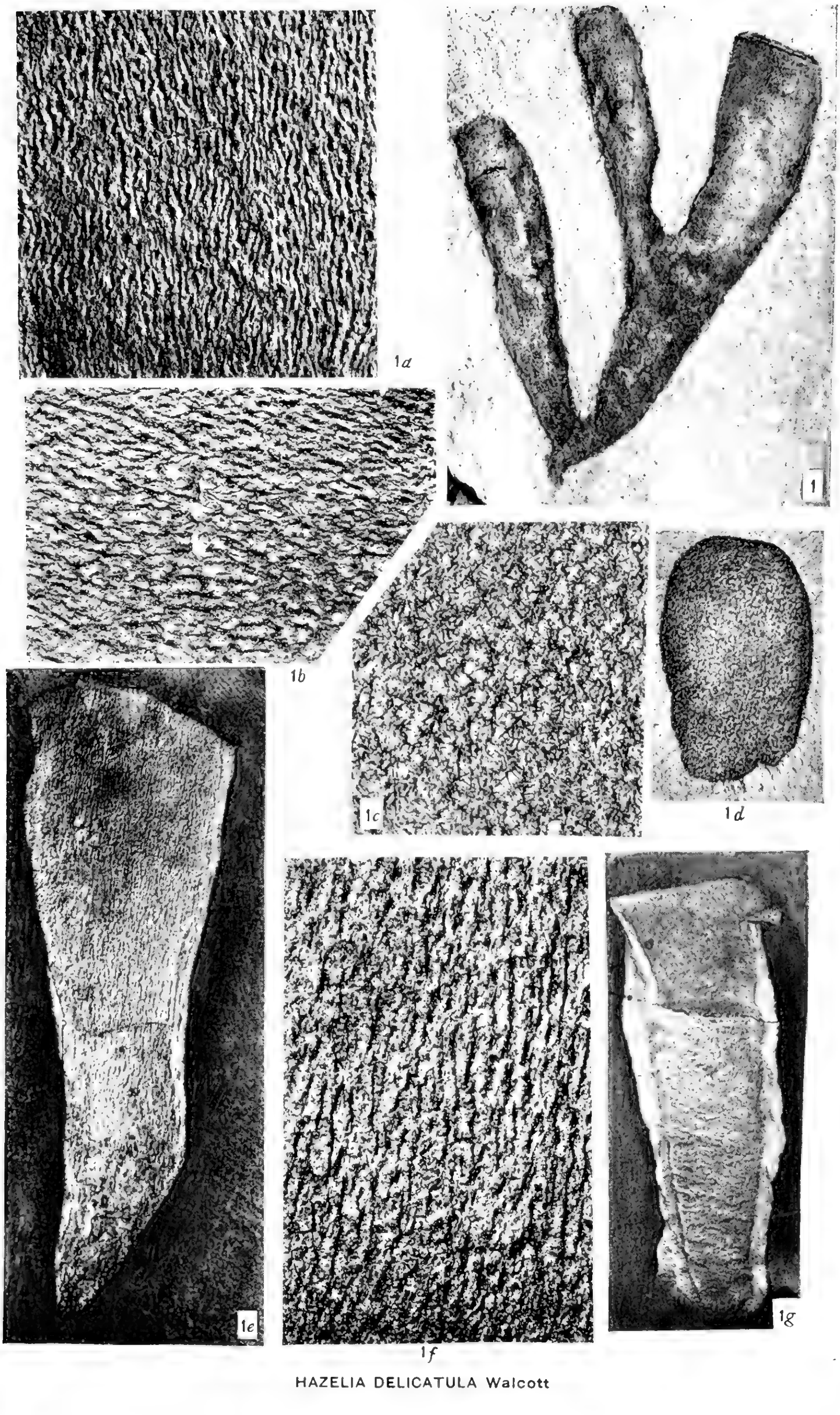
1*d*. (Natural size.) An upright elongate rounded frond broken off at the base. U. S. National Museum, Catalogue No. 66468.

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

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

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

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



HAZELIA DELICATULA Walcott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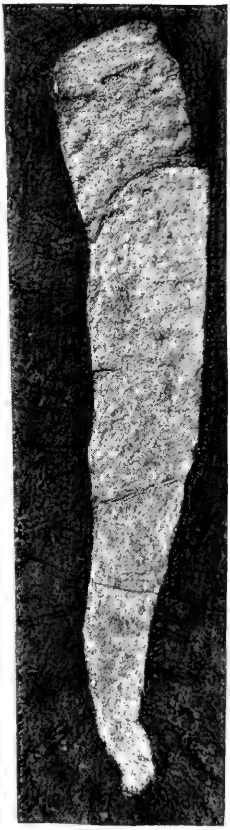

1a


2


3a


3


3b

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

DESCRIPTION OF PLATE 71

PAGE

Hazelia obscura Walcott 287

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

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

Hazelia ? grandis Walcott.. 285

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

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

Hazelia nodulifera Walcott.. 287

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

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

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

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

DESCRIPTION OF PLATE 72

PAGE

Sentinelia draco Walcott 290

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

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

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

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

Corralio undulata Walcott 288

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

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

Hazelia conferta Walcott 283

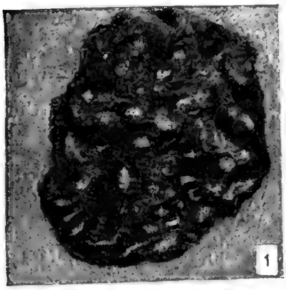
FIG. 3. (Natural size.) View of type specimen illustrating compression of a relatively soft sponge. The pressing out of the gelatinous tissue from beneath the dermal membrane is well shown at the left side and towards the lower end. U. S. National Museum, Catalogue No. 66476.

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

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

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

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



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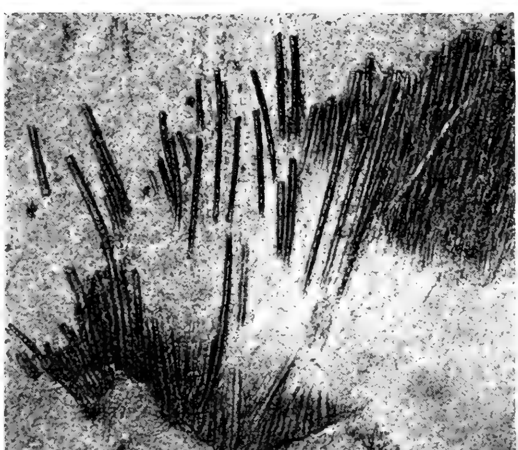

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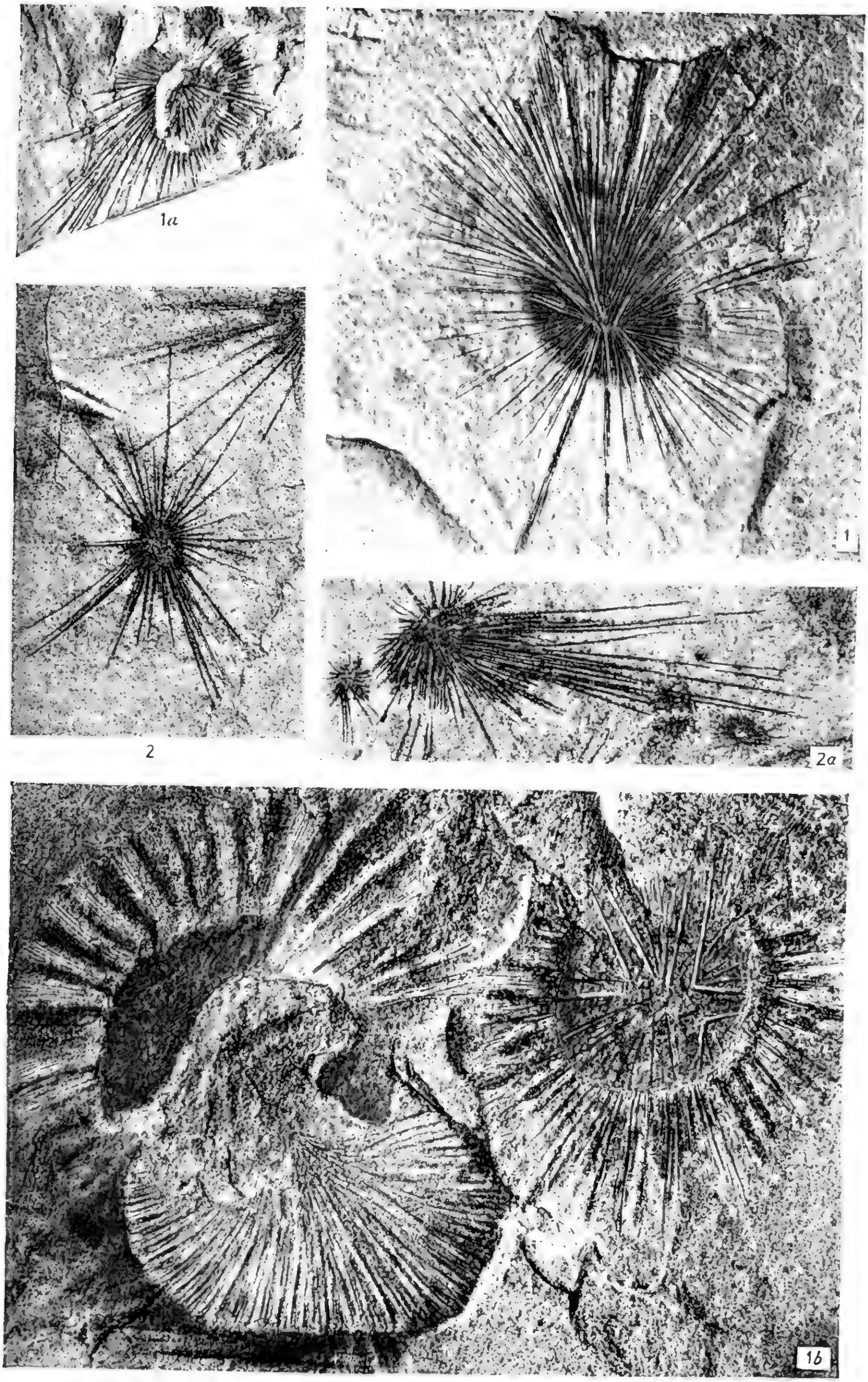
1. Sentinelia draco Walcott
2. Corralia undulata Walcott
3. Hazelia conferta Walcott
4. Choia carteri Walcott



1. Choia carteri Walcott
2. Choia ridleyi Walcott

DESCRIPTION OF PLATE 73

PAGE

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

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

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

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

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

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

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

DESCRIPTION OF PLATE 74

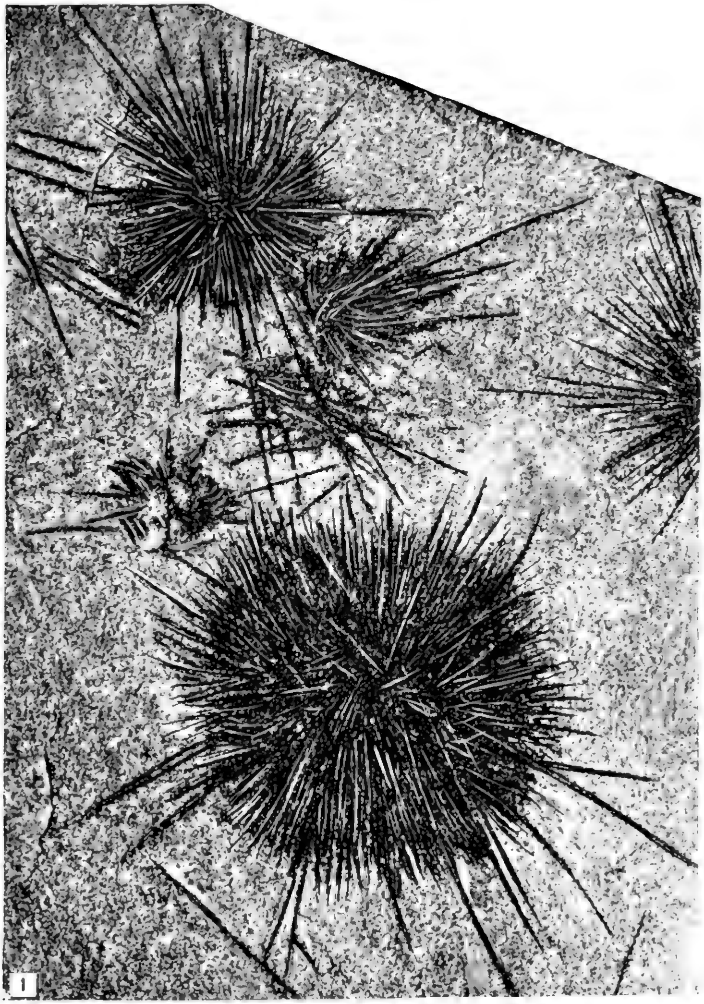
PAGE

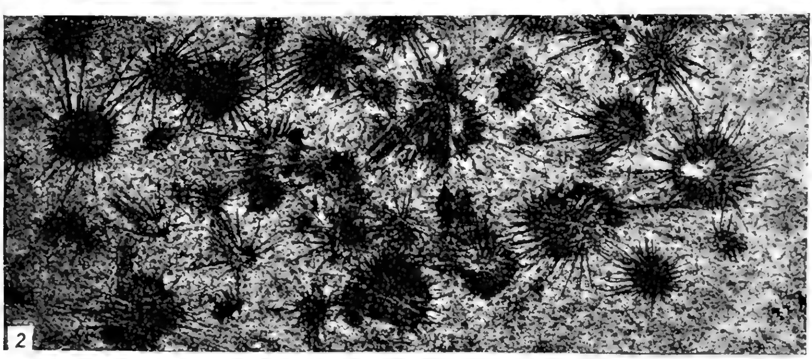
Choia ridleyi Walcott (see pl. 73, figs. 2, 2*a*) 294

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

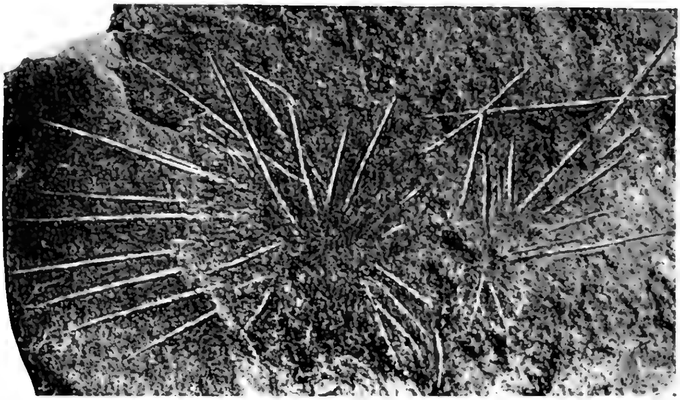
1*a*. (× 2.) A group of disks on a fragment of shale. U. S. National Museum, Catalogue No. 66487.

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





CHOIA RIDLEYI Walcott



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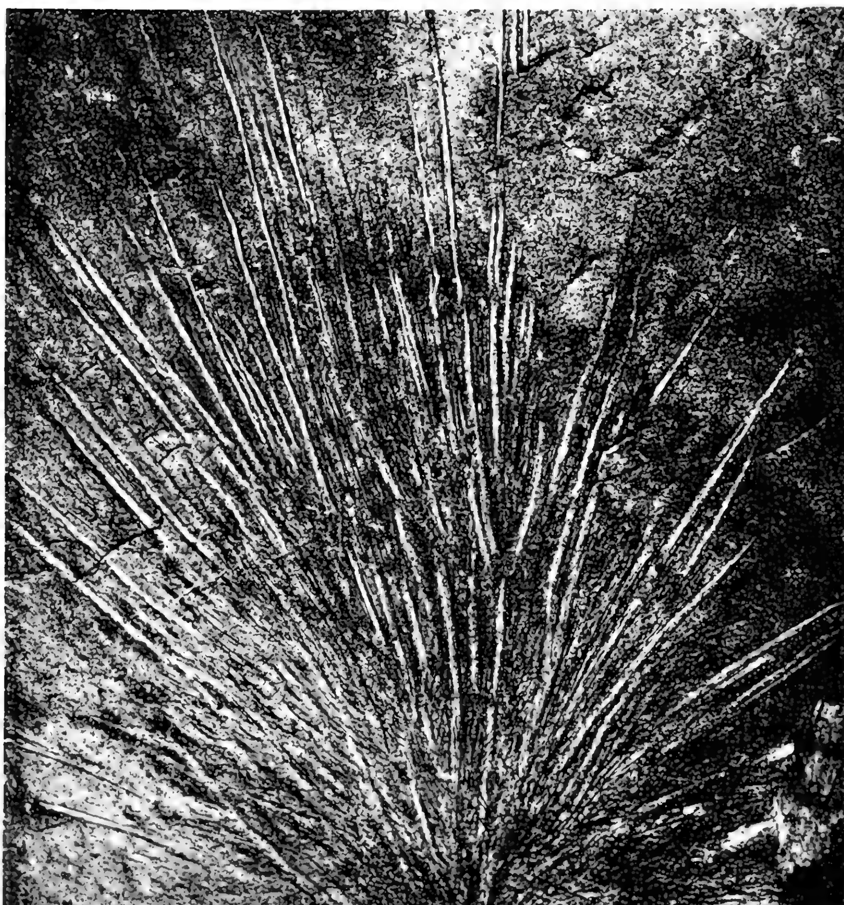

2

1. Choia utahensis Walcott
2. Choia carteri Walcott

DESCRIPTION OF PLATE 75

PAGE

Choia utahensis Walcott 295

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

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

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

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

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

DESCRIPTION OF PLATE 76

PAGE

Choia hindei (Dawson) 295

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

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

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

Hazelia palmata Walcott (see pl. 69) 282

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

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

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

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

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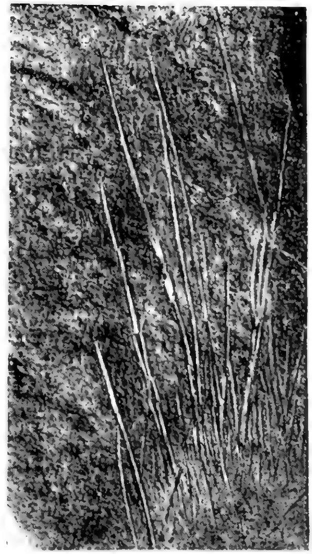

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2

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

HAMPTONIA BOWERBANKI Walcott

DESCRIPTION OF PLATE 77

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

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

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

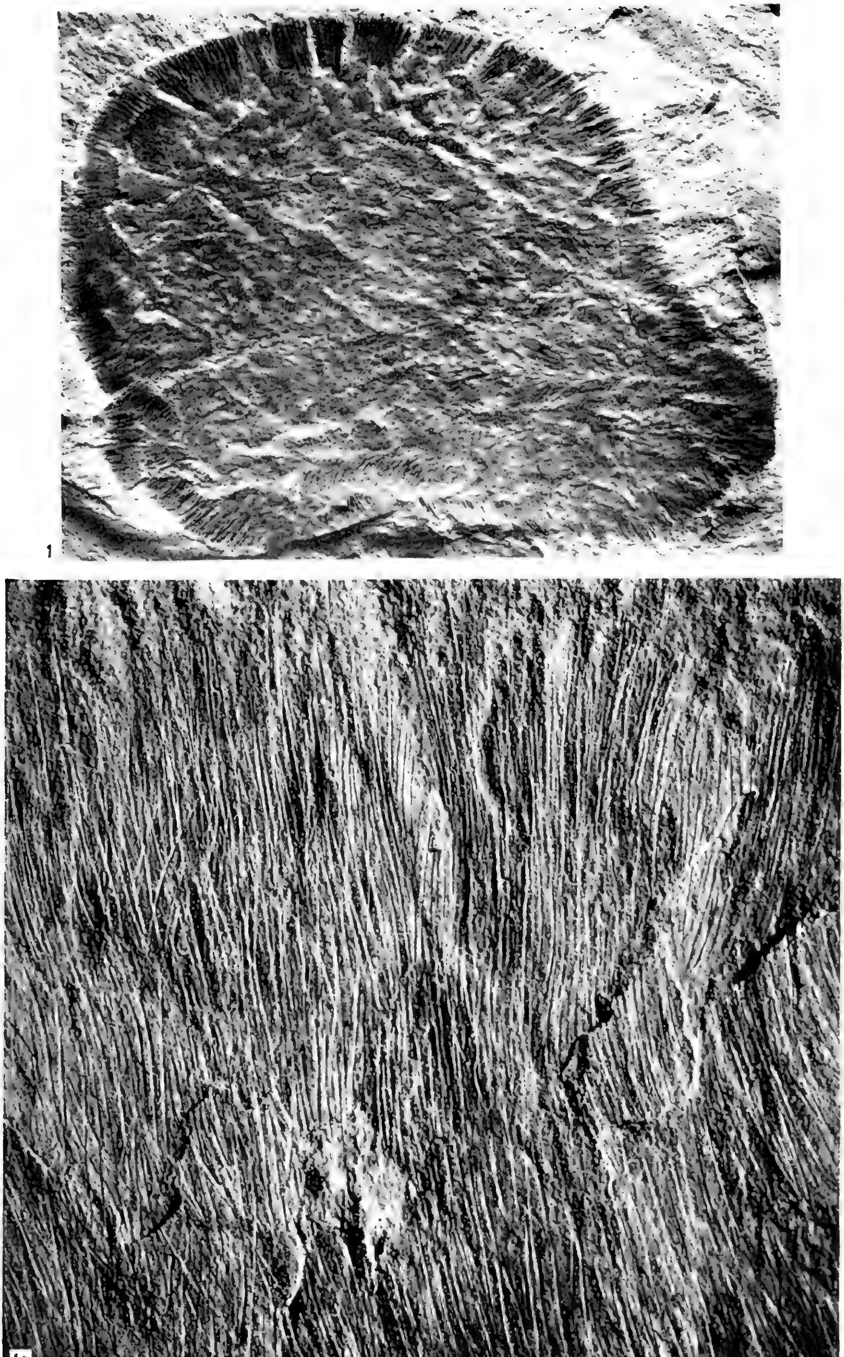
DESCRIPTION OF PLATE 78

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

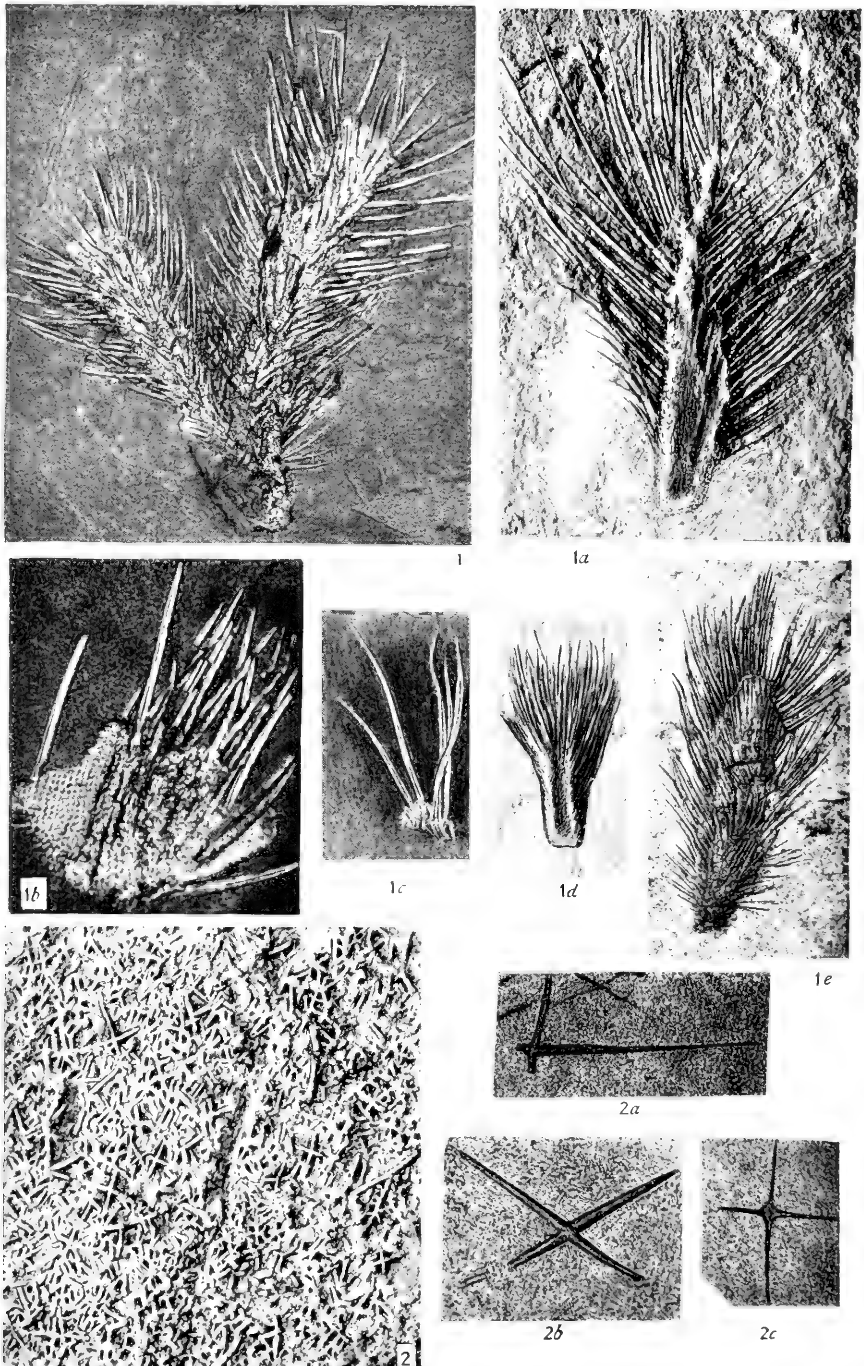
FIG. 1. (Reduced to one-half size.) Outline of a large sponge 200 mm. in its greatest diameter. U. S. National Museum, Catalogue No. 66493.

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

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



HAMPTONIA BOWERBANKI Walcott



1. Pirania muricata Walcott
2. Protospongia erixo Walcott

DESCRIPTION OF PLATE 79

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

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

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

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

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

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

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

The specimens represented by figs. 1*d* and 1*e* are from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 (701 m.) above the Lower Cambrian and 3.540 feet (1,089 m.) below the Upper Cambrian in the *Ogygopsis* zone of the Stephen formation, at the great " fossil bed " on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia.

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

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

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

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

DESCRIPTION OF PLATE 80

PAGE

Protospongia fenestrata Salter 304

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

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

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

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

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

Protospongia hicksi Hinde 307

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

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

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

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

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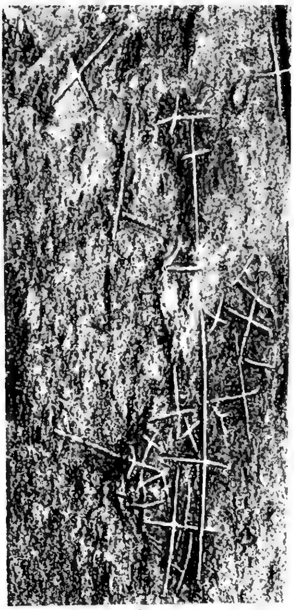

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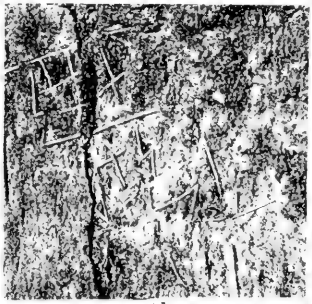

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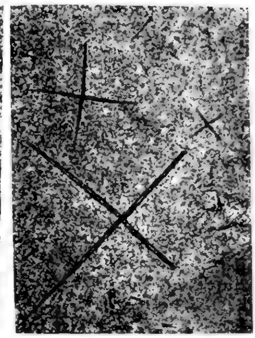

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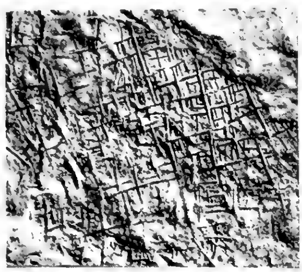

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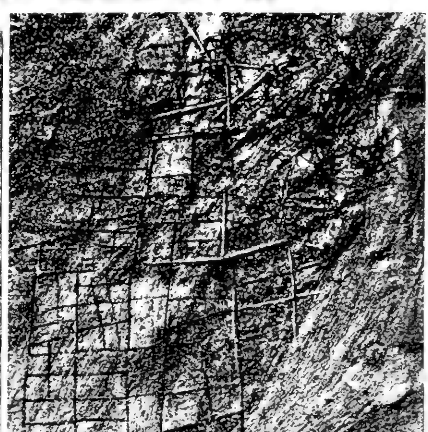
3a



3b

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

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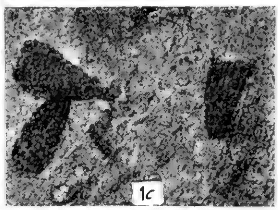

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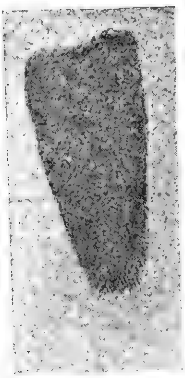

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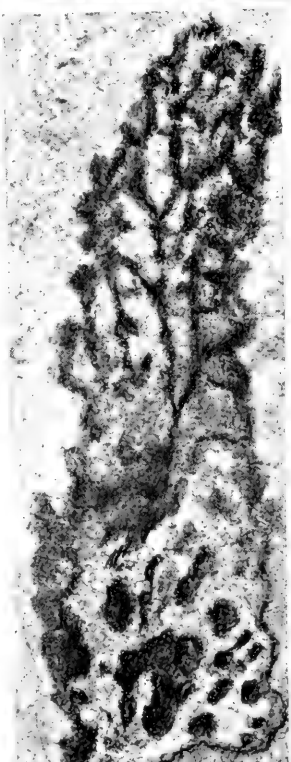

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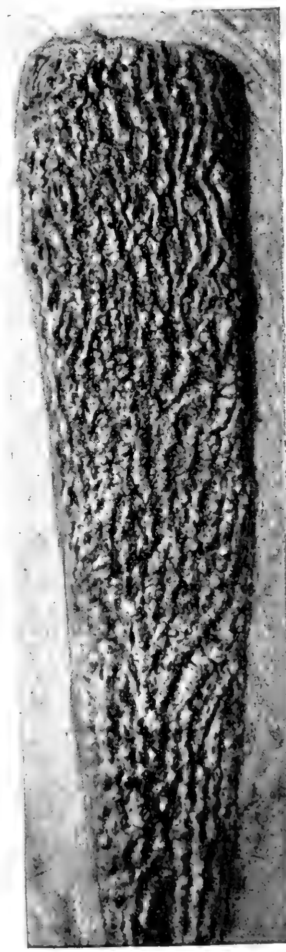


2a

1 Diagoniella hindei Walcott
2. Vauxia dignata Walcott

DESCRIPTION OF PLATE 81

PAGE

Diagoniella hindei Walcott.. 310

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

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

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

Vauxia dignata Walcott.. 321

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

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

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

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

DESCRIPTION OF PLATE 82

PAGE

Vauxia bellula Walcott.. 320

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

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

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

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

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

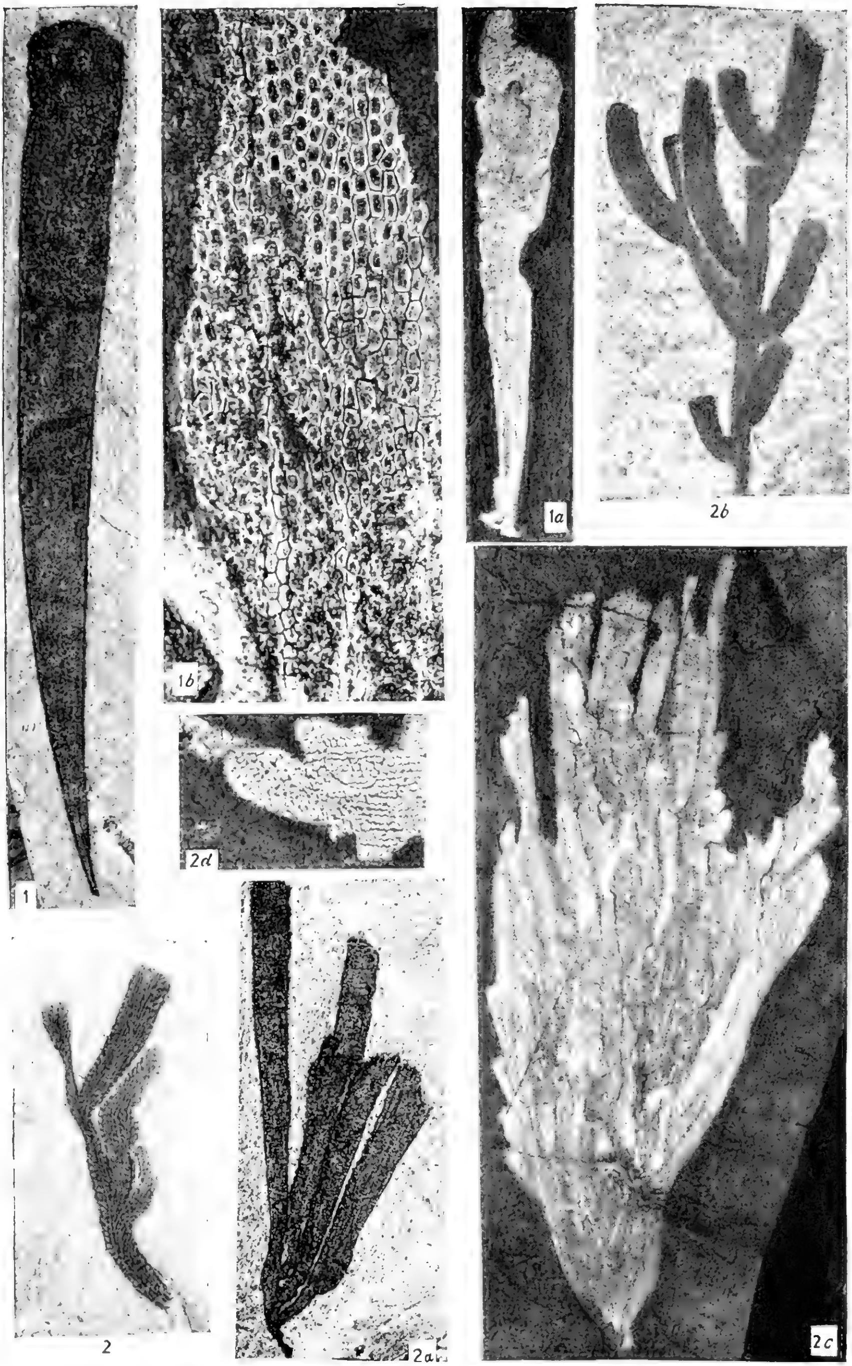
2a. (Natural size.) A specimen having a main stem, three branches and one secondary branch. U. S. National Museum, Catalogue No. 66510.

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

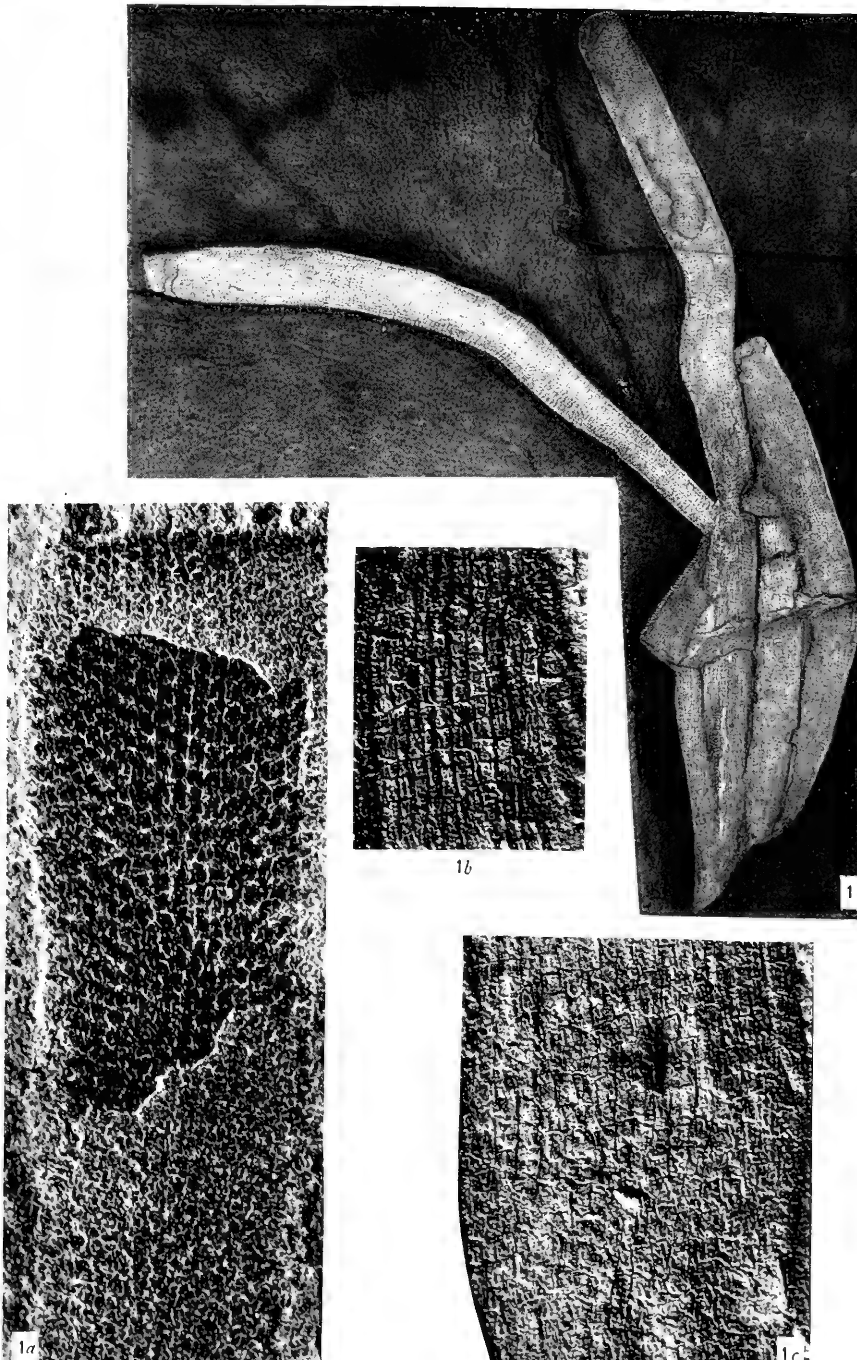
2c. (Natural size.) A closely branched sponge with small branches. U. S. National Museum, Catalogue No. 66512.

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

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



1. Vauxia bellula Walcott
2. Vauxia gracilenta Walcott



VAUXIA GRACILENTA Walcott

DESCRIPTION OF PLATE 83

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

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

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

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

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

DESCRIPTION OF PLATE 84

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

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

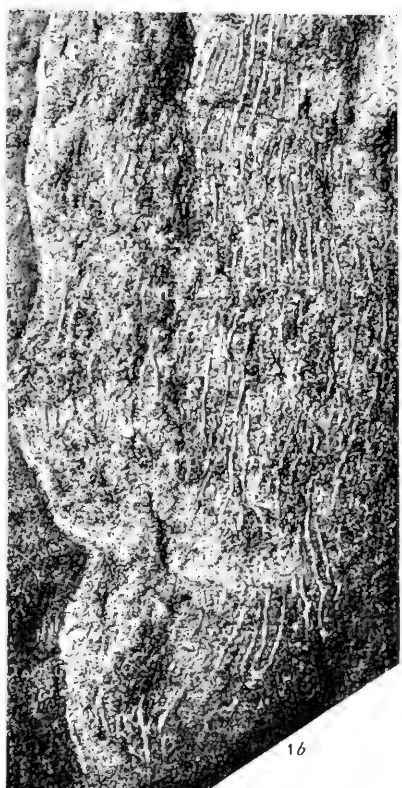
1*b*. (× 6.) Enlargement of the lower portion of specimen represented by fig. 1, to illustrate the spicular structure.

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

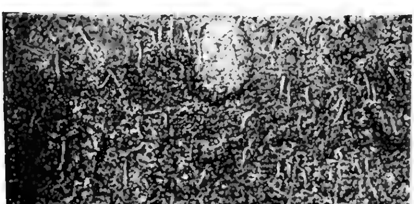
The specimens represented on this plate are all from locality 35k, Middle Cambrian: Burgess shale member of the Stephen formation; on the west slope of the ridge between Mount Field and Wapta Peak, 1 mile (1.6 km.) northeast of Burgess Pass, above Field, on the Canadian Pacific Railway, British Columbia.

1

1a



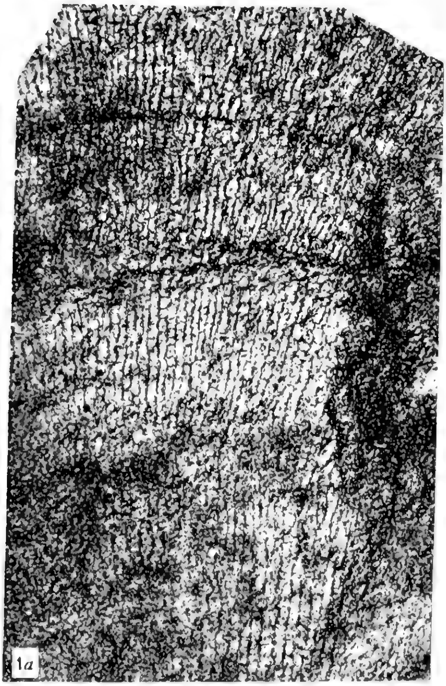
1b



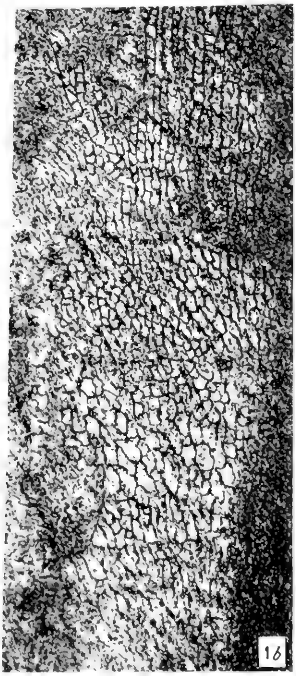
1c

VAUXIA DENSA Walcott

1



1a



1b

VAUXIA (?) VENATA Walcott

DESCRIPTION OF PLATE 85

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

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

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

DESCRIPTION OF PLATE 86

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Eiffelia globosa Walcott.. 324

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

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

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

Chancelloria eros Walcott (see pl. 88)................................ 329

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

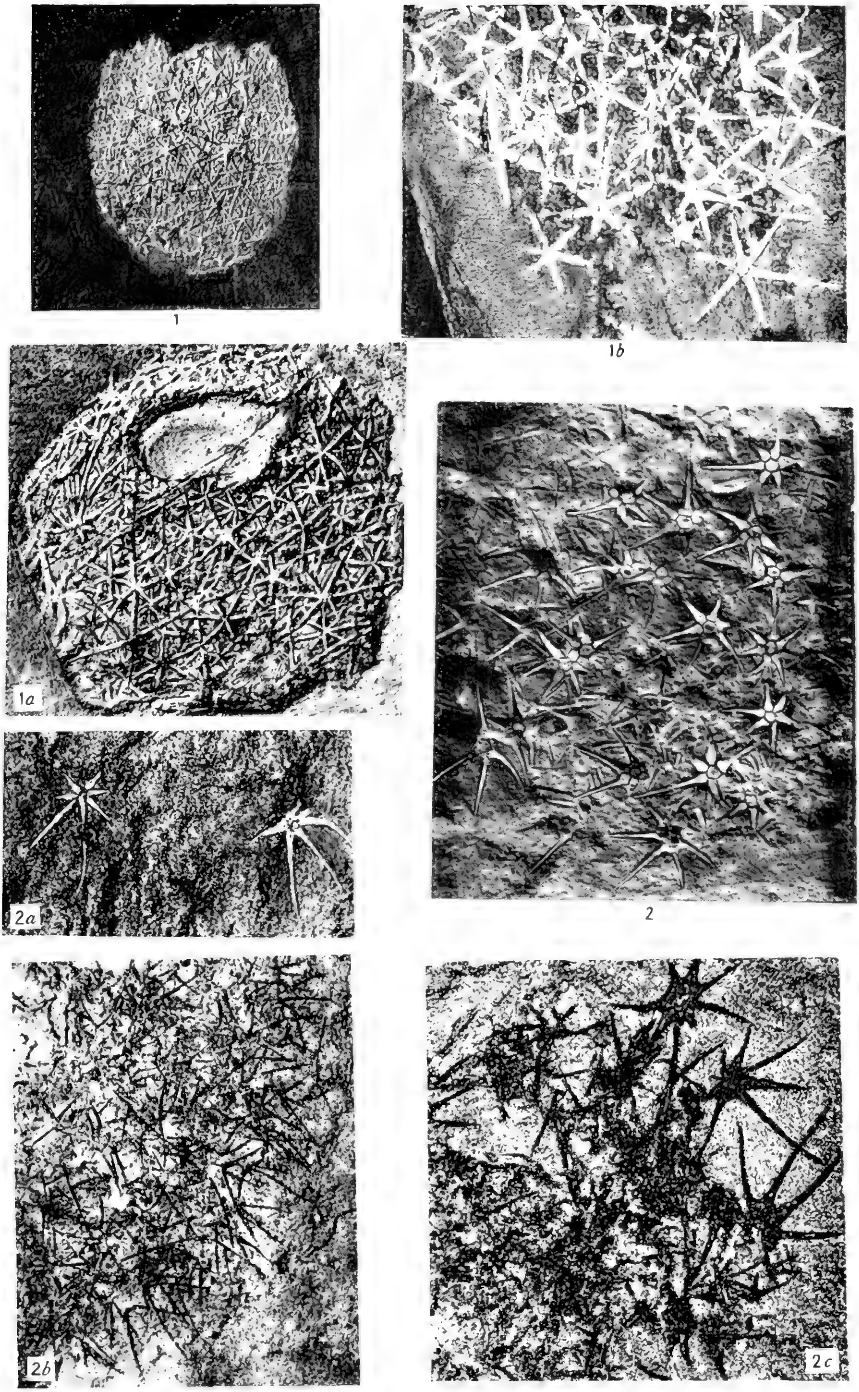
2*a*. (× 6.) Separate spicules flattened on the surface of the shale. U. S. National Museum, Catalogue No. 66525.

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

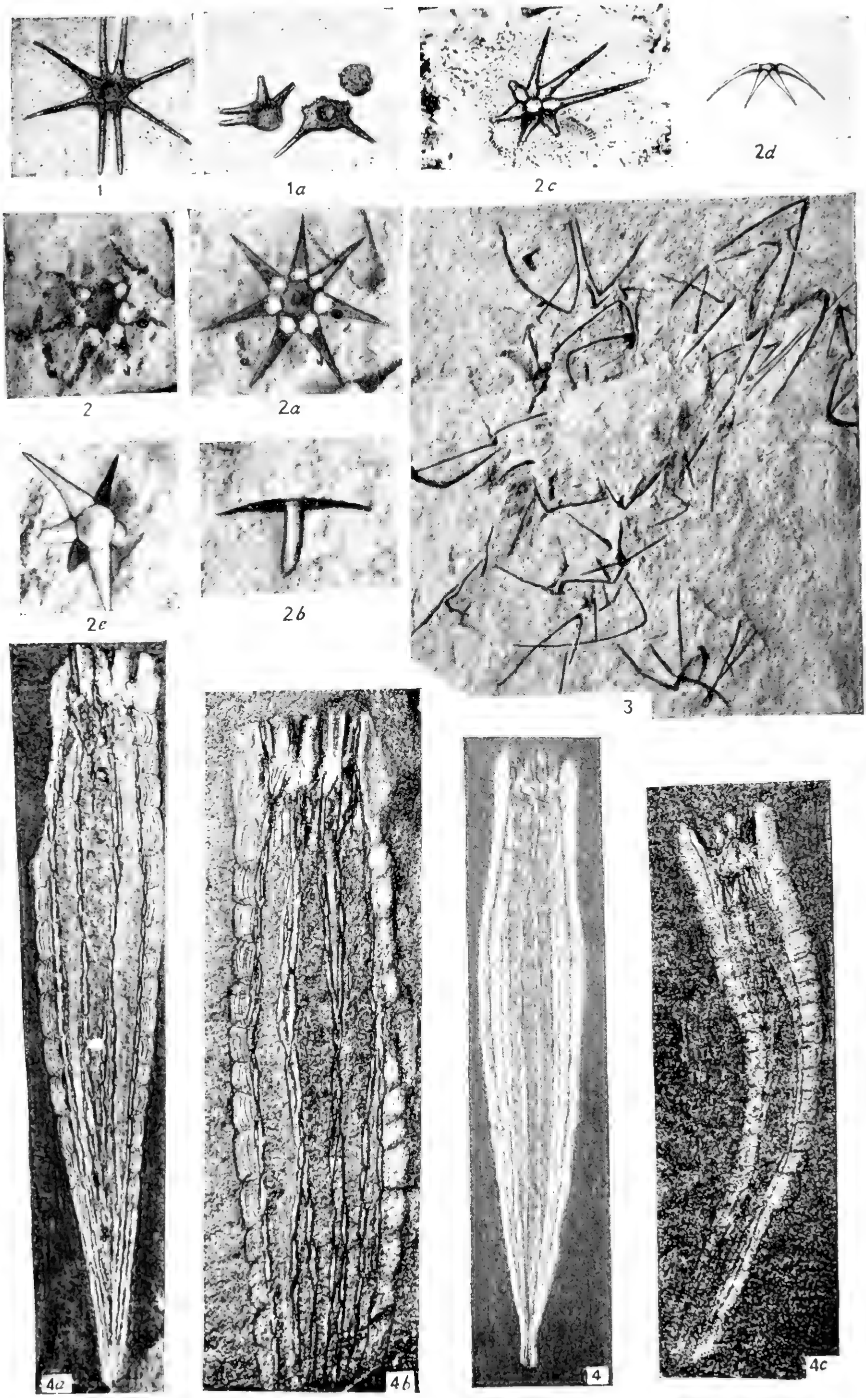
2*b*. (× 4.) Portion of probable inner wall of the body flattened on the surface of the shale with delicate spicules broken and crushed. U. S. National Museum, Catalogue No. 66529.

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

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



1. Eiffelia globosa Walcott
2. Chancelloria eros Walcott



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

DESCRIPTION OF PLATE 87

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Chancelloria libo Walcott.. 332

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

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

Chancelloria drusilla Walcott.. 331

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

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

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

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

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

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

Chancelloria yorkensis Walcott.. 332

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

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

Takakkawia lineata Walcott.. 277

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

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

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

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

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

DESCRIPTION OF PLATE 88

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Chancelloria eros Walcott (see pl. 86) 329

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

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

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

The specimen represented by fig. 1*b* is from locality 14s, Middle Cambrian: *Ogygopsis* zone of the Stephen formation; about 2,300 feet (701 m.) above the Lower Cambrian and 3.540 feet (1,089 m.) below the Upper Cambrian, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railroad, British Columbia, Canada.

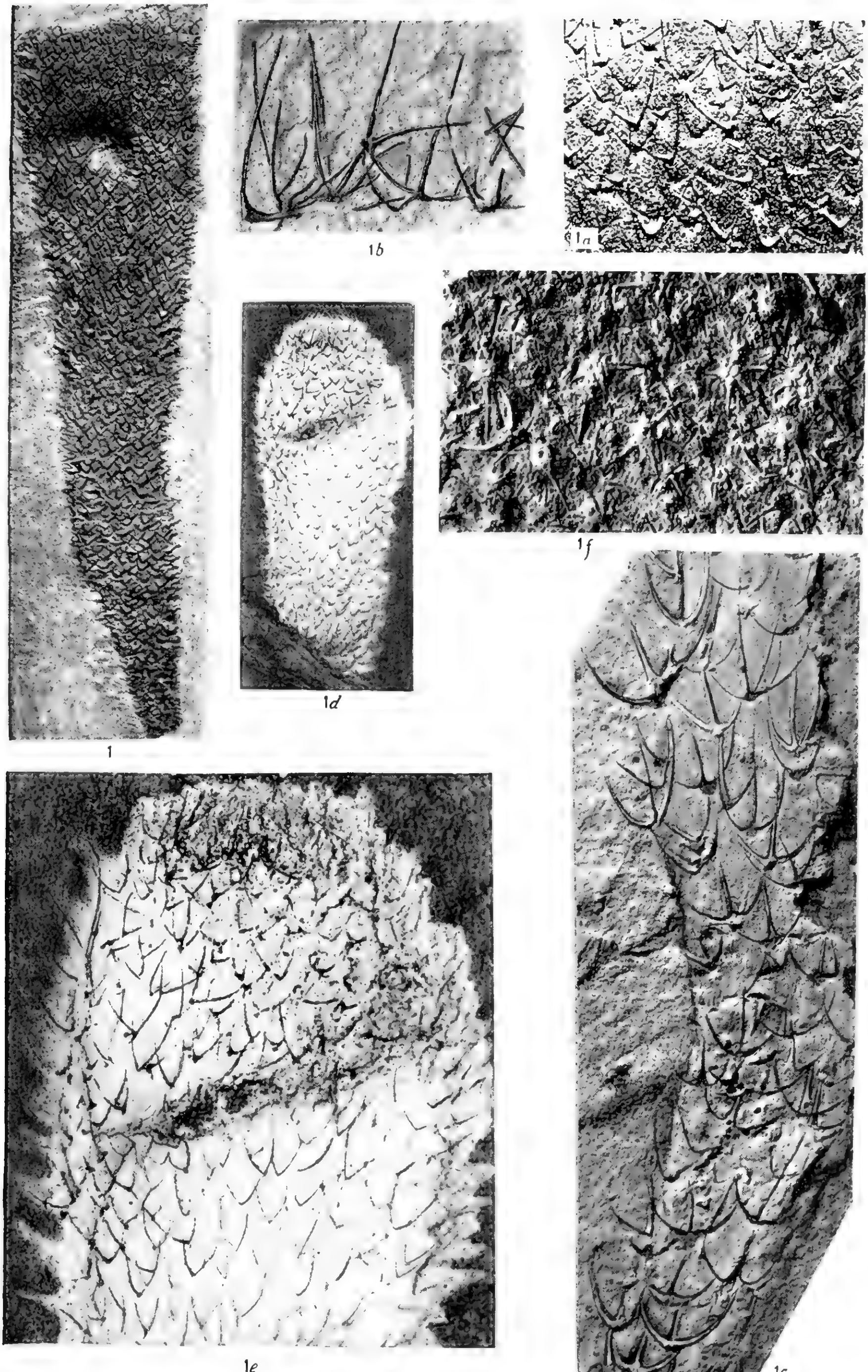
1*c*. (× 3.) A broken-down surface illustrating spicules with 2, 3 and 4 of their rays exposed. The 6- and 7-rayed spicules are shown in fig. 1*f*. U. S. National Museum, Catalogue No. 66527.

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

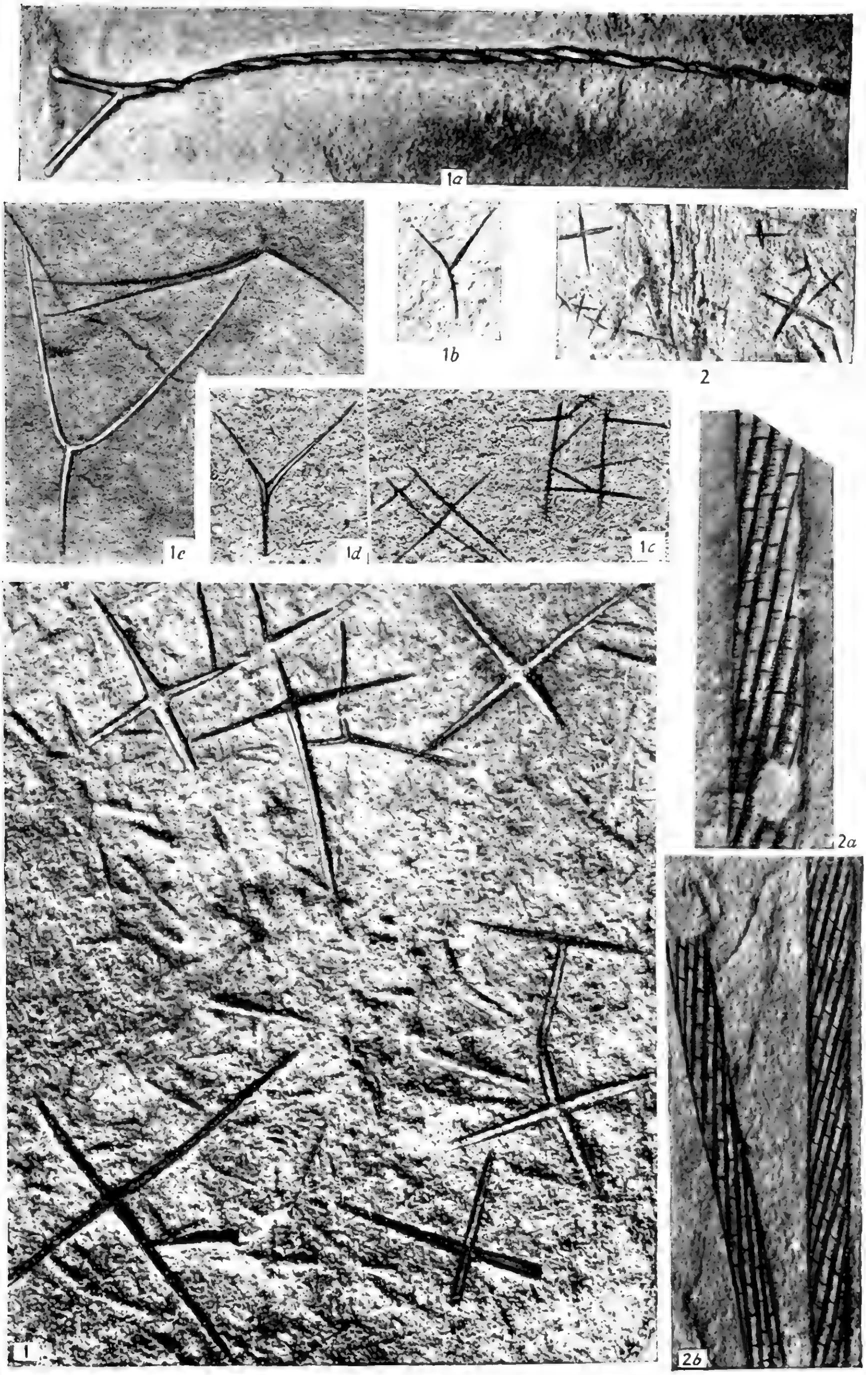
1*e*. (× 3.) Enlargement of the surface of fig. 1*d* to illustrate portion of spicules showing at the surface.

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

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



CHANCELLORIA EROS Walcott



1. Kiwetinokia utahensis Walcott
2. Kiwetinokia spiralis Walcott

DESCRIPTION OF PLATE 89

PAGE

Kiwetinokia utahensis Walcott 313

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

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

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

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

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

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

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

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

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

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

Kiwetinokia spiralis Walcott 314

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

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

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

The specimens represented by figs. 2, 2*a*, 2*b* are all on same surface of one specimen, from locality 10z, Middle Cambrian: Marjum formation; about 2,900 feet (884 m.) above the Lower Cambrian and 1,500 feet (457.2 m.) below the Upper Cambrian in the central part of the limestone forming 1a of the Marjum limestone, in the long cliff about 2 miles (3.2 km.) southeast of Marjum Pass, House Range, Millard County, Utah.

DESCRIPTION OF PLATE 90

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

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

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

Hazelia delicatula Walcott (see pl. 70) 284

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

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

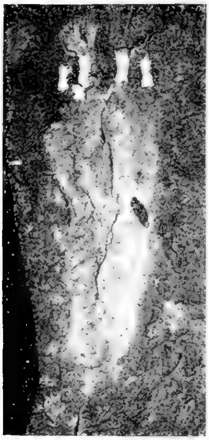
4. (× 2.) An elliptical frond with an elevated center of growth that is somewhat doubtfully referred to this species. U. S. National Museum, Catalogue No. 66779.

Hazelia mammillata Walcott 286

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

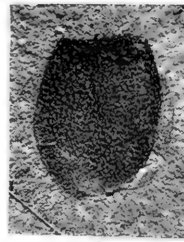
3a. (× 2.) Enlargement of specimen represented by fig. 3 to more clearly show the oscula and pores.

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



1

2a



2

1a

3

3a

4

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

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 7

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 7.—NOTES ON STRUCTURE OF NEOLENUS

(With Plates 91 to 105)

BY
CHARLES D. WALCOTT

(Publication 2584)

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 7.—NOTES ON STRUCTURE OF NEOLENUS

By CHARLES D. WALCOTT

(With Plates 92, 94)

CONTENTS

ILLUSTRATIONS

INTRODUCTION

During the past twenty-five years I have published from time to time preliminary results of investigations, even though I realized that a few months' additional work might give data for more reliable conclusions and protect me from reasonable criticism. I thought it better to present the data with tentative conclusions and stimulate others to investigation rather than to wait for a time of relief from administrative duties. A recent contribution on "Appendages of Trilobites"[1] is an example of hurried investigation under pressure of many duties, also of indifferent illustration brought about by conditions incident to the great world war and my absence during publication while engaged in field-work. I regarded it as probably my last word on the subject for with a large accumulation of notes, illustrations and fossils from the Cambrian formations it did not seem probable that I would return to the subject again. When, however, my old friend, Dr. Charles Schuchert, questioned the presence of epipodites on the limbs of *Neolenus*,[2] I decided to ask three well-known invertebrate paleontologists to make a detailed examination of the material and record their opinion as to whether there was sufficient evidence to warrant the conclusion that in addition to the endopodite and exopodite of the limb of *Neolenus* there was also present another element that was clearly an epipodite. The three paleontologists, Messrs. E. O. Ulrich, Rudolf Ruedemann, and R. S. Bassler, very generously consented to make the investigation and their report under the title, "Notes on Ventral Appendages of *Neolenus*," is as follows:

NOTES ON VENTRAL APPENDAGES OF NEOLENUS SERRATUS

We, the undersigned, recognize, excluding antennules and caudal rami, three kinds of appendages in *Neolenus serratus*, namely, endopodites, exopodites, and "epipodites." Besides these there is in specimen 58580 (pl. 18) an appendage that Dr. Walcott interpreted as an endite or one of a smaller set of epipodites but which we believe to be in this specimen merely the round outer lobe of a displaced exopodite. We observed no convincing evidence of "exites" as a distinct kind of appendages. The parts shown in the upper half of figure 3, plate 20 (representing specimen No. 65515) and which seem to be the basis of the "exites" shown in diagram plate 31, we conceive as a protopodite and the next two succeeding segments of an endopodite that was displaced in such a manner as to take an anterior direction and so that it lies flat (instead of vertical as usual) in the matrix.

REGARDING DISTINCTNESS OF "EPIPODITES" FROM THE EXOPODITES

In general outline—disregarding the setiferous fringe—the two sets of appendages are essentially similar. Both consist of a larger pedunculate inner lobe and a shorter more rounded terminal lobe. The outline of the conjoined lobes is rather regularly, and on the whole gently, arcuate on the anterior side, but the opposite edge or fringed side is biarcuate with an angular indentation at the point of articulation between the two lobes. However, it is to be observed that the specimens show considerable variation in the form, or rather

[1] Smithsonian Misc. Coll., Vol. 67, No. 4, pp. 115-216, Dec., 1918.

[2] American Journ. Sci., Ser. 4, Vol. 47, 1919, p. 231.

outline, of these appendages. This seems due mainly to differences in the angle that the relatively flat bodies held at the time of entombment to the plane of sedimentation and to consequent modifications produced by the compression in the outline which, of course, represents a vertical projection. There doubtless also was some original difference in the form and size of the bodies depending on their relative position in the animal. The size of the exopodites increases in anterior direction to the front of the thorax.

Now, as to structural differences between the two sets of appendages:

(1) In the exopodites the surface of the lobes is plain and even, but under the lens shows minute anastomosing subimbricating ("terrassen") lines with a dominant transverse direction—such as are commonly found on tests of crustaceans. No traces of such lines are observable in the epipodites.

(2) The setiferous fringe in the exopodites consists of two distinctly separate and different parts, one arising from the edge of the proximal, the other from the edge of the distal lobe. The fringe on the posterior edge of the main or larger lobe consists of long, closely approximated, now flat and laterally in contact, band-like fimbriæ or setæ, which at a minimum are as long as the width of the body of the lobe and may reach twice that length. These fimbriæ seem to have been firmly attached to the lobe and without any basal contraction or articulation, and they are smaller, hence more numerous in a given space, in the posterior than in the more anterior exopodites. At the first of the thoracic segments about 27 of these fimbriæ were counted in 10 millimeters. At the last of the thoracic segments and on the pygidial appendages the number increases to about 40 in the same space. This increase in number of fimbriæ is relative rather than absolute, being essentially proportionate to the size of the exopodite. In the epipodites the corresponding fringe consists of minute, well-separated, relatively short, cylindrical, acutely pointed spines. The maximum length of the spines does not exceed one-sixth the width of the lobe bearing them. In both the exopodites and the epipodites the fringe of setæ on the distal lobes is essentially of the same nature as that on their respective proximal lobes. However, it will be observed that in both cases the former are finer and on the exopodites also very much shorter.

(3) The surface of the epipodites exhibits no trace of the transverse inosculating lines which are generally present on the exopodites, being, so far as these wrinkles are concerned, entirely smooth under magnification. On the other hand certain structures are rather clearly indicated on the epipodites that are wholly wanting on the exopodites. Most important of these is a line of denser substance running some distance within and parallel to the margin of both lobes. On closer inspection small denticles are observed projecting from one side of this inner line. From these and other corroborating facts observed it is inferred that both surfaces of the epipodites bore two spiniferous carinæ which united on the smaller lobe. Except at these carinæ the walls of the epipodites seem to have been exceedingly thin and at least more tenuous than those of the exopodites. On account of their isolated and exposed position, not being held together like the exopodites by long overlapping fringes of setæ, and lying between the endopodites and outside the exopodites, they were much more liable to be lost.

These epipodites have been observed in only one specimen. This specimen evidently shows the lateral aspect of the legs, as proven by their curvature and the row of ventral spines on their concave sides. It also shows that the epipodites lie in the same plane with the legs, one interpolated between each pair of the latter and as they expose their broader sides must obviously have held a similarly vertical position. This inference seems almost unavoidable when we consider further that any other orientation of the leaf-like epipodites would have interfered with the movement of the legs. Again, it finds support in the fact that the marginal spines of the epipodites are found on one edge only, and this is on the ventral side the same as on the legs, which being the exposed side is where they would naturally be expected to occur.

On the other hand, the exopodites, as indicated in all of many specimens, were disposed horizontally. These two sets of appendages, therefore, were not only in separate planes, but in each segment approximately perpendicular to each other. This fact, coupled with their obvious weakness of attachment, tenuity of substance, and their isolated and exposed position would seem sufficiently to account for the relative infrequency of display of epipodites in specimens preserving appendages.

Regarding the exopodites several of the specimens suggest that the setiferous fringe is double—in other words, composed of two similar fringes, the one underlying, the other overlying the lobes of the next posterior exopodite.

(Signed by) E. O. ULRICH.
RUDOLF RUEDEMANN.
R. S. BASSLER.

June, 1919.

COMMENTS ON PRECEDING NOTES

The painstaking, thorough study made by Messrs. Ulrich, Ruedemann, and Bassler in June, 1919, led them to conclude that the difference between the exopodites and the large epipodites of the limb of *Neolenus serratus* was of such a fundamental character that the epipodites could not be considered as identical with the exopodites. After reading their notes on my return in October, 1919, from three months' absence in field-work I again examined the specimens and confirmed the conclusions given in my paper of 1918 [1] and corroborated by the independent study of Messrs. Ulrich, Ruedemann, and Bassler to the effect that the ventral thoracic limb of *Neolenus serratus* has an endopodite forming a walking leg, a large two-jointed exopodite with fringes of long, slender filaments or fimbriae on the large proximal joint and fine short filaments on the small distal joint, also a large epipodite consisting of two joints resembling those of the exopodite in form but differing radically in the marginal filaments of the proximal joint, the inner lines of fine carinal spines [2] and the tenuous character of the entire appendage.

They consider that the evidence for a small epipodite in the restoration of the limb of *Neolenus serratus* is not sufficiently sup-

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[1] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, pl. 20, figs. 3, 4; pl. 21, fig. 6; pl. 23.

[2] Shown in fig. 4, pl. 20 (idem), but by oversight not mentioned in text or description of plate.

ported by the one specimen supposed to show it (pl. 18, fig. 1), and in this I am in agreement. The suggestion that the flattened lobes on the sides of the specimen represented by figures 3 and 4, plate 20,[1] in advance of the endopodites and epipodites might be an exite attached to the protopodite was made only as a possible interpretation, and I cannot differ seriously with Dr. Schuchert or Messrs. Ulrich, Ruedemann, and Bassler in their conclusion that the so-called lobes (exites) represented only a protopodite and displaced segments of one or more endopodites. This is a fair interpretation of the specimen and in future restorations of *Neolenus serratus* both the suggested and so-called small epipodites and exites should be eliminated.

I here wish to express my sincere appreciation of the work of Messrs. Ulrich, Ruedemann, and Bassler, in their study of the material representing the ventral appendages of *Neolenus serratus.*

CORRECTION

In description of figure 1, plate 22, mention is made of the ends of three epipodites projecting beyond the exopodites. The removal of some of the overlying exopodites shows that the supposed distal joints of epipodites are distal joints of exopodites. The most important feature of this figure is the position of the exopodites above the endopodites which are seen projecting backward from beneath the fringes of the exopodites. This character is also shown by figures 1-3, plate 19, and figure 6, plate 21.

STRUCTURE OF THE EXOPODITE AND EPIPODITE

The unsatisfactory reproduction of most of the illustrations of the 1918 paper on the "Appendages of Trilobites" has led to the making of new photographs of what may be termed the critical specimens of the exopodite and epipodite, several of which are reproduced on plate 92 of these notes. Figure 1 represents the two upper epipodites of figure 3, plate 20, of the 1918 paper[2] as clearly as it was possible for Dr. R. S. Bassler to photograph them; in figure 2 the spines of the carinae and the fine filaments on the outer margin have been brought out in relief by darkening the background; figures 3 and 3*a* represent an attempt by Mr. L. W. Beeson, Chief Photographer of the U. S. National Museum, to bring out more definite detail of the

[1] Smithsonian Misc. Coll., Vol. 67, No. 4, Dec., 1918.

[2] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, pl. 20.

upper epipodite of figure 1. He has succeeded in securing a little more clearness but it is practically impossible to photograph and then reproduce the original more clearly than on plate 92. Figure 4 is a photographic enlargement of the lower epipodite of figure 4, plate 20, of the 1918 paper. I have outlined the carinae and the short spines as they are indistinct in figure 4, plate 20. These figures, 1-4, show quite a different structure for the epipodite from that of figures 5 and 6 of the exopodite. The general form of the joints in the two is roughly similar as they occur flattened and somewhat distorted in the shale.

Exopodite.—The exopodites represented by figure 6, plate 92, have been shortened and transversely wrinkled by compression, and the distal lobe pushed down. I think the normal outline of the proximal joint of an exopodite was similar to that represented by figure 6, plate 21 (loc. cit.), and for the distal joints, by figure 1, plate 23 (loc. cit.). I have endeavored to represent the form of the exopodite in text figure 13 and on plate 92 of this paper.

The filaments in the compressed specimens (pl. 92, figs. 5, 6) of the large proximal joint appear to be flat with rounded ends and round or cylindrical near where they are inserted into a sheath or socket in the posterior margin; the probabilities are that in their natural condition they were rather strong, slender tubes similar in general form and function to the branchial filaments of the lobster (*Homarus americanus* H. M. Edw.) or of *Meganyctiphanes norvegica* M. Sars in which the filaments are inserted along the thin margin of the epipodite of the thoracic appendages in a manner comparable with those of the exopodite of *Neolenus*. The epipodite of *Diastylis stygia* G. O. Sars, of the order Cumacea has branchial lamellae of a somewhat similar form.

The filaments of the distal joints are inserted along the ventral and outer margin. They are proportionally much shorter and more slender and needle-like than those of the proximal joint and are more like the slender spines that occur on the ventral edge of the joints of the endopodite.

The proximal joints of the exopodites of figure 6, plate 92, have been shortened and transversely wrinkled by lateral compression, and they also give the erroneous impression that the sheaths of the filaments extended nearly across the joint.

A diagrammatic outline of a portion of the body and filaments of a proximal joint of an exopodite is shown by text figure 11.

Epipodite.—The specimens of the epipodite of *Neolenus* were thoroughly studied by Messrs. Ulrich, Ruedemann, and Bassler, and much additional information is recorded in their report. During my recent examination a fortunate view by reflected light brought out the interesting fact that the marginal setae or spines of the proximal joint were inserted in the margin at the point of projection of the minute fluting of the margin, and that they were not spinous extensions of the exoskeleton of the epipodite. The fine spines or setæ of the "carinæ" are not as well preserved as those of the ventral margin nor is the character of their insertion in the exoskeleton known or indicated. It may be that they were inserted in

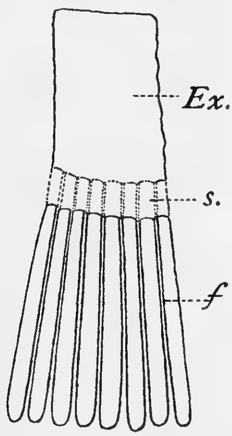

FIG. 11.—Diagrammatic outline of a portion of a proximal joint of a thoracic exopodite of *Neolenus*. *Ex* = body of joint; *s* = sheath into which the filaments (*f*) are inserted.

the same manner as the row of fine spines or setae crossing some of the endites of the trunk limbs of *Apus cancriformis*.

The fine spines or filaments on the lower (ventral) border of the proximal joint appear to be similar in form to those of the margin of the flabellum of the seventh trunk limb of *Apus cancriformis* or of the gill lobe of the second limb of *Apus lucasanus*. These resemblances are merely suggestive, but they assist in the interpretation of the fossil specimens.

The filaments or spines of the distal joint are long, fine and closely set in along the ventral and outer edge. They appear to be proportionally finer than the filaments of the distal joint of the exopodite.

A diagrammatic outline of a portion of the proximal joint of one of the epipodites is given in text figure 12, also a vertical section of the same; whether there were "carinæ" on both sides of the epipodite as on the endites of *Apus cancriformis* is not fully determined, but they are so represented on the restoration (fig. 12*b*).

The natural side outline of the epipodite is unknown but it was probably not very unlike that of the upper one of figure 1, plate 92. There is no evidence that this specimen has been distorted by compression or movement within the matrix; it has been flattened to a thin film as have nearly all specimens in the Burgess shale.

Comparison of exopodite and epipodite.—As already stated, the exopodite and epipodite of *Neolenus* have the same general form and if the filaments on the two were similar and the exopodite showed

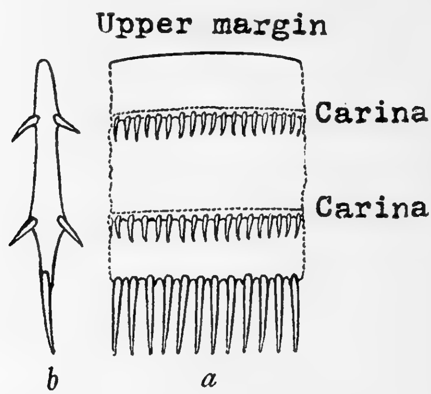

FIG. 12.—(*a*) Diagrammatic outline of a portion of the proximal joint of the epipodite of *Neolenus*. (*b*) Vertical section of fig. 12*a*.

traces of the presence of "carinæ" similar to those of the epipodite there would be no question raised as to the identity of the epipodites shown by figures 1 and 2, plate 92, and the exopodites shown by figure 6, plate 21, and plates 22, 23 of the 1918 paper. In addition to the epipodites being proportionally somewhat smaller and shorter, the fringing filaments of the epipodites are quite dissimilar. It has been suggested that the strong filaments of the exopodite have been broken or pulled off from joints of the specimen, represented by figure 1, plate 92. (See also figs. 3 and 4, pl. 20, of the 1918 paper.) A study of the fringing filaments or spines of the epipodite clearly shows that they are inserted in the margin of the exoskeleton at the crests of the fluted margin (text fig. 12) and that the large filaments of the exopodite are inserted between the crests (text fig. 11) and almost touch each other at the points of insertion. In my notes of the 1918 paper I did not pay attention to the details of structure of

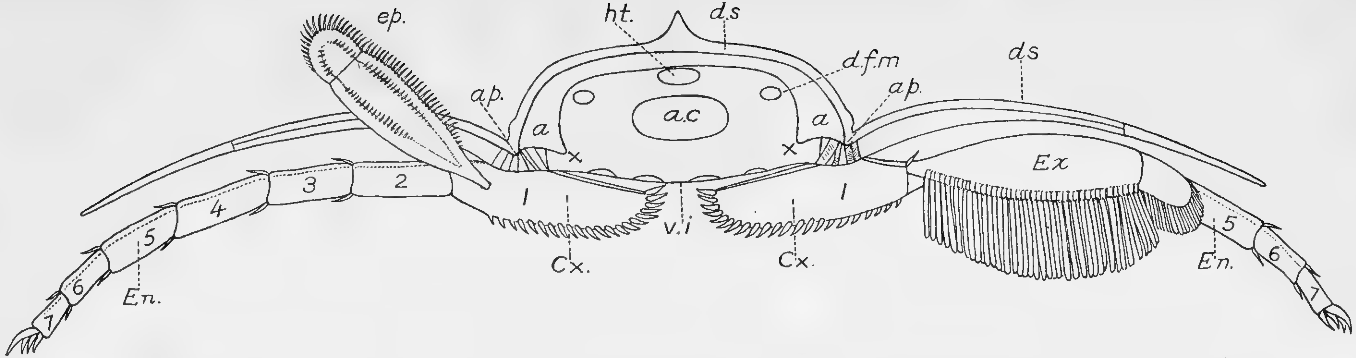

FIG. 13.—*Neolenus serratus* Rominger. *d. s.*=dorsal test. *a.*=articular fold and process at *x*. *a. p.*=axial process. *v. i.*=ventral integument. *a. c.*=alimentary canal. *ht.*=position of heart. *d. f. m.*=dorsal flexor muscle. *cx.*=coxopodite. *en.*=endopodite formed of six joints attached to coxopodite. *ep.*=epipodite attached to coxopodite. *ex.*=exopodite probably attached to side of basipodite (second (2) joint).

Both epipodite and exopodite are represented in an unnatural position; the epipodite may have been turned down but the fringed exopodite was undoubtedly subparallel to the ventral surface of the pleurosternites and above the endopodites. The epipodite is attached to the coxopodite and the second joint (2) basipodite supports the exopodite or the two latter are united at or near the point of union with the distal end of the coxopodite.

The articular fold (*a*) and process (*x*) are only cut across when the section is transverse to the axis of the tergite and along its anterior margin. In figure 13 both the articular fold and the dorsal test of the transversely median line of the tergite are shown, although they cannot both be cut by the same transverse line. See text figure 16, p. 384.

This is a posterior view of a transverse section of the thorax. The fine spines of the epipodite should be on the lower margin in the figure. (See text fig. 14.)

the fringing filaments of the exopodite and epipodite as it seemed so clear that the two were dissimilar, as shown by the figures on plates 20, 21, 23, that I decided to let the illustrations tell their own story.

There are a number of specimens showing the exopodites and there is not one that shows evidence of a spinous "carina" or of fringing filaments broken away from the margin of the large proximal joint so as to give anything like the appearance of the short marginal setæ or spines of the proximal joint of the epipodite.

Transverse section of the thorax of Neolenus.—Text figure 13 is a restoration of a posterior view of the appendages of the thorax of *Neolenus* differing from that published in 1918[1] in the omission of the small hypothetical exite and the small tentatively assumed epipodite; there are also changes of detail in the exopodite and epipodite. The interior boundary lines of the exopodite that were introduced by the draftsman and overlooked have been omitted and the character of the spines and filaments more clearly defined.

Diagram of thoracic limb.—The thoracic limb shown by the diagrammatic outline of text figure 14 follows the interpretation of the limb given in figure 13. The limb is straightened out so as to present the ventral side of the coxopodite and endopodite; the filaments of the exopodite are above the dorsal side of the endopodite and the epipodite is flattened out so as to show its outline and "carinal" spines. The exact points of attachment of the exopodite and epipodite have not been determined, but I think they are approximately as represented in figures 13 and 14, and on plate 92.

Diagrammatic ventral view of the appendages of Neolenus.—The figure on plate 94 is drawn on the same base as the restoration on plate 31 of the 1918 paper. The latter being unsatisfactory both in drawing and reproduction, a new figure has been prepared in which the small epipodite and exite of the former figure have been omitted for reasons already given (ante p. 369), and the coxopodites, endopodites, and large epipodites represented so as to give a clear view of each in approximately their supposed natural position. The endopodites are removed on the right side from six of the thoracic limbs so as to show the exopodites with their fringe of filaments projecting backward and overlapping; two of the cephalic limbs have an exopodite attached, the other two and those of the postero-cephalic limbs being omitted in order to avoid confusion; the two exopodites on the cephalic limbs probably extended outward on a

[1] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, pl. 18, fig. 2.

line with the endopodite, but they are represented as extending forward in order to bring them out more distinctly.

Six epipodites are represented on the left side, those of the other

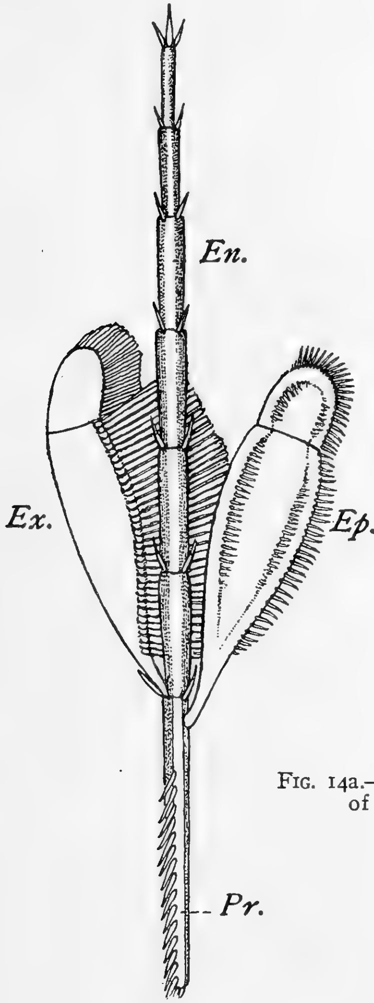

FIG. 14a.—Cross section of joints 1-5.

FIG. 14.—Diagrammatic outline of a thoracic limb.

limbs being omitted. In a natural state the epipodites were probably situated above the endopodites and exopodites.

Exopodites of Marrella.—The filaments of the anterior exopodites of *Marrella splendens* Walcott [1] are similar in form to those of the

[1] Idem, Vol. 67, No. 4, 1918, p. 140.

exopodite of *Neolenus serratus* (Rominger), and appear to be arranged along the margin of the joints in the same manner. These will be further illustrated and described in a paper following this, which it was my intention to publish as Number 5 of this volume, but which was deferred on account of an opportunity to collect more specimens of *Marrella* during the field season of 1919. Attention is called here to the conclusion based on a large number of specimens that the so-called epipodite of the limb of *Marrella* mentioned in the paper of 1912[1] is formed of a number of exopodites with their filaments matted down together.

AFFINITIES OF THE TRILOBITES

Dr. W. T. Calman[2] in a review of my paper on the "Appendages of Trilobites" calls attention to the absence of a carapace in the trilobite as one of the most important differences from what the primitive crustacean may be supposed to have been like[3] as he considers it a reasonable conclusion that the fold must have been present in the ancestral stock of the Crustacea.

I did not discuss the affinities of the trilobites at length as I wish to consider them in connection with other crustaceans from the Burgess shale. Attention was called to resemblances between the ventral appendages of the trilobite and those of modern crustaceans not so much as indicating their affinities as to show that elements such as epipodites for instance were present both on the limb of the trilobite and that of Anaspides.

The number of cephalic appendages for *Calymene* was fairly well determined by Walcott in 1881[4] from sections cut through the head, and determined conclusively for *Triarthrus* by Beecher in 1895[5] and inferentially for *Neolenus* by Walcott in 1918.[6]

[1] Smithsonian Misc. Coll., Vol. 57, No. 6, 1912, pl. 26, fig. 4.
[2] Geol. Mag., London, Vol. 6, Dec. 6, 1919, pp. 359-363.
[3] Idem, p. 363.
[4] Bull. Mus. Comp. Zool., Vol. 8, 1881, p. 201, pl. 1, and restoration pl. 6.
[5] American Geol., Vol. 15, pp. 93-98, pl. 4.
[6] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, p. 127, pl. 16.

SUPPLEMENTARY NOTES

(With Plates 91, 93, 95-105)

CONTENTS

ILLUSTRATIONS

INTRODUCTION

The preceding notes were held in page proof during my absence in the Canadian Rockies during the field season of 1920 in hopes that trilobites with attached appendages might be found, but not a fragment of an appendage was seen. In this connection it may be of interest to state that I have collected only fourteen specimens of *Neolenus*[1] with more or less well preserved ventral appendages. It is, therefore, not surprising that it has not been possible to work out complete details of structure, or that there should be differences of opinion in relation to the interpretation of some of the specimens. To those who can do so we extend an invitation to visit the National Museum and study the specimens of *Neolenus*. The Beecher material of *Triarthrus* at the Peabody Museum, New Haven, Connecticut, and the Walcott material of *Ceraurus* and *Calymene* at the Museum of Comparative Zoology at Cambridge, Massachusetts, are also accessible to students.

On my return from the field in October, 1920, I learned that a memoir on the structure of the trilobite, by Dr. Percy E. Raymond, was in press. This caused me to still further delay publication, in the hope that some new evidence might be presented by Raymond. A copy of the memoir was received in January, 1921.[2]

[1] Throughout these supplementary notes when the genera *Neolenus, Calymene, Ceraurus,* and *Triarthrus* are mentioned, the species referred to are as follows: *Neolenus serratus* Rominger, *Calymene senaria* Conrad, *Ceraurus pleurexanthemus* Green, and *Triarthrus becki* Green.

[2] The Appendages, Anatomy and Relationships of Trilobites. Mem. Conn. Acad. Sci., Vol. VII, 1920.

On application to Dr. Samuel Henshaw, Curator of the Museum of Comparative Zoology, he generously permitted Dr. Raymond to send me all of the Walcott sections of *Calymene* and *Ceraurus,* which has given me the opportunity to complete the study of the slides abandoned in 1918, and to make an unusually fine set of photographs some of which are illustrated on plates 97, 100, 103 of these notes.

Dr. Schuchert very kindly sent me the Beecher types of *Triarthrus becki* for reexamination and photographing, and I may at a future time have some of the photographs reproduced along with new material that may be available.

In the preparation of the photographs I have been greatly indebted to the cordial cooperation and skill of Dr. A. J. Olmsted, Chief Photographer of the U. S. National Museum. Miss Frances Weiser has carefully redrawn in ink all my pencil sketches, and Mrs. Walcott has touched out many bright spots on the photographs caused by the light reflecting from sections of minute crystals of calcite.

THE RAYMOND MEMOIR

This is a fine contribution and gives evidence of prolonged, thorough study, keen observation, and a comprehensive grasp of detail and the broader aspects of the subject. Students of the crustacea may or may not agree with Dr. Raymond's conclusions on the "Relationship of the trilobites to other Arthropoda" and "that the trilobite is the most primitive of the arthropods," but they will find the memoir presents the evidence known to him and his interpretations and generalizations with unusual clarity of statement and illustration.[1]

This elaborate memoir clearly indicates how little we really know of the detailed structure of the trilobite, the small amount of material available for study, and what a splendid opportunity there is for the tireless investigator who will search the Paleozoic rocks of the world for exceptional layers in deposits like those of the Burgess shale, Utica shale and Trenton limestone.

The memoir needs an index despite its rather full table of contents. It would also be more convenient for reference if the descriptions of the figures on the plates each had a page reference to where they are described or mentioned.

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[1] After studying the typical specimens of *Neolenus serratus* Rominger in which ventral appendages were preserved, Dr. Raymond wrote me under date of February 22, 1919, and sent sketches of his interpretation of the specimens, which is essentially the same as that given in his memoir.

I shall now comment upon a few of Raymond's observations and illustrations in order to present to the student a slightly different point of view of them.[1]

Epipodites.—In the preceding pages (pp. 366-374) reference is made to the large epipodites of *Neolenus,* the evidence for the existence of which was not satisfactory to Raymond, but which is so to Messrs. Ulrich, Bassler, Ruedemann, and Walcott. Raymond's diagrammatic outlines of the "so-called epipodite" (fig. 4, p. 26) (specimen No. 65515) was evidently drawn from the upper appendage shown by figure 1, plate 92 of these notes. He failed to recognize, or at least to indicate in his drawing, the well marked line of union of the proximal and distal joints, the two carinæ with their fine spines, and that the spines on the ventral margin were unlike the strong slender branchial tubes (filaments) of the exopodite (pl. 92, fig. 5).

Raymond's diagrammatic outline, figure 3, page 26, was probably drawn from the exopodite near the center of the specimen represented by figure 6, plate 92 of these notes. His statement that the fine "setæ"[2] of his figure 4 represent fragments of the "setæ" similar to those of the proximal and distal sections of figure 3, clearly indicates a confused conception of the nature of the branchial filaments of the exopodite and the fine slender spines of the epipodite. The character of the branchial filaments of the exopodite is shown in figure 5, plate 92, and text figure 11, page 371, and my interpretation of the delicate spines of the epipodite by figures 2 and 4, plate 92, and text figure 12, page 372 of these notes.

Raymond in his memoir agrees with the view of Messrs. Ulrich, Bassler, and Ruedemann (ante p. 366) that there is insufficient evidence to establish the presence of the small epipodite and the suggested exites of Walcott, in *Neolenus* and with Schuchert in objecting to the presence of the so-called exites and all epipodites large

[1] Throughout these supplementary notes reference to plates 91 to 105 is to plates accompanying this paper.

Walcott 1881 refers to paper published in 1881, Bull. Mus. Compt. Zool., Vol. VIII, No. 10.

Walcott 1918 refers to paper published in 1918, Smithsonian Misc. Coll., Vol. 67, No. 4, pp. 115-215.

Raymond 1920 refers to Dr. Raymond's Memoir, Conn. Acad. Sci., Vol. VII.

[2] Dr. Raymond uses the term "setæ" for the lamellar elements of the exopodites. Dr. W. T. Calman (Geol. Mag. Vol. VI, 1919, p. 361) in reviewing Walcott's paper of 1918 calls attention to his use of the term and suggests that "the form of the elements is very different from that usually indicated by the term setæ."

or small. His restorations of the ventral surface of *Neolenus* consequently omit the large epipodites recognized by Walcott and Messrs. Ulrich, Bassler, and Ruedemann.

Articular socket.—Figure 2, page 24 of Raymond is an outline sketch of two of the endopodites of *Neolenus* (specimen No. 58589) in which a notch is noted (in the figure) on the lower margin of the outer end of the proximal joint (coxopodite) and a corresponding projection on the opposite upper margin. I did not note the "notch" when studying the specimen (No. 58589) in 1917, but I now find that it is shown in three of the limbs (text fig. 15, p. 383) at the point of union of the coxopodite[1] and basipodite. Carefully reexamining the specimen and uncovering the posterior margin of the proximal joint of the next three anterior limbs, I found on all what appears to be the "notch" or "articular socket of the coxopodite" of Raymond, where the second joint (basipodite) unites with the first joint (coxopodite), and that there is not a "notch" on the margin of the coxopodite as described by Raymond on the evidence afforded by limb marked *D* of our text figure 15 (specimen No. 58589). There is a slight thickening or irregularity on the upper or anterior margin of the coxopodite that may have been the margin of the opening for the insertion of the muscles uniting it to the axial processes[2] of the dorsal test of the axial lobe.

I have called attention to this so-called "articular socket" of Raymond, elsewhere referred to by him as a "ball-and-socket" joint (p. 126), as it appears to be the evidence that led him to reverse the natural position of the coxopodite in his restorations of *Neolenus* (figure 7, p. 30, figure 8, p. 31) so that the ventral side is uppermost and the dorsal side below, while the remaining joints of the endopodite are in a natural position as shown by specimen No. 58589 (see text figure 15) and No. 58588 (plate 93, figure 2).

Raymond states (p. 25) "Because the spines on the endobases are dorsal it does not follow that those on the endopodite were, for the position of the coxopodite in a crushed specimen does not indicate

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[1] Dr. Calman (Treatise on Zoology, Lankester, Pt. VII, 1909, p. 146) gives a diagram of a malacostracan thoracic limb in which the coxopodite and basipodite form the protopodite, and the exopodite is attached to the basipodite. As I considered that the endopodite and exopodite of *Neolenus* were attached to the long proximal joint of the thoracic appendage, it followed that I considered the proximal joint of *Neolenus* to be the protopodite and formed of a combined coxopodite and basipodite. This has led to my often using the term incorrectly.

[2] Walcott, 1875, Notes on *Ceraurus pleurexanthemus*. Ann. New York Lyc. Nat. Hist., Vol. XI, p. 162, pl. XI.

the position of the endopodite even of the same appendage." The above was written in connection with his description of specimen No. 58589, in which the coxopodites of four cephalic limbs are shown, also the attached endopodites. I have had photographs made of the coxopodites and endopodites which are reproduced as text figure 15 and figure 2, plate 91 in which it does not seem at all probable that all four of the coxopodites have been reversed although thoroughly flattened by compression in the sediment; on the contrary they are in a normal position in relation to the endopodite; the coxopodite *D* has the marginal spines finely preserved as shown by figure 2, plate 91. The coxopodites of specimen No. 58588, illustrated by our figure 2, plate 93, clearly prove their position in relation to the endopodite, and that it is the same as in specimen No. 58589 (text figure 15).

Raymond considers that he has recognized the "ball-and-socket" joint in two of Walcott's thin sections of *Calymene* (slide No. 63, figure 15, p. 53) and *Ceraurus* (slide No. 128, figure 17, p. 58). The evidence for this is very unreliable, as in many sections of both *Calymene* and *Ceraurus* a hollowing out occurs where any projecting point approaches closely to a fragment of what was a portion of an appendage or a filling of the visceral cavity. This is shown in figure 8, plate 2, Walcott, 1881, and figure 3, 4, 5, plate 91; figure 18, plate 95, of these notes. There does not appear to be evidence either in the specimens of *Neolenus* or the sections of *Calymene* or *Ceraurus* to sustain the "ball-and-socket" joint theory.

Attachment of ventral limbs to dorsal test.—I inferred in 1881 that the coxopodite was attached to the ventral membrane by "a small round process projecting from the posterior surface of the large basal joint, and articulating in the ventral arch somewhat as the legs of some of the Isopods articulate with the arches in the ventral membrane." This incorrect view was based on several sections (Walcott, 1881, plate 2, figures 3 and 6; plate 3, figure 9; plate 5, figures 1 and 3) where a narrow extension appears to unite the appendage and the ventral surface. Other sections suggest that the coxopodites of the cephalic region were attached in *Calymene* near their proximal end (Walcott 1881, plate 1, figures 6, 7, 8) while those of the thorax were attached further out towards the distal end (Walcott, 1918, plate 26, figures 6, 7).

Walcott (1918 p. 159) wrote:

> The exact form of attachment to the ventral integument is unknown, but as stated under *Neolenus* it was probably narrow and long and connected the dorsal side of the protopodite with the ventral integument and interior supports somewhat as the limbs of *Apus* and *Limulus* are attached to the body.

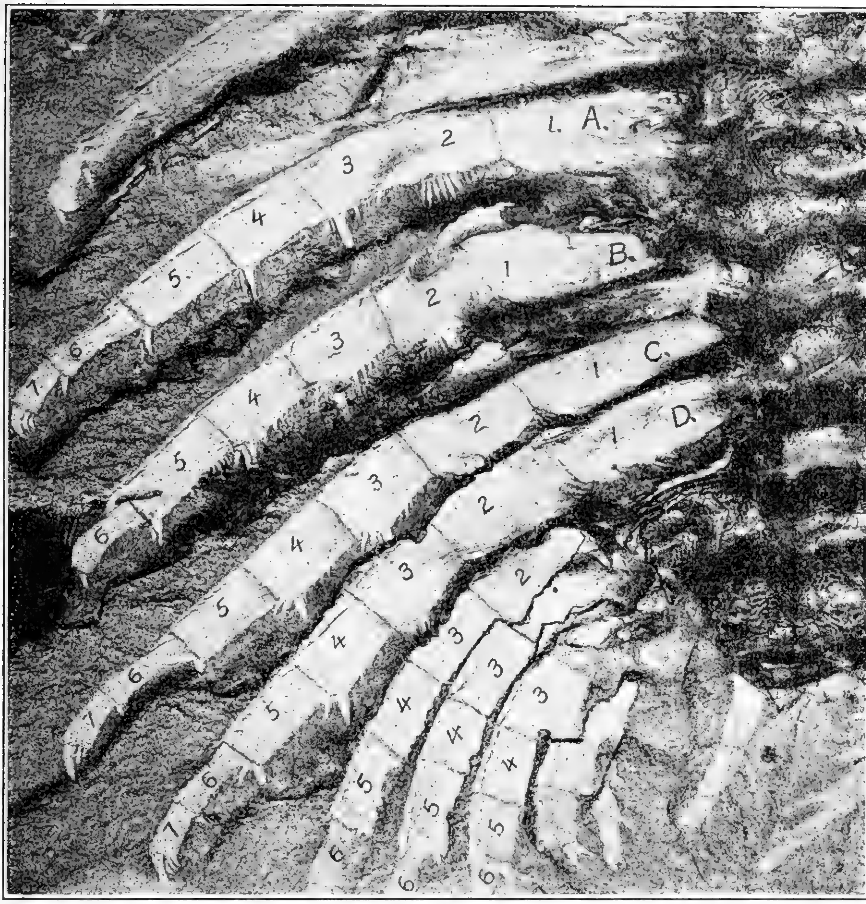

FIG. 15. (× 5) *Neolenus serratus.* This is a reproduction of a photograph of a portion of specimen No. 58589 illustrated by Walcott (1918, pl. 18) by a retouched photograph in which the coxopodites were too much "restored" by the artist. I succeeded recently in removing a little of the adhering dorsal test of the specimen so as to give a better view of the coxopodites of three of the limbs *A, B* and *C* (figure 15). These, as well as the posterior coxopodite *D,* show the notch of Raymond to be at the junction of the coxopodite (1) and basipodite (2), also that the coxopodite (1) is in a natural position in relation to the basipodite (2) and not reversed as assumed by Raymond in his restorations of *Neolenus* (figures 7 and 8, pages 30, 31). The line of the union of the ends of the joints of the endopodite and the distal end of the coxopodite are usually very distinct when seen by reflected light, but it is impossible to get all details in any one photograph as may be seen by comparing the coxopodite *D* of figure 15 with *D* of figure 2, plate 91.

A, B, C, D. Coxopodites of the four posterior limbs of the thorax.

1 = coxopodite.
2 = basipodite.
3 = ischiopodite.
4 = meropodite.
5 = carpopodite.
6 = propodite.
7 = dactylopodite.

I have not used the term appendifer proposed by Raymond (p. 20) as it does not appear to be the process to which the coxopodite of the ventral limb articulated as he supposed. In fact there are two processes, the one beneath the dorsal furrow at the union of the mesotergite and pleurotergite, and the usually more prominent one on the ventral crest of the fold formed where the articular extension of the mesotergite arches over to unite with the mesotergite (see figs. 1, 3, 4, 5, of plate 102); this latter process may be called the mesotergite process, and the one beneath the dorsal furrow the axial process. I have not seen any evidence that either process extended down to or through the ventral integument. They appear to have been points of attachment for the internal muscles and the axial process afforded

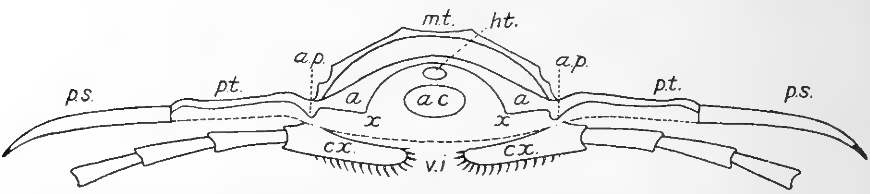

FIG. 16.—*Ceraurus pleurexanthemus* Green. Diagrammatic outline of a transverse section of thorax that cuts across the deepest part of the ventral fold of the anterior articular extension of the mesotergite. A section a little in advance or back of this would not touch the lateral downward extensions of the fold *a. a.* or the low processes on the latter at *x. x.* The axial processes *a. p.* are on the anterior margin of the mesotergite at its union with the pleurotergite *p. t.* The spinous extension of the pleurotergite is lettered *p. s.* and the mesotergite *m. t.*

The relations of the dorsal test and its ventral processes to the ventral membrane and appendages are shown by the dotted outlines. *v. m.* = ventral membrane. *cx.* = coxopodite.

a strong base for the muscles connecting the coxopodite of the ventral limb to the dorsal test. The mesotergite process was not as favorably situated and not as firmly supported as the axial process to serve as a base for the muscles of the ventral limb. A diagrammatic outline of the dorsal test and the two processes that is based on figure 4, plate 102 is here inserted as text figure 16. This illustrates at *a. p.* the axial process and at *x.* the mesotergite process, formed by the downward extension of the sharp fold of the anterior extension of the mesotergite as an articular process upon which the posterior reflexed margin of the mesotergite rests both when the thorax of the trilobite is straightened out and when it is enrolled. An outline of this structure is shown by figures 3 and 4, plate 96.

That many transverse and longitudinal sections of the thorax of *Calymene* and *Ceraurus* show a narrow attachment between the coxopodite and the ventral integument indicates that the coxopodite as well as its elongate connection with the ventral integument was when in a natural position slightly oblique to the longitudinal axis of the trilobite; this causes the peculiar subtriangular sections of the coxopodite and the narrow point of contact between it and the ventral integument. See figures 6 and 17, plate 95; figure 9, plate 99. A few slides have cut across the longitudinal line of the coxopodite and given such sections as those represented by figures 1, 3, 4, 6, 11 and 15, plate 26, Walcott 1918. Of these, figure 11 (figure 6, plate 101 of these notes) and figure 4, give the best longitudinal sections but none show clearly the point of contact of the coxopodite and the ventral integument, although it is suggested in figures 3, 4, 5 and 11, plate 26, 1918.

The ventral surface of the test of the thorax of *Ceraurus* is illustrated by figure 4, plate 102. Without such an illustration it would be exceedingly difficult to interpret the processes cut across in both *Ceraurus* and *Calymene*. Figure 5 of plate 102 also indicates the presence of strong points of attachment for muscles on the ventral side within the dorsal furrow ridge and on the axial process.

It is highly probable that the dorsal margin of the coxopodite, where the muscles passed through, was closely set into the edges of the elongate opening for the passage of muscles through the ventral integument, very much as in *Limulus*.

The genera *Neolenus* and *Isotelus* especially having almost no processes beneath the mesotergite, the muscles must have been attached directly to the dorsal test as in *Limulus,* and like the latter there must have been quite a distance between the ventral integument and the dorsal test that was largely filled in with muscles and the internal organs of the body. It is difficult to conceive of any kind of a direct joint between the proximal joint of the ventral limbs and the dorsal test.

On the basis of the above data and the known method of attachment of the limbs of *Limulus,* I venture to indicate the approximate position of the muscles that held the coxopodite of the limb of *Neolenus* in position and made it a strong, effective ambulatory leg (text figure 13, p. 373). This form of attachment to the ventral surface of the dorsal test, and in a less degree to the ventral integument, would give a strong fulcrum and the necessary firmness to enable the trilobite to use its endopodite as a walking leg and to push itself along on the surface of soft sand and mud, and to force the front of its cephalon into soft sediment when in search of food. Raymond mentions " the prowling of trilobites " around in mud in search of prey (p. 103). That some species crawled over and pushed their way into the mud and silt is beautifully shown by the records left on the argillaceous shales and sandstones of the Upper Cambrian (Walcott, 1918, plates 37-42). On many of these trails the imprint of the long coxopodites and endopodites is finely preserved (idem, plate 38, figures 3-6). It is an interesting coincidence that trilobite tracks and trails are often the most abundant on surfaces where annelid trails are most numerous (idem, plate 42, figure 3).

The processes beneath the mesotergite of *Cryptolithus tessalatus* Green are beautifully shown in some of Dr. Beecher's specimens; they are proportionally much larger than those of *Calymene* and *Ceraurus* and must have given a strong support for the muscles of the stout ventral limbs of this species.

Position of the limbs in life.—*Neolenus serratus* had a thin test, but when it is compared with the test of the king crab (*Limulus*) it has about the same thickness in specimens of the same approximate size. The test of the axial and pleural lobes of *Neolenus* was reinforced by rounded ridges and local increases in thickness that gave it strength and, when attached to the ventral integument by muscles, a rigidity that would permit of relatively great strain being applied to it without flexing or breaking. With the muscles of the coxopodite of the limbs of *Neolenus* extending through the ventral integument to the strong axial process and its base, the limb had a firm base of support and the animal could use its legs (endopodite and long coxopodite) to walk clear of the surface or push its way through the surface of soft mud or sand in search of food, or sink and emerge from it very much as *Limulus* does. Young specimens of *Limulus* with the most delicate test manage to push themselves into mud and sand so as to be nearly concealed from view, and from the study of the tracks and trails I have referred to as of trilobitic origin, it seems very probable that *Neolenus* and trilobites of a similar form had the same habits.

The position of the flat coxopodites and the flattened joints of the endopodites of *Neolenus* was probably nearly vertical with a slight backward slant; this is the position of the legs in *Limulus* and in the closely arranged limbs of *Apus*, and with a relatively slow moving, usually creeping, animal like *Neolenus, Isotelus* and allied forms, such an arrangement would not materially affect their movements by causing resistance in passing through the water when swimming. The section of the coxopodite and proximal joints of the endopodite of *Neolenus* is broad at the top, with deep, nearly straight, sides and a slightly rounded ventral edge; this gave great strength and kept the flat-lying shafts and fimbriæ of the exopodites from drifting down between the endopodites.

> In considering the position of the appendages in life, one must always remember one great outstanding feature of trilobites, the thinness and flexibility of the ventral membrane. The appendages were not inserted in any rigid test but were held only by muscular and connective tissue. Hence we must premise for them great freedom of motion, and also relatively little power. The rigid appendifers, and the supporting apodemes discovered by Beecher, supplied fulcra against which they could push but their attachment to these was rather loose. (Raymond, p. 74)

Ventral integument.—Dr. Raymond (p. 50) refers to the ventral membrane of *Ceraurus* and *Calymene,* but does not discuss the work of Beecher[1] on the ventral integument of trilobites in which he describes five oblique and transverse thickenings on the mesosternites and homologizes them with apodemal structures of other crustacea, and suggests that they afforded points of attachment for the ventral muscles. If we consider the transverse arches in the ventral integument and the transverse thickening on them, it becomes apparent that the ventral integument of the axial lobe was much stronger than it is usually considered to be, and that it gave a firm base of support and the opportunity for a close articulation of the coxopodites of the ventral limbs, which were controlled by strong muscles passing from the coxopodite through the ventral integument to the ventral surface of the mesotergite and the axial process. A section of the ventral integument with the thickened sternites is illustrated by figure 4, plate 101 and figure 1, plate 105.

Notes on individual specimens of Neolenus.—Dr. Raymond has given at length the results of his study of six of the best preserved specimens of *Neolenus* that have more or less of the ventral appendages preserved. I am in accord with most of his conclusions, but will mention a few points where there is a slightly different point of view.

SPECIMEN NO. 58589 (P. 24)[2]

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 18, fig. 1; pl. 20, fig. 1; pl. 91, fig. 2; text fig. 15

This is the specimen in which Raymond discovered the "articular socket" on the coxopodite. I have spoken of this (ante p. 381) as his interpretation reverses the natural position of the dorsal and

[1] Amer. Jour. Sci., Vol. 13, 1902, pp. 165-174, pls. 4-5.

[2] The specimen numbers refers to the catalogue number in the records of the U. S. National Museum, and the page reference to the Raymond Memoir.

ventral margins of the coxopodites, although the sketch (fig. 2, p. 24) shows them in their correct position in relation to the endopodite. Since Raymond studied this specimen I have removed a fragment of the dorsal test covering a portion of the coxopodites of the two anterior to those from which he made his sketch, and am now reproducing them as text figure 15 (p. 383) of these notes. A photograph of three of the four coxopodites and attached endopodites is illustrated by figure 2, plate 91, where on coxopodite *D* the proximal and ventral spines are shown; also see figure 2, plate 93, for relation of coxopodites and the endopodites. I think Raymond is correct in interpreting the small epipodite of Walcott as probably the terminal portion of an exopodite as I have already mentioned (ante p. 369).

If I understand the position of the "notch" that Raymond mentions as occurring on the coxopodite (our text figure 15 and figure 2 of plate 91), his measurement of the length of the coxopodite is 1.5 mm. too long, as the union of the coxopodite and basipodite was at the notch and not 1.5 mm. out from it.

SPECIMEN NO. 65514 (P. 26)

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 19, figs. 1-3

This is the specimen mentioned by Walcott (1918, p. 185, description of figure 3) as having two large epipodites. There are no epipodites shown on it or in the figures of it, nor is it mentioned in the text. I must have, as Raymond suggests, considered the ends of the exopodites as the ends of the epipodites; this occurred when writing the description of the plate figures.

SPECIMEN NO. 65519 (P. 27)

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 21, fig. 6

The exopodites of this specimen may be in a natural position but there is no certainty of it, as the fragments of the endopodites beneath the cephalon have been crowded forward and very much displaced.

SPECIMEN NO. 65520 (P. 27)

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 22, fig. 1

Raymond mentions the "low rounded appendifers at the anterior angle of each axial tergite." A close inspection and the study of other specimens in which the slender axial processes are preserved, indicates that the latter have been broken off from all of the downward projecting rounded bases situated on the ventral surface of the mesotergites of this specimen at their anterior margin and directly beneath the dorsal furrow. A low rounded ridge crosses each mesotergite at its point of union with the pleural extension of the segment, and an interior oblique ridge, corresponding to the pleural groove of the dorsal surface, merges into the base of the axial process, as does the rounded transverse ridge on the anterior margin of the axial segment, thus giving a strong rigid support to the base of attachment of the muscles extending from the coxopodite of the ventral limbs to the axial process of the dorsal test and the immediately adjoining surface of the mesotergite. The axial process is slender and slightly inclined into the axial lobe but not as much so as that of *Ceraurus;* it is as Raymond states, more rounded in the pygidium of this specimen but this is probably owing to the condition of preservation of this particular specimen.

The exopodites on the right side have been very much compressed and all bent forward and crowded to the right. Walcott considered that the distal ends of three epipodites projected from beneath the exopodite on the right side, but this is doubtful, and I accept Raymond's view that they are probably the distal joints of three of the exopodites.

SPECIMEN NO. 65515 (P. 28)

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 20, figs. 3, 4; pl. 92, fig. 1, 2, 3, 3*a*, 4

The appendages of this specimen have been described and discussed by Messrs. Ulrich, Ruedemann, and Bassler (ante pp. 366-368), and I have agreed to their opinion that the so-called exites of Walcott are not what I interpreted them to be. This is also the view of Raymond, and he also eliminates the epipodites, considering them to be merely exopodites without the fimbriæ. The specimen is a difficult one to photograph and to study, but on our plate 92, figures 1, 3, 3a, the attempt is made to reproduce the epipodites as photographed, also for comparison the exopodites of specimen No. 65521. It is unfortunate that Raymond did not make photographs of this and other critical specimens and reproduce them, as Walcott's figures of 1918 are nearly all badly reproduced. They should have been originally reproduced by the photogravure or similar process, but the war time cost was prohibititive. The exites of Walcott (1918, plate 20, figures 3, 4) appear to be the coxopodites of three of the ventral limbs, the anterior of which has attached to it the basipodite; the coxopodites have been shortened and compressed to a thin film.

SPECIMEN NO. 65513 (P. 30)

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 16, figs. 1, 2

The limbs, coxopodites and endopodites of this specimen all appear to have been crowded over from the left to the right side so as to be in reverse of their natural position; two of the legs are above and the two posterior beneath the exopodites. Whether they are "cephalic legs" as stated by Walcott (1918, description of fig. 1, plate 16) or thoracic appendages, cannot be determined. The displacement is not unlike that of the appendages of specimen No. 65514, as shown in the upper part of figure 3, plate 19, Walcott 1918.

There are a few other specimens worthy of notice as my observations in the paper of 1918 are too general to be of service in a review of the structure of the appendages of *Neolenus*.

SPECIMEN NO. 58588

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 15, fig. 1; pl. 17, fig. 3; pl. 91, fig. 1; pl. 93, figs. 1, 2

This slab, with its two fine trilobites preserving both thoracic and pygidial appendages, is of great interest. The upper one of the two specimens shown on plate 15 (1918) is the matrix, but our figure 1, plate 91, is a photograph of the trilobite itself with ventral appendages projecting from beneath or exposed by the exfoliation of the dorsal test.

Only a few traces of the exopodites remain and in these the fimbriæ are matted and rolled together in an indistinguishable, fibrous, cord-like appendage on the right side and widely but faintly distributed over the surface on the left side. The coxopodites and endopodites on the right side have been displaced and pushed outward and slightly backward so as to bring the proximal end of the coxopodite almost beneath the dorsal furrow; only a fragment of an endopodite projects from beneath the left side. The backward displacement of the appendages has brought eight of the legs opposite the pygidium, of which the five posterior belong with the pygidium. The sixth and seventh thoracic segments have been crowded into each other with the result that of the limb opposite the seventh axial segment of the thorax, only the broad shaft of the exopodite is partly preserved, the endopodite having been either torn away or pressed deep into the sediment and lost to view. Counting this lost leg, the three thoracic legs opposite the pygidium, and three of those opposite the thorax, we have seven thoracic legs, or one for each segment. There is a leg opposite both the first and second axial thoracic segments and the occipital segment of the cephalon, and one in advance of it, the proximal end of the coxopodite of which touches the dorsal furrow beside the glabella a little in advance of the occipital segment. The total is sixteen endopodites or legs, or one for each segment of the pygidium and thorax, and four for the cephalon, a fifth pair of cephalic appendages being represented by the long slender antennules. This is the only specimen thus far found of *Neolenus serratus* that has as large a number of the ventral limbs so nearly in their natural position. The fact that the ventral integument and limbs have been squeezed out and shifted to the right and slightly back from their natural position indicates that the muscles holding the appendages and integument in position had sloughed off under pressure; the marvel of it is that the coxopodites and endopodites held together so well.

After studying the specimen I found that the coxopodites and the proximal joints of the endopodite were in echelon with the ventral margin of each limb passing beneath the anterior dorsal margin of the next posterior limb. I then began to remove the covering anterior margin of some of the limbs so as to expose the ventral margin of the next anterior limb; this resulted in bringing into view several coxopodites and basipodites with their spinose ventral side. and what was of greater interest, the fact that the spinose margin of the coxopodite in undisturbed complete limbs was on the ventral side as in the basipodite and other joints of the endopodite, thus fully corroborating the evidence of specimen No. 58589, represented by our text figure 15 (see plate 91, figure 2). There is not any evidence of an "articular socket" on any of the coxopodites of specimen No. 58588, but the supposed "notch" of Raymond occurs on the ventral margin of several limbs at the union of the coxopodite and endopodite. Two of the cephalic limbs preserve the six joints of the endopodite and the coxopodite (figure 1, plate 93) in their natural relation to each other; the coxopodite is slightly shorter than that of the thoracic limb, and the entire limb is slightly shorter and smaller as indicated by the following measurements in millimeters.

	Cox.	Bas.	Ischi.	Mer.	Carp.	Pro.	Dactyl.	Total
Cephalic limb (2d)..	8.	4.5	4.	4.	4.	2.75	2.	29.25
Thoracic (4th)......	9+	4.5	3.75	3.75	4.	3.	2.5	30.5
Pygidial (2d).......	4+	3.	2.5	2.5	3.5	2.5	1 75	19.75+

The ischiopodite and meropodite of the pygidial limb may have been shortened by compression and the carpopodite lengthened a little, but in all the limbs there is always a possibility of a slight distortion of the joints by compression; as a whole, however, they retain their form and proportions in a surprisingly accurate manner.

The enlarged figures on plate 93 bring out in fine detail the endopodites of *Neolenus.*

SPECIMEN NO. 57656

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 17, fig. 1

In the description of figure 1, plate 17, it is said that the caudal rami have been dragged backward, pulling with them a portion of the under edge of the body cavity. While this may be correct in part, the edge of the supposed body cavity or ventral integument is probably a displaced coxopodite with four joints of the endopodite on the right side and a fragment of a coxopodite with a joint of the endopodite on the left side.

SPECIMEN NO. 65521

Smithsonian Misc. Coll., Vol. 67, 1918, pl. 23, fig. 1

This is the ventral side of the test with the limbs partially preserved on the right side so as to show the ventral side of the outer portion of a number of the exopodites and a few of the endopodites. Walcott (1918, description of figure 1, plate 23) considered that the distal lobes of some of the larger epipodites were preserved, but I now agree with Raymond that there is not good evidence for this, and that the distal lobes are those of exopodites. The anterior exopodites on this specimen have their fimbriæ finely preserved, as is shown by figure 5, plate 92, of these notes.

Restoration of ventral surface of Neolenus.—The theoretical transverse section by Raymond of a thoracic segment and appendages (fig. 7, p. 30) has the coxopodite of the limb articulating with the downward projecting axial process (appendifer). The spine-bearing ventral side and curved proximal end of the coxopodite is represented in a dorsal position, which reverses the position of the coxopodite in specimen No. 58589 (our text figure 15, and figure 2, plate 91) both in relation to the dorsal test and the joints of the endopodite. In the Raymond restoration of the ventral surface (figure 8, p. 31) the coxopodites of the cephalic region are represented with the spinose ventral side sloping downward and forward with the shaft of the exopodite attached to the ventral side of the endopodite, as in figure 7, or, as I interpret the sketches, the coxopodite is drawn in its normal position beneath the cephalon in figure 8, and upside down in figure 7.

The restoration of the ventral surface of *Neolenus* by Raymond is most effective, as it shows the broad side of the coxopodite and endopodite, it being understood that both are in an unnatural position. The exopodites are diagrammatic but with their very deep (broad in the figure) proximal end joining the coxopodite, those of the thorax and pygidium must be in an artificial position. My impression is that the proximal end of the exopodite was a narrow rounded shaft as in our figures 13 and 14, pages 373, 375; for if it were flat and as deep as Raymond shows it, and attached to the deep, flat basipodite, it would be impossible for the exopodite with its flat, broad shaft and long fimbriæ to lie flat or horizontal above the endopodites without breaking away from the proximal end of the basipodite. If, on the contrary, it was attached to the limb in about the same manner as the exopodite of the first thoracic limb of *Anaspides tasmaniæ* G. M. Thomson (Walcott, 1918, plate 35, figure 2) it would have had the position and flexibility essential to its functioning effectively.

The position of the coxopodites in figure 8, page 31, is somewhat puzzling, as those of the cephalon are evidently intended to show the spiniferous margin as ventral and sloping forward, while those of the thorax and pygidium suggest that the spiniferous margin is dorsal and projecting forward. This position is also suggested by the position of the outline of the " articular socket " on the anterior margin near the distal end of the coxopodite.

Attention should be called here to the position of the basal joints of the thoracic limbs of *Apus* (Walcott 1918, plate 36, figure 4), which slope forward when viewed from the ventral side and have the spines on the ventral side and proximal end. I do not recall a crustacean limb that has a series of sharp spines on the dorsal side of the coxopodite or endopodite.

Raymond has inserted a metastoma and crowded the two anterior cephalic appendages against the posterior end of the hypostoma; this may be correct but as long as we have no evidence in *Neolenus* to base it upon it may be misleading.

In my restoration, plate 94, I have omitted the small epipodites and exites of the restoration of 1918 (plate 31), brought the inner ends of the gnathites of the cephalic limbs closer together and made a single round anal opening as the double opening of the 1918 restoration was based on a specimen (No. 58588) that a recent photograph shows to have been imperfect at that place. I have been misled a number of times by the effect produced by the direction from which the light strikes this specimen and also others when too hastily studied.

NOTES ON CERAURUS, CALYMENE, AND TRIARTHRUS BECKI

Illustrated on pls. 91, 95-103

Translucent sections cut from both *Ceraurus pleurexanthemus* and *Calymene senaria* show the alimentary canal, what may have been the heart and the main flexor muscles, and more or less of the outlines of the ventral integument and appendages.

The slides of *Calymene* will be arranged in their numerical order, and those of *Ceraurus* will follow. Most of the slides illustrated are described but a few are so simple that they are referred to only in the description of the figures on the plates or in the general text.

Unless otherwise mentioned all the slides are in the collection of the Museum of Comparative Zoology, Cambridge, Massachusetts.

CALYMENE SENARIA Conrad

Slide No. 5, M. C. Z. (plate 98, figure 6). Transverse section of a partially enrolled *Calymene* cutting an anterior segment of the thorax and diagonally through the cephalic appendages and the hypostoma; fragments of the slender epipodites occur on both sides above the oblique sections of the endopodites; some of the latter appear to indicate that one of the joints was hollow. There is a section of a small narrow cephalic limb just above the hypostoma on the right side and above are the sections of two large coxopodites, one of which on the left side has several obscure joints that are filled with small elongate oval-like bodies; the latter also occur scattered in clusters in the calcite and appear similar to those illustrated by figure 10, plate 98.

Slide No. 6, M. C. Z. (plate 101, figure 6). Transverse section of the cephalon of *Calymene*. This section is in some respects one of the best of the cephalic appendages of *Calymene*. It cuts across two pair of slender, short coxopodites that were presumably anterior and corresponding in position to the two small anterior cephalic limbs of figures 2 and 3, plate 101. The large upper pair of coxopodites appear to have been attached to the ventral surface (integument) near their proximal end; this is also suggested by slides No. 38 and 51 (Walcott 1918, plate 26, figures 6 and 9), also figure 7, plate 101.

The grouping of the proximal ends of the limbs in slide No. 6, also Nos. 38 and 51, strongly suggest oblique sections across the mouth with some of the surrounding gnathites. Slide No. 6 was illustrated by Walcott in 1881, plate 1, figure 6, and in 1918, plate 26, figure 11.

Slide No. 9, M. C. Z. (plate 101, figure 5; plate 95, figure 14). Transverse section of the cephalon of *Calymene* and the anterior mesotergite of the thorax cut so as to pass through the hypostoma, a portion of the three anterior limbs of the cephalon and the large coxopodite of the fourth pair of cephalic limbs; what may be a section of a portion of a displaced alimentary canal occurs as a short dark transverse crescent just beneath the mesotergite of the dorsal test: this is much like the crescent in figure 13, plate 95. This slide was imperfectly illustrated by Walcott, figure 9, plate 1, 1881. The section of the alimentary canal was omitted in the drawing supposed to represent a photograph of the slide.

Slide No. 20, M. C. Z. (plate 103, figure 14). Transverse section of an enrolled *Calymene*. This is valuable for the information it gives of the form of the cross section of the endopodites, which appears to have been nearly circular; the coxopodites were relatively flat and deep in section as indicated by the sections of *Calymene* on plate 101. See description of figure 14, plate 103, for further remarks on slide No. 20.

This slide was illustrated by Walcott 1881, plate 2, figure 10.

Slide No. 28, M. C. Z. (plate 99, figure 5. Walcott 1881, plate 3, figure 8. 1918, plate 27, figure 13). This is a section of one side of an enrolled specimen of *Calymene* in which the filaments of three or more exopodites have been cut across; a comparison should be made with the fine fimbriated exopodites of figure 1, plate 96, in order to better understand the exopodites of figure 5, plate 99, as the latter do not show the spiral structure of the arm; the first of the two right hand fimbriated appendages appears to have an elongate oval section which is probably of secondary origin; the right hand appendage may have been similar to the fimbriated appendage of figure 8, plate 100.

This has long been a very difficult section to understand, but with the discovery of the exopodite shown in figure 1, plate 96, the fimbriated structure is more readily interpreted.

Slide No. 29, M. C. Z. (plate 99, figure 9) of *Calymene* is partly represented by figures 8 and 9 of plate 97. The object of reproducing it entire is to show the transverse section of the longitudinally undulating integument of the mesosternite and its relation to the triangular sections of the coxopodites of the ventral thoracic limbs. This is a portion of figure 9, plate 3, of Walcott 1881, which is a drawing based on a photograph. A photograph of the entire section was published in Walcott 1918, plate 27, figure 4.

Beecher in his memorable article[1] on the "Ventral Integument of Trilobites," calls attention to this slide and considered that it indicated folds and that in some sections cut by Walcott a normal apodeme was indicated (loc. cit. p. 169).

The spiral arms of the exopodites and slender epipodites of this slide are illustrated by figures 8 and 9, plate 97. The shaft of the exopodite is shown in figure 8, with the sections of two spiral arms and beneath them the slender epipodites which are much better illustrated by figure 2 of this plate. In figure 9 there is a greater displacement of the spiral arms. It was on the appearance of these two arms, those of figure 10, plate 97, and those shown by figure 10, plate 3, Walcott, 1881, that I ventured to restore the exopodite with a double spiral. This is no longer tenable, as an exopodite with two arms of the character we now know them to be, is not probable and the evidence is insufficient. The slender arm next to the coxopodite may be a section of a thin edge of two or three joints of an endopodite. Walcott 1918, page 195, description of figure 4.

Slide No. 32, M. C. Z. (plate 97, figure 7. Walcott 1881, plate 4, figure 4; 1918, plate 27, figure 5*a*). Longitudinal section of the pleural lobe of a partially enrolled *Calymene* in which the spiral arms of two of the exopodites have been pushed out of their natural position, but fortunately they retain the proximal straight portion of the arm and its union with the spiral portion; one of these (the lower in figure 7) shows the proximal straight portion of the arm extended along and connected with five sections of the spiral portion; whether this is always the case is uncertain but from a comparison with the spiral arm of *Cyamus scammoni* Dall (see Walcott 1881, plate 4, figure 9) it may be that the simple straight portion of the arm passes directly into the spirals; further data is needed to determine just how the two parts are joined. Slide 29 (plate 97, figure 8) is in favor of the view clearly indicated by figure 7.

Slide No. 34, M. C. Z. (plate 105, figures 1 and 2). This is a thick longitudinal slice of the axial lobe of *Calymene*. One side is practically a duplicate of slide 35 (plate 101, figure 1) which was cut from the same specimen but on the opposite side of the median lobe. Both of these were a little to the right or left of the median

[1] Amer. Journ. Sci., Vol. 13, 1902, fig. 7, pl. 5.

line and do not cut the mesotergite process although they do pass through the sharp fold where the anterior articular extension of the mesotergite unites with the segment. (See Walcott 1881, plate 5, figure 6). The opposite side of No. 34 has 18 well defined mesosternite segments with an interarticular membrane uniting them, three faint posterior segments and traces of several coxopodites similar to the short sections of them in slide 36 (figure 4, plate 101).

What appears to be a section of the alimentary canal (figure 2) extends nearly the entire length of the thorax and pygidium; it is situated directly above the ventral integument. Fragments of two of three cephalic limbs occur beneath the cephalon. The mesotergites of the dorsal test have been drawn apart a little which has caused the ventral integument to pull away from the doublure of the posterior end of the pygidium. This also shows in slide No. 35 which was cut from the same specimen on the opposite side of the median axis of the dorsal test.

Slide No. 35, M. C. Z. (plate 101, figure 1). This beautiful longitudinal section of a partially enrolled *Calymene* cuts through the axial lobe of the dorsal test a little inside of the dorsal furrow for the anterior two-thirds or more of the length of the specimen, and then a little inward nearer the center of the axis of the pygidium; the ventral limbs are drawn forward and together so that they do not correspond in position with the mesotergites; there are 22 of the proximal portions of the limbs indicated, the anterior four of which are referred to the cephalon, thirteen to the thorax, and five to the pygidium. There were probably two or three more beneath the pygidium of which no traces are preserved. The section on the opposite side of the axial lobe of this trilobite (plate 105, figure 2) is almost identical with this (Walcott 1881, plate 5, figure 3), and the median section of the axial lobe (Walcott 1881, plate 5, figure 2; plate 105, figure 1) shows the thickened mesosternites of the ventral integument.

Most of the proximal joints (coxopodites) of the ventral limbs are joined to the ventral surface without any suggestion of intervening joint, but three have what appears to be a small very short joint between the coxopodite and the ventral surface; one of these appears very much like the anterior limb of the pygidium of figure 9, plate 103, where a short joint seems to be present between the coxopodite and the ventral integument.

Another interpretation of this is that the narrow connection between the coxopodite and the ventral side of the animal is a cross section of the space occupied by the muscles connecting the ventral integument and the axial processes and mesotergite of the dorsal test.

Slide No. 36, M. C. Z. (plate 101, figure 4; Walcott 1881, plate 5, figure 4). Longitudinal section of *Calymene* a little oblique to the median line of the axial lobe so as to cut the side of the hypostoma, the proximal parts of two of the cephalic limbs (one of which has been pulled out of place), six thoracic limbs, six of the thickened mesosternites and fragments of several limbs on the opposite side of the axial lobe from the cephalic and anterior thoracic limbs. This section is instructive as it illustrates the strong mesosternite segments and the direct contact of the coxopodites of the ventral thoracic limbs with the segments; slide 36 with slides Nos. 34 and 35, present a fine illustration of sections of the coxopodites parallel to the axis of the trilobite and of their relations to the ventral integument.

Slide No. 38, M. C. Z. (plate 101, figure 7). Transverse section through the cephalon, anterior thoracic segment of *Calymene* and obliquely across the hypostoma. The portion of the cephalic limbs cut across suggests the same structure as in slide No. 6, figure 6, plate 101, with one of the endopodites on the left side cut through so as to give the narrow section of the joints and the one on the right the broad section; the latter is not well shown in figure 7 as it too dark to photograph well. A drawing published by Walcott in 1881, plate 1, figure 8, shows the various parts more clearly. This drawing was republished in connection with a photograph in 1918, plate 26, figures 9, 10. The slender appendages on the left side in the drawing are also too dark to photograph. The difference in the right and left sides between the figures of 1918 and figure 6, plate 101, is owing to the light being transmitted through different sides of the translucent slide of rock.

Slide No. 45, M. C. Z. (plate 99, figure 2; plate 100, figure 3). Oblique transverse section through the posterior part of the thorax and the upper posterior margin of the cephalon of *Calymene*. The filamentous appendages on the right side of figure 2, plate 99, are enlarged in figure 3, plate 100, to show details of structure; the lobe or base of the appendage is attached to the side of the mass filling the visceral cavity beneath the axial lobe, but whether a short shaft or arm connected the lobe with the coxopodite of one of the thoracic limbs cannot be determined from this slide, but from the appearance of the sections in figures 4, 6, 8, plate 100, it is probable that such was the case. The manner of the insertion of the slender filaments or tubes into the lobe is shown by figures 5, 6. In looking at this slide it must be borne in mind that the trilobite was enrolled, that five segments of the thorax are cut across and that the filaments or tubes are long, relatively strong and do not resemble the filaments of the spiral arms of the exopodites.

This slide was illustrated by a drawing in Walcott 1881, plate 3, figure 1, and again in 1918, plate 27, figure 11.

Slide No. 53, M. C. Z. Part of a transverse section through the cephalon and an anterior thoracic segment of *Calymene*. The section cuts on the right side a mutilated coxopodite so as to give a roughly triangular outline, and below it on the left two smaller joints that may be portions of the coxopodites of two of the cephalic limbs; below and on the right there is a broadly jointed appendage that from the direction of the upper joint evidently belonged with the cephalic limbs, as it is within the cephalon and quite unlike the thoracic endopodites. This slide is illustrated by Walcott 1918, plate 26, figure 12, by a print made from a plate that represents the appendages in black with a white matrix, whereas the slide shows a black matrix with the appendages in white calcite.

Slide No. 63, M. C. Z. (plate 91, figure 3; plate 99, figure 4). Transverse thoracic section of *Calymene,* the most interesting feature of which is the displaced coxopodite of a ventral limb which has a depression midway of the upper margin into which a projection from the ventral surface projects forming the " ball-and-socket " joint of Raymond (page 53, figure 15); the narrow sections of two additional pairs of coxopodites occur below and a number of slender appendages on each side which may be drawn out spiral arms of exopodites.

Slide No. 118, M. C. Z. (plate 95, figure 16). Transverse section of Calymene with two dots in the space beneath the mesotergite of the dorsal test that may represent the position of the dorsal flexor muscles, and an arched, dark, line tentatively referred to as the heart. This is the " dorsal sheath " of Raymond's diagrammatic drawing of this slide (figure 21, page 79).

Slide No. 153, M. C. Z. (plate 98, figure 5; plate 103, figure 10). Raymond, page 79, figure 23. The descriptions of the figure 5, plate 98 and figure 10, plate 103, mention the principal features of this slide of *Calymene.*

Slide No. 200, M. C. Z. (plate 103, figure 12). This slide of *Calymene* is sufficiently described in the description of figure 12, plate 103.

Slide No. 211, M. C. Z. (plate 104, figures 1-3) is an oblique transverse thoracic section of *Ceraurus* which has cut across the articular fold of the mesotergite and the mesotergite process on the right side (figure 1) (see plate 101, figures 1-8); and two distorted coxopodites with several of the endopodites, exopodites and elongate epipodites; the latter are best seen in figures 2 and 3 with their elongate proximal joint which is very narrow at its proximal end and broad at the distal end where the evenly jointed portion of the epipodite unites with it; these proximal joints should be compared with figures 1-4, 6, plate 97. A portion of a spinose ventral margin of one of the joints of the endopodite is seen in the lower right hand corner of figure 2. The light colored flocculent parts in figures 2 and 3 result from the strong light passing through very thin parts of the slide.

CERAURUS PLEUREXANTHEMUS Green

Slide No. 13, M. C. Z. (plate 95, figure 6). Transverse thoracic section of *Ceraurus* showing what appears to be a partially compressed alimentary canal, an oblique triangular section of a coxopodite of a ventral limb on the right side, with fragments of an endopodite, and on the left side a distorted endopodite. Sections of slightly undulating ribbon-like appendages that may be portions of epipodites occur on both sides beneath the pleurotergites. This slide was illustrated by Walcott 1918, plate 26, figure 14.

Slide No. 16, M. C. Z. (plate 102, figure 10). Longitudinal section of *Ceraurus* cutting the side of the axial lobe of the dorsal test so as to section the mesotergite process of the articular fold, which gives two small rounded subtriangular outlines similar to those of figure 2, plate 102. When cut more obliquely the section of the processes are more elongate as in figures 6, 8, 9. Another interesting feature of slide No. 16 is the section of a long coxopodite of a thoracic limb with its narrow attachment to the ventral surface of the body and broad proximal end. The joints of the limb are undoubtedly distorted and merged so as to lose their individuality. This section was illustrated by Walcott 1881, plate 2, figure 16.

Slide No. 18, M. C. Z. (plate 103, figure 9). This is an instructive longitudinal section of *Ceraurus* in which the proximal portions of the ventral limbs of the pygidium are cut across; the sections of the coxopodites appear to represent the narrow, flat section and not the broad section seen in many transverse sections of the dorsal test.

An interesting and valuable feature of this slide are the clearly defined mesosternites. The posterior one of the pygidium has what appears to be a thin scale of the ventral integument adhering to it; the second from the posterior end blends in with the base of the ventral limb, and the third almost, but the fourth and fifth are clearly defined and separated by a sharp line of demarcation which is less well shown between the first, second and third sternites. The mesotergites of the dorsal test were crowded apart so that the mud of the matrix was forced under them and into the filling of the visceral cavity.

Particular attention is called to the short, narrow, transverse line between the coxopodite of the anterior limb and the mesosternite as it suggests a short joint, a feature also suggested by the next posterior limb by it narrowing between the coxopodite and the mesosternite. See also description of slide No. 35, page 397.

Slide No. 22, M. C. Z. (plate 99, figure 1; plate 100, figures 1, 2; Walcott 1881, plate 3, figure 2; 1918, figure 12, plate 27). Slightly oblique transverse section of the cephalon on the line of the eyes and anterior portion of the thorax of a partially enrolled *Ceraurus*. The cephalic limbs are grouped about the point that may have been the mouth, very much as in slide No. 6 (plate 101, figure 6), but the section is more oblique and cuts the deeper vertical section of the coxopodites (gnathites), and the hypostoma is cut almost on the plane of its marginal rim. There is a short transverse body near the end of the hypostoma between the proximal ends of the pair of gnathites that strongly suggests that a metastoma has been cut across; it has been replaced by clouded calcite which makes it difficult to photograph. The lower (in the photograph) left coxopodite has been pushed inward and impaled on the mesotergite process.

The fimbriated appendages in the space on each side between the axial lobe and the outer margin of the dorsal test must have been lying nearly horizontally beneath the dorsal test and attached to the coxopodites of either the posterior cephalic or anterior thoracic limbs. These fimbriated lobes (epipodites) are illustrated on plate 100, figures 1 and 2, and described under the heading fimbriated epipodites.

Slide No. 23, M. C. Z. (plate 100, figure 8; Walcott 1881, plate 3, figure 3. 1918, plate 26, figures 1 and 2). This is a transverse section of the cephalon and four segments of the thorax of *Ceraurus;* the coxopodites of six pair of limbs have been cut across, the right hand one of the posterior pair (Walcott 1918, plate 26, figures 1 and 2) showing a triangular section with a faint, slender, spiral arm of an exopodite projecting from its outer proximal margin; on the opposite side the coxopodite is badly distorted and broken up, but connected with it there is a support to a narrow vertical lobe or plate that carries numerous slender filaments, a photograph of which is reproduced as figure 8, plate 100. There is also a row of somewhat similar filaments next to the side of the cephalon and below the eye; these filaments were probably attached to several lobes similar to the one illustrated. The relations of the various parts mentioned is shown by figure 2, plate 26, Walcott 1918.

Slide No. 27, M. C. Z. (plate 95, figure 1; plate 103, figure 4) is a transverse section of a partially enrolled specimen of *Ceraurus* that has one of the best preserved sections of a large alimentary canal of a trilobite known to me. It is subcircular or broadly oval, with a narrow, short midway extension on either side that may have been an hepatic tube or the filled-in cavity of a flexor muscle; it has within it near the upper side a white, delicate convex or arching line that is a section of the articular extension of the mesotergite that is slightly out of its normal position, and above the canal and between it and the dorsal test there is a dark arching line that is a little longer than one-third the length of the arching mesotergite of the dorsal test; it may be a transverse section of the anterior incurving posterior margin of the mesotergite. (See plate 96, figures 3, 4). Raymond (p. 79, figures 21, 22) refers to these dark arched lines as dorsal (figure 21) or abdominal (figure 22) sheaths.

Slide 27 also cuts across on the left side a palmate fringed appendage (figure 5, plate 100) that is similar to the one illustrated by Walcott (1881, plate 3, figure 2; 1918, plate 27, figure 12). Eight filaments were attached along the outer fluted edge of a roughly triangular palmate base. A fragment of a similar structure occurs on the appendages of the two adjoining segments. The outlines of two of the ventral segments (mesosternites) are shown as well as the base of the ventral limbs.

Slide No. 80, M. C. Z. (plate 99, figure 6; plate 100, figure 6). Transverse thoracic section of *Ceraurus* in which the coxopodite of a distorted ventral limb is cut across, also the lobe of a fimbriated epipodite of the type illustrated by figures 2, 4, 5 of plate 100. On the opposite side of the section a somewhat similar structure has been pushed up against the side of the filling of the axial lobe of the dorsal test.

Raymond figures this slide as a diagrammatic drawing (page 49, figure 12) to illustrate what he considered to be a section of an exopodite and some of its "setæ" in a longitudinal section.

Slide No. 109, M. C. Z. (plate 97, figure 2; plate 98, figure 1). Transverse thoracic section of *Ceraurus* in which the coxopodites of the ventral limbs were displaced and distorted and several joints of the endopodites of five pairs cut across at different angles to the axis of the limb; several appear to have been hollow and filled with infiltered mud; on the left side there are three slender jointed epipodites (figure 2, plate 97), and on the right side fragments of slender epipodites and exopodites. Some of the joints or endopodites on the right side have slender spines attached to their lower inner margin, as seen in the section.

Slide No. 110, M. C. Z. (plate 95, figure 11). Oblique transverse thoracic section of *Ceraurus* in which the alimentary canal has been compressed and the ventral surface pushed up beneath the mesotergite of the dorsal test carrying the oblique sections of the ventral coxopodites with it; sections of portions of the exopodites that suggest spirals are cut across beneath the pleurosternite on the left side and fragments of endopodites below the coxopodites.

Slide No. 111, M. C. Z. (plate 104, figure 4; Walcott 1881, plate 2, figure 2; 1918, plate 27, figure 1). Transverse thoracic section of *Ceraurus* showing an unusual section of an endopodite, with five joints and faintly two distal joints that probably belong with the others, although they may not, as a short space separates them; above the endopodite there is a fragment of a spiral exopodite, and above this and between it and the ventral surface of the pleurotergite, fragments of three slender epipodites. In Raymond's interpretation of this slide he considered the lower slender epipodite to be the arm, and the cut across sections of the spiral of the arm of the coxopodite beneath, the filaments of an exopodite. (Page 58, figure 18).

Slide No. 112, M. C. Z. (plate 95, figure 15). Transverse section of the axial lobe of *Ceraurus* in which a dark narrow transverse area in the white calcite suggests a greatly compressed alimentary canal, or possibly but not probably, the heart, as indicated in figure 16 and 17; also a fimbriated appendage on the left side similar to that in figure 1.

Slide No. 114, M. C. Z. (plate 95, figure 19). Transverse thoracic section of *Ceraurus* in which sections of the supposed dorsal flexor muscles are represented by two large dark dots one on each side of the axial lobe of the visceral area; one or two similar dots occur in other sections (figures 16, 17, 18). The two lower dots are supposed to be sections of the mesotergite processes. A subtriangular section of two coxopodites of the ventral limbs are indistinctly shown, also what may have been the shaft of an exopodite on the left side apparently attached to the coxopodite.

Slide No. 115, M. C. Z. (plate 95, figure 17). Transverse section of *Ceraurus* cutting through the hypostoma and anterior portion of the cephalon on the left side and the anterior thoracic mesotergite of the thorax; the two small dark lateral dots in the axial lobe are referred to the dorsal flexor muscles, and the larger dot below on the right side to a section of a mesotergite process or a ventral flexor muscle; the dark arched line separated from the mesotergite by a narrow strip of calcite may possibly represent the heart. On the right side there is a triangular section of a coxopodite, and on the left side portions of two of the cephalic limbs that have considerable width. The upper fragment is probably a portion of a thoracic coxopodite. What may be the shaft of an exopodite occurs just beneath the filling of the pleural space on the left side.

Slide No. 117, M. C. Z. (plate 95, figure 10). Transverse thoracic section of *Ceraurus*. This section is of interest on account of the position of what was probably the alimentary canal, which has been distorted and crowded up against the mesotergite of the dorsal test. The position of the mesotergite process on each side is indicated, and in a general manner the base of the ventral limbs. Two downward curving points near the median line of the ventral integument suggest the proximal end of the coxopodites.

Slide No. 119, M. C. Z. (plate 95, figure 18). Transverse thoracic section of *Ceraurus* in which the position of two supposed dorsal flexor muscles are represented by irregularly rounded dark spots that are considered to have been holes left by the decomposition and removal of the muscles, the holes being subsequently filled by the infiltration of the silt forming the matrix. The spots in this slide should be compared with similar spots in figure 19. The two lower dark spots are supposed to be sections of the mesotergite processes. A partly triangular section of a ventral coxopodite is preserved on the left side, and 8 mm. to the left of the point of the coxopodite there is a fragment of an endopodite which has a notch into which another distorted fragment of an endopodite projects, thus forming a fine illustration of the "ball-and-socket" joint of the appendifer and coxopodite as described by Raymond (page 54, figure 15, page 53), except that the appendifer is not present and the socket is simply an indentation in a fragment of joint of the endopodite.

Slide No. 120, M. C. Z. *Ceraurus*. See description of plate 98, figure 4, page 442.

Slide No. 123, M. C. Z. (plate 102, figure 5). Transverse section of three slightly displaced thoracic segments of *Ceraurus* the upper one of which has on the right the thickened base of an axial process, and inward from it the fold of the mesotergite process, and below in the mass of calcite filling the space between the mesotergite and the ventral integument two sections of the mesotergite process. The lower segment has on the left side (in the figure) a knob-like section of the axial process and inward from it a mesotergite process on each side of the median line; the section cuts across the two mesotergite processes at such an angle as to give the effect of having cut obliquely across a short tube; figures 1 and 3, plate 102, show sections of this process cut at a different angle. In slide 123 (figure 5) the fold of the mesotergite articular extension is clearly shown.

Slide No. 147, M. C. Z. (plate 101, figure 8). Transverse section of an enrolled *Ceraurus* that is interesting on account of the sections of the coxopodites of the ventral thoracic limbs.

Slide No. 168, M. C. Z. (plate 103, figure 7). Longitudinal section of the cephalon, hypostoma and the anterior portion of the axial lobe of the thorax of a partially enrolled *Ceraurus.* The proximal ends of the cephalic limbs have been pushed in above the hypostoma and very much distorted; the thoracic limbs have been cut across at the coxopodite at such angle as to show the point of attachment of the shaft of the exopodite to the coxopodite in the three anterior limbs and doubtfully in the fourth posterior limb; just where the actual point of attachment to the coxopodite was is not revealed by this slide.

Slide No. 169, M. C. Z. *Ceraurus.* (plate 102, figure 6). See description of figure on plate 102, page 447.

Slide No. 174, M. C. Z. (plate 103, figure 6). Longitudinal section of the cephalon and thorax of a partially enrolled *Ceraurus* showing the proximal portion of two cephalic limbs and their position in relation to the hypostoma. The entire section is not illustrated by figure 6 as the limbs are displaced and the fragmentary sections of the joints are not instructive.

Slide No. 193, M. C. Z. (plate 102, figure 9). Longitudinal section of a partially enrolled *Ceraurus* which cuts through the side of the axial lobe within the dorsal furrow; above the hypostoma and between it and the posterior margin of the cephalon, four thick, evidently distorted, coxopodites have been cut across, and beneath the thorax six or seven imperfect coxopodites; the mesotergites of the dorsal test have been drawn apart so that their anterior articular projections are almost free from contact with the posterior part of the segment next in advance. A section of the fold of the articular projection occurs between the fourth and fifth segments and there are five sections of the mesotergite process anterior to it; the anterior section of the processes has apparently been pushed forward; a sharp mud-filled break in the cephalon occurs in advance of the posterior glabellar segment. The thick or broad sections of the two anterior limbs above the hypostoma should be noted as they are quite unlike the narrow anterior limbs of sections 15, 17, figures 2, 3, 5 and 6, plate 101.

Slide No. 198, M. C. Z. (plate 103, figure 8). This is another longitudinal section of *Ceraurus* in which the section of the cephalic limbs above the hypostoma are broad and strong as in slide No. 193, plate 102, figure 9. All the portions of the joints of the limbs exposed appear to have been forced out of shape and all form lost except that of a flexible tube stuffed with animal matter now replaced by calcite.

Slide No. 202, M. C. Z. (plate 95, figure 8). Transverse, slightly oblique thoracic section of *Ceraurus* in which the supposed alimentary canal has been compressed and forced below its normal position; on the left side the outline of the mesotergite process is unusually definite and may be compared with that in figure 10. The dorsal test of this section is finely preserved and there is more of the calcite representing the contents of the space between the pleurotergite and the ventral integument than is usually seen.

Slide No. 204, M. C. Z. (plate 97, figure 3; plate 98, figure 7). Transverse thoracic section of *Ceraurus* with subtriangular section of two large coxopodites, to the left one of which there is attached at the upper left side a short arm that has a faintly outlined slender prolongation that is presumably one of the slender epipodites; two other similar objects occur, one above and one below the arm mentioned. On the opposite side there is an indication that a slender arm was attached to the upper right side of the coxopodite and extended beyond as a slender appendage, suggesting that it had two or more joints (figure 3, plate 97); below this there is a slender appendage with a strong proximal joint that appears to have been undulating so as to give a section of an arm broken into short parts; a similar arm occurs below, also in figure 4, plate 97 (slide No. 208); the strong proximal joint is also seen in figures 1 and 4. The relative size of the coxopodites and the slender epipodites is well shown in this slide.

Slide No. 205, M. C. Z. (plate 95, figure 2; plate 102, figure 3) is a transverse thoracic section of *Ceraurus*. It has a transverse section of the alimentary canal beneath the axial lobe; four black dots on the right side nearly on the line of the dorsal furrow, and one a little to the right that may represent the flexor muscles of the mesotergite process; oblique sections of the coxopodites of several thoracic limbs, and in the space beneath the pleural lobe traces of displaced endopodites; the pair of lower coxopodites indicate their approximate position in relation to each other when in a natural position. A fine section of what may be a mesotergite process (appendifer) extends obliquely into the axial space at the lower right side of the mesotergite of the dorsal test (plate 102, figure 3). The section is slightly oblique to the longitudinal axis of the trilobite, which gives a peculiar appearance to the section of the test on the right side.

Slide No. 208, M. C. Z. (plate 97, figure 4; plate 98, figure 3). This transverse thoracic section of *Ceraurus* has a fine section of one of the slender epipodites with a large proximal joint, also a broken section of an undulating slender epipodite and below the latter a distorted spiral arm of an exopodite; there is also the skeleton outline of an endopodite with five or more joints, and the coxopodite. An undulating ventral integument beneath the axial lobe is suggested by the manner in which some calcite is crowded up against an irregular dark line of rock crossing from side to side. A portion of what may have been the filling of the alimentary canal occurs a little beneath the mesotergite of the dorsal test.

Slide No. 228, M. C. Z. (plate 95, figure 13). Transverse thoracic section of axial lobe of *Ceraurus* in which the supposed alimentary canal has been crowded up against the articular extension of a mesotergite of the dorsal test and taken the form of a crescent with a very definite outline.

Slide No. 231, M. C. Z. (plate 102, figure 8). Slightly oblique, longitudinal, thoracic section of *Ceraurus* cutting across several mesotergites of the dorsal test in such a manner as to show the three right hand segments, the outline of an oblique section of the anterior articular extension of the tergite and beneath on the left hand three sections of the mesotergite process. Compare this with the other figures on plate 102.

Slide No. 244, M. C. Z. (plate 95, figure 4; plate 102, figure 1). This is a transverse section of a partially enrolled *Ceraurus* cutting four thoracic segments nearly on the plane of the dorsal surface of the pleural lobes of the test and one upturned (down in the figure) segment beneath which there is a fine illustration of a section of the alimentary canal. The sections of the fold at the union of the articular extension with the body of the mesotergites are exceptionally good and serve to interpret the sections represented by figures 3, 6, 8, 9 and 10 of plate 102, and with figure 4, to visualize the mesotergite process as a downward lateral extension of the fold at the base of the anterior articular extension of the mesotergite.

Spiral branchiæ.—These appear to have given Raymond more concern than any other of my interpretations of the appendages exposed by the sections cut through specimens of *Calymene* and *Ceraurus*. I deeply sympathize with him as I found them most difficult to visualize and interpret. The reason for my originally accepting the "spiral" interpretation is as follows: When thinning down transverse and an occasional longitudinal section of *Calymene* and *Ceraurus* with emery dust on a glass plate, I occasionally noticed a row of minute oval dots on the section. As the removal of the surface of the slide progressed, the dots began to elongate transversely and more or less obliquely (see figure 1, plate 96), then to narrow at the center, and soon a double row of round dots appeared that indicated a cross section of a spiral. Continuing the cutting the dots became elongated, and soon reunited and narrowed to oval dots and finally disappeared, as the removal of the surface cut deeper into the specimen. From these progressive sections I inferred that coils of a more or less compact spiral wire-like filament had been cut through.

Subsequently I found that by cutting across closely coiled spirals of wire set in plaster (1918, plate 27, figures 10, 10*a*) most of the spiral-like structure seen in the sections of *Ceraurus* was duplicated in detail.

During the cutting of sections over a period of several winters, this experience was repeated from time to time and sketches made of the successive exposures of the apparent spiral structure, but I could not preserve all the data found while grinding down the sections as there were no facilities available to me for photographing opaque sections.

I did not observe any branchial filaments attached to the spirals cut or progressively worn through from side to side, but many filaments that were free or attached to others parts were cut both longitudinally, obliquely, and transversely. The filaments were rarely seen attached to any kind of a base, but occasionally they were as shown by figure 12, plate 27 of the paper of 1918 (which is a drawing from a photograph of a thin section); see also figures 11 and 13 on the same plate, though I did not associate these with the spirals.

I knew very well in 1918 that the spirals might possibly be explained as oblique sections of filaments such as occur on the exopodites of *Triarthrus* or *Neolenus,* as had been suggested by authors, but the conclusion that there was a spiral-like appendage independent of the blade or arm with filaments attached to the proximal joint of the limbs in *Calymene* and *Ceraurus,* was so firmly impressed on my mind that I could not abandon it.

Raymond (pp. 48-50) assembles a formidable array of arguments against the possibility of the presence of spiral exopodites, but after reading them I was still unconvinced but realized that the presence of a spiral-like structure in *Calymene* and *Ceraurus* was rendered exceedingly doubtful to the general student and that it was relegated to the class of disproved theories. As a last resort I decided to make thin sections of a number of specimens of *Calymene* collected by William P. Rust for the National Museum many years ago, and a few of *Ceraurus,* all of which came from the locality and layer of rock worked by Walcott prior to 1876. This was undertaken in the hope that a section might be cut across on the plane of an elongated arm of the exopodite and, if present, an attached fringe of filaments. Spirals were found and a few stray unattached filaments, but it was not until the next to the last slide of *Calymene* was rubbed down thin that a series of undoubted spirals was seen in shadowy outline; a little reduction in the thickness of the slide and the spirals became more distinct and a fringe of filaments was indicated; a further reduction and the filaments extended back to the spirals and joined them, and I had in my hand the evidence that I had searched for from 1873 to 1879 and at intervals since. (See plate 96, figure 1). The arm of the exopodite of *Calymene senaria* as it appeared in the section was clearly and unmistakably a spiral-like structure with a filament attached to the side of several segments of the spiral; all the spiral phenomena I had observed in my early work are beautifully shown in this slide by a series of round and elongated single and double rows of dots, faint and distinct spiral structure, and what was new, the mode of attachment of the filaments to the spiral arm.

Exopodite of Calymene.—The slide referred to in the preceding paragraph (U. S. National Museum, Catalogue No. 68379) is represented by figure 1, plate 96, and a restoration of a portion of the exopodite by text figures 17, 17*a.*

There are portions of nine exopodites cut across in the slide at a more or less oblique angle to the axis of the arm and attached filaments. The exopodites had been pushed back into the half enrolled posterior portion of the trilobite and displaced so that they were beneath the axial lobe with their longitudinal axes subparallel to the axial lobe of the dorsal test. As seen in the section (figure 1, plate 96) the upper arm (1) is represented by a row of small round white dots with a few oblique transverse segments on the left end, and transverse faint oblique lines that give a spiral appearance to the section of the arm. The second exopodite (2) has about 26 obliquely transverse segments and spiral structure indicated. The third (3) exopodite has a distinct spiral with about 24 oblique segments; the spiral structure is more pronounced in the fourth (4) and the 30 segments are more strongly outlined and some are broader, but the spiral structure is preserved about midway of the length of the arm; the fifth (5) exopodite has about 40 segments indicated and the section shows 16 or more long slender filaments a number of which are connected directly to the segments of the arm, but the section does not cut across the exact point of contact with the seg-

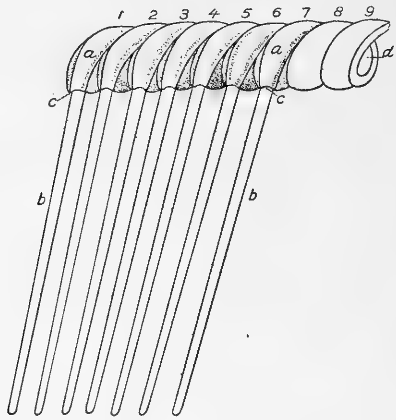

FIG. 17.—Diagrammatic outline of a dorsal view of a portion of a thoracic exopodite of *Calymene*. 1-9 = close coils of a spiral arm. 1-7 = bases (a) of seven branchial tubes (b) attached to dorsal side of the coils of the spiral arm. *a* = supporting base of branchial tube attached to spiral arm. *b* = branchial tube inserted in *a* at *c*. *d* = hollow interior of spiral arm of exopodite.

ments of the arm in a manner to clearly indicate the character of the union betwen them; this is found in the sixth (6) exopodite which has six filaments and portions of transverse spiral segments. The cut is diagonally across the segments and brings into view the thickened sheaths of three segments with the point of insertion of the

FIG. 17*a*.—Sectional view of diagrammatic outline of exopodite represented by fig. 17. (Lettering the same.)

filament into the supporting sheath. The seventh, eighth and ninth exopodites expose only a few segments of the arm, and afford no additional data on the structure of the exopodite.

My interpretation of the structure that when cut across gives a spiral outline in the sections of the exopodites in this slide is graphically shown by text figures 17, 17*a*.

The spirals seen in so many sections of *Ceraurus* and *Calymene* result from cutting across rounded, narrow, oblique coils of a hollow, spiral arm of the exopodite to which the bases or sheaths of

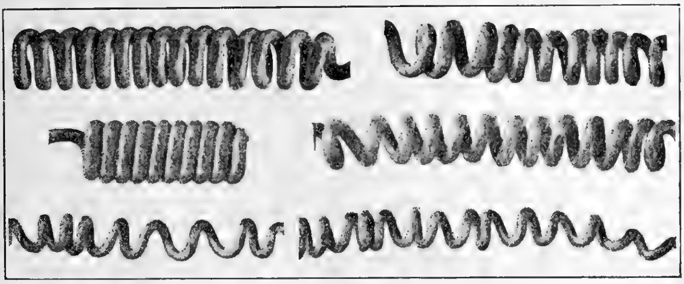

FIG. 18.—Photograph of several spirals formed of wire and flattened more or less by compression. These spirals suggest the probable form of the spiral arms of the exopodite of *Calymene* and *Ceraurus*.

long slender filaments (tubes) are attached; each obliquely arranged segment of the spiral is in vertical section, a portion of a spiral that was more or less flattened on the dorsal and ventral sides; the fila-

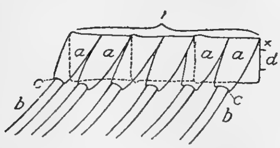

FIG. 19.—Diagrammatic outline of a dorsal view of a portion of the exopodite of *Triarthrus*. $a =$ three segments of the supporting arm. $b =$ supporting bases of branchial tubes, two attached to each joint of the supporting arm. $c =$ point of insertion of branchial tube into base *a*. $d =$ hollow interior of arm of exopodite.

ments were attached to the posterior end of a base or sheath attached to the dorsal side of the spiral coils of the arm; this is indicated by exopodite numbered 5 of figure 1, plate 96, and more definitely by

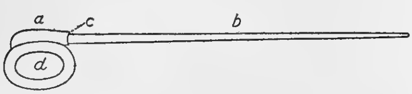

FIG. 19*a*.—Sectional view of diagrammatic outline of transverse section of exopodite represented by fig. 19. (Lettering the same.)

number 6, where the point of insertion of the slender filament is shown as well as can be in a section; the dorsal position of the sheath or base of the filaments is corroborated by the arm of the exopodite of *Triarthrus becki,* where it rests on and is attached to the dorsal side of the segmented section of the arm (see plate 95, figures 20-23).

The relation of the exopodites to the endopodite and coxopodite is not seen in slide No. 68379, but it is indicated by several sections one of which is represented by figure 2, plate 26, figure 4, plate 27, Walcott 1918 and plate 97, figure 8.

Exopodite of Ceraurus.—Many sections of the spiral arm of the exopodite of *Ceraurus* have been made since I began sectioning specimens in 1873, but none of them showed the connection between the spirals and the slender tubes or filaments, but the section of *Calymene* described above gives the key to the structure and indicates that the spirals of *Ceraurus* are sections of the arms of the exopodites and have exactly the same structure as those of *Calymene,* as may be seen by comparing the spirals of *Calymene* (figures 4, 5, 5*a*) with those of *Ceraurus* (figures 3, 6, 8, 9, plate 27, Walcott 1918).

Structure of exopodite of Calymene and Ceraurus.—None of the sections of either species clearly shows the proximal segment or shaft of the arm of the exopodite, but several afford data from which we may assume its character with a fair degree of certainty. Section 23 (M. C. Z.), Walcott 1918, plate 26, figure 2; sections 29, 30, 31 (M. C. Z.), Walcott 1881, plate 3, figures 9, 10; plate 4, figure 3, of *Calymene;* section 32 (M. C. Z.), Walcott 1881, plate 4, figure 4, of *Ceraurus,* figures 7, 8, 9, 10, plate 97 all indicate a simple slender elongate segment between the coxopodite and the obliquely transverse hollow spiral segments of the filamentous portion of the arm; fragments of the spiral portion of the arm are cut across in a number of sections but it was not until the restudy of the sections in connection with these notes that I succeeded in getting satisfactory photographs of the shaft and the connection between it and the spiral of the arm of the exopodite. These are reproduced in figures 7 and 8, plate 97, and indicate that several turns of the spiral arm were attached to the distal end of the shaft. The coil of the spiral appears to have been quite close when the animal was alive, but when subjected to the vicissitudes following death and entombment in the soft sediment, the spiral was loosened and often drawn out as illustrated by the spirals figured by Walcott in 1918, plate 27, figures 3-9, and on plate 97, figures 7-11 of these notes.

The elongate base of the filaments of the exopodite of *Triarthrus* are oblique to the axis of the arm, and the structure was probably the same in the exopodite of *Calymene* and *Ceraurus.*

The filaments of the exopodite of *Calymene* and *Triarthrus* are very slender tubes and in section give a beautiful fringe of fimbriæ as shown by figure 13, plate 27, Walcott 1918, and figure 1, plate 96, of this paper.

Arm No. 5 of figure 1, plate 96, of *Calymene* indicates that 39 or 40 segments have been cut across, and the proximal section exposed is evidently not the first one, but from its position I presume that there are not many more before the union with the shaft connecting the spiral arm with the coxopodite, so we may assume that the arms of the thoracic exopodites had between 35 and 40 segments (=coils of the spiral arm).

As far as may be determined from the evidence afforded by many sections of *Calymene* and *Ceraurus* cutting the arm of the exopodite, it is very rarely that the layer of sheaths or supports of the filaments (tubes) remained attached to the arm of the exopodite. The attachment of the sheaths to the spiral arm must have been relatively delicate and easily broken when the arms were displaced and the branchial tubes dragged about by movement in the soft sediment in which they were being embedded. This condition explains the presence of so many of the strong spiral arms of the exopodites and the absence of the supporting sheaths and the fringing tubes or filaments.

In the case of *Triarthrus becki* the animal settled down quietly on the surface of the mud and was not disturbed except by flattening out under pressure of accumulating sediment, which process sometimes displaced the limbs by sliding them out from beneath axial lobe; usually the endopodite and exopodite retain their natural position, being displaced only by the downward or upward pressure of the outer ends of the thoracic pleuræ or the margin of the pygidium or cephalon.

Exopodite of Triarthrus.—Raymond suggests that the spirals seen in sections of *Calymene* and *Ceraurus* are the result of cutting (p. 50) across the "setæ" of the exopodite, but he does not refer to the structure of the exopodite of *Triarthrus* in which there is a closely jointed rounded arm of many segments upon the upper side of which there is superimposed (plate 95, figures 20-23) diagonally and closely arranged slender, convex supports or sheaths of long, slender, round filaments similar to those cut across in *Calymene* (plate 96, figure 1). This structure was illustrated by Walcott (1918, plate 29, figures 2, 2*a* and 11) but he did not then compare it with the exopodite of *Calymene* and *Ceraurus*, as the connection between the fringing filaments of the arm of the exopodite of *Calymene* and the associated spirals was unknown. There is no evidence that the same kind of a jointed arm as that of the exopodite of *Triarthrus* was present in the exopodite of *Calymene* and *Ceraurus* but that there was a supporting spiral arm strengthened by the attached layer of sheaths of the fringing filaments appears to be well established.

The dorsal side of the arm of the exopodites of *Triarthrus* is finely illustrated by Beecher's photographs as reproduced by Raymond, plate III, figures 1, 5, 6; plate IV, figure 6, but none of them appear to show the many jointed supporting arm, nor do I find a reference to it by either Beecher or Raymond. It occurs on specimen No. 221, illustrated by Raymond, plate 5, figure 5, but his reproduction is too poor to show it clearly. Compare this figure with that on plate 95, figure 20 of this paper, as they appear to represent the same view of the exopodite.

In nearly all specimens of *Triarthrus* showing the exopodites it is the dorsal side that is exposed and the layer of basal sheaths of the filamentous tubes is so closely attached to the jointed supporting arm of the exopodite that the arm is entirely concealed from view except when occasionally the long distal segment of the arm projects a little beyond the distal end of the exopodite. It was only by a fortunate find that I became aware of the existence of the arm in *Triarthrus* and its relations to the sheath layer above it. The specimens showing it may be described as follows.

Specimen No. 65523, U. S. N. M. (plate 95, figures 22, 23) of *Triarthrus* has two of the jointed arm supports of the exopodite lying above the endopodites; the posterior one has eleven closely united joints, the length of each one of which is about 1.5 times as great as its diameter and the distal end has a slight raised rim against which the proximal end of the next joint impinges; the anterior arm has seven or eight joints that taper gradually to a short slender terminal joint. The arm with 11 joints has the bases or sheaths of 22 rounded tubes or filaments just above its anterior side, which indicates that there are about two tubes or filaments to each joint of the arm. The layer of supporting diagonal tubes of the filaments or tubes of each arm has been pressed forward so as to be almost clear of the jointed arm support, only a few of the round filaments resting on its dorsal side.

Specimen No. 65529, U. S. N. M. (plate 95, figure 20) shows three exopodites which have been displaced and pushed along parallel to the outer margin of the ventral surface of the dorsal test. The supporting arm has been compressed so as to slightly distort the joints and make them transversely a little oblique to the axis of the arm;

the series of bases of the tubes or filaments are also oblique in the same manner as those undisturbed in specimen No. 65523. The long exopodite of figure 20, plate 95, shows the ventral side of the supporting arm and its anterior upper edge where the layer of bases of the branchial tubes was attached to the arm.

Specimen No. 68387, U. S. N. M. (plate 95, figure 21) has two flattened arms of thoracic exopodites entirely concealed except at the distal end by the layer of obliquely aligned bases of the branchial tubes; of the latter there are more than forty, about two-thirds as long as that portion of the exopodite between the shaft at the proximal end and the round slender distal joint of the arm. The tubes are very slender, more or less flexuous, and terminate in a rounded blunt point; they may be compared with the branchial tubes of the exopodite of the thoracic limbs of *Marrella splendens*.

Pygidial endopodites of Triarthrus.—Raymond (p. 42) calls attention to the difference in interpretation of the development of the endopodites of small pygidia by Beecher and Walcott, Beecher considering them true endopodites in the specimen studied by him (No. 222, plate IV, figure 5, of the Raymond memoir) and Walcott considering the possibility of their being the transverse segments of the supporting arm of the exopodite (Walcott 1918, page 142, plate 29, figures 4, 5). Raymond states: "On careful examination, however, the specimen shows, as Beecher indicated, a series of endopodites in undisturbed condition (our plate 4, figure 5)."

A careful study of specimen 222 convinces me that Beecher and Raymond are correct in their interpretation of that specimen, and that the exopodite of specimen No. 65524, U. S. National Museum (Walcott 1918, plate 29, figure 5) has an apparently identical structure.

When I spoke of Beecher's interpretation I had in mind his figures 1 and 3 of 1894 (Amer. Jour. Sci., Vol. 47, 1894, plate 7) and his comparison with the larval endopodite of *Apus* (figure 4).

Anal plate.—Raymond illustrates what he calls the anal plate (figure 11, page 44, specimen No. 65525, U. S. N. M.) and states that the hemispheric mound at the middle of the anterior half is perforate for the opening of the posterior end of the alimentary canal. I find an uneven, somewhat jagged, depression near the posterior central part of the convex body of the "anal plate," but it is not clear that there is a perforation. Specimen No. 65524 (Walcott 1918, plate 29, figures 4, 5) has a similar structure but the "hemispheric mound" is covered with minute granulations and a longitudinal median depression extends the length of the convex portion; the marginal spines on this specimen appear to be the proximal portion of five of the pygidial limbs. The spines on specimen No. 65525 also appear susceptible of being interpreted as the coxopodites of very minute pygidial limbs.

It may be well to consider that the so-called anal plate may be the ventral integument of the posterior part of the pygidium which has been squeezed out from beneath the pygidium bringing some of the minute pygidial limbs along with it and that the dome may be the cast of the posterior portion of the axial lobe of the pygidium formed by the pressing of the ventral integument into it. More specimens are needed in order to arrive at a final conclusion.

NOTES ON INDIVIDUAL SPECIMENS OF TRIARTHRUS BECKI Green

Through the courtesy of Dr. Charles Schuchert of the Peabody Museum, Yale University, I have had the opportunity of looking over the type specimens of this species prepared and studied by Dr. Charles E. Beecher and recently illustrated by Raymond from the Beecher photographs. Some of the specimens have been photographed by Dr. A. J. Olmsted, chief photographer of the U. S. National Museum, who has obtained very excellent results. The specimens are excedingly difficult to photograph as the yellow pyrite and black, often shiny, shale reflect the light badly and usually the surface of the appendages is roughened by the finely botryoidal structure of the pyrite. I should like to reproduce a number of the photographs but that is impracticable in this paper. A few fragments are illustrated on plate 104, figures 12-15.

Specimen No. 211 (plate 104, figure 15). This is a portion of the specimen including the gnathites, the posterior portion of the hypostoma, the margin of which is broken away and a peculiar ribbed surface between the inner ends of the gnathites that may be formed by stout short spines attached to the inner end of the gnathites. No. 211 is illustrated by Raymond, plate II, figure 5.

Specimen No. 218 (plate 104, figure 13). This is a portion of the photograph that includes two of the posterior thoracic limbs that are in a peculiar position. The coxopodite, basipodite, and ischiopodite are turned up so as to show the thin ventral edge of the joints; the meropodite is tipped over so as to show the broad side of the joint which is nearly at right angles to the ischiopodite; the carpopodite is also lying on its side and is followed by the propodite and dactylopodite. It appears evident that the first three joints of the limb retained their natural position and the proximal four were bent back and are flattened broadside on the shale. The exopodites have retained their natural position on the dorsal side of the limb.

Raymond's interpretation of these limbs is shown by a diagrammatic drawing (figure 43, page 157) in which he has introduced a very short basipodite as the result of figuring the short ventral side of the joint and not noting that the dorsal side of the joint has slipped by and overlapped the ischiopodite.

Specimen No. 219 (plate 104, figure 14). This is a part of a photograph showing the apodemes very clearly. Raymond reproduces a photograph by Beecher (plate II, figure 6; plate IV, figure 4) which does not show them as well as in the original photograph.

Specimen No. 222 (figures 12, 12*a,* plate 104). These photographs are reproduced as the specimen shows the thin ventral edge of the joints of the endopodite, also by changing the point of view the flat anterior side of the joints. In figure 13 both the thin ventral edge of the three proximal joints of the limb are shown, also the flat side of the two succeeding joints.

Raymond illustrates No. 222 on plate IV, figure 5.

FIMBRIATED EPIPODITES OF CALYMENE AND CERAURUS

In addition to the spiral filamentous exopodites, several sections show a fringe of long rather strong fimbriæ attached to a more or less subtriangular base. The most striking examples are illustrated by figures 1-6, plate 100, of this paper. Raymond has given an interpretation of these in the restoration of the exopodite of *Ceraurus* (plate XI) which is represented as relatively short and about one-half the length of the endopodite; it is fringed with strong expanding filaments, the conception for which was probably derived from slide No. 22, illustrated by Walcott by a somewhat diagrammatic drawing in 1881, plate 3, figure 2, and 1918, plate 27, figure 12 and now by figure 2, plate 100. Several other slides show a somewhat similar structure; No. 21 (1918, plate 27, figure 11), No. 27 (Walcott 1921, plate 100, figure 5), No. 112 (Walcott 1921, plate 100 figure 4). All of which are of *Ceraurus* except Nos. 27 and 112 of *Calymene.* In each slide the supporting base of the fimbriæ or filaments is cut across at such an angle as to give a roughly subtriangular outline with the filaments attached on the broad outside margin. In slide No. 22 (plate 100, figure 2) the upper 12 filaments on the right side appear to be attached to a base and the lower four are probably the distal ends of filaments belonging to an adjoining base. In slide 45 (plate 100, figure 3) the filaments appear to belong to three bases; in slide No. 27 (plate 100, figure 5) they are attached to two, and in slide 112 (plate 100, figure 4) to one base. In none of these slides is there an indication of a long, broad arm or shaft of an exopodite such as is drawn in Raymond's restoration of *Ceraurus* (plate XI), or the long, narrow shaft in *Calymene* (figure 16, page 55), but several other slides appear to show sections of an elongate slender shaft, No. 109 (plate 97, figure 2), No. 12 (Walcott 1918, plate 27, figure 1); slide No. 12 may have been the one from which Raymond drew his figure 18, page 58, but which he refers to slide No. 111. The latter slide has a long slender appendage apparently attached to the section of the coxopodites beneath both the right and left pleural lobes. None of the slender appendages of these slides appear to have filaments attached to them, and several appear as though an undulating or straight ribbon-like tube had been cut longitudinally or slightly oblique to their axis and others are undoubtedly jointed; some resemble sections that might have been cut from the long cylindrical filaments of the branchiæ of *Cyanus diffusus* Dall (Walcott 1918, plate 28, figure 10).

In my paper of 1918 (page 150) the fimbriated appendages were considered to represent the epipodite of the ventral limbs, but Raymond (pp. 48-50) considers that they represent a section across the shaft of the exopodite with attached "setæ." The segmented spiral character of the arm of the exopodite of *Calymene* now being known, and the presence of a similar exopodite in *Ceraurus* being inferred from the spiral-like section of the arms, although the fringe of filaments has not been found attached to it, we have to interpret the other fimbriated appendages independently of the exopodites, as they do not appear to represent sections of the latter.

The exact form of the plate or body of this appendage cannot be accurately determined by the sections, but all of those seen have a roughly subtriangular section with a slender attachment to the coxopodite, or it may have been the basipodite as the two joints cannot be separated in the sections showing the fimbriated appendages under consideration. I am not convinced that the fimbriated appendages are undoubtedly epipodites but I do think that they are not exopodites. It has been suggested that they might be a modification of the exopodite attached to the cephalic limbs; this may be, but in one instance at least (figure 5, plate 100) they are *clearly* beneath a thoracic segment; in this section (No. 27, M. C. Z.) the slender arm of an expodite is shown on the right side and a little of the spiral structure of the arm.

It is not at all probable that the spiral arm of the exopodite of the thoracic limbs with its basal sheath and slender tubes would be replaced by such a structure as that shown by figures 1-6, plate 100. There is nothing in common between them except the fringing filaments.

The fringed epipodites of *Calymene* and *Ceraurus* (plate 100) are not unlike the epipodites of some of the thoracic limbs of the Euphausiacean *Meganyctiphanes norvegica*.[1] These epipodites are referred to as branchia; they are formed of a short base attaching them to the coxopodite of the thoracic limb and a transverse bar of varying form to which are attached numerous slender tubular filaments. Our figure 8, plate 100, may be compared with Dr. Calman's figure 141, *B* and *C*. The endopodite and exopodite of this species

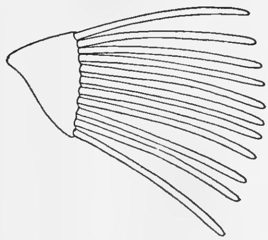

FIG. 20.—Outline of diagrammatic restoration of a fimbriated epipodite of *Ceraurus* based on figs. 1, 2 and 6, pl. 100.

are attached directly to the coxopodite. The epipodites hang freely at the sides of the body and are not covered by the carapace as are the podobranchiæ of the Decapoda and the trilobite.

The long slender jointed epipodites have a superficial resemblance to the branchiæ of the Amphipod *Paracyamus boopis*. (See Calman *idem.*, page 227, figure 135).

JOINTED EPIPODITES OF CALYMENE AND CERAURUS

Another distinct feature brought into prominence by recent photographs is that of the long, slender, rounded jointed appendages that occur in both *Calymene* and *Ceraurus*. In slide 109, plate 98, figure 1, these appendages are faintly seen, but with a very strong arc light they can be successfully photographed as shown by figure 2, plate 97. They are formed of long joints slightly expanded at their distal end and about three times as long as their diameter; these were attached to a larger proximal joint, figures 1, 3, 6, plate 97; figures 1-3, plate 104, and appear to have been nearly as long as the exopodite and to

[1] W. T. Calman, Treatise on Zoology, Lankester, pt. VII, 1909, fig. 141, p. 246.

have had five or more joints. The test of the joints was thin and readily distorted, as seen in figures 1, 3, 4, plate 97.

Some of the sections, figures 3, 4, plate 97, appear to have cut an undulating tube in which no joints are cut across. The few slides illustrated on plates 97, 104 exhibit the principal characters but they do not indicate as clearly as a direct comparison that these slender epipodites are smaller than the spiral arm of the exopodites and very much smaller than the jointed endopodite or leg of the trilobite; this is shown by figures 4, 7, 9, plate 98.

A jointed epipodite of this character is unknown to me, but as it cannot be an endopodite or exopodite and is a distinct recognizable form of appendage attached to the coxopodite, I think it best to tentatively refer to it as a peculiar form of epipodite situated above the exopodite beneath the ventral surface of the pleurotergites. Its function may have been to keep the branchial filaments or tubes of the exopodites clear of sediment and by gentle movement provide a constant supply of fresh water to them.

THORACIC LIMBS OF NEOLENUS, CERAURUS, CALYMENE AND TRIARTHRUS

The limbs of text figure 21 are very diagrammatic but they express my present conception of the parts that compose the thoracic limbs of the four genera named. It may be that the limbs of *Ceraurus* and *Calymene* will seem too complicated for a primitive crustacean, but all the elements shown appear to be present in the thin sections illustrated; the problem now is largely a question of interpretation and allocation of parts on the limbs. Dr. W. T. Calman states that the presence of epipodites and gnathobases suggests that the primitive crustacean limb was more complex than the simple biramous type.[1] Whether this view is correct or not the fact remains that the limb of the trilobites is far advanced along the line of evolution of the crustacean limb, also that the ancestors of the trilobite lived long before the advent of the Cambrian sea over the surface of the present continental areas. There is no attempt to show the details of the various parts of the limb, as they are outlined in the photographs of the sections on the plates and the diagrammatic text figures 11-14 for *Neolenus,* 16, 20 for *Ceraurus,* 17 for *Calymene,* 19 for *Triarthrus.*

[1] Treatise on Zoology. Lankester, pt. VII, 1909, pp. 8, 9.

Neolenus. (*A* of text figure 21). Ventral view of the coxopodite and six segments of the endopodite. The broad, flat arm of the exopodite is represented as attached to the limb at the proximal end of the basipodite and both join the distal end of the coxopodite in

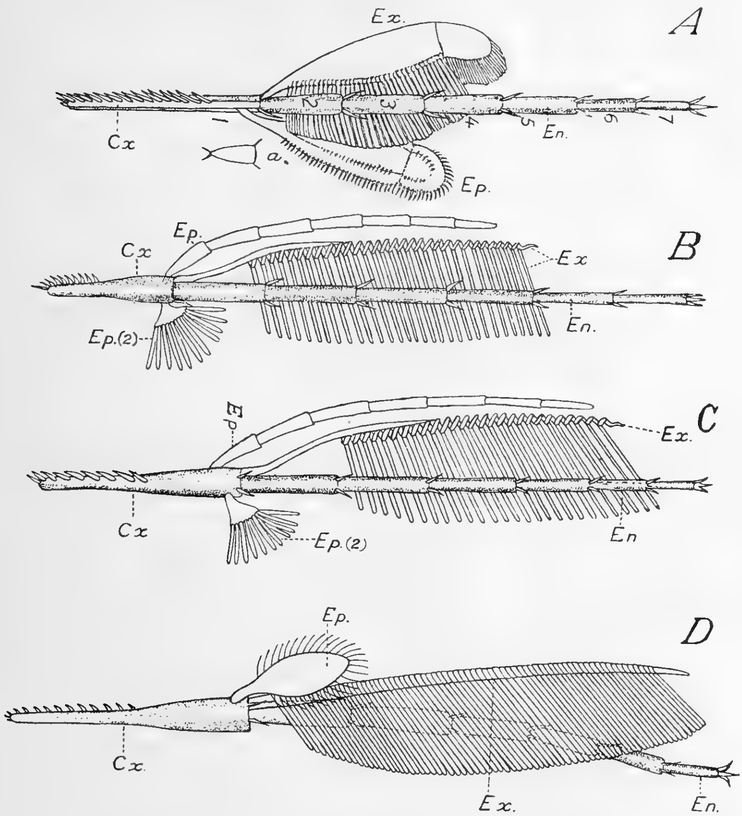

FIG. 21.—Thoracic limbs of *A* = *Neolenus;* *B* = *Ceraurus;* *C* = *Calymene,* and *D* = *Triarthrus.*

Legend. *cx.* = coxopodite. *en.* = endopodite. *ex.* = exopodite. *ep.* = fimbriated epipodite. *ep.* (2) = jointed epipodite.

In fig. *A,* 1 = coxopodite. 2 = basipodite. 3 = ischiopodite. 4 = meropodite. 5 = carpopodite. 6 = propodite. 7 = dactylopodite with terminal spines. Figs. *B, C, D* have the same joints in the endopodite as fig. *A.*

A, B and *C* are ventral veins, and *D* a dorsal view of the limb.

such a manner as to leave the fringed exopodite free to maintain a horizontal position above the endopodite; above and dorsal to the exopodite the plate-like epipodite is located; whether this is its natural position or whether it was located so as to be more or less between the endopodites is unknown, but from the location of most epipodites on the limbs of recent crustaceans it was presumably above both the endopodite and exopodite. A section of the coxopodite which is assumed to be sub-triangular in outline is outlined at (a).

Ceraurus. (*B* of text figure 21). Ventral view with the exopodite above the endopodite and the elongate slender epipodite outlined in the figure above the exopodite; although in a natural position it was probably just above the exopodite, which would place it back of it in the outline sketch; the second or fimbriated epipodite is represented as attached to the posterior side of the coxopodite near its distal end; several sections indicate that it may have been attached to the posterior margin of the broad dorsal or upper side of the coxopodite. (See figure 1, plate 99; figures 1 and 2, plate 100.)

The spiral arm of the exopodite shows only its lower or ventral side and the drawing of it and the attached slender tubes is purely mechanical; the manner of attachment of the tubes to the spiral arm is indicated in text figures 17, 17*a* of the exopodite of *Calymene.*

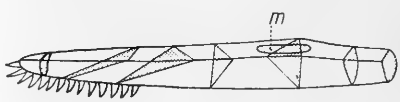

FIG. 22.—Outline of a coxopodite with sections drawn across it at various angles for the purpose of illustrating how varied the outline of the sections may be when a fossil coxopodite is cut at different angles. Some of these are shown in figs. 6 and 9, pl. 99; all on pl. 101; figs. 1 and 11, pl. 104.

Calymene. (*C* of text figure 21). The description of the thoracic limb of *Ceraurus* applies very closely to the limb of *Calymene;* they undoubtedly differ in details but in the sections it is difficult to determine to what extent except in the endopodites, and that the coxopodite of *Ceraurus* is probably shorter than that of *Calymene.* The joints of the endopodite of *Calymene* appear to have been rounder and less flattened and expanded at the distal end.

Triarthrus. (*D* of text figure 21). The thoracic limb of *Triarthrus,* like that of *Neolenus,* is known from more or less flattened specimens of it, while the limbs of *Calymene* and *Ceraurus* have been seen only in sections cut across them at various angles. The coxopodite is elongate, flattened so as to be deep on the sides, broad on the dorsal side, and thin on the ventral margin; the four proximal joints of the endopodite are flattened and the two distal joints rounded in cross section. The exopodite is more complicated than usually appears on the specimens showing the dorsal view, which is the one represented by *D,* figure 21. The dorsal view shows a long arm crossed diagonally by numerous narrow joint-like segments, and these are extended into long, slender, round filaments that judging from the branchial tubes of recent crustaceans, were slender tubes; on the dorsal side the narrow segments are not seen, but longer segments of a closely jointed arm that is well shown by figure 20, plate 95, of these notes, and in several of Beecher's specimens; the uncompressed undistorted form of the arm is best shown by figures 22, 23,

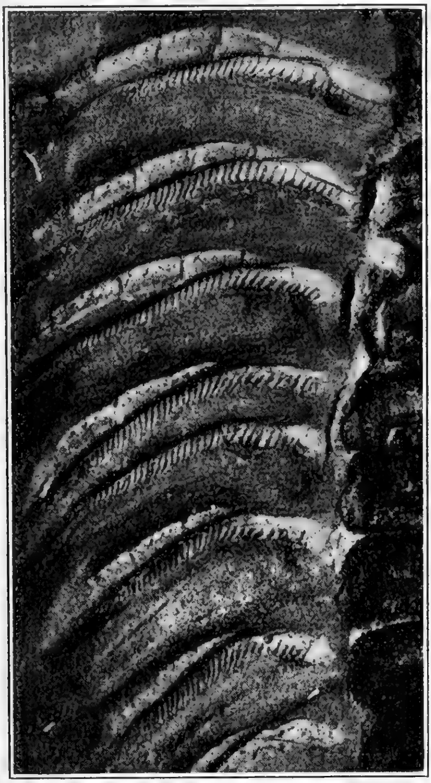

FIG. 23.—(× 12) Exopodites of *Triarthrus becki* Green. Photograph from specimen No. 204. Peabody Museum, Yale University.

plate 95, which is a dorsal view, the narrow segments having been detached from and pushed up off the jointed arm beneath.[1]

Raymond's diagrammatic outline of the thoracic limb of *Triarthrus* (page 126, figure 33) has on the exopodite a long solid proximal segment with fringing filaments corresponding to those of the closely jointed distal portion of the arm; this is based on specimen No. 204

[1] These are not true segments but a series of closely joined supporting sheaths of the fringing filaments. See exopodite of *Triarthrus*, fig. 23.

of Beecher, which is represented by a diagrammatic outline on page 155, figure 42. A careful study of the exopodites on specimen 204 and a comparison of them with the ventral side of other exopodites, shows them to be preserved in a natural condition up to the point where a secondary deposit of pyrite has merged the diagonally arranged supporting bases of the filaments into a continuous surface. On one of the posterior of the exopodites of 204 the process of merging the bases of the filaments is confined to the anterior side of the arm, and a few of them have escaped altogether. Sometimes the secondary deposit of pyrite forms a roughened botryoidal surface and in others it may be quite smooth.

From a study based on all the specimens available I think that the layer of supporting sheaths extends up to the point where the last proximal filament occurs and that the diagrammatic illustration (figure 33) of Raymond is incorrect.

The presence of an epipodite on the thoracic limb of *Triarthrus* has not been confirmed by additional evidence since the appearance of my paper of 1918, plate 30, figure 19. I have examined the specimen (No. 65525, U. S. N. M.) several times and can only repeat what I said in the description of the figure: "Photograph of a specimen that appears to indicate the presence of epipodites." It may be that the work that is soon to be done on a large number of specimens of *Triarthrus* may reveal more of this peculiar structure and prove or disprove that it represents an appendage independent of the endopodite and exopodite. Beecher largely obtained his remarkably fine results by working down on the ventral side of the trilobite, which would prevent his finding any small epipodite that might be attached to the dorsal side of the distal end of the coxopodite. As a tentative suggestion I still retain the outline of a small epipodite on the limb of *Triarthrus*.

SUPPOSED SPIRAL BRANCHIÆ IN SPECIMEN OF CALYMENE FROM OHIO

Mr. S. A. Miller called attention to a specimen of *Calymene* from the Cincinnatian series of Ohio, in which the fixed cheeks of the cephalon had been worn through so as to expose what he thought might be the cast of a spiral appendage.[1] The illustration strongly suggests that it is the arm of an exopodite such as occurs in the sections of specimens from the Trenton formation of central New York, but the examination of the specimen now at the U. S. National

[1] Journ. Cincinnati Soc. Nat. Hist., Vol. V, 1882, pl. 5, fig.8.

Museum shows that the ends of the posterior thoracic pleuræ have been pushed up against the inside of the pleural lobe of the cephalon so that when seen from above in the closely enrolled specimen they resemble the segments of the arm of the exopodite of *Calymene.* Dr. E. O. Ulrich was first to explain this curious and misleading specimen.

INTERNAL ORGANS

Alimentary canal.—Dr. Raymond adopts the view of Bernard (1894) and Jaekel (1901) that the alimentary canal of the trilobite was large, and publishes a drawing of a section of *Ceraurus* and one of *Calymene* (figures 22, 23, page 79) in support of it. My diagrammatic figure (1881, plate 4, figure 6; 1918, plate 28, figure 3) merely indicates the position and not the character of the canal, although figure 7, plate 3, 1881 shows the large "intestine" of *Ceraurus.* As I had occasion since 1918 to study the alimentary tract of crustaceans associated with *Neolenus serratus,* I also examined the photographs of many of the translucent sections of *Calymene* and *Ceraurus* to ascertain what light they might throw on the general question of the internal organs of the trilobite. The result is that I am now illustrating a number of the sections on plate 95, and describing them somewhat in detail: the evidence of the alimentary canal will first be considered.

In all of the many hundreds of sections of trilobites that I cut from the dark, fine grained Trenton limestone the visceral cavity beneath the axial lobe and the ventral appendages had been replaced by white calcite which outlined the parts with wonderful distinctness in contrast with the dark limestone matrix; the dorsal test and hypostoma were also usually replaced by calcite and often blended in with the calcite filling the visceral cavity, but sometimes distinctly separated from it by a clearly defined line; when any interior organ such as the alimentary canal was filled with food and mud while feeding or by infiltration after the death of the animal with fine, black calcareous ooze or silt, the canal retained its outline as shown by figures 1, 2, or it may have been distorted and forced out of place by compression, figures 3-12, plate 95. The section of figure 1 was probably at about the fourth thoracic segment, and it is probably the least compressed and distorted transverse outline of the alimentary canal of *Ceraurus* in the collection. The round dot on each side may be the section of an hepatic tube or sections of the flexor muscles. A very delicate white line indicating a firm structure arches from the two round lateral dots through the upper part of the dark alimentary canal that is a section of the articular projection of the next posterior mesotergite which has been pushed down a little; in figure 2 (specimen No. 205) the alimentary canal is nearly round and compares favorably with the section of figure 1; in figures 4-7, the canal has been somewhat flattened out by compression, also in figure 8, which is a slightly diagonal section; figures 8, 9, 10, show the canal displaced and distorted. What may be a portion of the canal or the heart in *Calymene* occurs in the upper portion of the axial lobe in the sections represented by figures 16, 17. As far as known to me none of the sections show the alimentary canal beneath the cephalon, but as Raymond states (pp. 80, 81), this is well shown in *Cryptolithus* from Bohemia. The restorations by Raymond, figure 24, page 81, of a longitudinal section, and figure 29, page 93, of a dorsal view of the alimentary canal are probably as nearly correct as can be made from available data.

Abdominal sheath.—The reproduction of the drawings (page 79, figures 21, 22) by Raymond of the " abdominal sheath," traced from photographic enlargements of slides No. 118 and No. 97, are not very conclusive evidence of the presence of such a sheath. The " dorsal sheath " of slide No. 118 is shown by our figure 16 plate 95, where it seems to represent an arched space filled in with the dark soft mud that constituted the matrix in which the trilobite was buried. The sheath of slide No. 97 may be a section of the articular extension of an adjoining mesotergite. There is in slide No. 27 (figure 1, plate 95 and figure 4, plate 103) a similar slender line arching over the upper part of the section of the alimentary canal that appears to have a definite outline like that of sections of the dorsal test (see figures 3, 4, plate 96).

Figures 3 and 4, plate 96, illustrate how it is possible that the so-called abdominal sheath is merely a section of the anterior part of the mesotergite where a vertical section cuts through the dorsal test, its anterior ventral extension and posterior articular extension. Such a section when cut transversely would give a section such as that of figure 4, plate 103.

Hepatic glands.—Under the heading of gastric glands (page 82) Raymond gives an historical outline of opinions of authors on the interior genal markings of trilobites, and concludes that they more likely represent either traces of the gastric cæca or of the circulatory system, and that the present evidence seems to be in favor of assigning to them the function of lodging the glands which secreted the principal digestive fluids. He speaks of similar markings occurring in *Naoria* and *Burgessia* of Walcott (1912, plates 27, 28), but does not state that the hepatic cæca of those genera are not markings on the test but are in the structure of the substance filling the space between the dorsal test and ventral membrane. Reference will be made to the probable hepatic glands of the trilobite in a paper that I now have in preparation on *Marrella, Burgessia, Naoria* and other Middle Cambrian crustaceans.

Heart.—Raymond states (page 85): "Nothing has been seen in the sections of *Ceraurus* and *Calymene* suggesting a heart." I thought the same until I noticed in slide No. 115 of *Ceraurus,* and No. 118 of *Calymene* (figures 16 and 17, plate 95), a dark, rather strong, arched line above the position of the alimentary canal that did not appear to be chitinous or to have any relation to the dorsal test. In both slides the arched line terminates at what may be sections of the dorsal flexor muscles of the axial lobe of the thorax; it is rather sharply marked by its dark color in contrast with the white calcite of the visceral cavity, and has a substantial thickness. It is customary to think of the elongate heart of a crustacean as circular or oval in outline, and it was not until I saw Dr. J. S. Kingsley's[1] drawing of the heart of *Limulus* as it appears in a transverse section of the abdomen that it occurred to me that the elongate arched line of slides 115, 118, might represent the heart of the trilobite. In the abdomen of *Limulus* the heart is transversely flattened and, with the large branchio-cardiac veins, extends nearly across the visceral cavity. This is merely a suggestion, but as I do not think the arched lines beneath the axial lobe of the dorsal test can represent the abdominal sheath or the articular anterior extension of the mesotergite, the theory that they may represent the heart may be worth consideration.

The heart of *Squilla mantis* is elongate, tubular and extends nearly the whole length of the thoracic and abdominal regions.[2] One can readily imagine such a heart flattening and curving over a mud-distended alimentary canal when the space was narrowed by compression between the dorsal test and ventral integument of the trilobite.

Musculature.—Dr. Raymond has presented the known evidence of muscles of the trilobite, but as he has not illustrated slide No. 114 which he mentions, I am giving a reproduction of a photograph of it in which the four dark spots occur, the upper two of which may represent the dorsal flexor muscles (figure 19, plate 95), also figures of five slides in which one or more similar spots occur. In slide No. 119, figure 18, plate 95, four dark spots occur almost as in slide No.

[1] Anniversary Mem. Boston Soc. Nat. Hist., 1880, pl. 2, fig. 4.

[2] Calman, Treatise on Zoology, Lankester, pt. VII, 1909, 324.

114; in figure 2, plate 95, of slide No. 205, three such spots occur on the right side along with two irregular spots; figure 17, slide No. 115, has a large ventral spot and two small dorsal spots; figure 16, slide No. 118, has two dorsal spots, and slide No. 27, figure 1, has twin circular dots on each side of the axial visceral cavity that indicate two ventral muscles near the cephalon. Raymond states that slides numbered 131, 140 and 199 also show similar spots.

The presence of these dark spots indicates a hollow tube-like opening in the substance of the matter filling the visceral area into which the silt filtered and replaced the muscle which had been removed after decomposition. When considering an explanation of the origin of the spots, I took a small alcoholic specimen of *Limulus* and cut out the dorsal carapace so as to leave the alimentary canal and flexor muscles exposed; the liver had decomposed so that the four strong flexor muscles were in strong relief; I then turned to Packard's drawing of a cross section through the cephalothorax in front of the heart, etc., of *Limulus*[1] and found the sections of four flexor muscles in the same relative position as the four spots in the sections of *Ceraurus*. In *Limulus* sections cutting across the flexor muscles further back beneath the cephalothorax show them in a different position, but I think we may reasonably infer that the spots in *Ceraurus* indicate the position of its flexor muscles. The replacement of casts of tubes and other organs in soft bodied animals by infiltration after the animal has been buried in silt or fine mud is beautifully illustrated by the replacement of tubes, etc., in the Middle Cambrian fossil medusæ.[2]

In some instances (figures 17, 18, 19, plate 95) the lower rounded triangular spots may be sections of the inward extension of the axial processes of the mesosternites of the dorsal test, as indicated by the sections represented by figures 1, 2, 3, 5-7, 10, plate 102. The upper spots do not permit of this explanation, and some of the ventral ones may be filled-in holes left by the decay of the muscles.

USE OF PYGIDIUM IN SWIMMING

Raymond presents several arguments in support of the theory that trilobites with large pygidia used them in swimming (pages 72, 73), but it is not easy to imagine a trilobite using its pygidium as an active agent in swimming or darting backward through the water to escape its enemies. The large pygidia were encumbered with a load of limbs

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[1] Anniversary Mem. Boston Soc. Nat. Hist. IV, 1880, pl. 2, fig. 2.

[2] Monogr. U. S. Geol. Survey, Vol. 30, 1898, pl. 4, figs. 7-12; pl. 17, fig. 3*a*.

composed of at least a separate endopodite and exopodite that were more adapted to creeping or walking and swimming forward than to being flattened against the ventral surface of the pygidium so as not to act as a drag in any quick motion of the pygidium or the backward movement of the animal. All the restorations of the trilobite by Beecher, Raymond, and Walcott indicate a ventral surface with the appendages so arranged as to facilitate a relatively slow forward movement when swimming or crawling. The species with large pygidia were well adapted to lying close to the bottom partly buried in the sand, mud or silt, which would have given them ample protection.

The species with small pygidia greatly outnumber those with large pygidia, and they survived in great numbers, although powerful enemies existed as far back as Middle Cambrian time. *Sidneyia inexpectans*[1] must have been a strong, rapid swimmer, and with its broad fan-like caudal fin could have readily overtaken and captured with its great chelate cephalic limbs any swimming trilobite.

COXOPODITES AND TRAILS OF TRILOBITES

Raymond long ago called attention, in the description of a new species of *Isotelus,* to the relation between the long "gnathobases" of *Isotelus* and certain markings on sandstones from the Chazy formation.[2] I had not noted this when preparing my paper of 1918 on the Appendages of Trilobites, and hence did not refer to it. I then called attention to tracks and trails supposed to have been made by trilobites, and spoke of the curious and interesting trails in which the impression of long endopodites (coxopodites) were very numerous, and gave several illustrations of them.[3] Some of the trails are so strikingly similar to what a trilobite would naturally make that there does not appear to be any other interpretation of them as there is no form in the associated invertebrate life that I can imagine making such trails.

ISOTELUS MAXIMUS Locke

Raymond concludes that the endopodites of *Isotelus* were composed of cylindrical segments (page 75), but I find that the specimen of *Isotelus maximus* Locke (Walcott 1918, plates 24, 25; U. S. National Museum Catalogue No. 33458) shows very distinctly verti-

[1] Smithsonian Misc. Coll., Vol. 57, 1911, pls. 2-5.

[2] Ottawa Naturalist, Vol. 24, pp. 131-133.

[3] Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, pls. 38-40.

cally flattened coxopodites and a slight flattening of the basipodite and of three proximal joints of the endopodites; the other joints of the endopodites appear to be rounded on the ventral side, but none of them show a complete transverse section of the joints; it is also to be recalled that the appendages of this specimen underwent more or less maceration and compression when embedded in the calcareous mud that now forms its matrix, and that it also was more or less abraded before being rescued from quarry rubbish and the wagon seat of the teamster who picked it up.

Raymond was unable to see the slender markings (page 36) that Walcott represented in the diagrammatic figure of the appendages of *Isotelus maximus* (Walcott 1918, plate 25), but I find they are still on the specimen and can readily be seen by reflected light when the surface of the rock is washed clean of dirt and finger marks and kept wet; the slender fimbriæ-like exopodite markings were evidently above and not below the endopodites, although the Walcott figure (Science, Vol. 3, 1884, page 280, figure 1) has the slender fimbriæ apparently below the two posterior endopodites on the right side of the figure, but the endopodites are outlined in the drawing from a slight and faint impression on the rock that leads to the distal joints which are imperfectly preserved. If the entire endopodites were present they would be above the fimbriæ in the drawing, or below them if the animal was in a natural position.

The coxopodites of *Isotelus* were probably used to aid in pushing the trilobite forward when on a sandy or muddy surface, as shown by trails on the surface of sandstones of the Middle and Upper Cambrian (Walcott, 1918, plates 37-40), but I think the short stout legs enabled the animal to creep about without difficulty both on the bottom under water, and in the shallows on the beach between tides.

ORDOVICIAN CRUSTACEAN LEG

Raymond (pages 56, 57) had difficulty in dealing with the slender crustacean legs (endopodites) that occur on the surface of limestone shale from the Trenton Point Pleasant formation near Covington, Kentucky. Walcott illustrated (1881, plate 6, figure 5) two of the legs, stating (page 207) that they compared with the leg as restored in *Calymene*. Walcott again in 1918 figured five of the legs (plate 36, figures 2 *a-d*) as they occur on specimen No. 65532 (U. S. National Museum catalogue) and gave a restoration of the leg (figure 1) with its eight joints which include a long slender distal joint (dactylopodite); a propodite about half as long as the distal joint; three joints (carpopodite, meropodite, ischiopodite) a little longer than the propodite; a sixth joint (basipodite) about as long as the propodite; a short seventh joint (coxopodite), and a still shorter eighth joint which corresponds to the precoxal joint of the thoracic leg of *Nebalia bipes,* as described by Hansen.[1] This leg is unlike that of the limb of any known trilobite as it has neither the long, strong coxopodite nor the broad joints of the endopodite. It also differs in the character of the joints and the manner of their articulation.

Raymond (page 57) was unable to count more than seven joints on any of the specimens of the legs; he evidently failed to see the small precoxal joint which occurs on four of the legs.

NOTE ON OCCURRENCE OF THE OLDEST KNOWN TRILOBITE

The oldest Cambrian fauna containing trilobites is the *Nevadia weeksi* fauna of Nevada. This fauna continues far below the *Mesonacis gilberti* fauna of the upper portion of the Lower Cambrian and there are no trilobites known from the 5000 feet (1524 m.) of strata in which it occurs except genera of the Mesonacidae, *Nevadia, Holmia, Olenellus,* except a fragment of a *Ptychoparia* somewhere in the upper 400 feet.[2]

Nevadia weeksi Walcott has a large cephalon, twenty-eight thoracic segments, a very small plate-like pygidium without a defined segment.[3]

Holmia rowei Walcott has a large cephalon, sixteen thoracic segments and a very small pygidium with one distinct segment.[4]

The above two species are all that were found in the lower strata. A fragment of what may have belonged to an *Olenellus* occurs 1000 feet (304.8 m.) or more above and over 3000 feet (914.4 m.) above the cephalon of a trilobite tentatively referred to *Olenellus, O. claytoni.*[5]

There are no traces in this primitive fauna of any trilobite with a large pygidium and the early stages of growth of the young of the Mesonacidae all have a very large cephalon and a minute pygidium.

The genera *Microdiscus* and *Eodiscus* appear in the later formations of the Lower Cambrian series. It would seem that if these

[1] Ann. and Mag. Nat. Hist. (6) XII, 1893, p. 422.

[2] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 189.

[3] Smithsonian Misc. Coll., Vol. 57, No. 6, 1910, pl. 23.

[4] Idem, pl. 29.

[5] Idem, pl. 40, figs. 9-11.

forms with a large pygidium were the primitive type of the trilobite they should occur in great variety and numbers in the earlier Cambrian faunas.

Raymond has assembled an interesting series of observations to sustain the view that the primitive trilobite was a flat, free swimming form with a subequal cephalon and pygidium, and his discussion will serve to stimulate the search for more and more primitive faunas in the older sedimentary formations.

CONCLUSION

The additional data added in these notes relates to the thoracic limbs of *Neolenus,* the spiral exopodites and epipodites of *Calymene* and *Ceraurus,* the exopodites of *Triarthrus,* and the large, clear photographs of the thin section of *Calymene* and *Ceraurus.* The items mentioned are not at all sensational in character but they add to our knowledge of the structure of the limbs of the trilobite. Each item has taken much time and energy to work out as it involved the examination of many specimens, the cutting of thin sections, and the taking of many photographs.

Copies of the principal photographs will be sent to at least sixteen of the museums of the world where special attention is given to invertebrate paleontology, in order that students may have access to some of the evidence on which my conclusions are based as direct from the specimens as it is possible to present it.

My interest in the organization of the trilobite has been revivified by this study and I hope to add a little more to what is now known, in the course of two or three years.

DESCRIPTION OF PLATE 91

PAGE

Neolenus serratus Rominger..................................369-375, 380-394

FIG. 1. (Natural size.) Photograph of a specimen preserving more or less of 15 ventral limbs, the antennules and one of the caudal rami on the right side. One ventral limb has been torn away at 7 and the shaft of an exopodite is partly preserved above limb No. 9; the latter is clearly shown in fig. 2, pl. 93. The 4 anterior or cephalic limbs as enlarged are shown by fig. 1, pl. 93, and the 8 posterior limbs by fig. 2, pl. 93. The numbers 1-4 = cephalic limbs; 5-11 = thoracic limbs; 12-16 = pygidial limbs.

The matrix of this specimen is on the upper portion of a piece of shale illustrated by pl. 15 of this volume (Smithsonian Misc. Coll., Vol. 67, 1918). U. S. National Museum, Catalogue No. 58588.

2. (× about 6.) The coxopodite *B, C, D,* of text fig. 15 (p. 383) enlarged and lighted from the lower right side so as to bring out the ventral and proximal spines on the coxopodite *D*. The lower ventral margin of coxopodite *C* passes beneath *D*, so as to conceal its ventral row of spines. Coxopodite *B* is free but molded over the impression of the pleural segment of the dorsal test; it has a few ventral spines, as has the basipodite (2), and the ischiopodite (3), and the meropodite (4).

The lettering and numbering is the same as for text fig. 15 (p. 383)

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

Calymene senaria Conrad 394

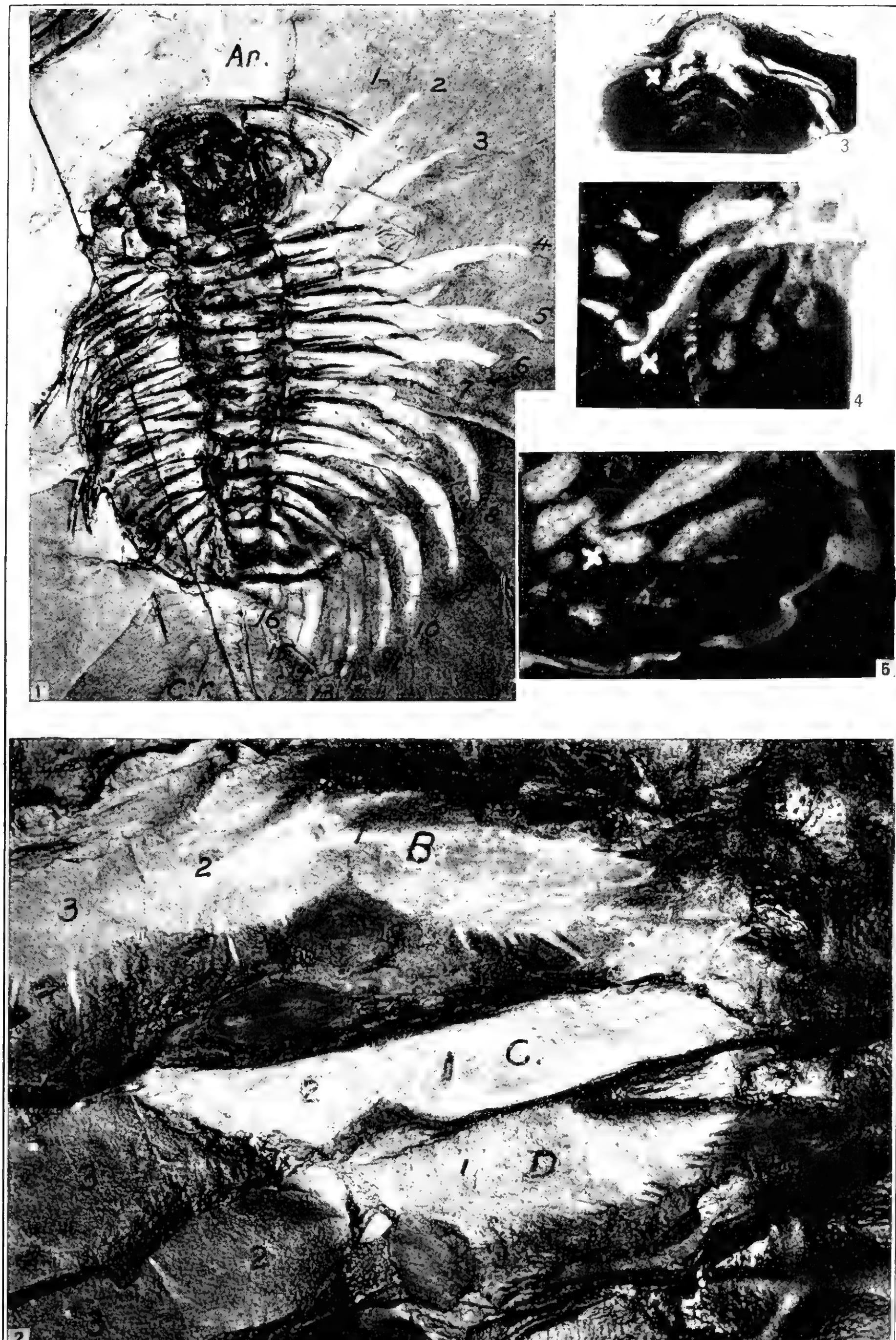
FIG. 3. (× 6.) (See fig. 4, pl. 99). Transverse thoracic section on which Raymond (p. 53, fig. 15) based the "ball-and-socket" joint theory of the mode of attachment of the ventral limb of this species. The joint being at x. (See also figs. 4 and 5). (Slide No. 63, M. C. Z.).

4. (× 8.) Portion of a transverse thoracic section in which a "ball-and-socket" joint-like effect occurs near the distal end of an endopodite at x. (Slide No. 48, M. C. Z.)

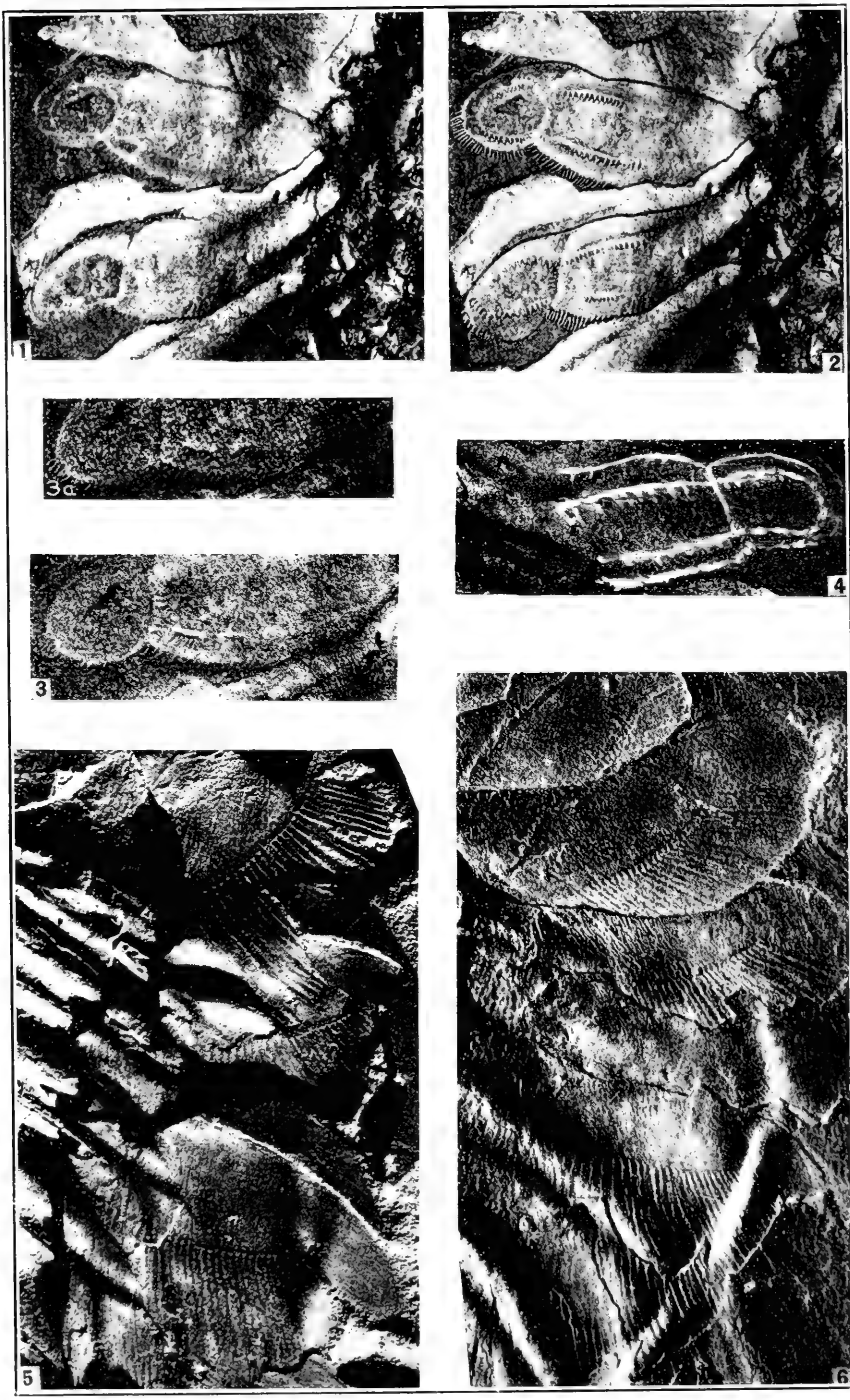
Ceraurus pleurexanthemus Green.................................. 400

FIG. 5. (× 6.) Portion of a transverse thoracic section in which a "ball-and-socket" joint-like effect occurs where a broken and distorted endopodite comes close to another fragment of an endopodite at x. (Slide No. 239, M. C. Z.)

The specimens illustrated are from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



LIMBS OF NEOLENUS, CERAURUS AND CALYMENE



EXOPODITES AND EPIPODITES OF NEOLENUS

DESCRIPTION OF PLATE 92

PAGE

Neolenus serratus (Rominger) (see pl. 20 of this volume, published in 1918) 369-375, 380-394

FIG. 1. (× 3.) Untouched photograph of two of the large epipodites of the thoracic limbs, showing their tenuous character, minute marginal and carinal spines, the lines of the carinae, and the distinctness of the large proximal and small distal joints. 389

2. (× 3.) Same photograph as that represented by fig. 1, on which the minute marginal and carinal spines have been outlined by darkening the background.

The specimen represented by figs. 1 and 2 is the same as that represented by fig. 3, pl. 20, Smithsonian Misc. Coll., Vol. 67, No. 4, 1918, U. S. National Museum, Catalogue No. 65515. Photograph by R. S. Bassler.

3. (× 3.5.) Untouched photograph of a slightly greater enlargement of the upper epipodite of fig. 1, in which the base of the carinal spines is more clearly indicated.

3*a*. (× 3.5.) Untouched photograph of the lower margin of the epipodite represented by fig. 3, in which the fine spines are more clearly defined. The spines should be compared with laminated filaments of the exopodite as shown on figs. 5 and 6. Photograph by L. W. Beeson. U. S. National Museum, Catalogue No. 65515.

4. (× 3.5.) Photograph of the matrix of one of the lower epipodites on the specimen illustrated by figs. 3 and 4, pl. 20, of brochure No. 4 of this volume (67), enlarged so as to show the carinal spines which have been retouched to bring them out more clearly.

Photograph by L. W. Beeson. U. S. National Museum, Catalogue No. 65515.

5. (× 3.) Untouched photograph illustrating narrow, fringing lamellar filaments of the thoracic exopodites. This enlargement is from the upper portion of the specimen represented by figs. 1 and 2, pl. 23, of brochure No. 4 of this volume (67). The exopodites are lying above and on the endopodites. Nearly all details of structure were lost in the reproduction of the original figures. 392

Compare lamellar filaments with fine fringing spines of epipodites, figs. 1-3. U. S. National Museum, Catalogue No. 65521. Photograph by L. W. Beeson.

6. (× 4.) Untouched photograph of posterior exopodites on the specimen represented by fig. 3, pl. 19, of this volume, in which the exopodites are lying above and on the endopodites. The photograph was made from the matrix. The lamellar elements or filaments of the posterior margin are clearly shown. In both of the exopodites the distal joint has been pressed slightly out of position and the short fringing filaments appear as a portion of the body of the joint which gives a false impression as to its form. U. S. National Museum, Catalogue No. 65514. Photograph by L. W. Beeson. 388

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

DESCRIPTION OF PLATE 93

Legend

ex = exopodite.	*car* = carpopodite.
cox = coxopodite.	*pro* = propodite.
bas = basipodite.	*dac* = dactylopodite.
mer = meropodite.	*cl* = terminal claws.
isch = ischiopodite.	

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Neolenus serratus Rominger 369-375, 380-394

FIG. 1. (× 3.3) Reproduction of a photographic enlargement of the four anterior limbs of the right side of fig. 1, pl. 91, (Specimen 58588) to illustrate the form of the cephalic limbs, which is similar as far as known, except in a few minor details, to that of the limbs of the thorax and pygidium... 390

2. (× 3.3) Reproduction of a photographic enlargement of the eight posterior limbs of the right side of fig. 1, pl. 91, to illustrate the spiniferous coxopodites and the close attachment of the endopodites to them. The jointing of the endopodites is clearly preserved, also the ventral margin of the endopodites, but their dorsal (anterior in the figure) margin has been cut away from the coxopodite and basipodite of three of the limbs where they rested on the ventral (posterior in the figure) margin of the next anterior limb and concealed the margin and spines of the ventral side. Three of the limbs show the "notch" of Raymond between the coxopodite and basipodite. Note the strong group of spines on the basipodite and ischiopodite and that the grouping of the ventral spines midway of the basipodite is successively nearer the distal end of the ischiopodite, meropodite, carpopodite, and propodite where it is at the end of this joint and the two succeeding distal joints. The large spine with the smaller spines corresponds to the ventral angle of the flattened joints of the endopodite of *Triarthrus becki*.[1]

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

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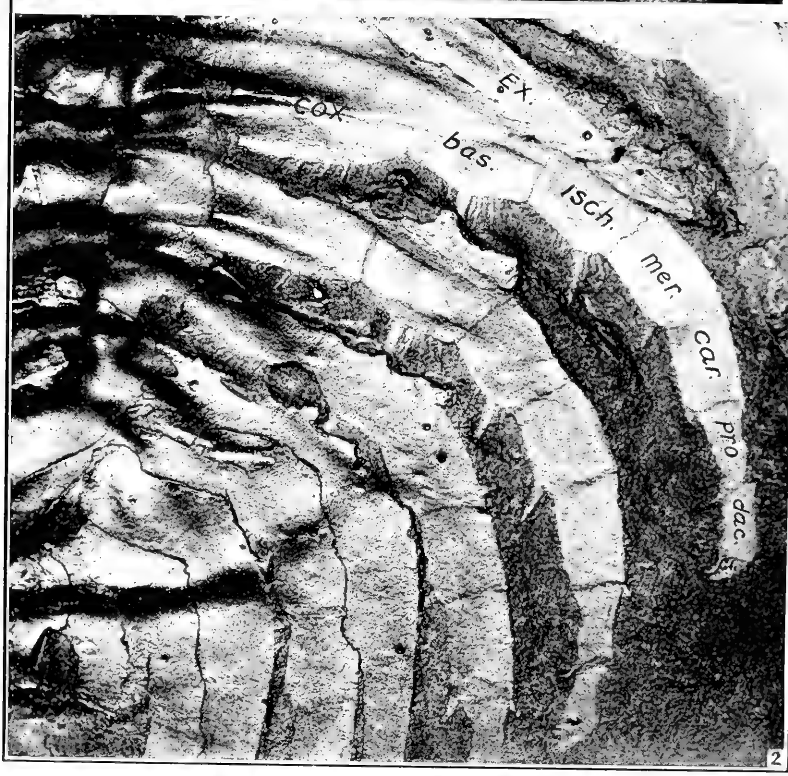
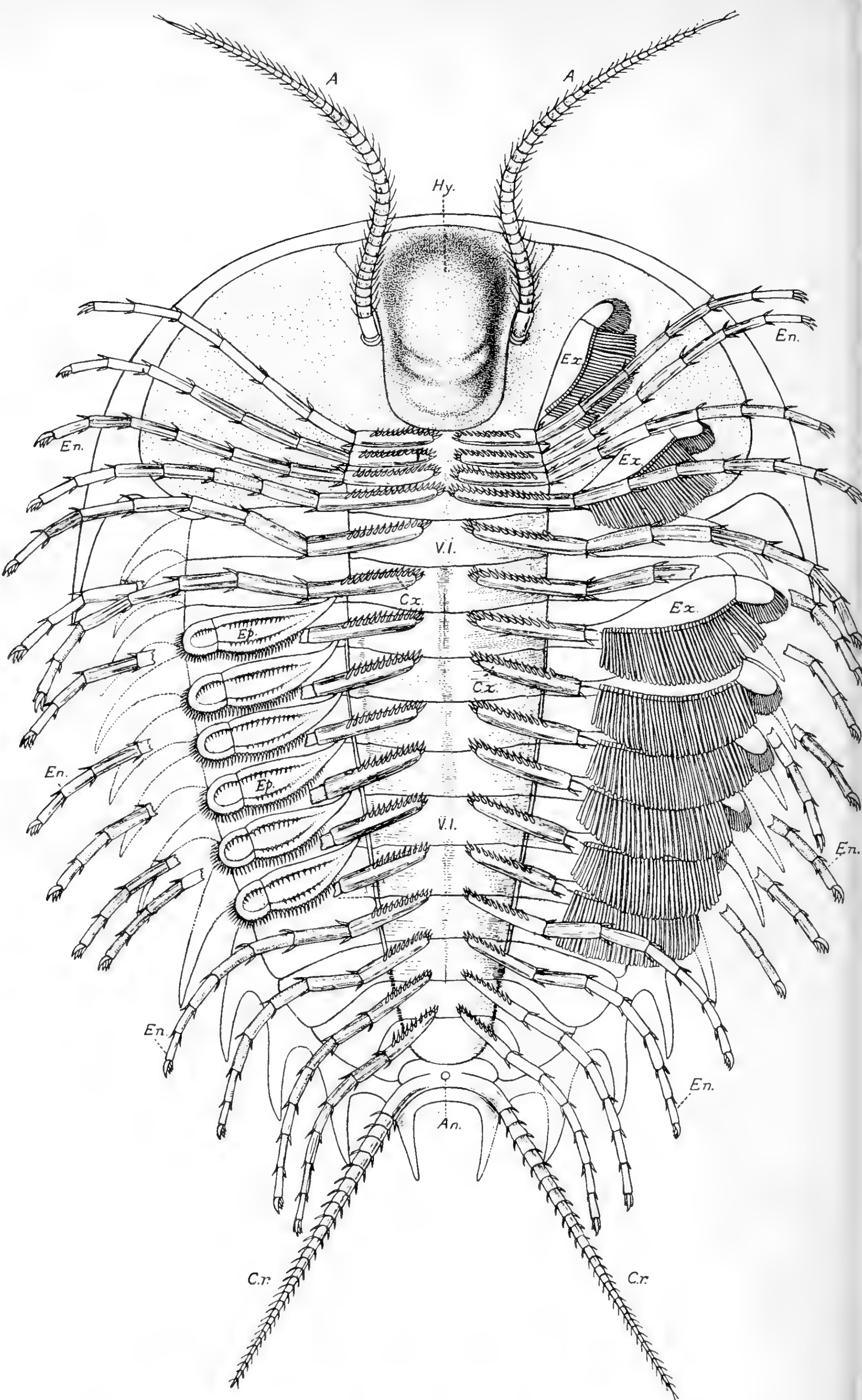
[1] Walcott, Smithsonian Misc. Coll., Vol. 67, 1918, pl. 30, fig. 20.

1



2

LIMBS OF NEOLENUS SERRATUS



RESTORATION OF VENTRAL SURFACE OF NEOLENUS SERRATUS (Rominger)

DESCRIPTION OF PLATE 94

Legend

d. s. = dorsal shield.	*en.* = endopodite.
hy. = hypostoma.	*ep.* = epipodite.
a. = antennules.	*ex.* = exopodite.
an. = anal aperture.	*cx.* = coxopodite.
c. r. = caudal rami.	*v. i.* = ventral integument.

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Neolenus serratus (Rominger) 392

FIG. 1. (About twice the large-sized specimens of the species.) This outline restoration differs in details from that published in 1918 (pl. 31) and in the omission of the small epipodite and exite attached to the coxopodite of the post-cephalic limbs.

The observer should note that the coxopodite and endopodite are seen from their narrow lower or ventral side; that the exopodites lie nearly in a horizontal position above the endopodites and that the epipodites are in a nearly flat position between the ventral membrane and the exopodites.

The arrangement of the cephalic limbs is diagrammatic, being based on their known position in *Triarthrus becki* and incomplete data for *Neolenus*.

DESCRIPTION OF PLATE 95

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Ceraurus pleurexanthemus Green....................................394-412

FIG. 1. (× 4.) Transverse section at about the fourth thoracic segment of a partially enrolled specimen showing alimentary canal; filamentous appendages on the left side close to the coxopodite of the thoracic limb and on the right side a spiral-like structure similar to that in fig. 1, pl. 96. In the lower part of fig. 1 there are circular dots on the line of the dorsal furrows of the dorsal test that may indicate the position of flexor muscles. (Slide No. 27, M. C. Z.)

2. (× 4.) Transverse thoracic section of an enrolled specimen with a distorted section of the alimentary canal. (Slide No. 205, M. C. Z.)

3. (× 4.) Diagonally transverse thoracic section with a small rounded section of what may represent the alimentary canal. (Slide No. 65, M. C. Z.)

4. (× 4.) Transverse thoracic section cut obliquely down through the axial lobe. (Slide No. 244, M. C. Z.)

5. (× 4.) Transverse thoracic section with the alimentary canal compressed as in fig. 6. (Slide No. 83, M. C. Z.)

6. (× 3.) Transverse thoracic section preserving the outline of a somewhat compressed alimentary canal, section of a coxopodite of a ventral limb and sections of ribbon-like slightly undulating appendages referred to as epipodites. See figs. 3 and 4, pl. 97. (Slide No. 13, M. C. Z.)

This section was illustrated by a drawing based on a photograph by Walcott, 1881, pl. 2, fig. 3, and a photograph in 1918, pl. 26, fig. 14.

7. (× 6.) Transverse thoracic section in which the alimentary canal has been greatly distended and distorted; see figs. 9 and 12. (Slide No. 135, M. C. Z.)

8 and 10. (× 3.) Transverse thoracic section in which an inward extension or process of the articular fold of the dorsal test is preserved on the left side at the union of the mesotergite and pleurotergite and above the coxopodite of the ventral limb. What may be the displaced alimentary canal is indicated by the transversely oval black space beneath the dorsal test of the axial lobe. (Slides M. C. Z. No. 117 = fig. 10, and No. 202 = fig. 8.)

9. (× 10.) Transverse thoracic section in which the upper margin of the enlarged alimentary canal appears to have been crowded up against the articular extension of a segment of the dorsal test as in figures 5, 6, 13. (Slide No. 39, M. C. Z.)

10. (See fig. 8.)

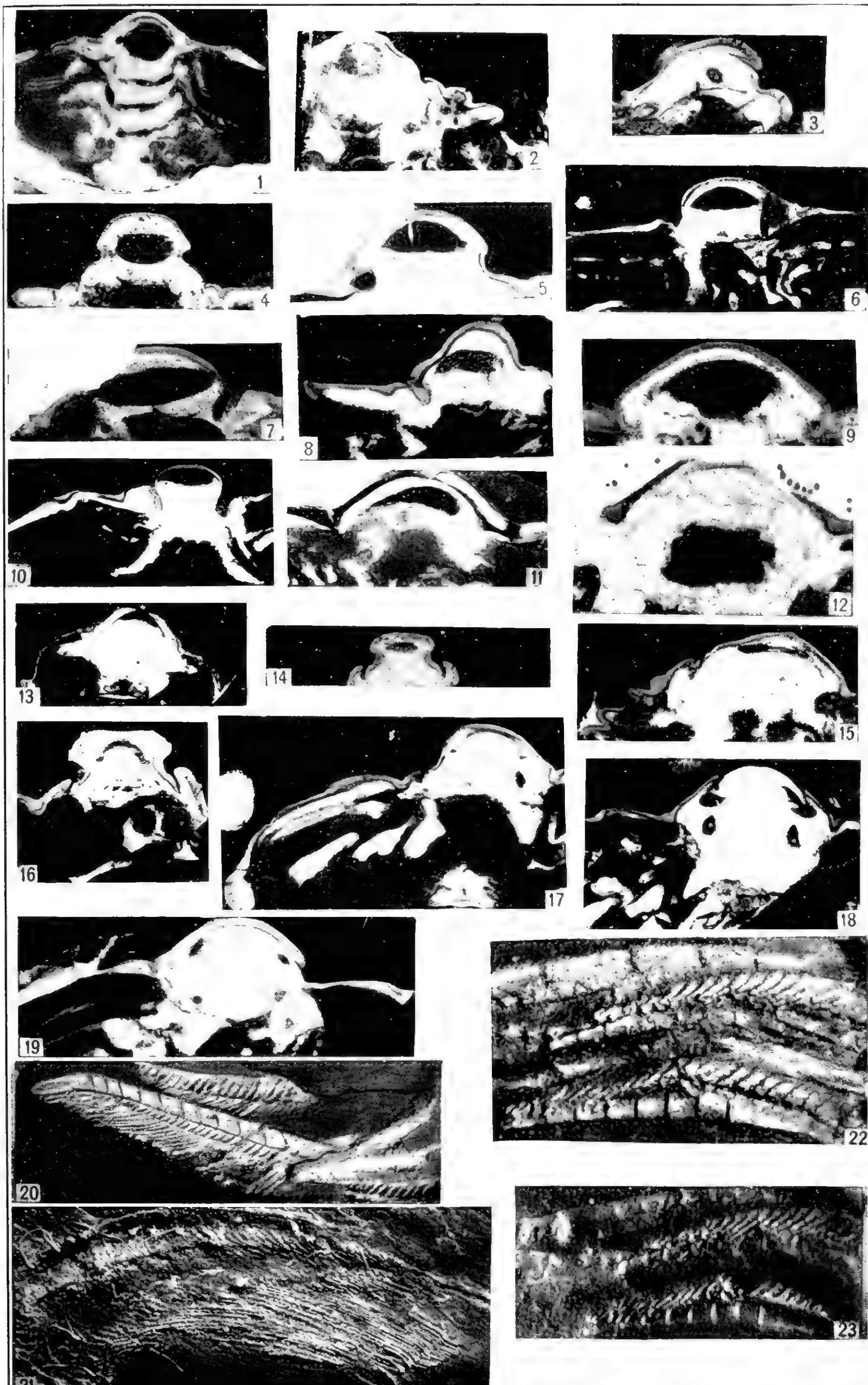
11. (× 4.) Transverse thoracic section of an enrolled specimen showing oblique compressed section of the alimentary canal and traces of coxopodites of ventral limbs. (Slide No. 110, M. C. Z.)

12. (× 10.) Transverse thoracic sections with a curiously distorted and displaced alimentary canal. (Slide No. 148, M. C. Z.)

13. (× 3.) Transverse cephalic section showing portion of a displaced alimentary canal crowded up against the articular extension of one of the mesotergites. (Slide No. 228, M. C. Z.)

15. (× 4.) Transverse thoracic section to illustrate what may represent a collapsed alimentary canal crowded high up in the visceral space of the axial lobe. (Slide No. 112, M. C. Z.)

17. (× 4.) Transverse thoracic section showing supposed position of two dorsal flexor muscles, a triangular section of a coxopodite, and on left side portions of three ventral limbs. (Slide No. 115, M. C. Z.)



SECTIONS OF TRILOBITES

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Calymene senaria Conrad..394-412

Fig. 14. (× 5.) Transverse section showing an elongate collapsed alimentary canal crowded up into the thoracic axial lobe; the entire section is shown by fig. 5, pl. 101. (Slide No. 9, M. C. Z.)

This section was illustrated by a drawing based on a photograph by Walcott, 1881, pl. 1, fig. 9.

16. (× 3.) Transverse thoracic section showing position of two supposed dorsal flexor muscles and what may be a trace of the transversely arched heart. (Slide No. 118, M. C. Z.)

18. (× 4.) Section similar to that represented by fig. 19, except that the two dark ventral spots are not quite in the same position. Attention is called to other details in the description of the slide. (Slide No. 119, M. C. Z.)

19. (× 4.) Transverse thoracic section showing supposed position of dorsal flexor muscles, section of coxopodites of ventral limbs, and points of fold of articular projection of a mesotergite. (Slide No. 114, M. C. Z.)

The slides represented by figures 1-19 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The sections illustrated are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

Triarthrus becki Green..413-415

Fig. 20. (× 15.) Exopodite with the joints of the supporting arm, flattened and appearing in a slightly oblique position instead of vertical as in figs. 22 and 23, also diagonally arranged branchial tube bases and slender flattened tubes. This specimen was illustrated by Walcott, 1918, Smithsonian Miscellaneous Collections, Vol. 67, pl. 29, fig. 11.

21. (× 12.) Long slender branchial tubes matted together so as to give the appearance of fine flat filaments of which there are about 40 attached to the bases attached to the arm of the exopodite. U. S. National Museum, Catalogue No. 68387.

22. (× 10.) Specimen illustrated by fig. 23 lighted from right side so as to show the joints of the supporting arm of the exopodite, also the bases of the branchial tubes, more in detail. This specimen was illustrated by Walcott, 1918, Smithsonian Miscellaneous Collections, Vol. 67, pl. 29, fig. 3. U. S. National Museum, Catalogue No. 65523.

23. (× 8.) This specimen reveals the ventral side of the jointed supporting arm of two of the exopodites and the dorsal layer of bases of the branchial tubes or filaments which have been displaced and pushed forward from the supporting arm; a portion of two of the endopodites projects from beneath the exopodites.

The specimens illustrated by figs. 20-23 are from locality 373, Ordovician: Utica shale; 3 miles (4.8 km.) north of Rome, Oneida County, New York.

DESCRIPTION OF PLATE 96

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Calymene senaria Conrad....................................394-412

FIG. 1. (× 15.) Photograph of a translucent longitudinal section of a partially enrolled trilobite in which the exopodites have been displaced and nine of them cut across so as to illustrate the spiral structure of the supporting arm. Exopodite number 5 has a number of the branchial tubes or filaments attached to the arm, and number 6 apparently cuts across the plane of the insertion of three of the branchial tubes into the supporting base. A few fragments of endopodites are cut across in the upper right corner of the photograph. More of the latter occur further forward in the slide as shown in fig. 2. The dorsal test of this specimen was exfoliated except a little of it on the pygidium as shown in fig. 2. (Slide No. 68379 U. S. N. M.) This slide was made March 8, 1921.

2. (× 4.) This is the same section as that illustrated by fig. 1. It illustrates how difficult it is to obtain a good photograph of the ventral limbs in a small enlargement of the section of the trilobite in the slide.

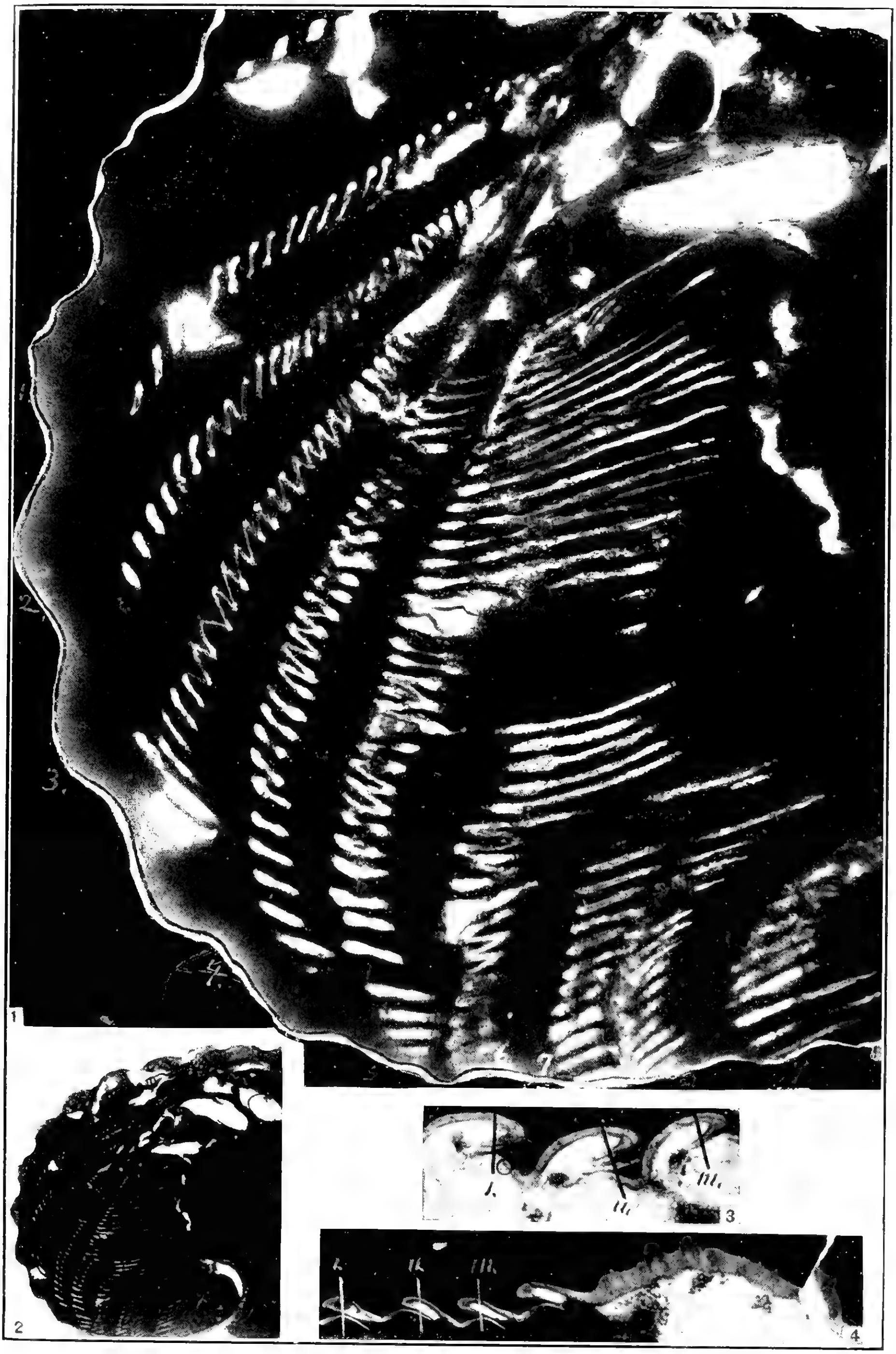
3. (× 10.) Enlargement of a longitudinal section of three segments of the axial lobe to illustrate the posterior under fold of the dorsal test and how transverse sections cut at I, II, and III would give two sections of the dorsal test, the lower one or the articular projection of the mesotergite apparently misled Dr. Raymond in interpreting it as an abdominal sheath. If the section had been cut nearer the center of the axial lobe it would have shown the articular extension of the axial segments about the same as in fig. 4. (Slide No. 68807, U. S. N. M.)

Ceraurus pleurexanthemus Green....................................394-412

FIG. 4. (× 10.) Longitudinal section of the axial lobe cutting the dorsal test of the cephalon and that of three anterior thoracic segments. The vertical white lines I, II, III, pass through the dorsal test of each segment in the same manner as the black lines of fig. 3. They cut the infolded posterior margin and the arched anterior articular extension of the mesotergite. This explains the section of the dorsal test with the "Abdominal sheath" of Raymond and an occasional second "sheath" as shown in transverse sections of the thorax. (See figs. 1, 3, 4, plate 95, and Raymond's figs. 21, 22, p. 79.)

Two sharply elevated tubercles with their hollow interior and minute canal penetrating the cephalic test are also finely preserved. Slide No. 159, M. C. Z.)

The specimens illustrated on this plate are from the Ordovician; upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES

DESCRIPTION OF PLATE 97

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Ceraurus pleurexanthemus 394-412

FIG. 1. (× 18.) Enlargement of the round, slender jointed epipodites that occur on the right side of section represented by fig. 4, pl. 98. The relative size of the endopodite, spiral arm of exopodite and these slender appendages is shown by fig. 4, pl. 98. Fig. 2 of pl. 97 shows the jointed character of the epipodites much more definitely. (Slide No. 120, M. C. Z.)

2. (× 16.) Enlargement of the round, slender jointed epipodites that occur on the right side of section represented by fig. 1, pl. 98. The three appendages in this section prove their jointed character and that they are hollow and either round or oval in cross section. (Slide No. 109, M. C. Z.)

3. (× 16.) Enlargement of two sections of round, slender undulating epipodites and a portion of one above that has been sectioned more on the line of its median axis. The position of these epipodites in the trilobite is shown by fig. 7, plate 98. (Slide No. 204, M. C. Z.)

4. (× 18.) Section somewhat similar to that represented by fig. 3, except that it has a section of a distorted spiral arm of an exopodite. The position of these parts of the ventral limb is shown by fig. 3, pl. 98. The difference in direction is owing to the photographs having been made with the light passing through from opposite sides of the slide. (Slide No. 208, M. C. Z.)

5. (× 18.) A round, jointed appendage that occurs near the hypostoma. Walcott suggested in 1918, p. 195, fig. 15, that it might have been an antennule. Raymond suggests, 1920, p. 52, that it is an endopodite. (Slide No. 78, M. C. Z.)

6. (× 18.) Another example of the slender epipodites in which the jointed structure is not preserved; the relations of these to the axial lobe of the trilobite is shown by fig. 8, pl. 98. (Slide No. 135, M. C. Z.)

11. (× 18.) Portions of three spiral arms of the exopodite, the upper one of which shows traces of spiral structure. The slide, including the spiral arms, was illustrated by Walcott in 1881, pl. 3, fig. 5. (Slide No. 25, M. C. Z.)

Calymene senaria Conrad....................................394-412

FIG. 7. (× 18.) Portions of the arms of two spiral exopodites showing the manner of attachment of the spiral arm to the shaft joining the arm to the coxopodite. These were illustrated by Walcott in 1881, pl. 4, fig. 4; 1918, pl. 27, fig. 5*a*. (Slide No. 32, M. C. Z.)

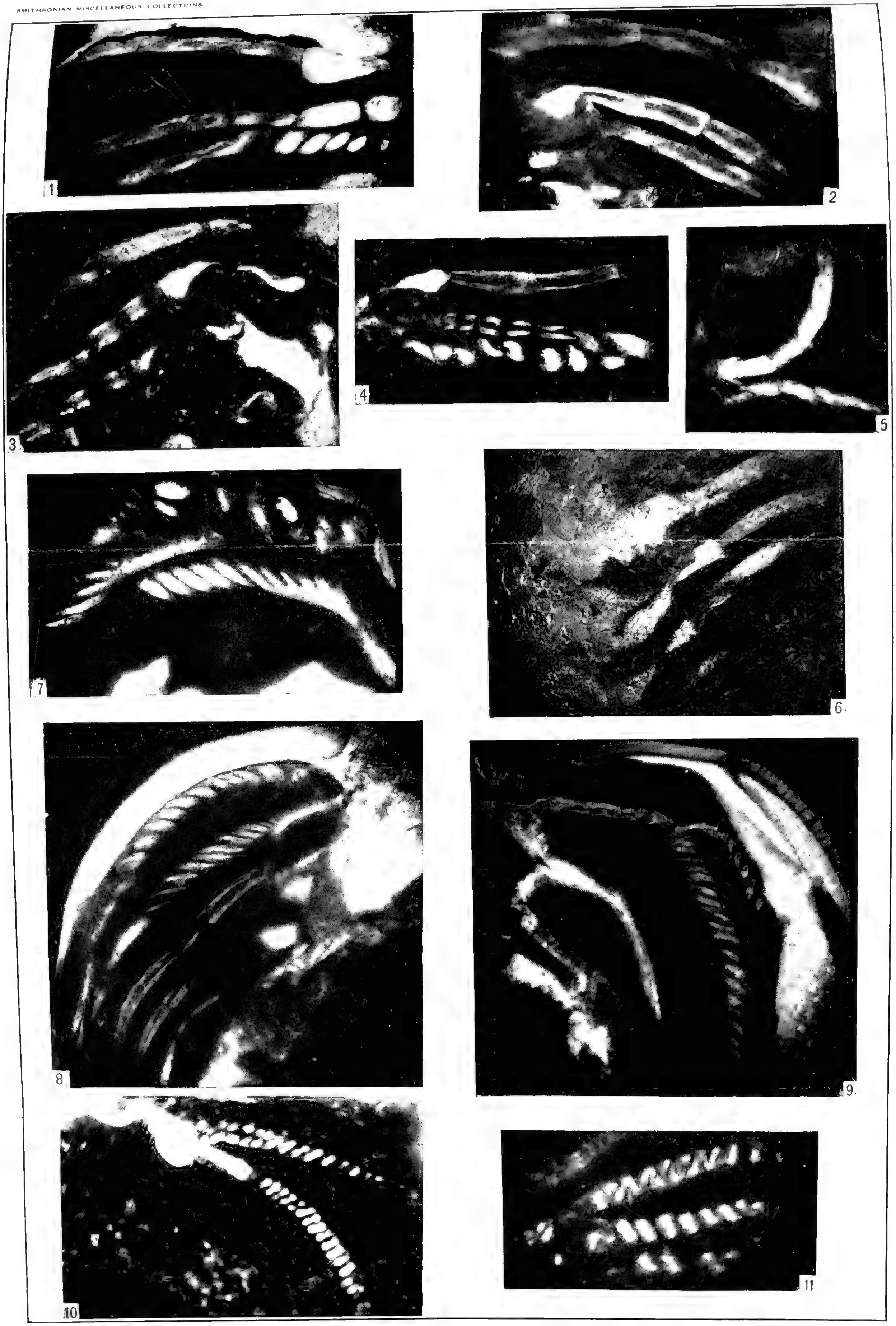
8. (× 18) Section cutting spiral arms of exopodites and slender elongate epipodites; the section containing these parts has been imperfectly illustrated by Walcott, 1881, pl. 3, fig. 9; 1918, pl. 27, fig. 4. (Slide No. 29, M. C. Z.)

9. (× 18.) Opposite side of the section of fig. 8; this shows the spiral arms of exopodites and what may be a section of the narrow side of the joints of an endopodite. (Slide No. 29, M. C. Z.)

10. (× 16.) Two spiral arms of exopodites. The upper spiral probably belongs to a different exopodite from the lower one as the latter has its shaft in position. This slide was illustrated by Walcott in 1881, pl. 4, fig. 3, and in 1918, pl. 27, fig. 5. (Slide No. 31, M. C. Z.)

The slides represented by figures 1-11 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The sections illustrated are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES (Exopodites)

DESCRIPTION OF PLATE 98

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Ceraurus pleurexanthemus Green....................................394-412

FIG. 1. (× 6.) Transverse thoracic section cutting obliquely across several endopodites and on the right side fragments of exopodites. On the left side there are two slender, short, jointed appendages that show the outlines of the longitudinal section of the joints; the lower one has three clearly defined joints and the longer upper one four joints. (See fig. 2, pl. 97.) In addition there is an oblique section of a coxopodite on the left side that has fine short spines on the proximal end and adjoining ventral margin. (Slide No. 109, M. C. Z.)

2. (× 6.) Slender short jointed appendage similar in form to those on the left side of fig. 1. It has five joints, and I formerly thought it might possibly indicate an antennule (Walcott, 1918, pl. 27, fig. 15). (Slide No. 78, M. C. Z.) See also fig. 5, pl. 97.

3. (× 6.) Transverse thoracic section of a partially enrolled specimen cutting across the coxopodite and endopodite of a thoracic leg, parts of a spiral-like section of the arm of an exopodite, and the proximal portion of a hollow slender appendage similar to that in figs. 1 and 2. (Slide No. 208, M. C. Z.)

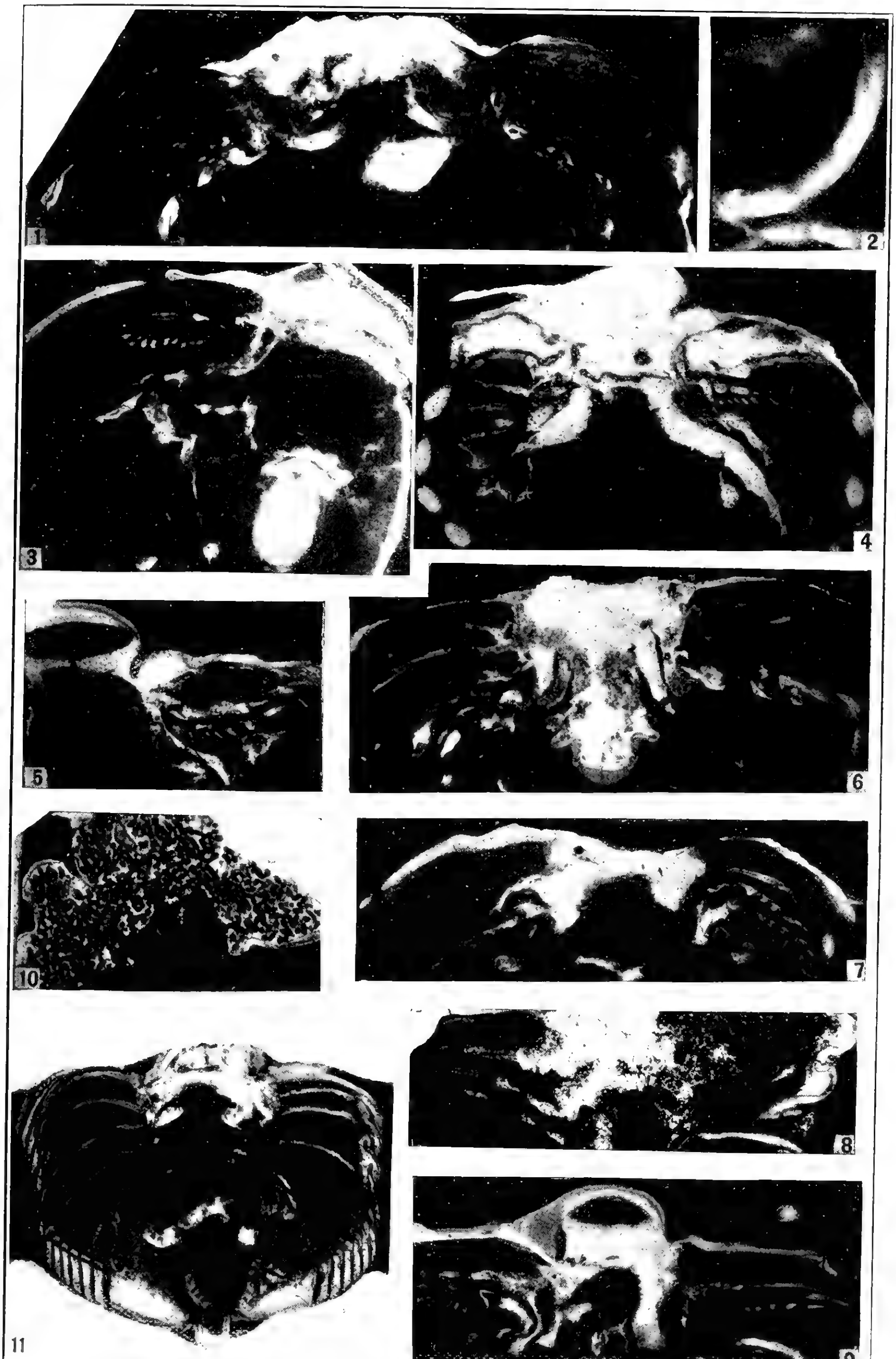
4. (× 6.) Transverse thoracic section of coxopodites and on the right side several spinose joints of an endopodite of a thoracic limb (See fig. 11, pl. 103); on both sides just beneath the ventral pleural lobes there is a slender ribbon-like appendage that is jointed on right side and attached at its proximal end to a strong base which is probably a section of the coxopodite (See fig. 1, pl. 97); a similar appendage occurs below in the section on the right side and below that a section of an elongate spiral-like arm apparently terminating in a drawn out portion of the spiral arm. (Slide No. 120, M. C. Z.) See fig. 1, pl. 97.

5. (× 6.) Transverse thoracic section showing distended alimentary canal, an axial process on the right side, some fragmentary remains of the arm of exopodites, and on the inner side of an endopodite a crescent shaped fimbriated margin. (See fig. 10, pl. 103.) (Slide No. 153, M. C. Z.) This slide was represented by a diagrammatic drawing in the Raymond Memoir, fig. 23, p. 79.

6. (× 4.) Transverse section cutting across the anterior portion of the thorax and some of the cephalic limbs of a partially enrolled specimen. The endopodites of the thoracic limbs are shown in transverse and oblique sections to the right and to the left of the cephalic appendages above the hypostoma; above the latter there are several slender appendages comparable with those of figs. 1, 3 and 4. (Slide No. 5, M. C. Z.) This slide was illustrated by Walcott, 1881, pl. 1, fig. 5.

7. (× 4.) Transverse oblique thoracic section of coxopodites with undulating slender appendages beneath the pleural lobes. (Slide No. 204, M. C. Z.) See fig. 3, pl. 97.

8. (× 8.) Transverse section cutting slantingly across the thorax so as to show on the left side a distorted coxopodite with slender appendages projecting into the area beneath the pleural lobes. (Slides No. 135, M. C. Z.) See fig. 6, pl. 97.



SECTIONS OF TRILOBITES

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FIG. 9. (× 6.) Transverse thoracic section showing section of distorted alimentary canal; section of a coxopodite on left side; distorted coxopodite on right side, and several slender appendages on each side apparently belonging with the coxopodites; also below sections of the arm of the exopodite. (Slide No. 13, M. C. Z.) This slide was illustrated by Walcott, 1881, pl. 1, fig. 3, and 1918, pl. 26, fig. 14.

10. (× 10.) Ova-like bodies imbedded in the calcite filling the anterior end of a partially enrolled specimen. (Slide No. 33, M. C. Z.)

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FIG. 11. (× 6.) Transverse section of an enrolled specimen cutting across the thorax and pygidium. The oblique sections of the ends of the six posterior thoracic pleuræ are interesting. This section shows faint outlines of four or five slender elongate appendages on each side beneath the pleural lobes and in the pygidium on the right side sections of four limbs, and on the left side what may be the supporting arm of an exopodite with five spiral-like segments attached to it. See fig. 7, pl. 100. (Slide No. 56 M. C. Z.)

All of the sections illustrated on this plate are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The specimens illustrated are from the Ordovician; upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

DESCRIPTION OF PLATE 99

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Ceraurus pleurexanthemus Green 394-412

FIG. 1. (× 4.) Transverse section of a partially enrolled specimen crossing the cephalon on the line of the eye and the thorax at about the first segment. The detailed description of this section is given in the text. (Slide No. 22, M. C. Z.) A drawing of this slide was published by Walcott in 1881, pl. 3, fig. 2, and again in 1918, pl. 27, fig. 12. (See figs. 1 and 2, pl. 100.)

3. (× 6.) Transverse section of the thorax of an enrolled specimen showing section of alimentary canal, with section of the articular extension of the stergite of the axial lobe, also on right side a triangular section of the arm of an epipodite with numerous filaments. (Slide No. 27, M. C. Z.) A drawing of this slide was published by Walcott in 1881, pl. 3, fig. 7. (See fig. 5, pl. 100.)

6. (× 4.) Transverse section of the thorax of specimen preserving the blade of an epipodite attached to the side of a distorted coxopodite; the outer crenulated margin and a number of the long filaments are shown. (Slide No. 80, M. C. Z.) See fig. 6, pl. 100.

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FIG. 2. (× 6.) Transverse section cutting across the upper posterior margin of the cephalon and the anterior upper side of the thorax in such a manner as to show the filled-in visceral cavity and the basal portion of several filamentous, presumably thoracic appendages, which are interpreted as epipodites. (Slide No. 45, M. C. Z.) See fig. 3, pl. 100.

A drawing based on this section was published by me in 1881 in which the right side was restored (fig. 1, pl. 3, Bull. Museum Comp. Zool., Harvard Coll., Vol. 8); also by a photograph in 1918, pl. 27, fig. 11.

4. (× 8.) (See pl. 91, fig. 3.) Transverse thoracic section cutting across coxopodites; six slender jointed appendages on the left side and four on the right side. Midway of the large coxopodite on the left side there is a rounded depression with a downward extension of the contents of the axial lobe extending into it. This slide is the one from which Raymond drew his diagrammatic outline (p. 53, fig. 15) illustrating the "ball-and-socket" joint. (Slide No. 63, M. C. Z.)

5. (× 10.) Obliquely transverse section of an enrolled specimen passing through the posterior portion of the pleural lobe of the cephalon and pleural lobes of four thoracic segments, and cutting obliquely across the filaments of several exopodites. (Slide No. 28, M. C. Z.)

A drawing from a photograph of this slide was published by Walcott in 1881, pl. 3, fig. 8, and a photograph of it in 1918, pl. 27, fig. 13. The exopodites were referred to as epipodites in the description of the figure.

7. (× 6.) Transverse thoracic section cutting lengthwise across two spiral arms of the exopodites. See fig. 10, pl. 97. Text description. (Slide No. 31, M. C. Z.)

A drawing from a photograph of this slide was published by Walcott in 1881, pl. 4, fig. 3, and a photograph of it in 1918, pl. 27, fig. 5.

8. (× 6.) Transversely oblique section of an enrolled specimen cutting across the filling of the thoracic visceral axial cavity and the bases of two irregular appendages with long, slender filaments attached to their outer edges. (Slide No. 112, M. C. Z.) See fig. 4, pl. 100.

SECTIONS OF TRILOBITES

9. (× 6.) Transverse thoracic section showing ridges on ventral integument, sections of coxopodites, and exopodites. See detailed description in text. (Slide No. 29, M. C. Z.) A drawing from a photograph of this slide was published by Walcott in 1881, pl. 3, fig. 9, and a photograph in 1918, pl. 27, fig. 4. (See figs. 8 and 9, pl. 97.)

All of the sections illustrated on this plate are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The specimens illustrated are from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

DESCRIPTION OF PLATE 100

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Ceraurus pleurexanthemus 394-412

FIG. 1. (× 20.) Section of a fimbriated epipodite in which the attachment of the fimbriæ to the blade is not well shown. Sections of somewhat similar specimens are shown by figs, 2-6, 8. The position of the section in this slide is shown by fig. 1, pl. 99, lower left side. (Slide No. 22, M. C. Z.)

2. (× 20.) Section of a fimbriated epipodite in which the fimbriæ are in contact with the blade, situated on the opposite side of the axial lobe in the same slide as fig. 1 (see pl. 99, fig. 1.)

6. (× 16.) A blade or arm of the epipodite cut across so as to show the fluted outer margin and a series of seven fimbriæ that appear to have been cut across close to their base, and a second series further out that were attached to a base either in advance of or behind the one preserved in the section. (Slide No. 80, M. C. Z.)

9. (× 30.) A section of the calcite replacing the contents of the body of the trilobite. The crystallization of the calcite has usually destroyed all traces of the ventral integument, the test of the limbs, and the membrane of the alimentary canal, etc. (Slide No. 120, M. C. Z.)

Calymene senaria Conrad....................................394-412

FIG. 3. (× 20.) Sections of two fimbriated epipodites. Their position in relation to the axial lobe of the trilobite is shown by fig. 11, pl. 27, Smithsonian Miscellaneous Collections, Vol. 67, 1918. This slide was the basis of the drawing of Walcott, 1881, pl. 3, fig. 1, in which the right side was restored from the data furnished by the left side of the slide. (Slide No. 45, M. C. Z.)

4. (× 20.) Sections of two fimbriated epipodites. Their position in relation to the axial lobe of the trilobite is shown by fig. 8, pl. 99. (Slide No. 112, M. C. Z.)

5. (× 18.) Sections of two fimbriated epipodites showing the fluted margin of the upper one and the strong fimbriæ. The position of the triangular shaped outline of the base or blade and its position in the slide is shown by fig. 3, pl. 99. A drawing of this section was published by Walcott in 1881, pl. 3, fig. 7. (Slide No. 27, M. C. Z.)

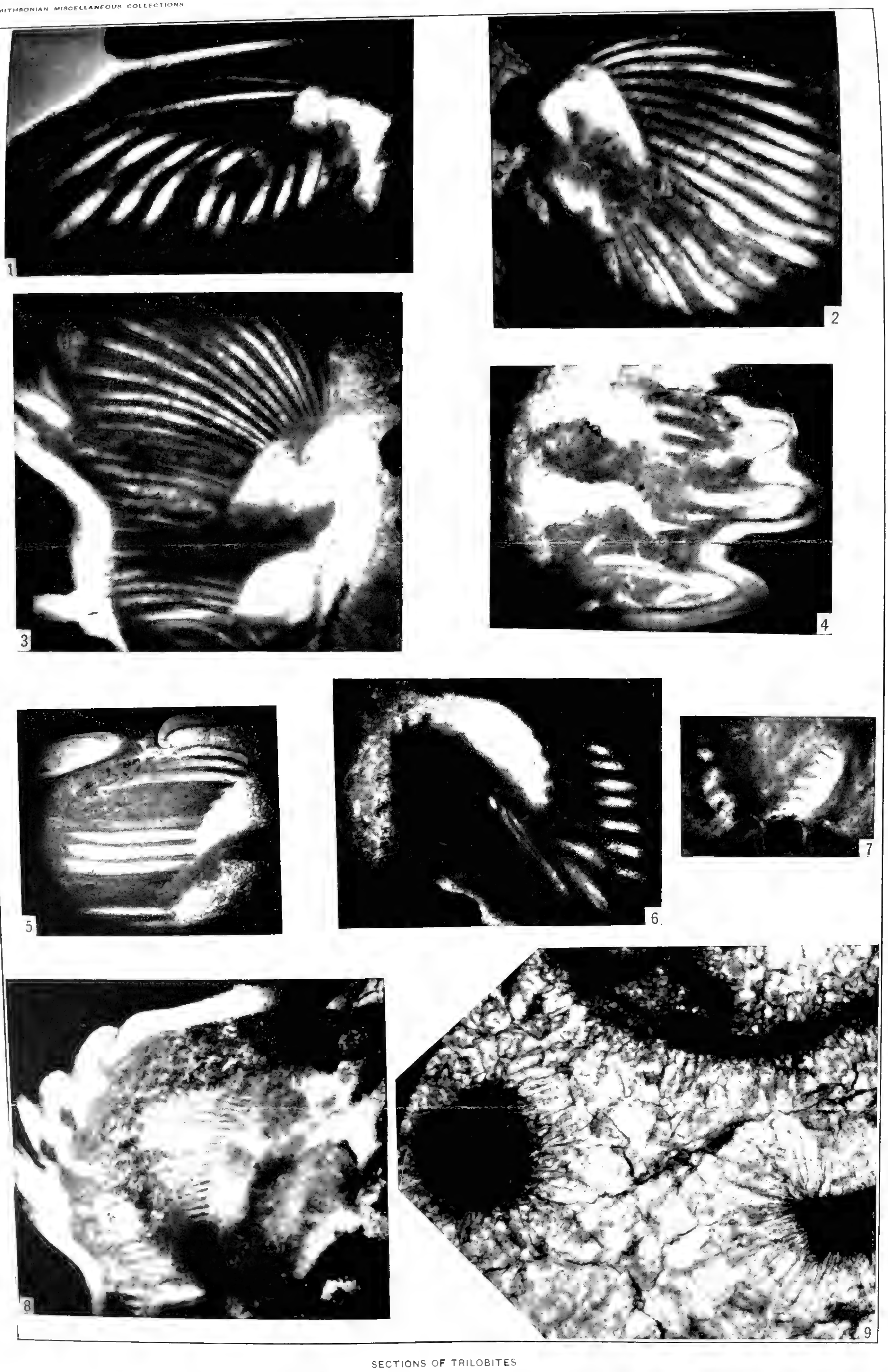
7. (× 18.) Section of a fimbriated arm that occurs beneath the posterior portion of the pygidium. See fig. 11, pl. 98. This may be the arm of an exopodite with the spiral attached to it as in fig. 7, pl. 97. (Slide No. 56, M. C. Z.)

8. (× 15.) Section of a fimbriated epipodite the position of which in relation to the coxopodite of the ventral limb is shown by fig. 3, pl. 3, Walcott 1881, also same figure on pl. 26, fig. 2, 1918.

This section of this slide also cuts across the filaments and spiral arm of two or three exopodites that have been displaced and pushed out against the pleural lobe of several thoracic segments. (Slide No. 23, M. C. Z.)

The slides represented by figures 1-9 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The sections illustrated are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES

DESCRIPTION OF PLATE 101

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Calymene senaria Conrad 394-412

Fig. 1. (× 6.) Longitudinal section of a partially enrolled specimen, a detailed description of which is given in the text, ante p. 397. Two other sections cut from this trilobite are illustrated by figs. 1 and 2, pl. 105. (Slide No. 35, M. C. Z.) A drawing from a photograph of this slide was published by Walcott in 1881, pl. 5, fig. 3.

Figs. 2 and 3. (× 3.) Longitudinal sections of the side of the axial lobe cutting through the cephalon, hypostoma, several thoracic segments, and the basal portions of the ventral limbs. (Slides No. 15 and 17, M. C. Z.) Drawings from photographs of these slides were published by Walcott in 1881, pl. 2, figs, 5 and 7.

4. (× 6.) Section crossing the axial lobe obliquely so as to cut the anterior coxopodites, then the thickened sternites of the thoracic segments, and back of these the coxopodites. (Slide No. 36, M. C. Z.) A drawing of this slide was published by Walcott in 1881, pl. 5, fig. 4.

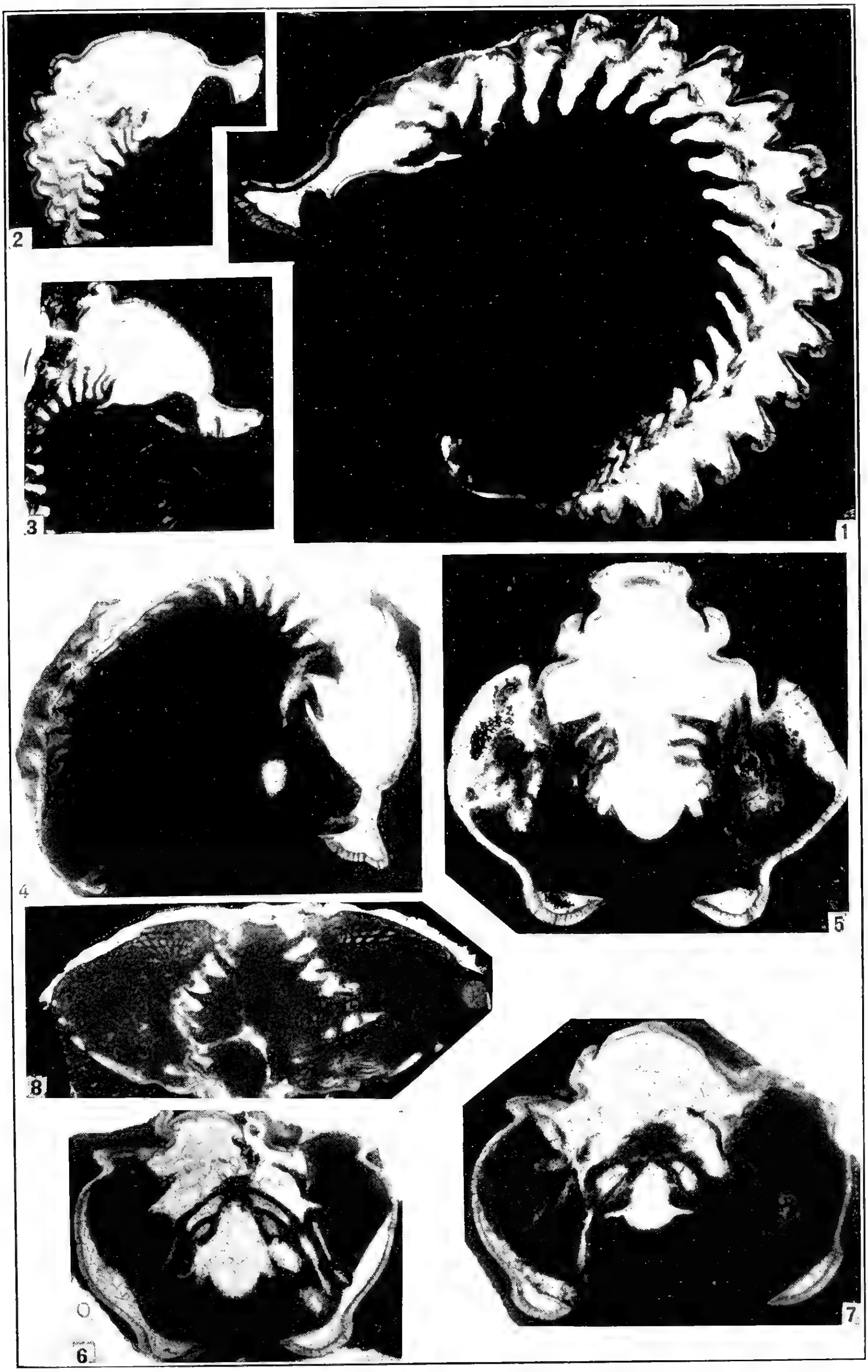
5. (× 6.) Transverse section cutting obliquely from the first thoracic segment down through the cephalon, hypostoma and cephalic limbs. For detailed description see text. (Slide No. 9, M. C. Z.) A drawing from a photograph of this slide was published by Walcott in 1881, pl. 1, fig. 9.

6. (× 6.) Transverse section cutting obliquely down across the cephalon, hypostoma and cephalic limbs. For detailed description see text. (Slide No. 6, M. C. Z.) A drawing from a photograph of this slide was published by Walcott in 1881, pl. 1, fig. 6, and a photograph in 1918, pl. 26, fig. 11.

7. (× 6.) Transverse section cutting obliquely down through from the first thoracic segment across the cephalon, hypostoma and cephalic limbs. For detailed description see text. (Slide No. 38, M. C. Z.) A drawing from a photograph of this slide was published by Walcott in 1881, pl. 1, fig. 8, and a photograph in 1918, pl. 26, fig. 9.

Ceraurus pleurexanthemus Green..

Fig. 8. (× 4.) Transverse section of an enrolled specimen cutting across the thoracic coxopodites and the spiral arms of several exopodites. (Slide No. 147, M. C. Z.)



SECTIONS OF TRILOBITES

SECTIONS OF TRILOBITES

DESCRIPTION OF PLATE 102

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Ceraurus pleurexanthemus Green 394-412

FIG. 1. (× 4.) Transverse section cutting four thoracic segments nearly on the plane of the dorsal surface of the pleural lobes and below one axial segment almost vertically so as to cross the alimentary canal. See pl. 95, fig. 4. The details of structure shown are described in the text. (Slide No. 244, M. C. Z.)

2. (× 6.5) Transverse section of an enrolled specimen cutting one thoracic segment almost vertically, and the remainder of the specimen obliquely so as to bisect several articular processes. (Slide 39, M. C. Z.)

3. (× 4.) Transverse thoracic section to illustrate a section of the ridge formed by the folding of the test of the axial lobe of a thoracic segment where the articular extension of the segment unites with the anterior ventral margin of the tergite. (Slide No. 205, M. C. Z.)

4. (× 4.) Ventral surface of four thoracic segments to illustrate the anterior articular extension of the mesotergite beneath the next anterior mesotergite, also where the fold is worn through the inward extension of an axial process as in fig. 1. (U. S. National Museum, Catalogue No. 68388.)

5. (× 6.) Transverse thoracic section showing below the inward extension of the fold of the articular extension of the mesotergite, and laterally a slight downward extension of the test at the dorsal furrows. (Slide No. 123, M. C. Z.)

6. (× 6.) Longitudinal thoracic section cutting across coxopodites of two endopodites and four infoldings of the articular process of the mesotergite. See fig. 8. (Slide No. 169, M. C. Z.)

7. (× 9.) Transverse thoracic section of the axial lobe cutting the ventral extension of the dorsal test at the dorsal furrow, also the anterior articular extension of the mesotergite and below the processes of the fold of the articular extension of the mesotergite. (Slide No. 68380, U. S. N. M.)

8. (× 4.) Oblique longitudinal thoracic section of several mesotergites of the dorsal test illustrating the folding of the articular extension of the mesotergite and the outline of the "processes" formed by them. (Slide No. 231, M. C. Z.)

9. (× 4.) An example somewhat similar to that represented by fig. 10. This section also shows traces of the cephalic appendages and an axial process beneath the cephalon. (Slide No. 193, M. C. Z.)

10. (× 3.) Another example of the cutting across the fold of the articular process as described in the text. This slide also has an interesting section of a coxopodite. (Slide No. 16, M. C. Z.) Illustrated by Walcott 1881, pl. 2, fig. 16.

The sections represented by figures 1-3, 5, 6, 8-10 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts. The specimens represented by figs. 4 and 7 are in the United States National Museum.

The sections are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.

DESCRIPTION OF PLATE 103

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Isotelus gigas DeKay.. 452

FIG. 1. (× 4.5) Transverse thoracic section cutting across the coxopodite of a ventral limb. (Slide No. 19, M. C. Z.)

2. (× 4.5) Section cutting across the coxopodites and the anterior limbs beneath the pygidium. (Slide No. 226, M. C. Z.)

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FIG. 3. (× 4.2.) Transverse section of the cephalon on the line of the eyes. (Slide No. 94, M. C. Z.)

4. (× 12.) Transverse section cutting across the articular extension of the mesotergite of a thoracic segment. See fig. 1, pl. 95. (Slide No. 27, M. C. Z.)

5. (× 6.2) Median longitudinal section of cephalon and hypostoma. (Slide No. 102, M. C. Z.)

6. (× 5.) Longitudinal section cutting a little obliquely through the cephalon and hypostoma. (Slide No. 174, M. C. Z.)

7. (× 4.2) Four ventral thoracic limbs cut across so as to show the attachment of the shaft of the exopodite to the coxopodites. There is also a suggestion that the parts about the mouth have been pushed forward above the hypostoma. (Slide No. 168, M. C. Z.)

8. (× 3.5) Longitudinal section through the limbs beneath the cephalon and anterior portion of the thorax. (Slide No. 198, M. C. Z.)

9. (× 3.5) Longitudinal section cutting the outer part of the axial lobe of the pygidium and posterior portion of the thorax so as to show a section of the proximal joints of the limbs beneath the pygidium. This section was figured by Walcott in 1881, pl. 2, fig. 8. (Slide No. 18, M. C. Z.)

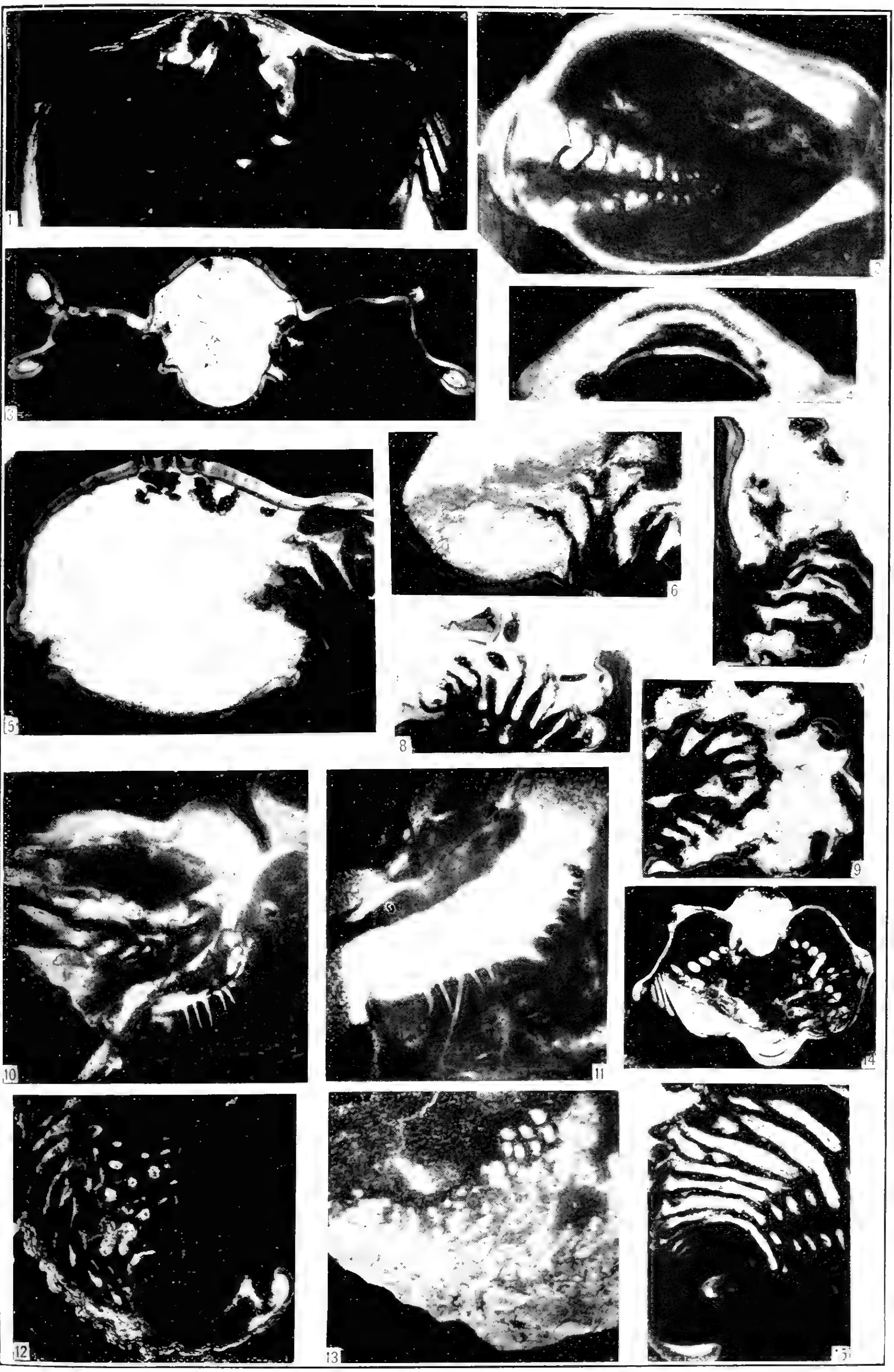
11. (× 16.) Longitudinal section of the proximal portion of the endopodite shown in fig. 4, pl. 98, which cuts across the fine spines along the ventral margin. Compare these with spines of the endopodites of *Neolenus*, pl. 93, fig. 2. (Slide No. 120, M. C. Z.)

Calymene senaria Conrad...394-412

FIG. 10. (× 16.) Longitudinal section of a thoracic limb with endopodite and fragments of exopodites. The spines on the ventral margin of the proximal joint are of interest for comparing with those of *Ceraurus*, fig. 11. A diagrammatic drawing of this section is given by Raymond, p. 79, to illustrate the alimentary canal and the infolding of the dorsal test at the dorsal furrow which he identifies as an appendifer. (Slide No. 153, M. C. Z.) See fig. 5, pl. 98.

12. (× 5.) Longitudinal section of an enrolled trilobite in which the exopodites have been displaced and cut across at varying angles so as to show the almost round transverse section with a dark spot indicating that the muddy matrix had been forced into some of the joints of the endopodite. (Slide No. 200, M. C. Z.)

14. (× 4.2) Transverse section of an enrolled specimen cutting obliquely through the head, hypostoma and almost vertically through a thoracic segment and the articular extension of a mesotergite of another segment which forms a narrow dark crescent in the axial lobe. The important feature of the section is the series of round and broadly oval sections of the thoracic endopodites. Faint traces of exopodites occur in the lower portion of the figure. (Slide No. 20, M. C. Z.) Illustrated by Walcott 1881, pl. 2, fig. 10.



SECTIONS OF TRILOBITES

The sections represented by figures 1-15 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts, with the exception of fig. 13.

The sections are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York, with the exception of fig. 13 which is from the Cincinnatian rocks, Marysville formation, Cincinnati, Ohio.

DESCRIPTION OF PLATE 104

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Ceraurus pleurexanthemus Green 394-412

FIG. 1. (× 6.) Transverse section of the thorax. See figs. 2 and 3. (Slide No. 211, M. C. Z.)

2. (× 18.) Left side of fig. 1 enlarged to show elongate epipodite, fragment of coxopodite, and spines on a joint of the endopodite. (Slide No. 211, M. C. Z.)

3. (× 18.) Right side of fig. 1 enlarged to show proximal joints of an epipodite and its position in relation to the coxopodite. See fig. 2, also pl. 97, figs. 1, 3, 6. (Slide No. 211, M. C. Z.)

4. (× 16.) Enlargement of five joints of an endopodite, a fragment of a spiral arm of an exopodite and two elongate epipodites. (Slide No. 111, M. C. Z.)

This slide was figured by Walcott 1881, pl. 11, fig. 2, and in 1918, pl. 27, fig. 1. Two more joints are shown in the endopodite of the latter figure but they are too faint to photograph clearly, and as there is a slight gap betwen the fifth joint of fig. 4 and these faint joints, no attempt is made to show them in fig. 4.

5. (× 6.) Transverse section cutting down through the cephalon and hypostoma. The interesting feature is the two round dark spots just beneath the dorsal test with a projection on the outer upper side that curves inward almost around a dot of white calcite; all around the edges of the dark spots minute short spines appear to project into the calcite; there is a confused cellular structure between the two spots that may represent hepatic cæca, and a small circular ring above may indicate the heart; the dark spots evidently represent a bilateral structure within the head. (Slide No. 68386, U. S. N. M.)

Trinucleus concentricus Eaton 451

FIG. 6. (× 10.) Transverse section of an enrolled specimen cutting the cephalon, hypostoma and some of the ventral appendages. (Slide No. 230, M. C. Z.)

7. (× 25.) Enlargement of right side of fig. 6 to show the outline of endopodites, faint traces of exopodites one of which suggests a spiral structure, and transverse section of several endopodites in the lower right side of the slide. The exopodites are too faint to photograph clearly. (Slide No. 230, M. C. Z.)

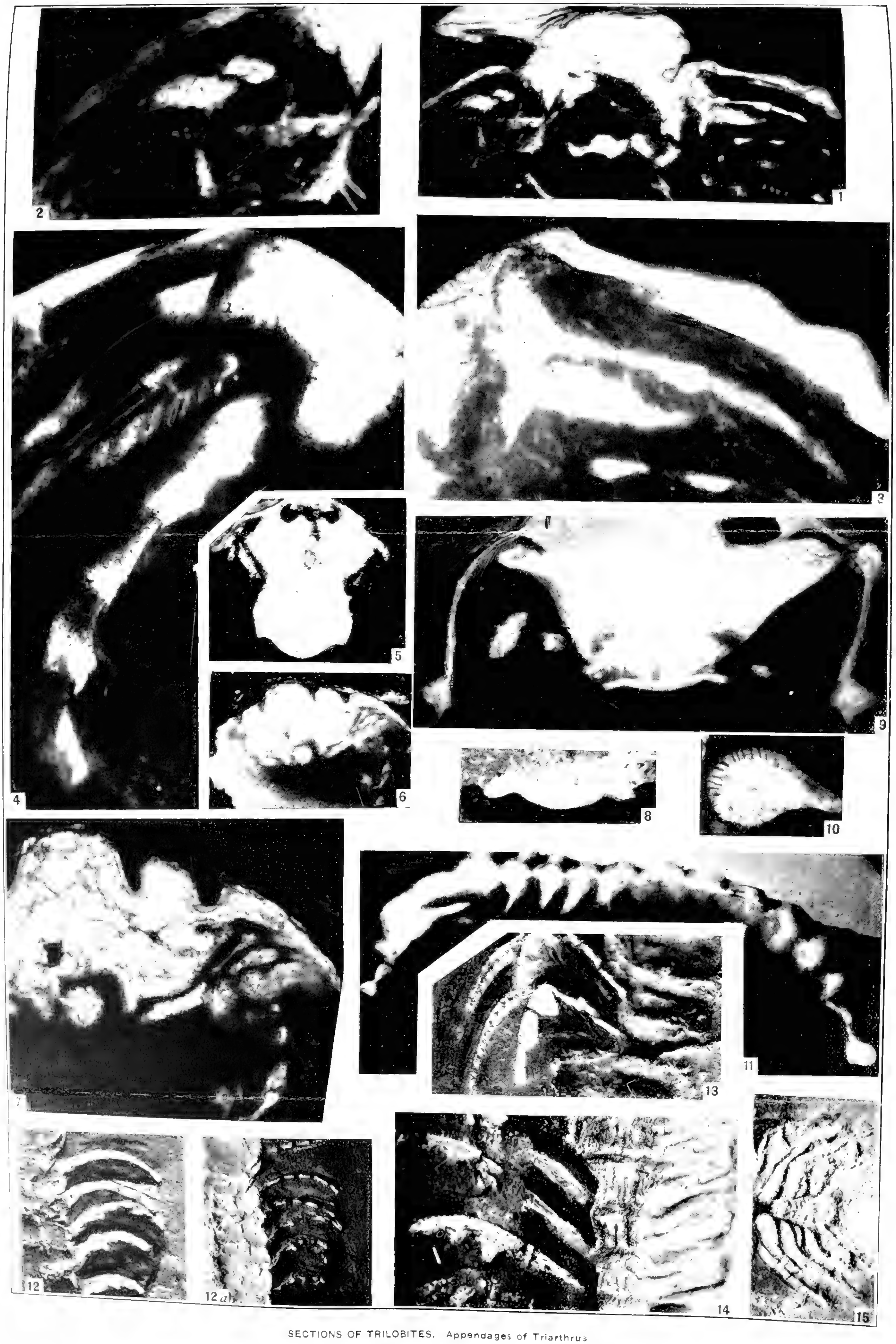
8. (× 15.) Transverse section cutting an hypostoma about midway of its length. (Slide No. 68383, U. S. N. M.)

9. (× 18.) Transverse section cutting the cephalon on the line of the eyes and the hypostoma nearer its posterior end than in fig. 8. There are traces of two cephalic limbs on each side and above the hypostoma. (Slide No. 68384, U. S. N. M.)

10. (× 40.) Enlargement of the section of the eye on the right side of fig. 9. The corneal lenses are finely shown but the outer cornea has been destroyed.

11. (× 18.) Longitudinal section of the axial lobe cutting the cephalon, thorax and pygidium. The traces of the bases of the thoracic limbs are similar to those of *Calymene*. See pl. 101. (Slide No. 68385, U. S. N. M.)

The specimens illustrated by figs. 1-11 are from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES. Appendages of Triarthrus

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Triarthrus becki Green......................................413-415

Fig. 12. (× 12), 12*a* (× 7). Two photographs of one of the Beecher specimens showing the side view of the broad joints of five thoracic endopodites and a view of the narrow ventral margin of the same. This specimen gives a very clear idea of the form of the joints of some of the thoracic endopodites. (Specimen No. 222, Peabody Museum.) This specimen is illustrated by Raymond, pl. 4, fig. 5.

13. (× 10.) Photograph of ventral view of two endopodites with accompanying exopodites coming from beneath them. The four distal joints of the endopodites are lying with flat side up while the ischiopodite and basipodite and the coxopodite show their narrow ventral edges. (See description of specimen No. 218, Peabody Museum, in the text.)

This specimen is reproduced by Raymond, pl. 6, fig. 3, and a diagrammatic figure p. 157, fig. 43.

14. (× 7.) A photograph of Beecher type specimen showing the "apodemes" of the ventral integument. (Specimen No. 219, Peabody Museum.)

This specimen is reproduced by Raymond, pl. 2, fig. 6.

15. (× 10.) A photograph of Beecher type specimen of cephalic limbs; this is one of the finest illustration of the gnathites worked out by Beecher. (Specimen No. 211, Peabody Museum.)

A photograph of this specimen is reproduced by Raymond, pl. 2, fig. 5.

The specimens illustrated by figs. 12-15 are from locality 373, Ordovician: Utica shale; 3 miles (4.8 km.) north of Rome, Oneida County, New York.

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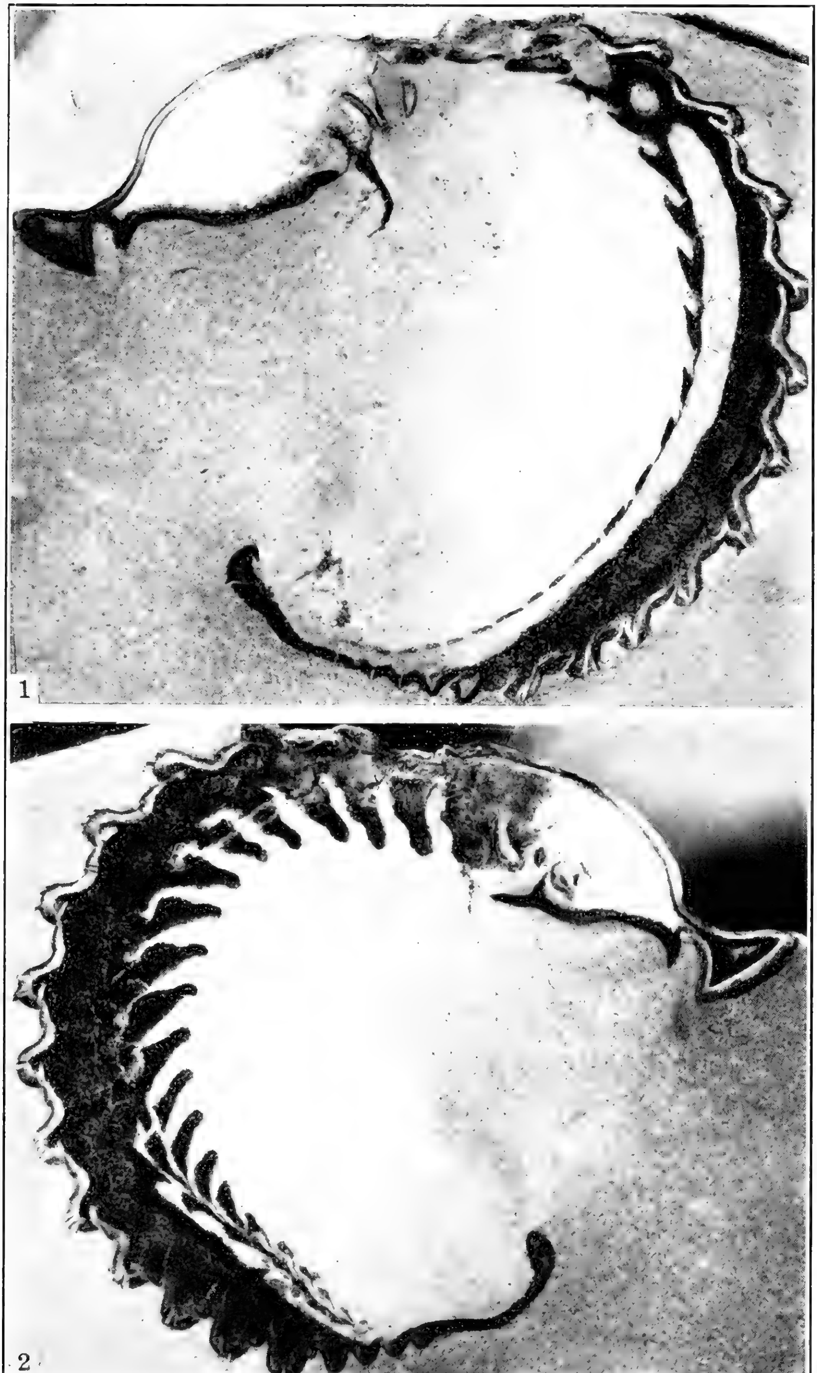
Calymene senaria Green.. 396

FIG. 1. (× 8.) Longitudinal section of the axial lobe that is slightly oblique to the median line; it cuts across the base of some of the coxopodites of the anterior thoracic limbs, and posteriorly the thickened sternites of the ventral integument. The section is described in detail in the text. (Slide No. 34, M. C. Z. Illustrated by Walcott 1881, pl. 5, fig. 2, and again in 1918, pl. 28, fig. 8.) On fig. 6 of pl. 5, 1881, the line c-c represents the location of this section across the trilobite.

2. (× 8.) Opposite side of the opaque slide of fig. 1. This cuts the axial lobe a short distance from the dorsal furrow of the test and like fig. 1 is slightly oblique to the median line of the lobe, with the result that the proximal joints of the posterior thoracic limbs are difficult to interpret. (Slide No. 34, M. C. Z. Illustrated by Walcott 1881, pl. 5, fig. 1.) On this the line a-a′ of fig. 6 represents the location of this section across the trilobite.

The sections represented by figures 1 and 2 were made by me and are now in the Museum of Comparative Zoology at Harvard College, Cambridge, Massachusetts.

The sections are of trilobites from the Ordovician: upper portion of the Trenton limestone; 1 mile (1.6 km.) east of the middle fall of Trenton Falls, on the West Canada Creek, in the town of Russia, Herkimer County, New York.



SECTIONS OF TRILOBITES

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 67, NUMBER 8

CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 8.—NOMENCLATURE OF SOME POST CAMBRIAN AND CAMBRIAN CORDILLERAN FORMATIONS (2)

BY
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CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

NO. 8.—NOMENCLATURE OF SOME POST CAMBRIAN AND CAMBRIAN CORDILLERAN FORMATIONS (2)

By CHARLES D. WALCOTT

CONTENTS

NOMENCLATURE

A number of new names have been given to sedimentary formations in connection with the study of sections of pre-Devonian formations in the Canadian Cordilleran trough of Alberta and British Columbia. One of these occurs in the Robson Peak district and others in the area about the headwaters of the Saskatchewan River, Alberta and elsewhere in the Cordillera of western America.

ROBSON PEAK DISTRICT

In my brief paper on the Cambrian formations of the Robson Peak District [1] the upper 3000 feet (914.4 m.) of the section in the Robson Peak massif was included under the Ordovician system in the Robson formation. There was not much opportunity to get at this portion of this section on Robson Peak and no detailed section of the formation was made or fossils systematically collected from it except near its base at Billings Butte.[2] During the field work of the past four years a formation has been delimited between the Upper Cambrian Lyell formation and the Ordovician Sarbach formation that was found to be characterized by a fauna, one zone of which could be compared with the fauna of the lower portion of the Robson formation. This led to a review that resulted in the decision to arbitrarily delimit the lower porton of the Robson formation as a distinct formation and name it the Chushina formation.

Chushina Formation

(ozarkian, lower)

Locality.—North slopes of Phillips and Lynx mountains [3] and Billings Butte, Robson Park, British Columbia, Canada.

Derivation.—From Chushina glacier.[4]

Character.—Bluish gray, thin-bedded limestones.

Thickness.—The base of the formation is placed at the lowest layer of rock containing the Hungia [5] fauna (locality 61q), although it is highly probable that the upper portion of the Lynx [6] limestones may contain a fauna that will include it in the Chushina formation. The upper limit is arbitrarily placed 1500 feet (457.2 m.) above where the shale and thin-bedded limestones give way to massive beds of limestone forming the main mass of the upper portion of Robson Peak.

Organic remains.—The fauna at Billings Butte includes several genera that may be referred to as typically Lower Ozarkian and post-Cambrian, *i. e.,* Orthoceras, Apatocephalus, Hungia, Symphysurina.

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[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pp. 336-337.

[2] Loc. cit., p. 336.

[3] Loc. cit., pl. 58, fig. 2; pl. 59, fig. 2.

[4] Loc. cit., pl. 57, fig. 2.

[5] Loc. cit., p. 336.

[6] Loc. cit., p. 337.

GLACIER LAKE DISTRICT

In a preliminary outline of the Glacier Lake section,[1] which is about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada, names are proposed for the following pre-Devonian formations:

SARBACH FORMATION

(ORDOVICIAN)

Type locality.—Upper gray limestones and shales forming cliffs beneath the dark Devonian limestone on Mount Sarbach and the eastern and northern ridges of Mounts Outram and Forbes above Glacier Lake, which is about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Mount Sarbach (10,700 feet, 3261.3 m.) which is directly east of the Glacier Lake section.

Character.—Thick-bedded 6 inches (15.2 cm.) to 16 inches (40.6 cm.), gray limestones, 700 feet (213.3 m.), and argillaceous shales with thin, irregular layers of limestone, 420 feet (128 m.).

Thickness.—Above Mons Glacier at head of Glacier Lake canyon valley 1120 feet (341.3 m.), of which the upper 700 feet (213.3 m.) is estimated.

Organic remains.—Lower Ordovician (Canadian).

Observation.—The Sarbach formation was recognized in the Clearwater section 33 miles (53.1 km.) southeast of Glacier Lake, where it has a thickness of 1172 feet (357.2 m.) and a well marked fauna at several horizons.

At Fossil Mountain, 18 miles (28.9 km.) southeast of the Clearwater section, the Sarbach has a thickness of 1090 feet (332.2 m.), and at Ranger Canyon in the Sawback Range 21 miles (33.8 km.) southwest of Fossil Mountain there is no trace of the Sarbach, the Devonian being separated from the subjacent Mons formation by a few feet of dark shale of undetermined age.

MONS FORMATION

(OZARKIAN, LOWER)

Type locality.—Alternations of calcareous shale forming steep and ragged slopes near the lower and southeast side of Mons glacier near the base of a northwest ridge extending down from Mount

[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.

Forbes. About 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Mons Peak, 10,114 feet (3082.7 m.), and Mons Glacier.

Character.—Massive beds of calcareous shale with intercalated layers of gray limestone above with a massive-bedded dull gray limestone and calcareous shale below.

Thickness.—In the Glacier Lake section 1480 feet (451.1 m.), made up of calcareous shale 235 feet (71.6 m.), massive gray limestone 740 feet (225.5 m.), and calcareous shale below 505 feet (153.9 m.) thick. Thirty-three miles (53.1 km.) to the southeast, at the head of the Clearwater River, the Mons has a thickness of 1414 feet (430.9 m.), and at Ranger Canyon, 72 miles (115.8 km.) southeast from Glacier Lake, it is 1390 feet (423.6 m.) thick. It is absent in the section of the Rocky Mountains front at Ghost River 24 miles (38.6 km.) east of Ranger Canyon.

Organic remains.—A post-Cambrian pre-Ordovician fauna of Lower Ozarkian age.

Observations.—The Mons formation in all known localities is directly and, as far as known, conformable superjacent to a series of massive layers, 10 inches to 60 inches (25.4 cm. to 152.4 cm.), of magnesian limestone averaging over 1000 feet (304.8 m.) in thickness of the Upper Cambrian Lyell formation.

Lyell Formation

(CAMBRIAN, UPPER)

Type locality.—Massive-bedded gray and oolitic limestone at head of Glacier Lake canyon valley about 2 miles (3.2 km.) above head of lake and about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Mount Lyell, 11495 feet (3505.6 m.), on the Continental Divide northwest of Glacier Lake. The Southeast Lyell glacier terminates at the head of Glacier Lake canyon valley.

Character.—Massive-bedded cliff forming rough weathering magnesian limestone forms the upper portion of the formation, with thinner-bedded gray and oolitic limestones beneath.

Thickness.—At the type locality in Glacier Lake canyon valley the upper magnesian beds have a thickness of 1270 feet (387.1 m.) subjacent to which the thick- and thin-bedded gray limestones extend down 430 feet (131 m.) a total of 1700 feet (518.1 m.) for the formation. Thirty-three miles (53.1 km.) to the southeast at the head of the Clearwater River it has a thickness of over 1700 feet (518.1 m.), and at Ranger Canyon in the Sawback range 72 miles (115.8 km.) southeast from Glacier Lake, the great upper limestone is 1325 feet (403.8 m.) thick and the lower beds 335 feet (102.1 m.).

Organic remains.—An Upper Cambrian fauna is fairly well developed in the lower oolitic limestones.

Observations.—The Lyell formation corresponds in stratigraphic position to the Ottertail formation of the Kicking Horse River section southwest of Field, British Columbia.

Sullivan Formation

(CAMBRIAN, UPPER)

Type locality.—Gray limestone above with arenaceous shale and interbedded limestone on the north side of Glacier Lake canyon valley and the south cliffs and slopes of Sullivan Peak about a mile east of the foot of Southeast Lyell glacier. Glacier Lake is about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Sullivan Peak, 7858 feet (2395 m.).

Character.—Hard, gray, rather thin-bedded semicrystalline limestone above, with arenaceous shales predominating below. The dominant feature is the development of arenaceous shales.

Thickness.—At the type locality in Glacier Lake canyon the upper limestone has a thickness of 325 feet (99 m.). The arenaceous shales and interbedded limestones continue down for 1115 feet (339.8 m.), making a total thickness of 1440 feet (438.9 m.).

Organic remains.—Upper Cambrian fauna of about the horizon of the Eau Claire formation of the northern Mississippi valley section.

Observations.—The Sullivan formation is strongly developed in the vicinity of Thompson Pass, 33 miles (53.1 km.) northwest of Glacier Lake, and it is present in part in the Ranger canyon section of the Sawback range.

Arctomys Formation

(CAMBRIAN, UPPER)

Type locality.—A bluish-gray laminated limestone superjacent to a series of siliceous shales on the lower, southern slope of Sullivan Peak above Glacier Lake about a mile east of the foot of Southeast Lyell glacier. Glacier Lake is about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Arctomys Peak (9162′ (2792.5 m.)) which is 8 miles (12.8 km.) east-southeast of Mount Lyell, and above the head of Southeast Lyell glacier.

Character.—Bluish-gray irregularly laminated cliff-forming limestones which are more or less magnesian in some layers. This limestone is underlain by a series of arenaceous and silicious shales with bands of hard, finely laminated, dove colored limestone.

Thickness.—Upper cliff-forming limestone 520 feet (158.5 m.). The siliceous shales and limestone below have a thickness of 866 feet (263.9 m.) which gives 1386 feet (422.4 m.) for the formation.

Organic remains.—The character of the sedimentation appears to have been unfavorable for the presence and preservation of vegetable and animal life. The few fossils found indicate the Upper Cambrian fauna.

Observations.—The Arctomys formation in the Siffleur River section 25 miles (40.2 km.) east of Glacier Lake has a thickness of 725 feet (221 m.) and appears to have been a shallow water and probably a brackish water deposit. It is separated from the subjacent Murchison formation by a great disconformity resulting from the non-deposition of the Eldon formation, which has a thickness of 2728 feet (831.5 m.) on Mount Bosworth, 37 miles (59.5 km.) to the south.

Murchison Formation

(cambrian, middle)

Type locality.—Thin-bedded bluish-black limestones in cliffs on southwest side of Siffleur River, 3.5 miles (5.6 km.) from Saskatchewan River and 40 miles (64.3 km.) north, 12° west, of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Mount Murchison, which is about 8 miles (12.9 km.) west of the Siffleur section.

Character.—Thin-bedded, hard bluish-black and gray limestones.

Thickness.—On the Siffleur the Murchison has a thickness of 497 feet (151.5 m.). At Glacier Lake 220 feet (67.1 m.) of the upper portion of the formation is exposed.

Organic remains.—A few Middle Cambrian species of the Stephen fauna.

Observations.—The Murchison occupies the stratigraphic position of the Stephen formation of the Kicking Horse Pass section, but it is not given that name as the contained fauna is not sufficient to closely identify it, and in an area where non-deposition of formations occurs on such a great scale, strata separated by an interval of 38 miles (61.1 km.) may be a portion of some unknown formation or a portion only of the formation it most nearly resembles in that province.

KICKING HORSE CANYON

Glenogle Formation

(ORDOVICIAN)

Type locality.—Glenogle Creek, Lower Kicking Horse Canyon, a little east of Glenogle station on the Canadian Pacific Railway, British Columbia, Canada. The section of the formation was studied by Dr. R. G. McConnell and Dr. John A. Allan[1] on Glenogle Creek and the next small creek to the west, both of which flow into the Kicking Horse River.

Derivation.—From Glenogle station and creek.

Character.—Argillaceous and with finely arenaceous shales, black, brown and gray in color and more or less fissile in thick bands.

Thickness.—About 1,700 feet (518 m.).

Organic remains.—Lower Ordovician graptolites.

Beaverfoot Formation

(SILURIAN ?)

Type locality.—Crests of Beaverfoot Range east of Columbia River valley and south of Canadian Pacific Railway, British Columbia, Canada.

Derivation.—From Beaverfoot Range.

Character.—Thick-bedded gray dolomites and quartzites, with a few bands of interbedded arenaceous shale.

Thickness.—On the northern end of the Beaverfoot Range, 800 feet (243.8 m.). To the south it thickens up to 1,850 feet (563.9 m.).

Organic remains.—Silurian ? corals.

FRONT RANGE

Ghost River Formation

The type locality is about 51 miles (82.1 km.) west 20° north of Calgary, Alberta, Canada, in the first small canyon south of Ghost River canyon and opening on Ghost River as the river bends to the

[1] Ann. Rept. Geol. Sur. Canada (for 1886) 1887, Pt. D, pp. 22-24 D. Geol. Sur. Can. Memoire No. 55, Geol. Ser. No. 46, 1914, p. 100.

south. At the Devil's Gap, about 2 miles (3.2 km.) further south, the formation dips westward and disappears 1.75 miles (2.8 km.) east-northeast of the eastern end of Lake Minnewanka.

The formation includes 285 feet (86.8 m.) of thin-bedded and shaly, buff colored magnesian limestones lying conformably between the Middle Cambrian limestones beneath (Cathedral formation) and the superjacent Devonian beds (Intermediate limestone of McConnell). They are a very conspicuous formation on the summit of the outer cliffs for many miles along the Rocky Mountains front from the South Fork of Ghost River north to the Red Deer River, and the only representative of 23,960 feet (7,303.0 m.) of strata that occurs in the Kicking Horse Pass section, 50 to 60 miles (80.5 to 96.6 km.) to the westward between the Cathedral limestones and the Devonian.

The lower layers of the formation rest conformably on the Cathedral limestone of the Middle Cambrian, and in fact there is almost a gradation between the two except that the gray thin-bedded limestones of the Cambrian are not repeated above in the shaly magnesian limestones. The transition to the dark gray Devonian limestones above is abrupt and suggests a somewhat sudden and deep depression of the sea bed.

The interval between the Cambrian and Devonian along the line of the present Rocky Mountains front was largely one of non-deposition, as the evidence of erosion along the several miles of exposure of the contact between the magnesian limestones of the Ghost River formation and the Cambrian beneath and the Devonian above on Ghost River is almost negligible.

Fauna.—No fossils or traces of life were seen in or on the rocks of this formation.

Mount Wilson Quartzite

Clearwater River.—At the head of the Clearwater River canyon 54 miles (86.9 km.) northwest of the Ghost River section, there are a few layers of quartzite in the interval between the Devonian and the subjacent Ordovician Sarbach formation. They have a maximum thickness of 24 feet (7.3 m.) and were evidently a thin deposit of washed sand spread unevenly over the upper surface of the Sarbach formation.

Mount Wilson.—At Mount Wilson on the north side of the Saskatchewan River and 84 miles (135.2 km.) northwest of the Ghost River section, a quartzite similar to that at the head of the Clearwater River forms a massive cliff beneath the Devonian and above the Sarbach formation. It is not the same lithologic formation as Ghost River magnesian limestones, but it occupies a similar stratigraphic position beneath the Devonian, and is a deposit in the Ghost River interval. It is an important stratum at Mount Wilson, where it has an estimated thickness of over 250 feet (76.2 m.) and it is prominent in the cliffs of Mount Murchison. It is named the Mount Wilson formation and correlated in stratigraphic position with Ghost River formation. No fossils were found in the great piles of quartzite blocks that had fallen from the precipitous cliffs high up on the mountain.

This quartzite thins gradually northward on the North Fork of the Saskatchewan River until opposite the mouth of Alexandra River it is not over 100 feet (30.4 m.) thick, and two miles further north it can only be distinguished by a few thick layers beneath the dark Devonian limestone.

On the south side of Mount Wilson facing the Saskatchewan River the quartzite caps the eastern half of the high cliffs, but it has been removed by erosion from the western half. It occurs on the north and west side of Mount Murchison, but it is not as thick as on Mount Wilson, and it becomes thinner on the northeast side of Mount Murchison.

As far as known, the Mount Wilson quartzite originally covered an area with a major axis of about 95 miles (152 km.) in a north-northwest by south-southeast direction, and a minor axis of 6 to 8 miles (9.6 to 12.8 km.), as indicated by known outcrops. It was a deposit of fine white sand in the shallow sea that preceded the Devonian coral reefs and black calcareous silt in which they were embedded.

OCCURRENCE IN SAWBACK RANGE

On Ranger Brook in the heart of the Sawback Range, 24 miles (38.6 km.) west of the Ghost River section, the dark fossiliferous[1] Devonian limestones rest with apparent conformity on light gray limestones of the Mons[2] formation of the Lower Ozarkian, and beneath the latter the Upper Cambrian Lyell[3] and upper portion of the Sullivan[4] formations, the section of which is broken by a fault that brings the limestones beneath the Sullivan formation against the

[1] Noted Stromatopora, Atrypa reticularis (Linn.), and numerous poorly preserved corals.

[2] Ante, p. 459.

[3] Ante, p. 460.

[4] Ante, p. 461.

Devonian. The Mons, Lyell, and Sullivan formations have a combined thickness of over 3,000 feet (914.4 m.) and do not occur beneath the Devonian in the Ghost River section, and the Ordovician Sarbach formation of the Clearwater Canyon section is not present between the Devonian and the Mons formation.

Another section on the east slope of Fossil Mountain near Baker Lake, 20 miles (32.1 km.) north-northeast of Ranger Canyon section and 38 miles (61.1 km.) west-northwest of Ghost River section, has on the east and south slopes of the mountain a fine outcrop of the lower strata of the Devonian carrying numerous fragments of Stromatopora and corals. Beneath the Devonian there is a series of thin layers of magnesian limestone with layers of chert one to two inches (2.5 to 5.0 cm.) thick which may be between the layers or form part of a layer. They are 35 feet (10.7 m.) in thickness and strongly delimited from the dark coarse Devonian limestones above and the light gray relatively soft Ordovician (Sarbach) limestones below by their lithological characters, but there is no evidence of a physical unconformity between them. They correspond in position and partly in character to the strata of the Ghost River formation and are without traces of fossils.

EUREKA MINING DISTRICT, NEVADA

Goodwin Formation

(OZARKIAN, LOWER)

Type locality.—Goodwin Canyon is northeast of the town of Eureka, and heads in the arenaceous and calcareous shales of the Dunderberg formation;[1] it descends over the limestones of the Pogonip Formation to where Shadow Canyon unites with it.[2]

Derivation.—From Goodwin Canyon in the Eureka Mining District.

Character.—The argillaceous and fine grained arenaceous shale of the Dunderberg shale formation with some interbedded calcareous shale pass gradually upward into purer bluish-gray limestones distinctly bedded, which were formerly included in the lower Pogonip formation.

Thickness.—In the Eureka District section both Goodwin and Shadow canyons cut across the Pogonip limestone which Hague esti-

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 184.

[2] See Atlas accompanying Geol. Eureka District, Nevada, Monogr. U. S. Geol. Surv., Vol. XX, 1883, Map No. 8.

mated to be 2,700 feet (822.9 m.) thick east of the Jackson mine. In the White Pine District the Pogonip was estimated to have a thickness of over 5,000 feet (1,524 m.). The portion of the Pogonip now referred to the Goodwin formation is 1,500 feet (457.2 m.) thick.

Fauna.—At an horizon about 200 feet (60.9 m.) above the base (locality 201a):

Obolus (Westonia) iphis Walcott
Lingulella pogonipensis (Walcott)
Acrothele sp.
Acrotreta idahoensis Meek
Schizambon typicalis Walcott
Eoorthis hamburgensis Walcott
Syntrophia nundina Walcott
Tellinomya ? hamburgensis Walcott
Agnostus sp. ?
Apatokephalus finalis (Walcott)
Hungia eurekensis Walcott
Hungia flagricauda White
Hungia hamburgensis Walcott
Hungia inexpectans Walcott
Elrathia (?) annectans (Walcott)
Calvinella tenuisculptas Walcott
Ptychostegium cf. hecuba Walcott
Ptychostegium mccoyi Walcott
Symphysurina eurekensis Walcott
Symphysurina major Ulrich (Mss.)
Symphysurina mesleri Ulrich (Mss.)
Symphysurina spicata Ulrich (Mss.)
Eurekia sp. undt.

The next highest well marked fauna is about 800 feet (243.8 m.) above and contains (locality 203):

Syntrophia nundina Walcott
Ptychostegium congeneris (Walcott)
Hystricurus tuberculatus (Walcott)

OZARKIAN

This is not the place for a discussion of the Ozarkian system of Ulrich,[1] but I wish to briefly outline it in order that the position of the Sarceen series (p. 471) within it may be clear. As proposed, Ozarkian included a group of formations occurring in the Ozark

[1] Dr. Ulrich is now making a thorough study of the stratigraphy and faunas of the formations included by him in the system, and it is anticipated that all available data will soon be in the process of publication.

Mountains of Missouri and elsewhere, above the Upper Cambrian and below the Canadian. Some of the sections are as follows:[1]

EASTERN MISSOURI

CANADIAN

Disconformity.

OZARKIAN

	Feet	Meters
Gasconade.		
Cherty dolomite	265	80.8
Fauna.—Large number of gasteropods, etc.		
Proctor.		
Massive bedded dolomite	60	18.3
Eminence.		
Light colored cherty dolomite	200	61.0
Fauna.—Gasteropods, cephalopods, trilobites.		
Disconformity.		
Potosi.		
Light gray to dark bluish gray massive dolomite	300	91.4
Fauna.—Unknown.		
Of the above, the Potosi dolomite is referred to the Lower Ozarkian.		
	825	251.5

Disconformity.

In the southern Appalachians of Central Alabama, Ulrich distinguishes five formations which he includes in the Ozarkian as follows:

CANADIAN

Disconformity.

OZARKIAN

	Feet	Meters
Chepultepec.		
Cherty magnesium limestone	1200	365.7
Fauna.—Many species of gasteropods and cephalopods. Ulrich states that at least ten of the species occur in the Gasconade formation in Missouri and a number in the Oneonta of Wisconsin, Minnesota and Iowa.		
Copper Ridge.		
Cherty dolomite	2000	609.6
Fauna.—Fossils rare, mainly Cryptozoans.		

[1] Data taken from Ulrich, Bull. Geol. Soc. Amer., Vol. 22, 1911, pp. 630-632, and Vol. 24, 1913, p. 51.

Dr. Ulrich included the Roubidoux and Jefferson City formations in the Ozarkian as published in 1911. In 1912 he referred the Jefferson City to the Middle Canadian and the Roubidoux to the Lower Canadian in a paper not yet published (Bull. Geol. Soc. Amer., Vol. 24, p. 51), but from which Dr. R. S. Bassler took the data for the Ozarkian-Ordovician correlation published in 1915, Bull 92, U. S. National Museum, Vol. 2, 1915, plate 2.

	Feet	Meters
Bibb dolomite.		
Fine grained dolomite	500	152.4
Fauna.—Unknown.		
Ketono dolomite.		
Gray fine dolomite	600	182.9
Fauna.—Unknown.		
Briarfield dolomite.		
Silicious blue and gray dolomite	1250	381.0
Fauna.—Unknown.		
Maximum thickness	5550	1691.6
Disconformity.		

The Chepultepec and Copper Ridge formations are referred to the Upper, and the Bibb, Ketono, and Briarfield to the Lower Ozarkian.

In the Northern Appalachians the central Pennsylvania section includes:

OZARKIAN

	Feet	Meters
Larke dolomite	250	76.2
Fauna.—Unknown.		
Mines cherty dolomite	250	76.2
Gatesburg dolomite	1750	533.4
A band of bluish black limestone named Ore Hill contains a large Lower Ozarkian fauna that may be compared with the lower Mons fauna of the Cordilleran area.		
Total Ozarkian	2250	685.8

The New York section of the Ozarkian is composed of the following formations:

Little Falls dolomite (Little Falls)	350	106.7
Hoyt limestone with a well-marked fauna (Saratoga)	120	36.6
Theresa dolomite	50	15.2
Potsdam sandstone	110	33.5
	630	192.0

The fauna of the Hoyt limestone and upper portion of the Potsdam sandstone is comparable with that of the lower Mons of Alberta and the Madison sandstone of Wisconsin.

In the upper Mississippi valley area the Ozarkian is not strongly developed:

Disconformity
Oneota dolomite
Great disconformity
Madison sandstone
Mendota dolomite
Disconformity

Ulrich correlates the Oneota dolomite with the Gasconade of Missouri and the Madison sandstone with the Hoyt limestone of New York.[1]

Using the correlation table of Ulrich in part as modified by Bassler, and inserting two columns to represent the sections of Alberta and British Columbia, the table (fig. 24) presents a broad correlation of the Ozarkian system in North America.

LOWER OZARKIAN IN ALBERTA

As my field studies progressed in western Alberta, Canada, it became more and more evident that there was a well-defined formation between the Upper Cambrian and the pre-Devonian Ghost River interval that was characterized by a fauna easily distinguished in its central and upper portions from the Upper Cambrian fauna by the presence of cephalopods, gasteropods and types of trilobites represented in the succeeding Canadian faunas of the Ordovician. In the lower part of the formation the fauna is predominantly Upper Cambrian, but trilobites of the genera Megalaspis, Niobe ?, Asaphellus, Hungia, Symphysurina, midway of the Mons Formation strongly foreshadow the change to the Ordovician fauna, and the change in sedimentation also aids in drawing a line of demarcation between the massive Lyell limestones of the Upper Cambrian, and the shales and thin-bedded limestones of the Mons formation of the Lower Ozarkian.

In the Glacier Lake section the Mons formation has a thickness of 1480 feet (451.1 m.) of which the lower 505 feet (153.9 m.) is composed of shales and thin-bedded limestones. Below the shales the thick-bedded limestones of the Lyell formation extend down for 1,270 feet (387 m.) forming a bold ridge terminating in high cliffs. Thirty-eight miles (61.1 km.) to the southeast of Glacier Lake at the head of the Clearwater River canyon the Mons formation has a thickness of 1,414 feet (430.9 m.) with shales and thin-bedded limestones in the lower portion. Below there is a series of massive-bedded magnesian limestones 910 feet (277.3 m.) in thickness of the Lyell formation. Forty miles (64.3 km.) southeast of the Clearwater section in the Ranger canyon section of the Sawback range, the Mons formation is directly beneath the Devonian limestones and has a thickness of 1,390 feet (423.6 m.) and a bed of thin layers of shaly limestone and shale form the lower portion of the formation. This is underlain by a series of thick-bedded arenaceous and magnesian limestones of the Lyell formation with a thickness of 1,325 feet

[1] See Ulrich, Bull. Geol. Soc. America, Vol. 22, 1911, pp. 627-647.

CAMBRIAN-OZARKIAN-ORDOVICIAN CORRELATION TABLE.

		General Time Scale	Central Pennsylvania	Alabama	East Missouri	Wisconsin	Alberta Saskatchewan	Alberta and B.C.
CANADIAN	UPPER	Bellefonte (Pa.)	Bellefonte dol.		Powell ls.	Shakopee dolomite	Sarbach	
		Axeman (Pa.)	Axeman ls.		Cotter ls.			
	MIDDLE	Nittany (Pa.)	Nittany dol.		Jefferson City ls.			
	LOWER	Stonehenge (Pa.)	Stonehenge ls.	Pelham ls.	Roubidoux ss.			
		Dictyonema bed	Represented ?					
OZARKIAN	UPPER	Gasconade (Mo.)		Chapultepec ls.	Gasconade ls. (Gunter ss. member)	Oneota dolomite		Goodsir ?
		Copper Ridge (Tenn.)		Copper Ridge ch.	Proctor dol.			
		Eminence (Mo.)			Eminence chert			
	LOWER	Sarceen	Larke Mines Gatesburg	Bibb dol.	Potosi ls.		Mons	Goodsir
				Ketona dol.		Madison ss.		
				Briarfield dol.		Mendota ls.		
CAMBRIAN	UPPER	St. Croixan	Warrior ls. Pleasant Hill ls.	Nolichucky sh. Maryville ls. Rogersville sh.	Elvins form. Bonne Terre dol. Lamotte ss.	St. Croixan: Jordan ss. St.Lawrence f. Franconia ss. Dresbach ss. Eau Claire ss. St.Simon ss.	Lyell Sullivan Arotomys	Ottertail, Chancellor Sherbrook Paget Bosworth
	MIDDLE	Acadian	Waynesboro ?				Murchison Cathedral	Eldon Stephen Cathedral Ptarmigan
	LOWER	Waucoban					Mt. Whyte St. Piran	Mt. Whyte St. Piran Lake Louise Fort Mt.

FIG. 24.

(403.8 m.). About 132 miles (212.4 km.) north of the Glacier Lake section at Mount Robson the Chushina formation has an arbitrarily assigned thickness of 1,500 feet (457.2 m.), but neither the upper nor lower limits have been determined.

The fauna of the Billings Butte beds of this formation may be compared to that of the lower portion of the Mons formation, but it will be necessary to make a detailed study of the section before a close comparison can be made between the Mons and the Chushina as my reconnaissance of 1912 did not take in the details of the formations above the Middle Cambrian.[1]

In the Kicking Horse Pass and River section the Mons formation has not been recognized, but its stratigraphic equivalent is indicated by the fauna in the lower portion of the Goodsir formation, which includes:

Obolus mollisonensis Walcott
Lingulella moosensis Walcott
Lingulella sp. undt.
Agnostus sp.
Agnostus sp.
Moosia degener Walcott
Moosia grandis Walcott
Sodalitia canadensis Walcott
Sodalitia allani Walcott

In the absence of fossils from other horizons in the Goodsir, and as the formation is practically a lithologic unit, I am placing the entire series in the Ozarkian. See notes under Mons, Chushina, and Goodwin in this paper.

SARCEEN

This term is proposed as a series name to include the various formations referred to the Lower Ozarkian on the North American continent. The type formation is the Mons, which occurs in the Rocky Mountains of western Alberta, Canada (ante, p. 459). The correlated formations in the Cordilleran trough of the Rocky Mountains are Chushina (ante, p. 458) on the north; Goodsir, at least in part, on the south in Canada; in the United States the St. Charles formation of Idaho and Utah; the Red Lion formation of Montana; the Goodwin formation (ante, p. 466) of Nevada, and the Notch Peak formation of Utah.

On the eastern side of the continent the most typical formations are the Potsdam sandstone and Hoyt limestones of New York and western Vermont; the Gatesburg dolomite of central Pennsylvania, and

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pp. 336-337.

the "Potosi," Ketona, Briarfield of Alabama. In the interior region the Wilberns formation of Texas; the Potosi formation of Missouri, and the Mendota, Madison and Devils Lake of Wisconsin.

Derivation.—From the Sarcee Indian tribe, which ranged in western Alberta north of the Blackfeet (Siksika) tribe and hunted up the river valleys to the Continental Divide.

Thickness.—In the Canadian Cordilleran region from 1,480 feet (451.1 m.) Mons to 6,040 feet (1,841.0 m.) Goodsir. In northern Utah, 1,311 feet (399.6 m.) St. Charles. In central Nevada 1,500 feet (451 m.) Goodwin formation.

In the Appalachian trough from 2,500 feet (762.0 m.) in Alabama to 350 feet (106.7 m.) in New York.

The Lower Ozarkian in Missouri is represented in part by the Potosi dolomite which is about 300 feet (91.4 m.) thick.

Organic remains.—The fauna of the Mons formation of Alberta is large and varied. The following genera and species occur in the limestones 18 feet (5.5 m.) below the summit of the formation (locality 64p):

Eoorthis cf. wichitaensis Walcott
Syntrophia isis Walcott
Ophileta leo Walcott
Eccyliomphalus josephus Walcott
Eccyliomphalus labeo Walcott
Bucaniella lelex Walcott
Raphistoma melius Walcott
Lophospira laodice Walcott
Hormotoma lamus Walcott
Straparollina isades Walcott
Orthoceras longus Walcott
Orthoceras robsonensis Walcott
Ptychostegium fulvia Walcott
Ptychostegium victori Walcott

At a lower zone, 60 feet (18.2 m.) below the summit of the formation the collection included (locality 66u):

Lingulella sp. undt.
Syntrophia
Eoorthis
Ctenodonta ? lucan Walcott
Platyceras lais Walcott
Megalaspis ? eucerus Walcott
Megalaspis ? sp. undt.
Maryvillia galeria Walcott

Near the base of the Mons formation in the Glacier Lake section the following species occur (localities 64f, 64n):

Cystid (fragment)
Eoorthis sp. undt.

Huenella sp. undt.
Scenella ?
Ptychaspis eurydice Walcott
Elvinia phyllus Walcott
Saukia ? glaucus Walcott
Obolus cf. leda Walcott 64n
Blountia sp. undt. 64n
Saukia splendens Walcott 64n

In the Clearwater canyon section 33 miles (53.1 km.) east-southeast of the Glacier Lake section, the following genera and species occur 288 feet (87.7 m.) above the base of the Mons (locality 65y):

Obolus sp. undt. (fragments)
Lingulella cf manticula White
Eoorthis iones Walcott
Agnostus sp.
Modocia ibicus Walcott
Hungia flacilla Walcott
Symphysurina eugenius Walcott
Acrocephalites gentius Walcott
Niobe ? nonius Walcott
Niobe ? phormis Walcott

About 100 feet (30.4 m.) from the base (locality 65w):

Cystid (plates)
Eoorthis iones Walcott
Straparollina sp. undt.
Irvingella ? undt.
Niobe ? echides Walcott
Amphion ?? sp. undt.
Symphysurina entellus Walcott
Rogeria ? ephorus Walcott
Asaphellus euclides Walcott

In the Robson Peak section the lower fauna of the Chushina formation corresponds in a general way to the lower fauna of the Mons formation (locality 61q):

Lingulella cf. desiderata Walcott
Lingulella ibicus Walcott
Obolus ino Walcott
Acrotreta cf. idahoensis Walcott
Acrotreta cf. sagittalis Salter
Eoorthis cf. desmopleura (Meek)
Eoorthis cf. wichitaensis Walcott
Straparollus ? lavinia Walcott
Bellerophon ? lavassa Walcott
Cyrtolites meles Walcott
Orthoceras robsonensis Walcott
Agnostus sp. undt.

Menomonia gyges Walcott
Blountia galba Walcott
Cyrtometopus ? sp. undt.
Moxomia hecuba Walcott
Hystricurus gallus Walcott
Hystricurus bituberculatus (Walcott)
Apatocephalus bröggeri Walcott
Apatocephalus fronto Walcott
Hungia articauda Walcott
Hungia billingsi Walcott
Hungia flacilla Walcott
Hungia laxicauda Walcott
Hungia striata Walcott
Hungia flagricauda (White)
Ptychostegium amplum Walcott
Ptychostegium robsonensis Walcott
Ptychostegium robsonensis valaltum Walcott
Ptychostegium canadensis Walcott
Ptychostegium spinosum Walcott
Symphysurina spicata augusta Walcott
Symphysurina canadensis Walcott
Symphysurina lynxensis Walcott
Symphysurina spicata major Walcott
Symphysurina numitor Walcott
Symphysurina perola Walcott
Symphysurina spicata Walcott

The St. Charles formation of northern Utah has a large and varied fauna. The upper zone includes (locality 185z):

Eoorthis cf. desmopleura (Meek)
Syntrophia sp. ?
Ctenodonta cf. lucan Walcott
Bucaniella ? isades Walcott
Bucaniella ? leos Walcott
Eccyliomphalus lacidos Walcott
Straparollina milo Walcott
Ophileta leo Walcott
Raphistoma menos Walcott
Orthoceras utahensis Walcott
Endoceras sp.
Hystricurus sp. undt.
Blountia sp. undt.
Asaphus ? sp. undt.
Ptychostegium idahoensis Walcott

About 75 feet (22.8 m.) below the following species occur (locality 54b):

Lingulella manticula (White)
Billingsella coloradoensis Meek
Syntrophia nundina Walcott
Hungia hera Walcott

Some 1,200 feet (365.8 m.) from the top, near the base of the St. Charles, the fauna has a very strong Upper Cambrian character (locality 4y):

Obolus wortheni Walcott
Lingulella desiderata Walcott
Acrotreta idahoensis Walcott
Acrotreta idahoensis sulcata Walcott
Billingsella coloradoensis Meek
Agnostus *a*
Agnostus *b*
Saukia marica Walcott (54u)
Saukia oneidaensis Walcott
Elrathia lycus Walcott (54u)
Elrathia sp. (54t)
Taenicephalus lycoria Walcott
Taenicephalus mutia Walcott (5a)
Maladia americana Walcott
Idahoia sp. undt. (5a)
Idahoia serapio Walcott
Idahoia licinia Walcott
Anomocare sp. undt. (54u)
Anomocarella lucius Walcott
Anomocarella macar Walcott
Anomocarella sp. undt.
Wilbernia fronto Walcott (5e)
Wilbernia (Ulmia) martha Walcott

In the Eureka District section of central Nevada, the Goodwin formation (=lower 1,500 feet (457.2 m.) of the Pogonip formation of the Fortieth Parallel Survey) carries a fauna which is partially listed under the description of the Goodwin formation (ante, p. 466).

Observations.—The preceding tentative faunal lists are given in order that the student may have some conception of the fauna characteristic of the Sarceen or Lower Ozarkian series in the Cordilleran area. It is now planned to publish illustrations and notes on the fauna in 1923.

The Sarceen series may be compared with the Tremadoc series of Europe; both the Tremadoc and Sarceen series of formations are above the typical Upper Cambrian and beneath the Ordovician; both series are well defined stratigraphically and by their contained faunas.

The term Sarceen if generally accepted will replace the term Saratogan as used by Ulrich,[1] who used it to include the formations of the Lower Ozarkian. Walcott[2] proposed Saratogan as a group term

[1] Bull. Geol. Soc. America, Vol. 22, 1911, pp. 332-3, 338.
[2] Jour. Geol., Vol. 11, 1903, pp. 318-319.

to include the Upper Cambrian formations, as at the time he considered the Potsdam sandstone and Hoyt limestone of the Saratoga New York section to belong to the Upper Cambrian. With the reference of these formations to the Ozarkian and the fact that no Upper Cambrian formation occurs at or near Saratoga, the name is not appropriate for the Upper Cambrian series of formations.

It is not improbable that as the faunas are more thoroughly studied by Dr. E. O. Ulrich, a middle division of the Ozarkian will be established to include the Eminence and related formations.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
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CAMBRIAN GEOLOGY AND PALEONTOLOGY

IV

No. 9.—CAMBRIAN AND OZARKIAN BRACHIOPODA, OZARKIAN CEPHALOPODA AND NOTOSTRACA

(WITH PLATES 106 TO 126)

BY
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IV

No. 9.—CAMBRIAN AND OZARKIAN BRACHIOPODA, OZARKIAN CEPHALOPODA AND NOTOSTRACA

By CHARLES D. WALCOTT

(With Plates 106-126)

CONTENTS

[1] C. and M. = Chushina and Mons formations.

ILLUSTRATIONS

INTRODUCTION

The field reconnaissance of the pre-Devonian formations of Alberta and British Columbia, Canada, that I have been conducting the past six seasons has resulted in the accumulation of collections that have received preliminary study and are now being prepared for illustration and description.

The first paper resulting from this field-work was issued in March, 1923, on the " Nomenclature of Some post-Cambrian and pre-Cambrian Formations."[1] In this, preliminary lists of fossils are given and among them three brachiopods that are described in this paper, *Lingulella ibicus* Walcott, *Eoorthis iones* Walcott, *Syntrophia isis* Walcott. *E. iones* is now referred to *Protorthis.*

In addition to the above there are 50 new species and one variety listed in the table of contents. These include not only those from the Cordilleran area of Canada, but a few from various localities in the United States that have been found in older collections from various sources now in the U. S. National Museum.

[1] Smithsonian Misc. Coll., Vol. 67, No. 8.

The species are distributed as follows:

Ordovician	6
Ozarkian	26
Cambrian	20
	52
Common to Ozarkian and Ordovician	2
Total new species	50
One new variety.	

Brachiopods are relatively rare in genera and species in the formations in which I have been working in Alberta and British Columbia. This in a measure is owing to their destruction by wave and current action, and also to the fact that conditions accompanying the great calcareous deposits do not appear to have afforded them a favorable habitat. An occasional quiet bay or inlet provided food and shelter from the strong tides and currents, and in these, colonies of a few species flourished in great numbers.

The species described by me since the preparation of Monograph 51, published in 1912 are

Obolus mollisonensis Walcott[2]
Lingulella moosensis Walcott[2]
Lingulella ? allani Walcott[2]
Mickwitzia muralensis Walcott[3]
Lingulella chapa Walcott[3]
Lingulella hitka Walcott[3]
Obolella nuda Walcott[3]
Micromitra (Paterina) charon Walcott[4]
Obolus damo Walcott[4]
Acrothele clitus Walcott[4]
Wimanella catulus Walcott[4]

The present paper also includes the only two cephalopods, and one Notostracan thus far discovered in the Mons formation. The study of the gasteropoda of the Sarceen[5] formations is well advanced, also the description and illustration of new genera of trilobites. It is planned to include these papers in Volume 75 of Smithsonian Miscellaneous Collections.

Through the courtesy of Dr. Olaf Holtedahl, I have had the opportunity of studying a small collection of brachiopods from Novaya

[1] Mong. U. S. Geol. Surv., No. 51, 1912.
[2] Smithsonian Misc. Coll., Vol. 57, No. 7, 1912, pp. 231, 232.
[3] Idem, No. 11, 1913, pp. 310-312.
[4] Smithsonian Misc. Coll., Vol. 67, No. 3, pp. 69-70.
[5] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 471.

Zemlya, Russia, which he discovered there.[1] The brachiopods are described and illustrated in this paper and they will also be published later in Norway with the associated trilobites. The fauna is essentially of a lower Ozarkian Mons facies and belongs, as Dr. Holtedahl states, with the Pacific Province and not the Atlantic. The genera and species of brachiopods include *Lingulella cf. desiderata* Walcott, *L. arctica* n. sp., *Acrotreta* sp. undt., *Obolus* (*Westonia*) sp. undt., *Billingsella holtedahli* n. sp., *B. ? oppius* n. sp., *Eoorthis sabus* n. sp., *Huenella triplicata* n. sp.

The photographs of brachiopods illustrated in this paper were made by Dr. Charles E. Resser, of the U. S. National Museum, and the retouching of photographs was done by Miss Francis Wieser.

BRACHIOPODA

DESCRIPTION OF SPECIES

Genus MICROMITRA Meek

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 332, for synonymy, description and illustration.

MICROMITRA ZENOBIA Walcott

Plate 106, figs. 1-7

Micromitra zenobia Walcott, 1912, Mong. U. S. Geol. Surv., No. 51, p. 342, text fig. 23. Describes and illustrates species with one text figure.

The type of this species occurs in the Burgess shale of the Stephen formation, and the specimens illustrated in this paper occur in a calcareous shale about 1,000 feet (304.8 m.) distant from the type locality and a little above the horizon at the type locality. All the shells are flattened and more or less distorted; none of them exhibit the interior surface and only traces of the pseudo cardinal area are preserved; they afford, however, fine illustrations of distortion with considerable fracturing of the test of the shell, and are worth illustrating on that account.

The associated fossils are:

Pirania muricata Walcott
Obolus sp. undt.
Hyolithellus flagellum Matthew
Hyolithes sp. undt.
Scenella varians Walcott
Ptychoparia ? cordilleræ (Rominger)
Neolenus serratus (Rominger)

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[1] Amer. Jour. Sci., 5th Ser., Vol. 3, 1922, pp. 343-348.

Formation and locality.—Middle Cambrian: (61j) Stephen formation. Buff weathering band of calcareo-argillaceous shale. West slope of Mt. Field, near Burgess Pass Ridge about 3,200 feet (975.3 m.) above Field on the Canadian Pacific Railway, British Columbia, Canada.

MICROMITRA (IPHIDELLA) PANNULA (White)

Plate 106, figs. 16, 17

For synonymy see Mong. U. S. Geol. Surv. No. 51, 1912, p. 361.

Two specimens of this species are illustrated on account of the fine preservation of the delicate spines or setæ attached to the surface of the shell. Many hundreds of these shells from calcareous shales were without a trace of the spines, but in the fine silicious Burgess shale several have them attached.

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

Genus OBOLUS Eichwald

See Mong. U. S. Geol. Surv., No. 51, 1912, for synonymy and description.

OBOLUS ION, new species

Plate 106, figs. 8-10

This is a medium size species of *Obolus* comparable with *O. tetonensis* Walcott.[1] It has similarly shaped valves except that some of the ventral valves of *O. ion* are more acuminate, in this respect resembling the ventral valve of *Lingulella acutangula* Roemer,[2] but the dorsal valves have more the outline of those of *Lingulepis*.

Dimensions.—Ventral valve 7 mm. in length, maximum width 6 mm. Dorsal valve 6 mm. in length, 5.5 mm. maximum width.

Formation and locality.—Ozarkian: (16q) Mons formation. Thin-bedded gray limestone. Brisco range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of 3d bridge on Banff-Windermere motor road. About 15 miles (24.1 km.) from Lake Windermere in Columbia River Valley.

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[1] Mong. U. S. Geol. Surv. No. 51, 1912, p. 417, pl. 9, figs. 5, 5*a-c*.

[2] *Idem*, pl. 17, fig. 1.

(16y) Mons formation; compact gray limestone crowded with broken fossils; Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road.

(17n) Mons formation; thin gray nodular limestone interbedded in argillaceous shale. North side of Stoddart Creek Canyon near its mouth, 6 miles (9.6 km.) south of Sinclair Canyon, Stanford Range, on east side of Columbia River Valley, all in British Columbia, Canada.

OBOLUS LEDA Walcott

Plate 106, figs. 12-15

Obolus tetonensis leda Walcott, 1912, Mong. U. S. Geol. Surv., No. 51, p. 417. (Variety described but not illustrated.)

This is the representative in the basal portion of the Ozarkian Notch Peak formation of *Obolus tetonensis* Walcott which occurs in the Upper Cambrian of the Teton Mountains of Wyoming. It differs from *O. tctonensis* in its more elongate dorsal valve, thinner shell and finer concentric surface striæ.

Dimensions.—A large ventral valve 3.5 mm. in length has a maximum width of 2.5 mm. A dorsal valve 5 mm. long has a maximum width of 3.5 mm.

Formation and locality.—Ozarkian: (30 m.) Notch Peak formation. Compact dove colored limestone 140 feet (42.6 m.) from base of 1e of section. North slope of Notch Peak about 5 miles (8 km.) south of Marjum Pass, House Range, Millard County, Utah.

A shell that is closely related to *O. leda* occurs with the Hungaia faunule of the Stanford Range. It has the same thin, shiny shell and form, but is a little larger.

Ozarkian: (17p) Mons formation. Thin layer gray limestone interbedded in argillaceous shale, north side of Sinclair Canyon about 450 feet (137.1 m.) above creek, and a little west of Radium Hot Springs, Brisco Range.

(17v) Mons formation. Thin layer of soft gray limestone interbedded in shale 1g of section and 221 feet (67.3 m.) above base of section. Southwest angle of Sabine Mountain, 1 mile (1.6 km.) north of Kootenay River Bridge and about 2 miles (3.2 km.) northeast of Canal Flats Station on the Canadian Pacific Railway.

(21i) Mons formation. Thin-bedded gray limestone interbedded in shale. Kicking Horse Canyon above second bridge on Canadian Pacific Railway, about 1.5 mile (2.4 km.) east of Golden. All in British Columbia, Canada.

OBOLUS MYRON, new species

Plate 107, figs. 1-3

In outline of the valves, this species recalls *Obolus mcconnelli* Walcott from the Middle Cambrian, especially the variety *decipiens*,[1] but the nearest species is *Obolus tetonensis* Walcott and its variety *ninus*.[2] Both species are from the Upper Cambrian. *O. myron* differs from *O. tetonensis* in the broader outline of the valves and more obtuse apex of the ventral valve.

Dimensions.—A ventral valve 7.5 mm. long has a maximum width of 5.5 mm. A flattened and distorted dorsal valve is 5.5 mm. long and 7 mm. in width.

Formation and locality.—Upper Cambrian: (63x) Ottertail formation. Thin-bedded limestones about 500 feet (152.4 m.) above argillaceous shales of Chancellor formation; Wolverine Pass between Mounts Drysdale and Grey (11 miles (17.6 km.) southwest of Vermilion Pass, Alberta), in British Columbia, Canada.

OBOLUS PERONE, new species

Plate 106, fig. 11

This species is represented by a few fragments and one dorsal valve that proves it to have been a rather large and thick shell marked by concentric striæ and lines of growth. This dorsal valve is a little distorted but it appears to have been wider than long, the length being 11 mm. and maximum width 14 mm.

The one imperfect specimen indicates a species related to *Obolus maera* (Hall and Whitfield), (Mong. U. S. Geol. Surv., No. 51, 1912, pl. 10, figs. 2, *2a-e*) and it may be compared with compressed forms of *Obolus apollinis* Eichwald (*idem*, pl. 14, figs. 6, *6a*).

Formation and locality.—Upper Cambrian: Ottertail limestone on Moose river southeast of Field, British Columbia, Canada.

Type in collection of Geological Survey of Canada at Ottawa.

OBOLUS TETONENSIS Walcott

Plate 107, figs. 4, 5

Obolus tetonensis Walcott, 1901, Proc. U. S. Nat. Museum, Vol. 23, p. 684. (Described as a new species.)

Obolus tetonensis Walcott, 1905, *Idem*, Vol. 28, p. 327. (Same as above.)

Obolus tetonensis Walcott, 1912, Mong. U. S. Geol. Surv., No. 51, p. 417, pl. 9, figs. 5, *5a-d*. (Species discussed, illustrated and localities given.)

This form of *Obolus* is widely distributed in the Cordillera of western North America. It occurs in the Bisbee District of Arizona,

[1] Mong. U. S. Geol. Surv., No. 51, 1912, pl. 23, figs. *3a*, 4.

[2] *Loc. cit.*, pl. 9, figs. 5, *5a-e*; pl. 11, figs. 1, *1a-g*.

the Teton Mountains of Wyoming, and at several localities in Montana, and as far as I can determine from the ventral valves it is present in the Mount Robson section of British Columbia. The figures of the two valves illustrated on plate 107, figures 4, 5, may be compared with those of two of the ventral valves from the type locality. (See pl. 9, figs. 1, 1*a*, Mong. 51, U. S. Geol. Surv.)

The types of *O. tetonensis* occur in association with *Lingulepis acuminata meeki* Walcott, *Billingsella coloradoensis* (Shumard) and *Acrotreta microscopica tetonensis* Walcott. This fauna of locality 4e is referred to the Middle Cambrian by Walcott (Mong. 51, p. 417), but this is evidently a mistake as my field label has Upper Cambrian on it, and the fauna as I understood it in 1898 was of Upper Cambrian age. Now that this fauna has been removed from the Upper Cambrian and placed in the Ozarkian, *O. tetonensis* and its associates at locality 4e will be referred to the lower zone of the Ozarkian. All of the localities of *O. tetonensis* are either in the Upper Cambrian or basal Ozarkian. This is evidently the case with locality 4h (Mong. 51, p. 166) which also has *Lingulepis acuminata* Conrad, a species that occurs most abundantly in the Lower Ozarkian Hoyt limestone fauna of New York.

The stratigraphic references to Upper and Middle Cambrian in Monograph 51 are subject to revision as they were made at a time when the boundaries of the Upper Cambrian in the Cordilleran area were not well established. *O. tetonensis* appears to have lived in the Upper Cambrian seas and continued on into the Lower Ozarkian, and an almost identical form occurs in the lower Canadian fauna of Fossil Mountain (locality 67n) (pl. 107, figs. 7, 7*a*, 8), except that the latter has the exterior surface of a *Westonia*.

Dimensions.—A ventral valve 9 mm. in length has a maximum width of 7 mm. and an associated dorsal valve 7 mm. in length has a maximum width of 7 mm.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

OBOLUS cf. TETONENSIS Walcott

Obolus tetonensis Walcott, Mong. U. S. Geol. Surv., No. 51, 1912, p. 417, pl. 9, figs. 5, 5*a-d*. (Described and illustrated.)

A few fragmentary specimens of a species closely related to *O. tetonensis* were found in a hard gray limestone of the lower Mons formation in the Glacier Lake section. Comparison may also be made with *Obolus matinalis* (Hall) from the Upper Cambrian, Franconia sandstone of Wisconsin. Better specimens are needed for study and illustration before a satisfactory specific identification can be made.

Formation and locality.—Ozarkian: (64n) Mons formation (Lower) near base of 1c of field section. Cliff on southeast side of Mons Glacier above head of Glacier Lake Canyon Valley about 50 miles (80.5 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. Similar specimens occur at the following localities:

(16u) Mons formation. Beds of dove gray limestones 30 inches (76.2 cm.) thick, interbedded in gray argillaceous shale. South end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs.

(16y) Mons formation. Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road.

(21e) Mons formation. Gray thin-bedded limestones. South end of Brisco Range on northeast side of Sinclair Canyon about 800 feet (243.8 m.) up the canyon from the first bridge west of entrance to canyon on the Banff-Windermere motor road.

(17y) Mons formation. Hard gray limestone. West slope of Stanford Range, east side of Columbia River Valley, 5 miles (8 km.) south of Sinclair Canyon and .5 mile (.8 km.) north of Stoddart Creek. All in British Columbia, Canada.

OBOLUS TEUTA, new species

Plate 107, fig. 6

This is one of the *Obolus tetonensis*-like forms that occurs in a slightly different zone of the Mons formation than *O. ion*. It is much like the latter but differs in its less acuminate ventral valve and less elongate dorsal valve. The latter is somewhat like the dorsal valve of *O. tetonensis*.

Dimensions.—A ventral valve 9.5 mm. in length has a maximum width of 7 mm. A dorsal valve 10 mm. long has a width of 8 mm.

Formation and locality.—Ozarkian: (16r) Mons formation, Brisco Range, north side of Sinclair Canyon about 1,200 feet (365.7 m.) above bridge No. 5, on Banff-Windermere motor road, British Columbia, Canada.

(17y) Mons formation; west slope Stanford Range, east side of Columbia River Valley, 5 miles (8 km.) south of Sinclair Canyon and 0.5 mile (.8 km.) north of Stoddart Creek, British Columbia, Canada.

OBOLUS WHYMPERI, new species

Plate 121, figs. 4-7

This is one of the *Obolus mcconnelli* forms of *Obolus* that occurs at a lower stratigraphic horizon in the silicious shales beneath the upper calcareous beds of the Mt. Whyte formation. It differs principally from *O. mcconnelli* (Walcott) in the more elongate outline of the valves and average larger size. The shells are fairly abundant on the surface of a hard, fine, arenaceous, gray shale that occurs on the lower slopes of Mt. Whymper.

The species is named in honor of Edward Whymper, explorer and mountain climber in the Canadian Rockies.

Formation and locality.—Lower Cambrian: (68e) Mt. Whyte formation, east lower slope of Mt. Whymper, above Vermilion Pass, British Columbia, Canada.

OBOLUS (WESTONIA) OLLIUS, new species

Plate 121, figs. 8-10

Lingulella stoneana Weller, 1903, Geol. Surv. New Jersey, Rept. Pal., Vol. 3, p. 112, pl. 1, fig. 6. (Described and discussed.)

Lingulella stoneana Whitfield Weller, 1903, Geol. Surv. New Jersey, Rept. Pal., Vol. 3, p. 112, pl. 1, fig. 6. (Described and discussed.)

Obolus (*Westonia*) *stoneanus* Walcott, 1912, Mong. U. S. Geol. Surv. No. 51, p. 465, pl. 49, figs. 2, 2*a*. (Illustrates specimen from New Jersey now referred to *O.* (*W.*) *ollius.*)

This species differs from *O.* (*W.*) *stoneanus* (Whitfield) of the Upper Cambrian of Wisconsin in outline and in the direction of the raised transverse outlines which bend back on the cardinal and lateral slopes more towards the beak than in *O.* (*W.*) *ollius.*

Formation and locality.—Upper Cambrian (11c) "Hardystone Quartzite," Newton, New Jersey.

OBOLUS (WESTONIA) TERTIA, new species

Plate 107, figs. 7, 7*a*, 8

The striking difference between this species and *Obolus dolatus* Sardson[1] of the Oneota dolomite is in the character of the outer surface. On *O.* (*W.*) *tertia* the concentric raised lines of growth are strong, irregularly spaced, and the entire surface is slightly roughened

[1] Mong. U. S. Geol. Surv., No. 51, p. 390, text figs. 35*a*-*c*.

by very minute inosculating raised lines that give almost the same effect as similar lines on the surface of *Obolus* (*Westonia*) *ella* Hall and Whitfield.[1]

It is closely related to the latter widely distributed species by surface characters and form of ventral valve, but the outline of the dorsal valve is less transverse.

Dimensions.—A convex ventral valve 8 mm. long has a maximum width of 6.75 mm. A flattened ventral valve 6.5 mm. long is 7 mm. in maximum width.

Formation and locality.—Ordovician: (67n) Sarbach formation, in a hard, dirty gray, thick-bedded limestone weathering to a light buff color. Northeast slope of Fossil Mountain, 8.7 miles (13.9 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. Also (21 o) Buff brown and gray shaly limestone 75 feet (22.8 m.) below 21n. On low ridges southeast of lower end of Baker Lake and Fossil Mountain.

OBOLUS (FORDINIA) NESTOR, new species

Plate 108, figs. 1, 2

This species is founded on a dorsal valve showing the cast of a portion of the visceral area and the exterior of an associated ventral valve. The dorsal valve resembles that of *Elkania desiderata* (Billings) (Mong. 51, pl. 51, fig. 1*d*), and the ventral valve that of *Obolus* (*Fordinia*) *gilberti* Walcott (*loc. cit.*, pl. 51, fig. 5). The generic reference is doubtful as the dorsal valve does not show sufficient of the visceral area to clearly indicate whether it belongs to *Obolus* (*Fordinia*), *Elkania,* or *Dicellomus.*

Dimensions.—The dorsal valve is 6.5 mm. in length with a maximum of 7 mm. The associated ventral valve is smaller with a length of 3.5 mm. and a maximum width of 3 mm.

Formation and locality.—Upper Cambrian: (64w) Lyell formation. Drift blocks of limestone. Sawback Range, Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km) north-northeast of Massive Switch on Canadian Pacific Railway, Alberta, Canada.

Genus LINGULEPIS Hall

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 544, for synonymy and description.

For convenience of reference and listing of species I have during the past few years been using *Lingulepis* as a genus rather than as a

[1] *Loc. cit.,* pl. 47, fig. 10.

subgenus of *Lingulella*. The attenuate form of the posterior portion of the ventral valve is, however, so persistent and so well marked that it may be as well to return to the usage of the author of the genus and give *Lingulepis* full generic value. It is a very excellent horizon marker in the Lower Ozarkian and Upper Cambrian formations of the Cordilleran and Appalachian areas and of the Middle Cambrian in New Brunswick. The species *L. acuminata* (Conrad) is widely distributed in the Appalachian area and the Mississippi Valley, and similar forms occur at Mount Robson, British Columbia, and far to the south in the Cordilleran ranges of Utah and Nevada.

The species I have described as *L. nabis* is the only new one that has come to my attention since 1910.

LINGULEPIS NABIS, new species

Plate 109, figs. 4-7

This species differs from *Lingulepis acuminata* (Conrad)[1] in its uniformly smaller size, nearly straight lateral margins of the ventral valve and more elongate dorsal valve; it also appears to have had a thinner more flexible shell. The ventral valve resembles that of some forms of *Lingulepis exigua* (Matthew) (*loc. cit.*, pl. 43, figs. 1-1*b*) from the Middle Cambrian, but the dorsal valve is quite unlike the dorsal valve of *L. exigua*. The latter species is also much larger. It may also be compared with *L. spatula* Walcott (*loc. cit.*, pl. 19, figs. 5, 5*a*, 5*b*) from the Bright Angel shale formation.

A species closely resembling *L. nabis* occurs with a faunule of the Mons fauna in Sinclair Canyon. Unfortunately the specimens are all imperfect, which prevents close comparison and identification.

Dimensions.—A small ventral valve 4.25 mm. in length has a maximum width of 2.75 mm. A large dorsal valve 7.25 mm. in length has a maximum width of 4 mm.

Formation and locality.—Ozarkian: (16q) Mons formation in a thin-bedded gray limestone. Brisco Range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of third bridge on Banff-Windermere motor road. Also locality 16t which is about a mile further down Sinclair Canyon.

(16v) Mons formation. Soft gray thin-bedded limestone. Brisco Range, north side of Sinclair Canyon about 75 feet (22.8 m.) above the creek just below the fourth bridge on the Banff-Windermere motor road, which is 4 miles (6.4 km.) above the first bridge.

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[1] See Mong. U. S. Geol. Surv., No. 51, pt. 2, 1912, pls. 40-42.

(17n) Mons formation. Thin layer gray nodular limestone interbedded in argillaceous shale. North side of Stoddart Creek Canyon, near its mouth, 6 miles (9.6 km.) south of Sinclair Canyon, Stanford Range, on east side of Columbia River Valley. All in British Columbia, Canada.

Genus LINGULELLA Salter

See Mong. U. S. Geol. Surv., No. 51, 1912, for synonymy and description.

LINGULELLA cf. DESIDERATA Walcott

Plate 108, figs. 3, 4

Lingulella desiderata Walcott, 1898, Proc. U. S. Nat. Mus., Vol. 21, pp. 399-400. (Described and discussed as a new species.)

Lingulella desiderata Walcott, 1921, Mong. U. S. Geol. Surv., No. 51, p. 492, pl. 20, figs. 4, 4*a-c*, 5, 5*a-j*.

This widely distributed species that ranges from the Upper Cambrian into the Lower Ozarkian in the United States, is represented in the Mons fauna by a small shell that cannot readily be separated from the typical forms of the species. The ventral valve is similar but the one associated dorsal valve is more like that of *L. rotundata* (*loc. cit.*, pl. 20, fig. 2*d*).

The shell is thin and marked by fine concentric striæ.

Dimensions.—Ventral valve 4.75 mm. in length with a maximum width of 2.75 mm.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia.

Ozarkian: (16t') Mons formation. Thin layers of limestone interbedded in gray argillaceous shale. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above creek and a little west of Radium Hot Springs.

(16y) Mons formation. Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road.

(21d) Mons formation. Argillaceous shale and thin layers of dense gray limestone. Northern end of Stanford Range on southeast side of Sinclair Canyon just below Radium Hot Springs Pool. All in British Columbia, Canada.

LINGULELLA IBICUS, new species

Plate 108, figs. 5-8, plate 109, figs. 8, 9

The general form of this species is not unlike that of *L. bella* Walcott and *L. randomensis* Walcott [1] from the Upper Cambrian of Newfoundland. The valves of *L. ibicus* are more elongate than those of *L. bella,* and broader posteriorly than those of *L. randomensis.* Shell thin and marked by fine concentric striæ and lines of growth.

Dimensions.—A ventral valve 8.5 mm. in length has a maximum width of 4.75 mm., and a small dorsal valve 5.5 mm. long has a maximum width of 4.25 mm.

A dorsal valve of a *Lingulella* occurs in the Lyell formation of the Upper Cambrian (locality 64c) that is very similar to that of *L. ibicus* in outline and convexity. It may also be compared with the dorsal valve of *L. bella* Walcott (Mong. 51, pl. 19, figs. *2b, 2c*).

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia.

(16q) Mons formation. Thin-bedded gray limestone. Brisco Range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of third bridge on Banff-Windermere motor road.

(16u) Mons formation. Beds of dove gray limestones 30 inches (76.2 cm.) thick, interbedded in gray argillaceous shale. South end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs.

(16v) Mons formation. Soft gray thin-bedded limestone. Brisco Range, north side of Sinclair Canyon about 75 feet (22.8 m.) above the creek just below the fourth bridge on the Banff-Windermere motor road, which is 4 miles (6.4 km.) above the first bridge.

(16y′) Mons formation. Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on the Banff-Windermere motor road.

(17n) Mons formation. Thin layer gray nodular limestone interbedded in argillaceous shale. North side of Stoddart Creek Canyon near its mouth, 6 miles (9.6 km.) south of Sinclair Canyon, Stanford Range, on east side of Columbia River Valley.

[1] *Loc. cit.,* pl. 19, figs. 2, *2a-f* and pl. 21, fig. 5.

(17y) Mons formation; west slope Stanford Range, east side of Columbia River Valley, 5 miles (8 km.) south of Sinclair Canyon and .5 mile (.8 km.) north of Stoddart Creek, British Columbia, Canada.

(21f) Mons formation. Hard gray limestone interbedded in shale. North end of Stanford Range on southeast side of Sinclair Canyon, 180 to 200 feet (54.8 to 60.9 m.) above first bridge from mouth of canyon. All in British Columbia, Canada.

LINGULELLA MILTONI, new species

Plate 122, figs. 1-4

This species is closely related to *L. remus* (p. 494) in form and convexity of the valves. It differs in the straighter cardinal slopes and more transverse front of the ventral valve and the proportionally narrower and more elongate dorsal valve. There is considerable variation in the widening of the ventral valve as illustrated by figures 1 and 3. The average length of the ventral valve is about 5 mm. This shell (*L. miltoni*) was compared with *L. manticula* White in a list of fossils from Mount Robson[1] and the statement made that the fauna was very close to if not within the base of the Ordovician. At that time the Mons formation had not been determined nor its fauna recognized as distinct from the Cambrian beneath and the Ordovician above.

L. miltoni is associated with a rather large species of *Acrotreta* closely allied to *A. sagittalis transversa* (Hartt)[2] from the Upper Cambrian of Newfoundland.

The specimens of *L. miltoni* were found in a block of limestone derived from the beds above the *Hungaia* zone as exposed in Billings Butte (Extinguisher) and in the upper beds of Iyatunga (rearguard); these beds probably belong in the Chushina formation.[3]

Formation and locality.—Ozarkian: (61u) Chushina formation. Gray thin-bedded limestones, northeast slope of Robson Peak in moraine brought down from high on the mountain by Chupo Glacier terminating at the lower end of Berg Lake, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

LINGULELLA NECHOS, new species

Plate 108, figs. 12, 12*a*

Fragments of a large species of *Lingulella* are associated with *Obolus* (*Westonia*) *tertia* (*ante*, p. 487) that suggest *Lingulella davisi*

[1] Smithsonian Misc. Coll., Vol. 57, 1913, p. 336.

[2] Mong. U. S. Geol. Surv. No. 51, 1912, p. 708, pl. 72, figs. 1, 1*a-k*.

[3] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 458.

(McCoy) from the Lingula Flags of Wales. A dorsal valve has a length of 15 mm. with a maximum width of 10 mm. It is rather thick and its outer surface marked by strong concentric lines of growth following the edges of the laminated layers of the shell. The dorsal valve is more elongate and rounded subquadrate in outline than that of *Lingulella isse* Walcott.[1] The thick shell is like that of *Obolus* (*Lingulobolus*) *spissus* (Billings).[2]

Formation and locality.—Ordovician: (67n) Sarbach formation, in a hard, dirty gray, thick-bedded limestone weathering to a light buff color. Northeast slope of Fossil Mountain, 8.7 miles (13.9 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

(21 o) Buff brown and gray shaly limestone. On low ridges southeast of lower end of Baker Lake and Fossil Mountain.

LINGULELLA NEPOS, new species

Plate 108, figs. 9-11

The ventral valve of *L. nepos* is similar to that of *L. ninus* (pl. 108, figs. 15, 16) except that it is proportionally broader and the apex is curved over in a less abrupt manner. The associated dorsal valves are proportionally narrower. Shell thin and marked by fine concentric striæ and lines of growth and fine radiating striæ.

Dimensions.—A ventral valve 5.5 mm. long has a maximum width of 3.5 mm. and a broad associated dorsal valve is 2.25 mm. long with a maximum width of 2 mm. (fig. 9). An elongate dorsal valve (fig. 10) has a length of 3.25 mm. and maximum width of 1.75 mm.

Formation and locality.—Ozarkian: (16q) Mons formation in thin-bedded gray limestone. Brisco Range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of third bridge on Banff-Windermere motor road, British Columbia, Canada.

LINGULELLA NERVA, new species

Plate 108, figs. 13, 13*a*, 14

This species of the upper Mons might be a descendant of *Lingulella ibicus* or *L. remus* (see pl. 108, figs. 5-8) of the Ozarkian Chushina formation, but if so it has changed the outline of the valves, and they are also much more convex and thicker than the older species. *L. nechos* (pl. 108, figs. 12, 12*a*) is a much larger and more elongate shell.

[1] *Loc. cit.*, p. 510.

[2] *Loc. cit.*, p. 432, pl. 16, fig. 2.

Dimensions.—A convex ventral valve has a length of 7 mm. and a maximum width of 4.5 mm. A smaller associated dorsal valve is 5.5 mm. in length with a maximum width of 4 mm.

Formation and locality.—Ozarkian (16r) Mons formation, Brisco Range. North side of Sinclair Canyon about 1,200 feet (365.7 m.) above bridge No. 5, on Banff-Windermere motor road, British Columbia, Canada.

LINGULELLA NINUS, new species

Plate 108, figs. 15, 16

L. ninus differs from the associated *L. ibicus* and *L. remus* in the more attenuate posterior half of the ventral valve and the broader dorsal valve. It is not unlike some examples of the shorter forms of *Lingulella perattenuata* Whitfield.[1] Shell very thin with outer surface marked by fine concentric and radiating striæ.

Dimensions.—A small ventral valve 5.5 mm. in length has a maximum width of 3.5 mm. A large dorsal valve is 7 mm. in length with a width of 5.5 mm.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

LINGULELLA REMUS, new species

Plate 109, figs. 2, *2a*, 3

This is one of the *Lingulella acutangula*[2] type of shells in general form but it differs in details of outline and its thinner shell. The nearest species is the associated *L. ibicus* which differs from it in having proportionally more elongate and narrow valves. Shell thin with outer surface marked by fine concentric striæ and lines of growth and very fine lines radiating from the beak.

Dimensions.—Ventral valve 8 mm. long has a maximum width of 5 mm. A dorsal valve 6 mm. in length has a maximum width of 4 mm.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak,

[1] *Loc. cit.*, pl. 21, figs. 1*c*.

[2] *Loc. cit.*, pl. 17.

Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

Ozarkian (17y) Mons formation. Hard gray limestone. West slope of Stanford Range, east side of Columbia River Valley, 5 miles (8 km.) south of Sinclair Canyon and .5 mile (.8 km.) north of Stoddart Creek, British Columbia, Canada.

LINGULELLA SILIQUA, new species

Plate 108, figs. 17-19; pl. 109, fig. 1

This is one of the *Lingulella ibicus* (see pl. 108, figs. 5-8) group of shells in which the ventral valve is broad in front with the slightly rounded sides sloping back to form a somewhat acuminate beak. Most of the shells are flattened on the surface of a shaly limestone, but a few have a moderate convexity (fig. 5). The form of the ventral valve is somewhat like that of *L. ninus* (pl. 108, fig. 15). Flattened ventral valves are illustrated by figs. 17, 18, and what may be a dorsal valve by one of the shorter valves on fig. 19. Shells of medium thickness with outer surface marked by concentric striæ and lines of growth.

Dimensions.—A ventral valve 9 mm. in length has a maximum width of 5 mm. The associated dorsal valve is 8 mm. long with a maximum width of 5 mm.

Formation and locality.—Upper Cambrian: (63x) Ottertail formation. Thin-bedded limestones about 500 feet (152.4 m.) above argillaceous shales of Chancellor formation; Wolverine Pass between Mounts Drysdale and Grey (11 miles (17.6 km.) southwest of Vermilion Pass, Alberta), in British Columbia, Canada.

LINGULELLA cf. SIMILIS Walcott

See Mong., U. S. Geol. Surv. No. 51, 1912, p. 532, pl. 21, figs. 2, 3.

This little shell is abundant in the shales and thin layers of hard dove-colored interbedded limestone near the base of the Mons formation in Sinclair Canyon. It closely resembles *L. similis,* and as a similar form occurs in the Cordilleran Province in Nevada, it may have ranged from the Appalachian area of Tennessee across the Mississippi region and the Black Hills of South Dakota and up through the Cordilleran trough from the south.

Formation and locality.—Ozarkian: (21d) Mons formation; argillaceous shale and thin layers of dense gray limestone; northern end of Stanford Range on southeast side of Sinclair Canyon just below Radium Hot Springs Pool, British Columbia, Canada.

LINGULELLA WAPTAENSIS, new species

Plate 122, figs. 5-8

This is the Pacific Province representative of *L. ferruginea* Salter (see Mong. 51, U. S. Geol. Surv., 1912, pl. 29) of the Atlantic Province Middle and Upper Cambrian formations of eastern North America and northwestern Europe. It is a little less elongate and more rotund in outline but otherwise is very closely related to *L. ferruginea*. Nearly all the shells are also a little smaller as they average about 4 mm. in length and breadth as flattened in the shale. Often a group of the ventral valves are not over 3 mm. in length, with a slightly less width. Comparison should also be made with *L. lepis* Salter, which is a thicker shell with a somewhat different outline.

These shells often occur in groups on some of the partings of the dark silicious shale in the same manner as *Obolus mcconnelli*.

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

Genus ACROTRETA Kutorga

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 671, for synonymy, description, and illustration.

ACROTRETA ATTICUS, new species

Plate 109, figs. 10-12

The ventral valve of this species recalls some of the more elevated ventral valves of *A, sagittalis* Salter (Mong. 51, pl. 71, figs. 2, 2*a*) but it is more elevated and has a stronger apical callosity; the scars of the cardinal muscles are relatively smaller and more elongate. The exterior form and elevation of the valve is quite similar to the less elevated valves of *A. idahoensis* (Mong. 51, pls. 65 and 68) but the interior of the ventral valve of the latter species differs in the apical callosity, main vasular sinuses, and cardinal muscle scars. The associated dorsal valve has a long median ridge extending nearly to the front margin, which is another character of *A. sagittalis* that indicates the close relationship of the two species.

A. atticus is one of the largest species of the genus. A ventral valve 2.75 mm. in height has a transverse diameter at the margin of 4.5 mm. and a length of 4 mm. The dorsal valve is gently convex, the highest part is on the umbo, in advance of the slope to the minute beak that terminates on the margin of the valve.

A. atticus is relatively abundant in a hard gray limestone matrix in which the *Hungaia billingsi* fauna occurs.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

ACROTRETA DISCOIDEA, new species

Plate 109, figs. 13, 14

This form of *Acrotreta* is represented by three specimens of the ventral valve that are more depressed than the ventral valve of *A. sagittalis* (Salter) (Mong. 51, pl. 70, figs. 2 and 3) but unlike that species they have a very small apical callosity and weak vascular sinuses. The interior of the shell is marked by fine radiating lines and a shallow, narrow depression extending from the apical callosity to the front margin. Cardinal muscle scars small and not prominent as in *A. sagittalis* and many other species. The depressed beak curves over to the posterior margin.

The type specimen of the ventral valve has a length and width of 3.5 mm. which give a circular outline to the margin of the valve.

One ventral valve that has the circular outline, depressed beak and low convexity of the casts of the interior of this species has a slight median depression on the umbo and a surface slightly roughened by fine raised radiating lines broken by concentric lines of growth that give the appearance of the surface of *A. spinosa* Walcott (Mong. 51, p. 713, pl. 79, figs. 4*a*, 4*b*) but I am not sure that spines are present on *A. discoidea*. *A. spinosa* is an Upper Cambrian species from the Dunderberg shale of the Eureka District of Nevada.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

ACROTRETA cf. MICROSCOPICA Shumard

See Mong. U. S. Geol. Surv. No. 51, 1912, p. 693, pl. 67, figs. 1 to 10.

A small species of *Acrotreta* occurs in the *Hungaia* faunule of the Mons formation that is about the size and form of *A. microscopica*

(Shumard) from Packsaddle Mountain, Texas, in strata that are either high in the Upper Cambrian or in the Lower Ozarkian. This form has a wide range, and what appear to be similar forms occur in Oklahoma, Nevada, and British Columbia.

Formation and locality.—Ozarkian: (21i) Mons formation. Kicking Horse Canyon, above second bridge on Canadian Pacific Railway, about 1.5 miles (2.4 km.) east of Golden, British Columbia, Canada.

Genus ACROTHYRA Matthew

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 715-716.

ACROTHYRA GREGARIA, new species

Plate 122, figs. 9-12

This species would be referred to *Acrotreta* if it were not for the visceral area of the ventral valve (fig. 9). The dorsal valve has a long median septum and in convexity and outline is similar to the dorsal valve of several species of *Acrotreta;* the cast of the visceral area of the ventral valve is similar to that of *Acrothyra signata* Matthew (see Mong. 51, pl. 80, figs. 1*a* and 2). Nearly all of the ventral valves are compressed in the hard silicious shale but a few preserve the umbo and a beak that extends over a low area. The dorsal valve is slightly transverse and the ventral valve a little longer than wide.

Dimensions.—A large ventral valve has a length of 2 mm. with a width of 1.75 mm. A dorsal valve is 2 mm. in width and nearly as long. Large numbers of the valves are not over 1 mm. in diameter.

As far as known to me all the species of *Acrothyra* are of Middle Cambrian age. *A. gregaria* is the only species from the Pacific Province.

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

Genus NISUSIA Walcott

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 725, for synonymy, description and illustration.

NISUSIA SPINIGERA, new species

Plate 109, figs. 15-17

This is the only species of *Nisusia* known to me from an Upper Cambrian formation. In outline it suggests some of the smaller shells of *Nisusia festinata* (Billings) (Mong. 51, pl. 100, figs. 1*a*, and 1*h*) from the Lower Cambrian, but it differs from that and the Middle Cambrian species in details of area of ventral valve and outer surface. The area of the ventral valve recalls that of *N. festinata transversa* Walcott (*loc. cit.*, fig. 4 *b*). The area is high and with a broad delthyrium. The deltidium is not preserved. The outer surface (fig. 16) has long strong spines on the stronger radiating costæ and fine spines on the more delicate intermediate costæ.

Dimensions.—A large fragment of a ventral valve indicates a shell 10 to 11 mm. in length with a width of 11 to 13 mm. The other three specimens are much smaller.

Formation and locality.—Upper Cambrian: (63x) Ottertail formation. Wolverine Pass, British Columbia, 11 miles (17.6 km.) southwest of Vermilion Pass, on the Continental Divide.

NISUSIA BURGESSENSIS, new species

Plate 110, figs. 1-8

This species differs from *Nisusia alberta* Walcott (pl. 111, figs. 1, 1*a* and Mong. 51, p. 726, pl. 100, figs. 3, 3*a-d*) in its somewhat finer radiating costæ and concentric lines of growth. As far as can be determined from the compressed shells the area of the ventral valve is also lower and the valves are smaller.

A small specimen (fig. 1) has a few long, slender, curved spines attached to its outer margin, and older shells show small nodes on the costæ that served as the base of the spines.

The ventral valve is quite convex and the dorsal moderately so; usually the dorsal valves are flattened and the ventral valves more or less distorted.

Dimensions.—A large dorsal valve 15.5 mm. in length has a maximum width of 23 mm. The ventral valves are so flattened and distorted by compression in the hard shale that none of them preserve their original form.

This fine species of *Nisusia* is the Middle Cambrian representative of *N. festinata* (Billings) (Mong. 51, pl. 100) from the Lower Cambrian. As far as now known it occurs only with the Burgess shale fauna near Burgess Pass.

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

NISUSIA (JAMESELLA) ORIENS, new species

Plate 110, figs. 9-14*a*

Among described species *N.* (*J.*) *oriens* may be compared in form with *N.* (*J.*) *perpasta* (Pompecki) (Mong. 51, pl. 101, figs. 1, 2, 3) from the Lower Cambrian of Bohemia, but it differs greatly in not having strong radiating costæ and an elevated apex to the ventral valve; it also differs from all described species of *Nisusia* and *Jamesella* in the character of the surface costæ which are very fine and but slightly elevated.

The cardinal area of the ventral valve is high and divided midway by a large delthyrium that has a convex deltidium, but how far the latter extends over the delthyrium has not been determined; the cardinal area of the dorsal valve is low and divided by a broad delthyrium that was more or less covered by a convex deltidium.

Dimensions.—A large ventral valve 9 mm. in length has a maximum width of 12.5 mm., and the tongue of the median furrow extends 4.5 mm. beyond the plane of the side margin of the valve. A convex dorsal valve 8 mm. in length has a maximum width of 12.5 mm. Marked characters of this species are the deep, broad median sinus with its prolonged tongue and the high area of the ventral valve, the strongly and uniformly convex dorsal valve with its low area, and almost entire absence of a median range. Young shells have subequally convex valves and only traces of a median sinus on the ventral valve.

N. (*J.*) *oriens* ranges through quite a thickness of sandstone and arenaceous limestone about Forteau Bay.

Formation and locality.—Lower Cambrian: (41d) Reddish gray limestones of lower part of Archæocyathinæ zone, west side of Forteau Bay. The species also occurs (41b) in the lower 30 feet (9.1 m.) of the section at Forteau Point; (41c) 65 and 80 feet (19.8 and 24.3 m.) above base of Archæocyathinæ reef at Point Armour on the east side of Forteau Bay, and at 41v, Schooner Cave on west side of L'Anse au Loop.

All localities on north shore of Straits of Belle Isle, Labrador, Canada.

Genus WIMANELLA Walcott

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 745 for synonymy, description, and illustration.

WIMANELLA BOREALIS, new species

Plate 111, figs. 2-4

This shell in general form resembles *Wimanella ? anomala* from the Middle Cambrian shales of Alabama (Mong. 51, p. 745, pl. 87, figs. 1, 1*a-e*). It differs in having slightly stronger radiating ribs and in the sharper extension of the cardinal angles. Traces of the main vascular trunks occur on the natural cast of the interior of a ventral valve. This feature and the fine radiating ribs serve to bring the species near to the finer ribbed species of *Billingsella.*

Formation and locality.—Middle Cambrian: (61v) Titkana formation; gray shaly limestone in massive beds, on west slope of Titkana Peak, above Hunga Glacier, 3.75 miles (6 km.) northeast of summit of Robson Peak, northwest of Yellowstone Pass, western Alberta, Canada.

WIMANELLA OCCIDENS, new species

Plate 111, figs. 5-7

This is a rather thick calcareous shell with a smooth outer surface, high area on the ventral valve, a strong tripartite umbonal area and a well marked visceral area on both valves and a general outline like that of *Wimanella harlanensis* (Walcott) (Mong. 51, pl. 87, figs. 5, 5*a-c*). It is a smaller shell than the latter and occurs well up in the Upper Cambrian. There are a number of specimens in the collection but none finely preserved.

Dimensions.—The average size of the ventral valve is about 10 mm. in length by 10 mm. in maximum breadth. A dorsal valve 7.5 mm. long has a maximum width of 10 mm.

Formation and locality.—Upper Cambrian: (64l) Lyell formation. Gray limestone of upper part of 1b of section. Locality: South slope of ridge of Sullivan Peak, north side of Glacier Lake Canyon about 0.25 mile (0.4 km.) east of foot of Southeast Lyell glacier and about 48 miles (77.3 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Genus BILLINGSELLA Hall and Clarke

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 749, for synonymy, description and illustration.

BILLINGSELLA ARCHIAS, new species

Plate 112, figs. 1-5

This species is known only from more or less exfoliated biconvex valves showing imperfectly the cast of the visceral areas and main vascular sinuses. The interior of the ventral valve has a trifid, umbonal cavity, and strong main vascular trunks. The interior of the dorsal valve has an elongate visceral area with well defined lines of advance of the anterior and posterior adductor muscle scars extending far toward the front of the valve. Surface with fine, rounded radiating ribs with interspaces about the same width as the ribs. Shell thin, structure unknown. The shell usually adheres to the matrix to such an extent that only a few fragments of the outer surface are shown by the specimens in the collection.

Dimensions.—A ventral valve 10 mm. in length has a maximum width of 10.5 mm. on the plane of the margins of the valves.

The cardinal margin is a little shorter than the maximum width of the valve, which gives the shell a slightly rounded outline.

Among known species *B. archias* recalls *B. striata* Walcott (Mong. 51, pl. 86, fig. 4, 4*a-c*) by its surface ribs, and *B. exporecta Linnarsson* (Mong. 51, pl. 88, figs. 1, 1*a-l*) by the strongly marked interiors of the valves.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

Ozarkian: (16u) Mons formation. Beds of dove gray limestones 30 inches (76.2 cm.) thick, interbedded in gray argillaceous shale. South end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs, British Columbia, Canada.

BILLINGSELLA OLEN, new species

Plate 111, figs. 8, 9

The specimens of this species are not well preserved, but they indicate a shell with clearly defined rounded radiating ribs such as occur on *B. retroflexa* (Matthew)[1] and *B. rominger* Barrande.[1] Partial casts of the interior of the dorsal valve outline an umbonal cavity and rather strong vascular sinuses that extend nearly to the anterior margin of the valve.

The largest specimen, a dorsal valve, has a length of 6 mm., with a width of 8.5 mm. at the hinge line.

[1] See Mong. U. S. Geol. Surv., pt. 11, 1912, pl. 90, figs. 1, 1*a*, 1*b*, and figs. 2*e*, 2*f*.

This is the most recent species of the genus known to me, and the second in the Mons formation. It is in the faunule next above the *Hungaia* faunule in which *B. archias* occurs. It differs from the latter species in its smaller size, outline of the valves, and more coarsely ribbed outer surface.

Formation and locality.—Ozarkian: (21j) Mons formation. Kicking Horse Canyon above third bridge on Canadian Pacific Railway, about 2.5 miles (4 km.) east of Golden, British Columbia, Canada.

BILLINGSELLA ORIGEN, new species

Plate 121, figs. 1-3

This is a small shell with fine radiating surface costæ and a well defined median sinus on the dorsal valve. It differs from *B. archias* and *B. olen* Walcott in being more transverse and in having finer radiating surface costæ.

Formation and locality.—Ozarkian: (17t) Mons formation; in thick layers of gray limestone near top of Mons outcrop interbedded in hard shale; west slope of Sabine Mountain, 400 feet (121.9 m.) above south end of Columbia Lake, 2.25 miles (3.6 km.) north of Kootenay River Bridge, and about 2 miles (3.2 km.) northeast of Canal Flat Station, Canadian Pacific Railway, British Columbia, Canada.

Genus PROTORTHIS Hall and Clarke

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 738, for synonymy, description and illustration of species.

PROTORTHIS IONES, new species

Plate 113, figs. 1-7

All of the larger shells are more or less compressed in the somewhat shaly limestone, but from the small shells we learn that the ventral valve was moderately convex and with the beak extending over a rather low area the character of which is unknown. The dorsal valve is slightly convex with a shallow median sinus gradually widening from the beak to the front; cardinal area low with indication of a broad delthyrium. The outline of the valves is transversely subquadrate and roughly semicircular.

Outer surface marked by fine, rather sharp radiating ribs that increase in number towards the front by interstitial ribs coming in between the long ribs. Shell substance fibrous and finely punctate at least in the outer layer. An imperfect interior of the ventral valve indicates a trifed umbonal cavity with strong main vascular sinuses extending forward to the anterior third of the length of the valve. The interior of the dorsal valve shows a broad, short median septum, the impression of the posterior adductor muscle scars and the main vascular sinuses.

Dimensions.—A ventral valve 14 mm. in length has a maximum width of 18 mm. The proportions of the dorsal valve are the same except it is a little shorter.

The reference of this species to *Protorthis* is based on its fibrous, punctate shell, finely ribbed exterior surface, and the interior of the dorsal valve.

Formation and locality.—Ozarkian: (65w) Mons formation in 1d of section. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.7 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway. (66 o) Mons formation in light gray limestone of 1a of section. 8.7 miles (13.9 km.) northeast in an air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

A single fragmentary specimen from the upper Saskatchewan River appears to belong to this species. It comes from a ridge on east side of canyon 3 miles (4.8 km.) south of Wilcox Pass, North Fork of Saskatchewan River, Alberta, Canada.

Ordovician: (16z) Sarbach formation; thin-bedded dark argillaceous limestone in thick bands; Brisco-Stanford Range, about half way between second and third bridges, from mouth of Sinclair Canyon, in cliff on both sides of canyon, British Columbia, Canada.

Ordovician: (21 o) Sarbach formation; buff brown and gray shaly limestone 75 feet (22.8 m.) below 21n, on low ridges southeast of lower end of Baker Lake and Fossil Mountain about 7 miles (11.2 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

PROTORTHIS PORCIAS, new species

Plate 111, figs. 10-11

This species which is associated with *Protorthis iones* Walcott, differs from the latter in having very fine, even and regular radiating ribs. A small ventral valve has a strong cardinal area with an open delthyrium, but as the beak is broken off there is no evidence of the presence of plates closing a part of the delthyrium.

The specimens of the dorsal valve indicate that this is a more transverse and smaller shell than *P. iones*.

Formation and locality.—Ozarkian: (65w) Mons formation in 1d of section. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.7 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway. (65l) Same as 65w, but in 1c of section. (66p) Light gray limestone of 1b of section 8.7 miles (13.9 km.) northeast in an air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada. (16q) Thin-bedded gray limestone, Brisco Range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of 3d bridge on Banff-Windermere motor road, British Columbia, Canada.

A specimen from the upper Saskatchewan River (67h) indicates the presence of this species 3 miles (4.8 km.) south of Wilcox Pass, Alberta, in cliffs of the Mons limestones.

Ordovician: (67k) Sarbach formation; gray limestone, 2.5 miles (4 km.) from divide at head of Clearwater River Canyon, 21 miles (33.7 km.) north, 5° west of Lake Louise Station on the Canadian Pacific Railway. (21 o) Sarbach formation; buff brown and gray shaly limestone 75 feet (22.8 m.) below 21n, on low ridges southeast of lower end of Baker Lake and Fossil Mountain, about 7 miles (11.2 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

P. porcias and *iones* Walcott are the only species found both in the upper Mons formation of the Ozarkian and the superjacent Sarbach formation of the Ordovician. This occurs in the Clearwater Canyon section, also to the south, where the species is found in the Mons of Fossil Mountain, just north of Baker Lake, and in the Sarbach of Brachiopod Mountain on the south side of Baker Lake. The presence of a fibrous shell in the Mons is the first instance known to me of its occurrence below the Ordovician (Canadian).

Genus EOORTHIS Walcott

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 772, for synonymy, description and illustrations.

EOORTHIS BELLICOSTATA, new species

Plate 113, figs. 8-14

In general outline and size this species is most like *E. wichitaensis* (pl. 116 figs. 1-10). It differs in its uniform, regular and delicate sharp radiating surface costæ, which are beautifully preserved in the fine, hard Burgess shale. The surface costæ recall in their uniform size and regular arrangement the costæ of some specimens of *Billingsella coloradoensis* (Shumard). See Mong. 51, pl. 85, fig. 1b.

A few casts of the interior of ventral valves show the rather narrow cardinal area with a delthyrium of medium width and apparently open, as no traces of a deltidium appeared in the compressed shells; a narrow, short cardinal process extends from the posterior margin to a short distance in front of the delthyrium; teeth short and small. The interior of the dorsal valve has a narrow cardinal area, broad delthyrium and short cardinal process; anterior adductor muscle scars rather large.

Dimensions.—The largest ventral valve among several hundred specimens has a length of 13.5 mm. with a maximum width of 13.5 mm.; a dorsal valve with a length of 9.5 mm. has a maximum width of 12.5 mm. The average shell is from 2 to 3 mm. smaller.

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

EOORTHIS DESMOPLEURA (Meek)

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 777, pl. 96, figs. 1, 1*a-r,* for synonymy, description, and illustration.

This species is strongly characterized by its "sharply defined, slightly curved, unequal radiating plications, and finer unequal striæ, which on the central region of the valves are more or less gathered into five or six fascicles, the middle one of which corresponds to the sinus in the other valve" (Meek). In 1912 I illustrated one of the type specimens of *E. desmopleura* (*loc. cit.,* pl. 96, fig. 1*h*) along with a number of other specimens from the same general horizon and locality. In restudying the species in connection with somewhat similar forms from the Lower Ozarkian of Alberta, I find that two species are figured on plate 96 of 1912 as *E. desmopleura.* As now restricted the latter species is represented by figures 1, 1*a,* 1*b,* 1*c,* 1*d,* 1*e,* 1*g,* 1*h.* Figures 1*i-r* represent a new species *E. fascigera* and figure 2, which is designated as the variety *nympha* of *E. desmopleura,* is now raised to the rank of species.

With the above changes *E. desmopleura* (Meek) is restricted to localities 186, 186a, 187, 360f, as listed in 1912 (Mong. 51, p. 777), all of which are in the Lower Ozarkian west of Colorado Springs, Colorado. A somewhat similar form occurs at locality 30w, Notch Peak, House Range, Utah. With better specimens it is not improbable that the 30u specimens would be found to belong to some other species.

EOORTHIS FASCIGERA, new species

Plate 117, figs. 1-9

Eoorthis desmopleura (Meek), Mong. U. S. Geol. Surv., 1912, No. 51, pt. ii, pl. 96, figs. 1*i* to 1*r*.

This species was included by Walcott with *Eoorthis desmopleura* (Meek), but with further study of the types of that species and the group of shells having a more or less fasciculate arrangement of the radiating surface ribs it becomes necessary to remove the latter from *E. desmopleura*. They differ in being more transverse in outline, uniformly smaller size, and in the peculiar grouping of the surface radiating plications and raised lines. Usually there are four or five sharply sloping ridges radiating from the apex to the anterior margin of the shell, with the cardinal slopes ornamented only by the very fine radial raised lines; these lines cover the slopes of the strong plications and any spaces that may exist between them. The lines are well shown on figures 1-5. Some of the specimens referred to *E. desmopleura* have fascicles of sharp plications with very fine raised lines between them but none of them are exactly similar to those of *E. fascigera*.

Dimensions.—A ventral valve 6.5 mm. in length has a maximum width of 7.5 mm. Dorsal valve 6 mm. long by 8 mm. in maximum width.

E. desmopleura occurs in the Lower Ozarkian and *E. fascigera* in the Upper Cambrian where it is associated with *Syntrophia rotundata* Walcott (Mong. 51, p. 804, pl. 103, figs. 4, 4*a-e*). The horizon indicated is about that of the Franconia formation of Wisconsin which carries *Syntrophia primordialis* Whitfield and the fine species *Eoorthis remnicha* N. H. Winchell.

Formation and locality.—Upper Cambrian: (14k) Deadwood formation, Wolf Creek, Big Horn Mountains, 15 miles (24.1 km.) west-southwest of Sheridan, Wyoming.

(168) Deadwood formation. Tepee Creek, south-southwest of Sheridan, on road to Dome Rock, Sheridan County, Wyoming.

EOORTHIS IOPHON, new species

Plate 114, figs. 1-5; pl. 119, fig. 14

This species is one that has the general form and surface ribs and striæ of *Eoorthis wichitaensis* Walcott (pl. 116, figs. 1-10), from which it differs mainly in the extension of the cardinal angles.

Most of the valves are evenly and gently convex but a few ventral valves have a low mesial fold, and dorsal valves occur with a broad and shallow mesial sinus. The radiating ribs of the outer surface are very narrow, rounded close together and uniform in size, but in some specimens two or three fine ribs occur between the stronger and more elevated ribs. (See fig. 2.)

Dimensions.—The average ventral valve has a length of 8 to 10 mm. and width of 8 to 10 mm., and dorsal valve 7 to 9 mm. in length with a width of 8 to 10 mm.

Formation and locality.—Ozarkian: (65e) Mons formation. Drift block of soft, almost granular gray limestone. Above motor road at Ten Mile Canyon on southwest side of Sawback Range, 10 miles (16 km.) by motor road west-northwest of Banff. (67w) Gray limestone in loose blocks on debris slope of Mons formation. South side of Upper Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch on Canadian Pacific Railway. (66q) Light gray limestone, base of 1b of section. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

Mons formation: (17r) Gray limestone interbedded in shale. West slope of Sabine Mountain 500 feet (152.4 m.) above south end of Columbia Lake, 2 miles (3.2 km.) north of Kootenay River Bridge and about 2 miles (3.2 km.) northeast of Canal Flat Station on Canadian Pacific Railway. (21d) Argillaceous shale and thin layers of dense gray limestone. Northern end of Stanford Range on southeast side of Sinclair Canyon just below Radium Hot Springs Pool, British Columbia, Canada.

EOORTHIS LINEOCOSTA, new species

Plate 115, figs. 3-5

This is one of the largest of the Ozarkian species of *Eoorthis.* The valves are gently convex with a shallow sinus on the dorsal valve. It differs from *E. desmopleura* by its straight, fine ribs that radiate from the umbo just above the apex of the valves to the outer margin. A few fine ribs arise between the long ribs and extend to the front margin. This surface is more like that of *Eoorthis iophon* (pl. 114, fig. 1) than any other species from the Lower Ozarkian known to me.

Dimensions.—A ventral valve 12 mm. in length has a maximum width of 14.5 mm. The dorsal valve is from 1 to 1.5 mm. shorter in length than the ventral valve.

Formation and locality.—Ozarkian: (360a) Manitou formation. Red silicious limestone on west side of Trout Creek below Bergen Park, 7 miles (11.2 km.) north-northwest of Manitou, El Paso County, Colorado.

EOORTHIS OCHUS, new species

Plate 117, figs. 10-13

This species is the representative of *Eoorthis desmopleura* (Meek) which occurs in the Ozarkian of Colorado, Utah, Montana, etc.[1] It differs in having more regularly arranged sharp ribs that have uniform fine, radiating, elevated striæ on their slopes, the striæ also extending over the cardinal slope on the postero-lateral surface of the valves. The ribs and elevated striæ of *E. desmopleura* are not only more irregular in arrangement and number but also less prominent; one example, however, has very regular strong ribs but the elevated striæ are absent. *E. ochus* is a larger shell than *E. fascigera* Walcott (pl. 117 figs. 1-9) and its ribs and elevated striæ are more regular in distribution and character. It has developed the sharp radiating surface fascicles farther than in *E. fascigera;* is less transverse in outline of its valves, and occurs in a considerably higher horizon.

Formation and locality.—Ozarkian: (16u) Mons formation, south end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs, British Columbia, Canada.

(67t) Gray limestone *2e* of section. Southeast side of Douglas Lake Canyon Valley, 12.75 miles (20.5 km.) east, 5° north of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

EOORTHIS PUTILLUS, new species

Plate 114, figs. 6, 7; pl. 115, fig. 9

There is a wide variation in the strength and character of the radiating ribs of the shells referred to *Eoorthis desmopleura* (Meek) by Walcott (Mong. 51, U. S. Geol. Surv., pl 96). With the accumulation of material from widely separated localities some of the variations may be grouped as indicating distinct species and varieties. One of these that resembles the plano-convex small shells of *E. desmopleura,* occurs in large numbers in a layer of limestone of the Chushina formation. Among these, ventral valves average 5.5 to

[1] See Mong. 51, U. S. Geol. Surv., pt. 1, 1912, p. 777-778.

6.5 mm. in length and width and the dorsal valves 5 to 6 mm. in length and 5 to 6.5 mm. in maximum width. A few are larger and some below the average. None of them equal the size of the type specimens of *E. desmopleura*.

The surface of *E. putillus* is marked by sharply defined radiating plications that increase in number by the intercalation of additional ribs between the main ribs that originate on the umbo just in advance of the beak. The ribs or plications are grouped in fascicles on the central portion of the valves. A shallow median sinus occurs on the dorsal valve and a strong median fascicle of ribs represents a median fold on the ventral valve. There is considerable variation in the strength of the plications or ribs on different shells but all of them are sharp when on a well preserved surface.

When imperfect or abraded the young shells of *E. wichitaensis* Walcott may be mistaken for this species and it is often difficult to decide to which species many of the shells should be referred. *E. putillus* represents a widely distributed species in the Cordilleran area. On the north it occurs in the Mt. Robson District (61q) and to the south in British Columbia it occurs in the Lower Mons fauna (16q) of Sinclair Canyon. It is represented at the following localities.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

Mons formation: (65f) Hard, light gray limestone, upper portion of 1a of section. Block that fell from cliff above southeast Lyell Glacier, about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway. (67w) Gray limestone in loose blocks on slope of Mons formation. South side of Upper Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch on Canadian Pacific Railway. (21m) Thick-bedded hard dove colored limestone. On side of brook .5 mile (.8 km.) below Baker Lake at east base of Brachiopod Mountain and east-southeast of Fossil Mountain, 8 miles (12.8 km.) northeast in an air line of Lake Louise Station on the Canadian Pacific Railway. (21m′) Thick-bedded hard dove colored limestone 21 feet (6.4 m.) below 21 m. On side of brook .5 mile (.8 km.) below Baker Lake and east-southeast of Fossil Mountain, 8 miles (12.8 km.) northeast in an air line of Lake Louise Station on the Canadian Pacific Railway.

(16v) Soft gray thin-bedded limestone. Brisco Range north side of Sinclair Canyon about 75 feet (22.8 m.) above the creek just below the fourth bridge on the Banff-Windermere motor road, which is 4 miles (6.4 km.) above the first bridge.

Mons formation: (16y) Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road. (16y′) Compact gray limestone crowded with broken fossils from 25 to 30 feet (7.6 to 9.1 m.) above 16y. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on the Banff-Windermere motor road. (21e) Gray thin-bedded limestones. South end of Brisco Range on northeast side of Sinclair Canyon about 800 feet (243.8 m.) up the canyon from the first bridge west on the Banff-Windermere motor road. (21f) Hard gray limestone interbedded in shale. North end of Stanford Range on southeast side of Sinclair Canyon, 180 to 200 feet (54.8 to 60.9 m.) above first bridge from mouth of canyon, British Columbia, Canada.

A variety closely related to this species occurs at several localities.

Mons formation: (17n) Thin layer gray nodular limestone interbedded in argillaceous shale. North side of Stoddart Creek Canyon near its mouth, six miles (9.6 km.) south of Sinclair Canyon, Stanford Range, on east side of Columbia River Valley. (21i) Thin-bedded gray limestone interbedded in shale. Kicking Horse Canyon above second bridge on Canadian Pacific Railway about 1.6 mile (2.6 km.) east of Golden. (21j) Hard gray limestone interbedded in shales. Kicking Horse Canyon above third bridge on Canadian Pacific Railway, about 2.25 miles (3.6 km.) east of Golden, British Columbia, Canada.

EOORTHIS PUTILLUS LAEVIUSCULA, new variety

Plate 115, figs. 1, 2

This shell averages smaller than *E. putillus* and differs from it in having somewhat finer surface ribs or costæ, and may be considered a finely ribbed variety of the species, although some of the smaller shells of the latter closely resemble it.

Formation and locality. Ozarkian: (67q) Mons formation. Compact gray limestone 200 feet (60.9 m.) from top of 1a of section.

Southeast side of head of Douglas Lake Canyon Valley, 12.75 miles (20.5 km.) east, 5° north of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

(17y) Mons formation; west slope Stanford Range, east side of Columbia River Valley, 5 miles (8 km.) south of Sinclair Canyon and .5 mile (.8 km.) north of Stoddart Creek, British Columbia, Canada.

A very closely allied shell occurs at locality (16y), Mons formation. Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road. (17x) Gray finely granular limestone. West slope of Stanford Range, east side Columbia River Valley, 5.25 miles (8.4 km.) south of Sinclair Canyon and .25 mile (.4 km.) north of Stoddart Creek. Both in British Columbia, Canada.

EOORTHIS VICINA, new species

Plate 112, figs. 6-9

This is the Lower Ozarkian representative of *E. fascigera* (ante p. 507) of the subjacent Upper Cambrian. Both species have about the same range of variation in the gathering of the fine radiating ribs into fascicles except that in *E. vicina* the fascicles are depressed and less prominent and the average shells are much longer. The valves are rather uniformly and moderately convex and with only a slight mesial fold on the ventral valve and a slight flattening represents the mesial sinus on the dorsal valve.

Dimensions.—A ventral valve 7.5 mm. in length has a maximum width of 9 mm. A dorsal valve 8 mm. in length has a maximum width of 10.5 mm.

Formation and locality.—Ozarkian: (65x) Lower portion of Mons formation, 1f of section in a gray limestone. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.7 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway. (67w) Loose blocks of light gray limestone in slopes beneath cliff of Mons formation. South side of Upper Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch on Canadian Pacific Railway, Alberta, Canada.

(16u) Mons formation. Beds of dove gray limestone 30 inches (76.2 cm.) thick, interbedded in gray argillaceous shale. South end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs, British Columbia, Canada.

EOORTHIS WICHITAENSIS Walcott

Plate 116, figs. 1-10

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 790, pl. 94, figs. 1, *1a-o*, for synonymy, description, and illustration.

This species is widely distributed and has a considerable range of variation in outline and convexity of the valves and surface ribs and striæ. It is probable that a detailed study of large collections from various localities and stratigraphic zones of the Upper Cambrian and Lower Ozarkian would result in recognizing some variations as typical of certain stratigraphic zones. Such a study is needed not only for this species but for all species and in many cases genera of the Cambrian and Lower Ozarkian faunas.

By an error the specimen represented by figure 1, plate 94, of Mong. 51, was designated as the type of this species although it is more like *E. indianola* Walcott (pl. 97, figs. 2, *2a-b*) in having a high apex and in the character of its rounded surface ribs. In view of this I wish to designate figure 1f, plate 94, as having the typical form and surface of *E. wichitaensis*. The same type of surface is shown by figures *1b, 1d, 1e, 1g, 1h, 1i*. On figures 1, *1a, 1c,* the fine radiating ribs are uniform and close together. On figure *1d* stronger ribs occur and this feature is increased on figures *1e-n*. The almost smooth, finely ribbed variety of surface represented by figures *1p, 1q, 1r, 1s* is designated as the variety *laeviuscula* (Mong. 51, description of pl. 94).

Shells that appear to be identical with or closely related to *O. wichitaensis* Walcott occur at the following localities in Alberta:

Upper Cambrian.—Lyell formation: (64l) Head of Glacier Lake Canyon Valley about 2 miles (3.2 km.) above head of lake. Cliff on north side next to moraine of ice foot of Southeast Lyell glacier; about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

(66m) Sawback Range, second canyon northwest of Mount Edith, 4.75 miles (7.6 km.) west-northwest of Banff. (64t) Sawback Range, Ranger Brook Canyon, 10 miles (16 km.) in air line north-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch, on Canadian Pacific Railway, Alberta, Canada.

Ozarkian.—The Ozarkian form of this species is similar in average size, surface markings, and outline to the Upper Cambrian specimens, but it scarcely seems probable that the species has so great a vertical range in the formations and that it is the only surviving species of the Upper Cambrian Lyell fauna far up in the Mons formation. On this account I call attention to its presence in the Mons with considerable doubt as to its actual identity with *E. wichitaensis.*

(66q) Mons formation, in 1b of section. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway, at the east foot of Fossil Mountain, Alberta, Canada.

(17r) West slope of Sabine Mountain, 500 feet (152.4 m.) above south end of Columbia Lake, 2 miles (3.2 km.) north of Kootenay River Bridge and about 2 miles (3.2 km.) northeast of Canal Flat Station on the Canadian Pacific Railway, British Columbia, Canada.

Genus FINKELNBURGIA Walcott

See Mong. U. S. Geol. Surv., No. 51, 1912, p. 793.

FINKELNBURGIA NOBLEI, new species

Plate 115, figs. 6, *6a*, 7, 8, *8a*

Of this species we have portions of the exterior of the valves, two casts of the interior of the ventral valve and fragments of the cast of the interior of a dorsal valve.

The shell was relatively thick with the outer surface marked by fine flattened radiating costæ outlined by sharp, very narrow incised lines; the costæ vary from .5 to .75 mm. in width on the central portions of the shell.

A ventral valve 20 mm. in width has a length of 10 mm. and a depth at the umbo of 5 mm. The cast of the interior of the ventral valve shows a strongly defined umbonal cavity (pseudospondilium) and two strong vascular trunks. A fragment of a cast of the interior of the dorsal valve has the impression of the two anterior adductor muscle scars and the cast of the bases of the main vascular sinuses.

F. noblei is a larger shell than either *F. finkelnburgia* or *F. oseola* Walcott (Mong. 51, pl. 93). Its transverse outline recalls that of *F. oseola* but it differs from the latter in details of the interior of the valves and exterior surface.

Formation and locality.—Upper Cambrian: (73c) Muav formation. Hard gray limestone 200 feet (60.9 m.) above the base. Hermit Creek, Bright Angel Quadrangle (U. S. G. S.), Grand Canyon of the Colorado River, Arizona.

SYNTROPHIDÆ

The family *Syntrophidæ* is represented in the Cordilleran area by the following genera and species:[1]

Swantonia meeki Walcott	(Mong. 51, p. 797)	Lower Cambrian
Syntrophia cambria Walcott	(" " p. 800)	Middle Cambrian
" *nundina* Walcott	(" " p. 802)	Ozarkian
" *? unzia* Walcott	(" " p. 804)	Middle Cambrian
" *isis* Walcott	(*loc. cit.* p. 517)	Ozarkian
" *nisis* Walcott	(" " p. 517)	"
" *nonus* Walcott	(" " p. 518)	"
" *perilla* Walcott	(" " p. 519)	"
Huenella abnormis Walcott	(Mong. 51, p. 805)	Upper Cambrian
" *icetas* Walcott	(*loc. cit.* p. 520)	Ozarkian
" *juba* Walcott	(" " p. 521)	Ozarkian
" *hera* Walcott	(" " p. 520)	Upper Cambrian
" *lesleyi* Walcott	(Mong. 51, p. 807)	Ozarkian
" *simon* Walcott	(*loc. cit.* p. 521)	"
" *texana* Walcott	(" " p. 522)	Upper Cambrian
" *? weedi* Walcott	(p. 522)	" "
Clarkella montanensis Walcott	(Mong. 51, p. 810)	Ozarkian

For genera and species from other localities see Cambrian Brachiopoda, 1912.[2]

Genus SYNTROPHIA Hall and Clarke

Synonymy. See Mong. U. S. Geol. Surv. No. 51, 1912, p. 798.

In referring to this genus in 1912 I wrote: "The Cambrian type of *Syntrophia* is *S. rotundata* Walcott of the Upper Cambrian. It has a spondilium in each valve supported by a median septum, and a short area divided by a large open delthyrium." A second species was described and illustrated, *S. alata* Walcott, which has a similar structure. Several other species, notably *S. calcifera* Billings, were referred to *Syntrophia* on account of their external form, and in the case of *S. calcifera* the apparent evidence in one of the types (Mong. 51, pl. 104, fig. 1*b*) of a spondilium and median septum. Several species were found to have a pseudospondilium attached directly to the inner surface of each valve and at the same time to have a more or less radially plicated or ribbed surface; for these the genus *Huenella* was proposed (*loc. cit.*, p. 805) and seven species referred to it, *H. texana* being selected as the genotype. This species has a wide range in the radial plication of its surface on both valves. They may

[1] Reference to Mong. U. S. Geol. Surv., No. 51, 1912, will be indicated in this list by Mong. 51 and page, and to this paper by *loc. cit.* and page.

[2] Mong. U. S. Geol. Surv. No. 51, 1912, pp. 796-810

be covered with plications (Mong. 51, pl. 103, fig. 1*e*) or they may have a few (figs. 1*f*, 1*g*) or only a single plication (fig. 1*c*). Another species *H. abnormis* Walcott (Mong. 51, pl. 103, figs. 2, 2*a-e*) has a similar variation in surface character. This variation from the completely plicated or ribbed surface to the smooth shell has made it very difficult to assign the smooth surfaced species to either genus with certainty if the interior of the valves is unknown. I referred several of them to *Synthrophia* (Mong. 51, pp. 798-804) but with the discovery of interiors showing a pseudodeltidium they should be referred to *Huenella* or, if a new genus is to be created for the smooth nonplicate shells, to that new genus. At present I am not prepared to propose such a genus. Specimens of *Huenella texana* with a smooth surface largely predominate in a limestone from Cold Creek Canyon, Texas, (Loc. 71) while the plicated surface predominates among the shells from the limestone of Pack Saddle Mountain (Loc. 68). For the smooth shells I proposed the name of *H. texana laeviuscula* (Mong. 51, p. 808) but this name would equally well apply to the smooth shells from other localities where the plicated shells predominate. Among other species *Camerella calcifera* Billings (Mong. 51, p. 800, pl. 104, figs. 1, 1*a-i*) appears to be a smooth form of *Huenella* but one of the type specimens and a transverse section cut across in front of the beak appears to show a septum supporting a spondilium.

The new species described in this paper and referred to *Syntrophia* may be smooth surface forms of *Huenella* but this cannot now be determined.

SYNTROPHIA cf. CALCIFERA

Syntrophia calcifera (Billings), see Mong. U. S. Geol. Surv., No. 51, 1912, p. 800, pl. 104, figs. 1, 1*a-i*.

A number of specimens of a species of *Syntrophia* that cannot be readily separated from typical forms of *S. calcifera* occur in the central portion of the Mons formation. The species is referred to the Lower Ordovician in Monograph 51, but at present it is referred to the Ozarkian as defined by Ulrich.

Formation and locality.—Ozarkian: (16u) Mons formation. Dove gray limestone on north side of Sinclair Canyon, 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs.

(16y) Compact gray limestone, Sinclair Canyon, 500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on Banff-Windermere motor road.

(21e) Gray, thin-bedded limestones, Sinclair Canyon, about 800 feet (243.8 m.) up the canyon from the first bridge west on Banff-Windermere motor road. South end of Brisco Range, British Columbia, Canada.

SYNTROPHIA ISIS, new species

Plate 117, figs. 14-17

The general form of the valves is much like that of *Syntrophia campbelli* Walcott and *S. rotundata* Walcott (Mong. 51, p. 801 and pl. 103, figs. 4, 4*a-c*) except that the mesial fold of the dorsal valve extends from near the beak to the front margin and the ridges on the side of the mesial furrow of the ventral valve are much stronger, in this respect resembling the dorsal valve of *Huenella billingsi* Walcott (Mong. 51, pl. 102, figs. 5, 5*a, b*).

Dimensions.—A ventral valve 5.5 mm. in length on the median line has a maximum width of 6.25 mm. Dorsal valve 7 mm. long on the median line has a maximum width of 9 mm. Measurements on plane of the margins of the shell.

S. isis is fairly abundant and it occurs in the Cordilleran area from Glacier Lake southeast for 49 miles (78.8 km.) where it is found at Fossil Mountain and also at Ranger Canyon in the Sawback Range.

Formation and locality.—Ozarkian: (65f) Mons formation (Upper) in hard light gray limestone, upper portion of 1a of section. Block that fell from cliff above southeast Lyell Glacier, about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway. (66 o) Light gray limestone 1*a* of section 10 feet (3.0 m.) from top. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain. (64y) Sawback Range, Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch, on Canadian Pacific Railway, Alberta, Canada.

A closely related form occurs at locality 16u, Mons formation; beds of dove gray limestone 30 inches (76.2 cm.) thick, interbedded in gray argillaceous shale. South end of Brisco Range, north side of Sinclair Canyon about 600 feet (182.8 m.) above the creek and 700 feet (213.3 m.) west of Radium Hot Springs, British Columbia, Canada.

SYNTROPHIA NISIS, new species

Plate 119, figs. 1-3

This species is strongly characterized by having a median groove on the mesial fold of the dorsal valve, in this respect resembling

Huenella billingsi Walcott (Mong. 51, pl. 102, fig. 5*c*). The ventral valve has a deep broad mesial furrow that starts very near the apex of the valve and extends to the front margin.

This species is rare at Fossil Mountain and has not been recognized elsewhere.

Dimensions.—The largest dorsal valve has a length of 7 mm. on the median line; maximum width 9 mm., with a convexity of about 3.5 mm. Measurements on plane of the margin of the shell.

Formation and locality.—Ozarkian: (66 o) Mons formation (Upper) in light gray limestone of 1a of section, 10 feet (3 m.) from top. 8.7 miles (13.9 km.) northeast in air line from Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

SYNTROPHIA NONUS, new species

Plate 119, figs. 4-9

S. nonus is a relatively broad transverse form with a short anterior median fold on the dorsal valve and a rather shallow mesial furrow on the ventral valve. The valves are less convex than those of *S. isis*, *S. perilla* and *S. nisis,* in this respect resembling the Ordovician species *S. lateralis* (Whitfield) (Mong. 51, pl. 102, figs. 6*a-e*).

Dimensions.—The largest dorsal valve has a length of 7 mm. and a maximum width of 9 mm. Another dorsal valve is 5.75 mm. in length with a maximum width of 7.75 mm. A ventral valve with a maximum width of 11.5 mm. has a length of 7 mm. Measurements on the plane of the margins of the shell.

The short mesial fold of the dorsal valve is not unlike that of *S. nundina* Walcott (Mong. 51, pl. 102, fig. 4a) but it differs from the latter species in its transverse outline and less convex valves.

Formation and locality.—Ozarkian: (66 o and 66n) Mons formation (Upper) in light gray limestone. 8.7 miles (13.9 km.) northeast in air line from Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain. (21m, 21m′) Thick-bedded hard dove colored limestone. On side of brook .5 mile (.8 km.) below Baker Lake at east base of Brachiopod Mountain and east-southeast of Fossil Mountain, 8 miles (12.8 km) northeast in an air line of Lake Louise Station on the Canadian Pacific Railway. (67t) Gray limestone, *2e* of section, southeast side of head of Douglas Lake Canyon Valley, 12 miles (19.3 km.) east, 5° north, of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

(16y′) Mons formation. Compact gray limestone crowded with broken fossils. Brisco Range, north side of Sinclair Canyon about

500 feet (152.4 m.) above stream on edge of cliff and about 400 feet (121.9 m.) up the canyon from the first bridge west on the Banff-Windermere motor road, British Columbia, Canada.

(17x) Mons formation. Gray finely granular limestone. West slope Stanford Range, east side Columbia River Valley, 5.25 miles (8.4 km.) south of Sinclair Canyon and .25 mile (.4 km.) north of Stoddart Creek, British Columbia, Canada.

SYNTROPHIA PERILLA, new species

Plate 118, figs. 1-7

This is the largest and most abundant species of *Syntrophia* known to me from the Mons formation. It suggests *S. calcifera* (Billings) (Mong. 51, pl. 104, fig. 1, 1*a-i*) in some of its variations and like that species it changes greatly in convexity and outline from the young to its mature stage. This is most marked in the increase of convexity of the valves and the development of the mesial fold and sinus. The older and large shells are rare in the collection, while the young and smaller shells occur in large numbers.

Dimensions.—A large dorsal valve has a length on the median line of 13 mm., with a maximum width of 15.5 mm. A large ventral valve is 14.5 mm. long on the median line and 12.5 mm. in maximum width. Measurements on the plane of the margins of the shell.

Formation and locality.—Ozarkian: (65x) Mons formation (Lower), 1f of section. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.7 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway. (66n) Thin-bedded gray limestone, 1a of section 255 feet (77.7 m.) from summit of Mons. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

Shells that appear to be identical with this species occur in the Mons formation, Sinclair Canyon section (16q), and in the upper portion of the Upper Cambrian (64u, 64v) its presence is suggested by three rather small ventral valves.

(16q) Ozarkian: Mons formation. Thin-bedded gray limestone. Brisco Range, about 2 miles (3.2 km.) up Sinclair Canyon from Radium Hot Springs on north side of canyon near north end of 3d bridge on Banff-Windermere motor road and about 15 miles (24.1 km.) from Lake Windermere in Columbia River Valley, British Columbia, Canada.

(64u, v.) Upper Cambrian: Lyell formation Sawback Range, at head of northeast branch of Ranger Brook Canyon, 10 miles (16 km.) north-northwest of Banff and 3 miles (4.8 km.) north-northeast of Massive Switch on Canadian Pacific Railway, Alberta, Canada.

Genus HUENELLA Walcott

Huenella Walcott, 1908. See Mong. U. S. Geol. Surv., No. 51, p. 805.

Huenella differs from *Syntrophia* in having a more or less radial plicate surface and a sessile pseudospondilium instead of a free spondilium supported on a median septum.

There appear to be two species from the typical Mons formation and two that may be from the Upper Cambrian Lyell formation.

The fine ridges or raised lines on the surface of the two species may mean that they represent a genus distinct from *Huenella*. This type of outer surface is unknown to me on any of the species of *Syntrophia*.

HUENELLA HERA, new species

Plate 119, fig. 10

This species is represented by a specimen of the exterior and a natural cast of the ventral valve; it is moderately convex with a strong sinus that at the front is a little wider than the greatest width of the valve; a slight rounded ridge occurs on each side of the sinus and a few low narrow plications occur on the outer slopes and in the sinus. The general appearance of the valve is not unlike that of some ventral valves of *H. texana* Walcott and *H. abnormis* except that it is shorter and more transverse. The shell is exfoliated near the apex so as to show a cast of the pseudospondilium.

Dimensions.—Length 7 mm., maximum width 8 mm., measured on the plane of the margin of the valves.

Compared with other species this ventral valve approaches in form that of *H. simon* (pl. 118), but it is more transverse in outline and the surface plications are much stronger. It is more like some varieties of *H. texana* in its plications.

Formation and locality.—Upper Cambrian: (64w) Lyell formation. Drift blocks of limestone. Sawback Range, Ranger Brook Canyon, 10 miles (16 km.) in air line west-northwest of Banff, and 2 miles (3.2 km.) north-northeast of Massive Switch on Canadian Pacific Railway, Alberta, Canada.

HUENELLA ICETAS, new species

Plate 120, figs. 1-3

This species is characterized by a deep, broad median sinus on the ventral valve and a rather acutely ridged mesial fold on the dorsal valve that extends from near the posterior margin to the front margin. The surface is marked by about 14 narrow fine radiating ridges each side of the mesial fold of the dorsal valve and slight traces of similar ridges on the mesial fold. The entire surface of the ventral valve is marked by fine radiating ridges similar to those on the dorsal valve.

Dimensions.—A dorsal valve 7.5 mm. in length has a maximum width of 9.5 mm. and a ventral valve 7 mm. long has a maximum width of 9 mm., measured on the plane of the margins of the valves. There is considerable range in the proportions of length and breadth between the young and old shells, also in the strength of the mesial fold and sinus.

The ventral valve may be compared with that of *H. hera* (pl. 119, fig. 10) and the dorsal with that of *H. orientalis* Walcott (Mong. 51, pl. 104, figs. 3*a, b*).

Formation and locality.—Ozarkian: (65e) Mons formation (Lower) in soft, almost granular gray limestone. Above motor road at Ten Mile Canyon on southwest side of Sawback Range, 10 miles (16 km.) by motor road west-northwest of Banff, Alberta, Canada.

HUENELLA JUBA, new species

Plate 119, figs. 11-13

This species is characterized by the alate postero-lateral angles of the valves and strong mesial fold and sinus. The outer surface is marked by many fine radiating ridges or raised lines.

The largest shell is represented by a ventral valve 8.5 mm. in length with a width at the hinge line of 19 mm.

Formation and locality.—Ozarkian: (65e) Mons formation (Lower) in soft, almost granular gray limestone. Above motor road at Ten Mile Canyon on southwest side of Sawback Range, 10 miles (16 km.) by motor road west-northwest of Banff, Alberta, Canada.

(17t) Mons formation. Thick layers of gray limestone near top of Mons outcrop, interbedded in hard shale. West slope of Sabine Mountain 400 feet (121.9 m.) above south end of Columbia Lake, and 2.25 miles (3.6 km.) north of Kootenay River Bridge and about 2 miles (3.2 km.) northeast of Canal Flat Station, Canadian Pacific Railway, British Columbia, Canada.

HUENELLA SIMON, new species

Plate 118, figs. 8, 9

This species is based on a ventral valve that has the outline of *H. icetas* (pl 120, figs.1-3.) It differs in having in shells of similar size a broad, shallow mesial sinus instead of a deep, broad sinus. Surface marked by many radiating fine ridges or raised lines.

Dimensions.—A ventral valve has a maximum width of 10.5 mm. and a length of about 9 mm.

Formation and locality.—Upper Cambrian: (64z) Lyell formation in drift blocks of limestone. Ten Mile Canyon above motor road on southwest side of Sawback Range, 10 miles (16 km.) by motor road west-northwest of Banff, Alberta, Canada.

HUENELLA TEXANA Walcott

Plate 120, figs. 4, 6, 7, 8

Camerella sp. ? Shumard, 1861, Am. Jour. Sci., 2d ser., vol. 32, p. 221.
Syntrophia texana Walcott, 1905, Proc. U. S. Nat. Mus., vol. 28 p. 294.

Since the publication of "Cambrian Brachiopoda" (Mong. U. S. Geol. Surv., No. 51, 1912) two small slabs of limestone collected by Dr. Walter H. Weed have come to hand on which there are a number of beautifully weathered-out valves of this species. These include about the same range of variation in form and outer surface as for *H. texana,* and there are also a number of interiors showing the pseudospondilium, one of which is illustrated in figure 6. Comparison should be made between the illustrations of this species as it occurs in Texas (Mong. 51, pl. 103, figs. 1, 1*a*-*i*) and those from Wyoming.

Dimensions.—The average length of the Wyoming shells is about 7 mm. and maximum width 8.5 mm., measured on the plane of the margins of the valves. This is about the size of the specimens from Texas.

Formation and locality.—Upper Cambrian: (302g) Gallatin formation. Limestone on north slope of Crowfoot Ridge, south of Gallatin Valley, Yellowstone National Park, Wyoming.

On the same surface with *H. texana* a number of specimens of a finely ribbed species of *Huenella* occur, to which I have given the name *H. weedi.*

HUENELLA ? WEEDI, new species

Plate 120, figs. 5, 7, 8

This species occurs more or less abundantly weathered in relief on the surface of gray limestone in association with *Huenella texana* Walcott. The valves are less convex than those of *H. texana,* in this respect resembling those of *H. simon* (pl. 118, figs. 8, 9). The outer surface is similar to that of some specimens of *Eoorthis, E. wichitaensis* Walcott in having sharp narrow raised radiating ribs with one or more intercalated ribs between them. The type of surface also occurs in *H. juba* (pl. 119, fig. 13) and *H. icetas* (pl. 120, figs. 2, 3).

Dimensions.—A large, somewhat crushed ventral valve has a length of 8 mm. and a maximum width of 11.5 mm. A dorsal valve 8 mm. in length has a maximum width of 10.5 mm., measured on the plane of the margins of the valves.

Formation and locality.—Upper Cambrian: (302g) Gallatin formation. Limestone on north slope of Crowfoot Ridge, south of Gallatin Valley, Yellowstone National Park, Wyoming.

BRACHIOPODS FROM ISLAND OF NOVAYA ZEMLYA, RUSSIA

Dr. Olaf Holtedahl announced in 1922 the discovery by a Norwegian scientific expedition led by him, of an "Upper Cambrian Fauna of Pacific Type in the European Arctic Region" near the west coast of the southern island of Novaya Zemlya on the peninsula between Bessimyanni and Gribovii Fjords.[1] He noted the presence in the collections of several species of brachiopods and trilobites and correlated them with forms from western North America. Subsequently he sent the collection to me for examination and description.

The rock containing the specimens was carefully broken up in order to secure all the material possible for study. It was soon discovered that the brachiopods were related to species from the lower Ozarkian Mons fauna of the Cordilleran Province, and the trilobites were of post-Cambrian age. The entire fauna will be published in a report of the expedition. Meantime Dr. Holtedahl very kindly gave me permission to publish the brachiopods in this paper.

The brachiopods include: *Lingulella* cf. *desiderata* Walcott, *L. artica* n. sp., *Acrotreta* sp. undt., *Obolus* (*Westonia*) sp. undt., *Billingsella holtedahli* n. sp., *B. ? oppius* n. sp., *Eoorthis sabus* n. sp., *Huenella triplicata* n. sp. All of these have their representatives in the Upper Cambrian, also in the lower Ozarkian.

Most of the associated trilobites are distinctly of a Lower Ozarkian type and some may belong higher in the series.

Sub-genus WESTONIA Walcott

OBOLUS (WESTONIA) sp. undt.

A fragment of shell suggesting the outline of *O.* (*W.*) *finlandensis* Walcott[2] preserves the outer surface with the characteristic irre-

[1] Amer. Jour. Sci., 5th Ser., Vol. 3, 1922, pp. 343-348.

[2] Mong. U. S. Geol. Surv., No. 51, 1912, pl. 48, fig. 3.

gular inosculating transverse surface lines of *Westonia aurora* (Hall),[1] an Upper Cambrian shell.

Formation and locality.—Ozarkian: (67y) Russia, Island of Novaya Zemlya, west coast of southern island, north side of Gribovii Fjord.

Genus LINGULELLA Salter

LINGULELLA cf. DESIDERATA Walcott

Plate 123, figs. 3-5

This species belongs with a group of small forms that are represented by *Lingulella desiderata* Walcott[2] which has a wide area distribution and ranges from the Upper Cambrian into the Mons fornation of the Ozarkian. The Novaya Zemlya specimens are fairly well preserved and appear to be within the range of variation of the western North American species.

Formation and locality.—Ozarkian: (68b) Russia; Island of Novaya Zemlya; west coast of southern island; Mountains 7 km. northwest of the head of Bessimyanni Fjord.

LINGULELLA ARCTICA, new species

Plate 123, figs. 1, 2

This species agrees in size and outline with the various forms of *Lingulella bella* Walcott,[3] except that it is more elongate. There are only two specimens of the dorsal valve. The shell is largely exfoliated and on the cast of the interior the lines of advance of the central and anterior lateral muscle scars and median septum are outlined; the anterior lateral muscle scars extended into the anterior third of the valve. Fragments of the shell show it to have been of medium thickness and marked on the outer surface by fine concentric lines and striæ of growth.

A valve somewhat flattened by compression is 13 mm. in length and has a maximum width of 6.5 mm.

There is no closely related species to *L. arctica* in the Upper Cambrian or in the Mons formation of the Lower Ozarkian. Some of the smaller species from the latter formation are elongate, notably *L. ibicus*,[4] but they are quite distinct in outline of the valves.

Formation and locality.—Lower Ozarkian: (67y) Russia; Island of Novaya Zemlya, west coast of southern island; Gribovii Fjord.

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[1] *Loc. cit.*, pl. 46, 1h.

[2] Mong. U. S. Geol. Surv., No. 51, 1912, pl. 51, figs. 4 and 5.

[3] Mong. U. S. Geol. Surv., No. 51, 1912, p. 481, pl. 19, figs. 2*d-f*.

[4] Smithsonian Misc. Coll., Vol. 67, No. 9, 1924, pl. 108, figs. 5-8.

Genus ACROTRETA KUTORGA

ACROTRETA, sp. undt.

A very small species of *Acrotreta* is represented by several dorsal valves and crushed ventral valves from which the shell has been exfoliated. The cast of the interior of the dorsal valve shows a long, strong median septum such as occurs in both Middle and Upper Cambrian species, also the Mons formation of the Lower Ozarkian, which has two species *A. atticus* Walcott and *A. discoidea* Walcott. The dorsal valve of *A. atticus* is very much like that of the Novaya Zemlya species. The dorsal valves vary from 2 to 3 mm. in diameter.

Formation and locality.—Ozarkian: (67y) Russia, Island of Novaya Zemlya, west coast of southern island, north side of Gribovii Fjord, and (68b) Mountains 7 km. northwest of the head of Bessimyanni Fjord.

Genus BILLINGSELLA Hall and Clarke

BILLINGSELLA HOLTEDAHLI, new species

Plate 123, figs. 6-16

Dr. Holtedahl calls attention to a shell " that may be nearly related to *Billingsella coloradoensis*[1] that is quite abundant. I find that while the species resembles *B. coloradoensis* (Shumard) closely, it differs in its larger size, outline of cardinal angles, and more uniform surface plications.

Some of the smaller shells may belong to another species, but with the material available it seems best to retain them with the larger shells. The surface characters vary owing to the varying amount of exfoliation caused by adhering to the matrix. It is exceptional to find a specimen with the outer surface uninjured.

Formation and locality.—Ozarkian: (67y) Russia, Island of Novaya Zemlya, west coast of southern island, Gribovii Fjord.

BILLINGSELLA ? OPPIUS, new species

Plate 124, figs. 1-8

This species is characterized by the transverse outline of the valve and uniform rather coarse plications which increase in number by intercalation from near the beak towards the front of the valves. The transverse outline and plication of the valves is more like that of *Protorthis billingsi* (Hartt)[2] than either *Billingsella* or *Eoorthis*.

[1] Amer. Jour. Sci., 5th Ser., Vol. 3, 1922, p. 345.

[2] Mong. U. S. Geol. Surv., No. 51, 1912, pl. 99, figs. 1, 1*a*-*f*.

Formation and locality.—Ozarkian: (67y) Russia, Island of Novaya Zemlya, west coast of southern island, north side of Gribovii Fjord.

Genus EOORTHIS Walcott

Eoorthis Walcott, Mong. U. S. Geol. Surv., No. 51, 1912, p. 772.

EOORTHIS SABUS, new species

Plate 124, figs. 9-15

This species recalls, as Dr. Holtedahl mentions, *Eoorthis wichitaensis* (Walcott). It differs from it in its stronger higher umbo and more abrupt cardinal slopes on the ventral valve. The surface plications and elevated radiating lines vary considerably.

Formation and locality.—Ozarkian: (68b) Russia, Island of Novaya Zemlya, west coast of southern island, mountains 7 km. northwest of the head of Bessimyanni Fjord.

Genus HUENELLA Walcott

See Mong. U. S. Geol. Surv., Vol. 51, 1912, p. 805.

HUENELLA TRIPLICATA, new species

Plate 125, figs. 1-15

Huenella cf. *texana* Holtedahl, 1922, Amer. Jour. Sci., 5th Ser., Vol. III, p. 345, fig. 1. (Illustrates dorsal and ventral valves and compares them with *H. texana* Walcott.)

This species differs from *H. texana,* its nearest representative, in the more uniform distribution of narrow plications on the cardinal slopes, the presence of one or two narrow plications in the strong mesial sinus of the ventral valve, and three strong narrow plications on the high median fold of the dorsal valve.

The cast of the spondilium of the ventral valve is finely preserved in a number of specimens but the main vascular sinuses are somewhat indistinct. The cast of the interior of the dorsal valve shows a small shallow spondilium, anterior and posterior adductor muscle impressions; a rather low area and open delthyrium is preserved on a ventral valve.

The discovery of the genus *Huenella* in Novaya Zemlya by Holtedahl is most interesting, as it is there associated with a lower Ozarkian fauna. In western North America the genus occurs in both the Upper Cambrian and Lower Ozarkian. The species from the latter are *H. orientalis* Walcott, *H. texana* Walcott, and var. *laeviuscula*. *H. icetas* Walcott, and *H. juba* Walcott.

Formation and locality.—Ozarkian: (68b) Russia, Island of Novaya Zemlya, west coast of southern island, mountains 7 km. northwest of the head of Bessimyanni Fjord.

CEPHALOPODA

I have not met with any cephalopods in the Cambrian formations of America. They first appear in the Hungaia zone of the superjacent Lower Ozarkian of the Mt. Robson section and higher up in the upper part of the Mons formation which corresponds in a general way with Etage 3$a\gamma$ of Brögger's section.[1] He illustrates two species, *Orthoceras attavus,* plate 4, figure 9, by a fragment of a phragmacone of a small conch, and *Orthoceras* n. sp. (pl. 4, figs. 8 and 10) by fragments of a larger conch preserving a portion of the living chamber and the phragmacone. Both of these species may fall in the genus *Ellesmeroceras* Foerste.

The range of variation among the specimens of *Ellesmeroceras robsonensis* from the Chushina formation in the Robson district appears to include the specimens referred to the latter species that occur in association with a different grouping of genera and species which may be several hundred feet higher in the section of the Mons formation in the Glacier Lake district. It is possible that the cephalopods came from the Arctic province and did not reach the Glacier Lake district until long after appearing in the Robson district. In any event their presence with the Hungaia fauna in association with *Symphysurina* indicates a somewhat older fauna than that of the Upper Mons to the southeast.

The identity of *Endoceras* (?) *monsensis* of the Upper Mons fauna in the Hungaia fauna of the Robson district is more uncertain than that of *Ellesmeroceras robsonensis*, but it is a similar form and strengthens the view that the *Hungaia* fauna of the Chushina formation of the Robson district is allied to that of the Upper Mons.

Genus ELLESMEROCERAS Foerste

See Davidson University Bull., Vol. 19, 1921, p. 265. (Description and illustration of type species *E. scheii.*)

ELLESMEROCERAS ROBSONENSIS, new species

Plate 126, figs. 5-9*a*

Conch straight on both the ventral and dorsal sides. Apical angle 8° as viewed from the ventral side. Conch sometimes compressed

[1] Die Silurischen Etagen 2 und 3, 1882, pp. 30-177.

laterally so as to give a slightly oval transverse section but in most specimens the section is circular. Shell thin and readily broken. No trace of surface ornamentation has been observed.

A round conch 6.5 mm. in diameter at the base of the living chamber has five cameræ of almost equal length on a distance of 5 mm. from the living chamber. In a specimen 4 mm. in transverse diameter there are 5 cameræ in a distance of 4 mm., and another 5.25 mm.in diameter at the apical end has 16 cameræ in a distance of 18 mm. The sutures of the septa slope from the siphuncle along the median line of the ventral side downward and arch slightly backward at the sides and then forward so as to be slightly in advance of their position on the ventral side where they meet the median line on the dorsal side. On some specimens the sutures are almost at right angles to the axis of the conch.

The siphuncle is small, round and oval in compressed conchs; it is in contact with the ventral wall of the conch; in a compressed septum 6 mm. in its dorso-ventral diameter the siphuncle has a dorso-ventral diameter of 2.25 mm. by 1.75 mm. The septa are rather strongly concave so that their depth is equal to the space between the sutures. The siphuncle contracts a little between the septa, which gives it a slightly beaded appearance.

The outer chamber of the conch is not fully preserved, but one specimen indicates that it was slightly expanded towards the upper end.

Observations.—This is a small species of which many fragments are found in association with brachiopods and fragments of trilobites. The largest living chamber in the collection has a diameter of 8 mm. a little in advance of the last cameræ which indicates that the conch was not over 6 to 6.5 cm. in length.

This conch seems to fall within the genus *Ellesmeroceras* as described and illustrated by Foerste. The exact stratigraphic horizon of the type species is in doubt, but as the closely allied form *E. robsonensis* is from the Lower Ozarkian, it may be that the genotype is from the Lower Ozarkian, as it is a straight conch and not curved as are most of the Upper Ozarkian conches in which the siphuncle is in contact with the ventral wall. *E. scheii* Foerste is from Ellesmereland and is tentatively referred to the Canadian (Ordovician) by Foerste.

Formation and locality.—Lower Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson

Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

Mons formation: (64p) Cliff on southeast side of Mons Glacier, above head of Glacier Lake canyon valley, about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Mons formation: (65z) 1*a* of section. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.6 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Ozarkian: (66n) Mons formation. Thin-bedded gray limestone, 1*a* of section, 255 feet (77.7 m.) from summit of Mons. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

A fragment of a somewhat similar form of conch that may belong to *Ellesmeroceras* occurs at locality 30w. Lower Ozarkian: Notch Peak formation. Drift boulder supposed to have been derived from 1*a* of section. About 2 miles (3.2 km.) south of Marjum Pass, House Range, Millard County, Utah.

ENDOCERAS (?) MONSENSIS, new species

Plate 126, figs. 4, 4*a*, 4*b*

Conch annulated, straight, laterally compressed so as to give an oval dorso-ventral section. A septum with a major axis of 3.75 mm. has a transverse axis of 2.75 mm.; this specimen of the phragmacone has 5 strong narrow annulations in a distance of 8 mm., with rounded depressions between. No trace of surface ornamentation has been observed. Living chamber and siphuncle unknown.

A specimen 9 mm. in length has 5 cameræ of almost equal length: the sutures of the septa cross the ventral side at the foot of the lower (apical) slope of the annular ridge and slope backward so as to cross the front slope of the next posterior annular ridge midway between the ventral and dorsal median axial line and then curve forward to meet at the dorsal median axial line on the back slope of the annular ridge directly opposite the suture on the ventral side. Septa concave and nearly as deep as the length of the cameræ.

A portion of a phragmacone occurs with the Lower Ozarkian fauna at locality 185z that is similar to that of *E.* (*?*) *monsensis* except that the annular ridges are not as prominent, but as this may result from the condition of preservation, I am tentatively referring the specimen to this species.

Observations.—The largest conch in the collection has a dorso-ventral diameter of 3.75 mm. The outer shell of the conch was thin and readily crushed so as to throw the septa at a very oblique angle to the axis. Specimens are rarely seen even as fragments.

In the absence of surface markings, siphuncle and living chamber, I refer the species to *Endoceras,* pending the discovery of more complete specimens. It has some of the characters of *Ellesmeroceras* but the strong annulations may indicate other differences that may be of generic importance.

Formation and locality.—Lower Ozarkian: (64p) Mons formation, 18 feet (5.4 m.) from top of 1a of field section. Cliff on southeast side of Mons Glacier, above head of Glacier Lake Canyon Valley, about 50 miles (80.4 km.) northwest of Lake Louise Station on Canadian Pacific Railway. (66n) Thin-bedded gray limestone, 1a of section, 255 feet (77.7 m.) from summit of Mons. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain, Alberta, Canada.

(61q) Chushina formation: gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

The specimens from the Chushina formation are very small and slender and may possibly belong to another species.

Lower Ozarkian: (185z) St. Charles formation. Blacksmith Fork Canyon about 9 miles (14.4 km.) east of Hyrum, Cache County, Utah.

NOTOSTRACA SARS

Family TECHNOPHORIDÆ Miller

Technophoridæ Miller, 1889, North Amer. Geol. and Pal., p. 458.

S. A. Miller proposed this term to include the genus *Technophorus,* and referred one species to it, *T. faberi* Miller. He considered the species to be a lamellibranch, where it remained until 1913 when Dr. R. S. Bassler placed *Technophorus* along with *Euchasma, Eopteria* and *Ischyrina* Billings under the Branchiopoda and order *Notostraca,*[1] as he considered that the carapace was folded over on the

[1] Text Book pal. Zittle, Eastman, 1913, p. 733.

median ventral line as in *Apus* and that there was not any hinge line present.

All of the genera of the *Technophoridæ* have the dorsal shield folded sharply over the ventral median line so as to form a bivalve appearing shell that was considered to be that of a lamellibranch; this deception was accentuated by the interior of the carapace, which has on each side a ridge extending down from near the ventral median line more or less obliquely towards the margin of the carapace, and the casts of the interior showed also a strong beak projecting anteriorly. It was quite natural to compare the supposed lamellibranch with *Nuculites* and to refer it to the family *Ctenodontidæ.*

All of the genera mentioned have a strong rib or ribs extending from the highest point on the antero-ventral fold to the postero-lateral angle of the carapace, that gives them a very distinct character that is unlike that of the genus *Ozomia* now proposed for the species occurring in the Lower Ozarkian.

Genus OZOMIA, new genus

Carapace as folded on the median ventral line, equivalue, inequilateral, transverse; rounded subquadrilateral in outline on each side; moderately convex on each side; the margins of the carapace met beneath the dorsal side and gapped a little at the anterior and posterior ends; outer surface smooth. Interior of carapace on each side with a short clavicular-like ridge; adductor muscle scar between the ridge and anterior margin of the carapace.

Genotype.—*Ozomia lucan* Walcott.

Stratigraphic range.—Upper 50 feet (15.2 m.) of the Lower Ozarkian Mons formation.

Geographic distribution.—Cordilleran area from Glacier Lake near the head of the Saskatchewan River, Alberta, Canada, southeast 49 miles (78.8 km.) to Fossil Mountain and head of Douglas Lake Canyon north of Bonnett Peak; also about 800 miles (1287 km.) south in Blacksmith Fork canyon in northern Utah.

OZOMIA LUCAN, new species

Plate 126, figs. 1, 2, 3, 3*a*

This species is known only from natural casts of the interior of the two sides of the carapace; the casts indicate a moderate convexity; a rounded outline with a straight ventral margin from the high point out to the broadly rounded posterior ends; in some specimens the posterior fourth of the margin slopes upward and the anterior end is almost as broadly rounded as the posterior. The length of the carapace is a little greater than the distance from the median ventral fold to the margins. The largest undistorted specimen in the collection has a height of 9.25 mm. on each side and length of 11.5 mm. The sides gaped slightly at both the anterior and posterior ends, as indicated by the casts. The test was thin on the sides and in all localities and condition of preservation in the different layers of limestone it adheres to the matrix so closely that no traces have been observed of its outer surface; it was probably smooth or finely lined as the casts show only a faint trace of lines radiating from the anterior crest of the fold toward the postero-lateral margins.

The cast of the interior indicates a narrow deep clavicular-like ridge that extends about one-fourth the distance towards the antero-basal margin, or it may be directed towards the postero-basal margin; the two extremes of direction are illustrated by figures 1, 2, 3, pl. 121.

A rather large adductor muscle scar is faintly outlined between the clavicular-like ridge and the anterior margin.

Observations.—This is the only species of the genus known to me.

The type specimens of *O. lucan* are from the upper portion of the Mons formation, locality 66n. The species is also known from the Glacier Lake—Saskatchewan River area and southeast to the northern section of the Sawback Range, Alberta, and in the Blacksmith Fork section of northern Utah.

Formation and locality.—Ozarkian: (66n) Mons formation. Thin-bedded gray limestone, 1a of section, 255 feet (77.7 m.) from summit of Mons. 8.7 miles (13.9 km.) northeast in air line of Lake Louise Station on the Canadian Pacific Railway at the east foot of Fossil Mountain. (64p) 18 feet (5.4 m.) from top of 1a of field section. Cliff on southeast side of Mons glacier, above head of Glacier Lake Canyon Valley, about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (65g) Block that fell from cliff above southeast Lyell Glacier, about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway. (65z) 1a of section. North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.6 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway. (67r) Gray limestone in upper portion of Mons 16 feet (4.8 m.) from top of formation.

Southeast side of head of Douglas Lake Canyon Valley, 12.75 miles (20.5 km.) east, 5° north, of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

(185z) St. Charles formation, in limestones about 200 feet (60.9 m.) below No. 1 of section of 1912. Blacksmith Fork Canyon about 9 miles (14.4 km.) east of Hyrum, Cache County, Utah.

DESCRIPTION OF PLATE 106

PAGE

Micromitra zenobia Walcott 481

FIG. 1. (×2.) Ventral and dorsal valve, flattened, broken and a little distorted on the surface of shaly limestone. U. S. Nat. Mus., Cat. No. 69631.

2. (×2.) A ventral and dorsal valve compressed, broken and transversely distorted on surface of shaly limestone. U. S. Nat. Mus., Cat. No. 69632.

3. (×2.) A small ventral and dorsal valve illustrating transverse distortion. U. S. Nat. Mus., Cat. No. 69633.

4. (×3.) A ventral and dorsal valve vertically distorted. U. S. Nat. Mus., Cat. No. 69634.

5. (Natural size.) A distorted dorsal valve preserving concentric surface striæ. U. S. Nat. Mus., Cat. No. 69635.

6. (Natural size.) A dorsal valve shortened by distortion. U. S. Nat. Mus., Cat. No. 69636.

7. (Natural size.) A distorted ventral valve that has the outline of a dorsal valve of *Lingulella*. U. S. Nat. Mus., Cat. No. 69637.

The specimens represented by figs. 1-7 are from locality 61j, Middle Cambrian: Stephen formation; buff weathering band of calcareo-argillaceous shale; west slope of Mt. Field, B. C., Can.

Obolus ion Walcott 482

FIG. 8. (×4.) A less acuminate ventral valve than fig. 9. U. S. Nat. Mus., Cat. No. 69638

9. (×4.) A broad form of ventral valve. U. S. Nat. Mus., Cat. No. 69639.

10. (×4.) A partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69640.

The specimens represented by figs. 8-10 are from locality 16q, Ozarkian: Mons formation; thin-bedded gray limestone; Brisco Range, Sinclair Canyon, B. C., Can.

Obolus perone Walcott 484

FIG. 11. (×2.) Flattened and partially eroded dorsal valve. U. S. Nat. Mus., Cat. No. 69641.

The specimen represented by fig. 11 is from the Upper Cambrian: Ottertail limestone, Moose Creek, southeast of Field, B. C., Can.

Obolus leda Walcott 483

FIG. 12. (×6.) A ventral valve doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 69642.

13. (×6.) Ventral valve. The front margin outlined from fig. 14. U. S. Nat. Mus., Cat. No. 69643.

14. (×6.) Interior of ventral valve. U. S. Nat. Mus., Cat. No. 69644.

15. (×6.) Exterior of dorsal valve. U. S. Nat. Mus., Cat. No. 69645.

The specimens represented by figs. 12-15 are from locality 30m, Ozarkian: Notch Peak formation; compact dove-colored limestone, north slope of Notch Peak, House Range, Utah.

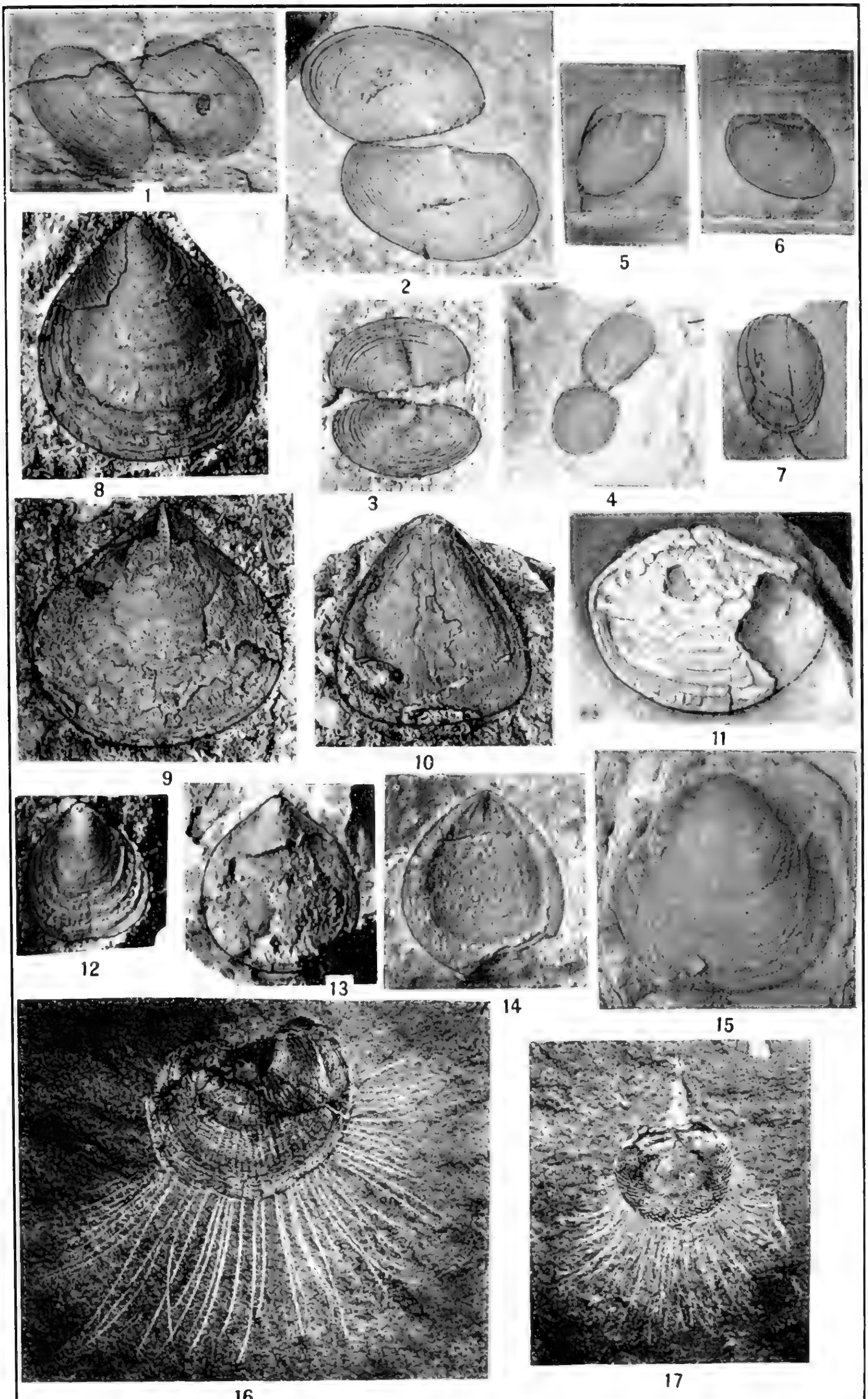
Micromitra (Iphidella) pannula (White) 481

FIG. 16. (×3.) A ventral valve with fine setæ beautifully preserved. U. S. Nat. Mus., Cat. No. 69646.

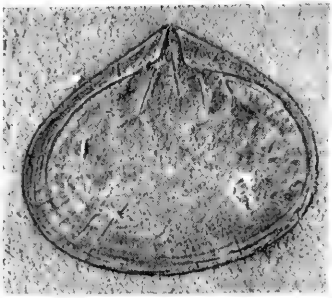
17. (×3.) Ventral valve preserving pedicle and setæ. U. S. Nat. Mus., Cat. No. 59801.

This specimen was illustrated in 1913, Research in China, Vol. 3, Cambrian Faunas of China, pl. 1, fig. 13.

The two specimens represented by figs. 16 and 17 are from locality 35k, Middle Cambrian: Burgess Shale, north of Field, B. C., Can.



MICROMITRA-OBOLUS.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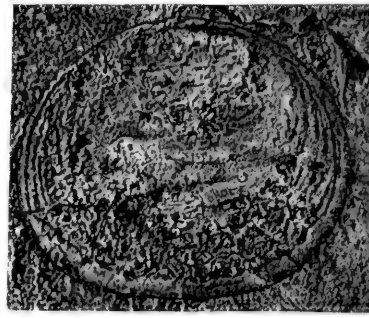
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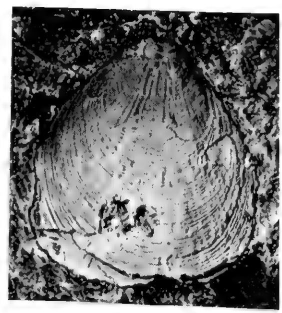
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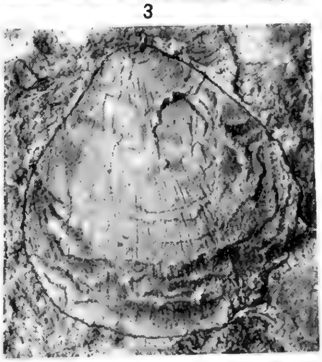
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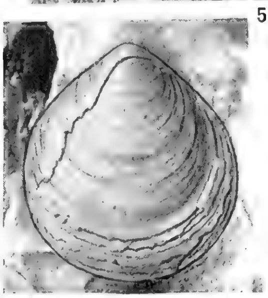
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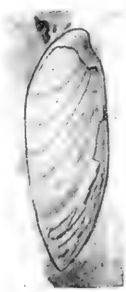
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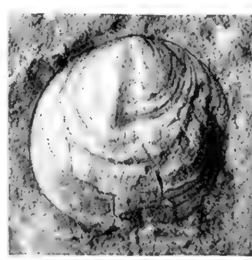
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OBOLUS.

DESCRIPTION OF PLATE 107

FIG. 1. (× 6.) Interior of a ventral valve flattened in shaly limestone so as to give it too much width. U. S. Nat. Mus., Cat. No. 69647.

2. (× 6.) Dorsal valve associated with the ventral valve fig. 1, widened by compression. U. S. Nat. Mus., Cat. No. 69648.

3. (× 6.) Exfoliated dorsal valve in limestone preserving the natural outline. U. S. Nat. Mus., Cat. No. 69649.

The specimens represented by figs. 1-3 are from locality 63x, Upper Cambrian: Ottertail formation; thin-bedded limestone, Wolverine Pass, B. C., Can.

FIG. 4. (× 4.) Partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69650.

5. (× 4.) Exfoliated ventral valve with front margin broken. U. S. Nat. Mus., Cat. No. 69651.

The specimens represented by figs. 4 and 5 are from locality 61q, Ozarkian: Chushina formation, gray limestone, Robson Peak District, B. C., Can.

FIG. 6. (× 4.) Partially exfoliated ventral valve. U. S. Nat. Mus., Cat. No. 69652.

The specimen represented by fig. 6 is from locality 16r, Ozarkian: Mons formation; Brisco Range, Sinclair Canyon, B. C., Can.

FIGS. 7, 7*a*. (× 4.) Exterior view of ventral valve and side outline showing convexity. U. S. Nat. Mus., Cat. No. 69653.

8. (× 4.) Dorsal valve associated with specimen represented by fig. 7. U. S. Nat. Mus., Cat. No. 69654.

The specimens represented by figs. 7, 7*a*, 8, are from locality 67n, Ordovician: Sarbach formation, in a hard, dirty gray, limestone, northeast slope of Fossil Mountain, Alberta, Can.

DESCRIPTION OF PLATE 108

PAGE

Obolus (Fordinia) nestor Walcott 488

FIG. 1. (×4.) Partially exfoliated dorsal valve in which the visceral area is outlined. U. S. Nat. Mus., Cat. No. 69655.

2. (×6.) A small ventral valve associated with the specimen represented by fig. 1. U. S. Nat. Mus., Cat. No. 69656.

The specimens represented by figs. 1 and 2 are from locality 64w, Upper Cambrian: Lyell formation, Sawback Range, Alberta, Can.

Lingulella cf. *desiderata* Walcott 490

FIG. 3. (×6.) Ventral valve with fine concentric striæ. U. S. Nat. Mus., Cat. No. 69657.

4. (×6.) A small convex dorsal valve. U. S. Nat. Mus., Cat. No. 69658.

The specimens represented by figs. 3 and 4 are from locality 61q, Ozarkian: Chushina formation; gray limestone, Robson Peak, B. C., Can.

Lingulella ibicus Walcott. (See pl. 109, figs. 8, 9) 491

FIG. 5. (×6.) A finely preserved ventral valve. U. S. Nat. Mus., Cat. No. 69659.

6. (×6.) U. S. Nat. Mus., Cat. No. 69817.

7. (×4.) A dorsal valve varying slightly in outline from fig. 8. U. S. Nat. Mus., Cat. No. 69661.

8. (×4.) A dorsal valve associated with the specimen represented by fig. 5. U. S. Nat. Mus., Cat. No. 69662.

The specimens represented by figs. 5-8 are from locality 61q. Same as for figures 3, 4 above.

Lingulella nepos Walcott 493

FIG. 9. (×6.) Partially exfoliated ventral valve. U. S. Nat. Mus., Cat. No. 69663.

10. (×6.) Well preserved dorsal valve. U. S. Nat. Mus., Cat. No. 69664.

11. (×6.) A small ventral valve preserving the outer surface of the test. U. S. Nat. Mus., Cat. No. 69665.

The specimens represented by figs. 9-11 are from locality 16q, Ozarkian: Mons formation, in thin-bedded gray limestone; Brisco Range, Sinclair Canyon, B. C., Can.

Lingulella nechos Walcott 492

FIGS. 12, *12a*. (×2.) Top view and side outline of a dorsal valve. U. S. Nat. Mus., Cat. No. 69666.

The specimens represented by figs. 12, *12a*, are from locality 67n, Ordovician: Sarbach formation, in a hard, dirty gray, limestone. Northeast slope of Fossil Mountain, Alberta, Can.

Lingulella nerva Walcott 493

FIGS. 13, *13a*. (×4.) Top view and side outline of ventral valve. U. S. Nat. Mus., Cat. No. 69667.

14. (×4.) Top view of dorsal valve. U. S. Nat. Mus., Cat. No. 69668.

The specimens represented by figs. 13 and 14 are from locality 16r, Ozarkian: Mons formation; Brisco Range, Sinclair Canyon, B. C., Can.

Lingulella ninus Walcott 494

FIG. 15. (×6.) Ventral valve preserving a little of the exterior surface. U. S. Nat. Mus., Cat. No. 69669.

16. (×4.) Partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69670.

The specimens represented by figs. 15 and 16 are from locality 61q, as given under figs. 3 and 4 above.

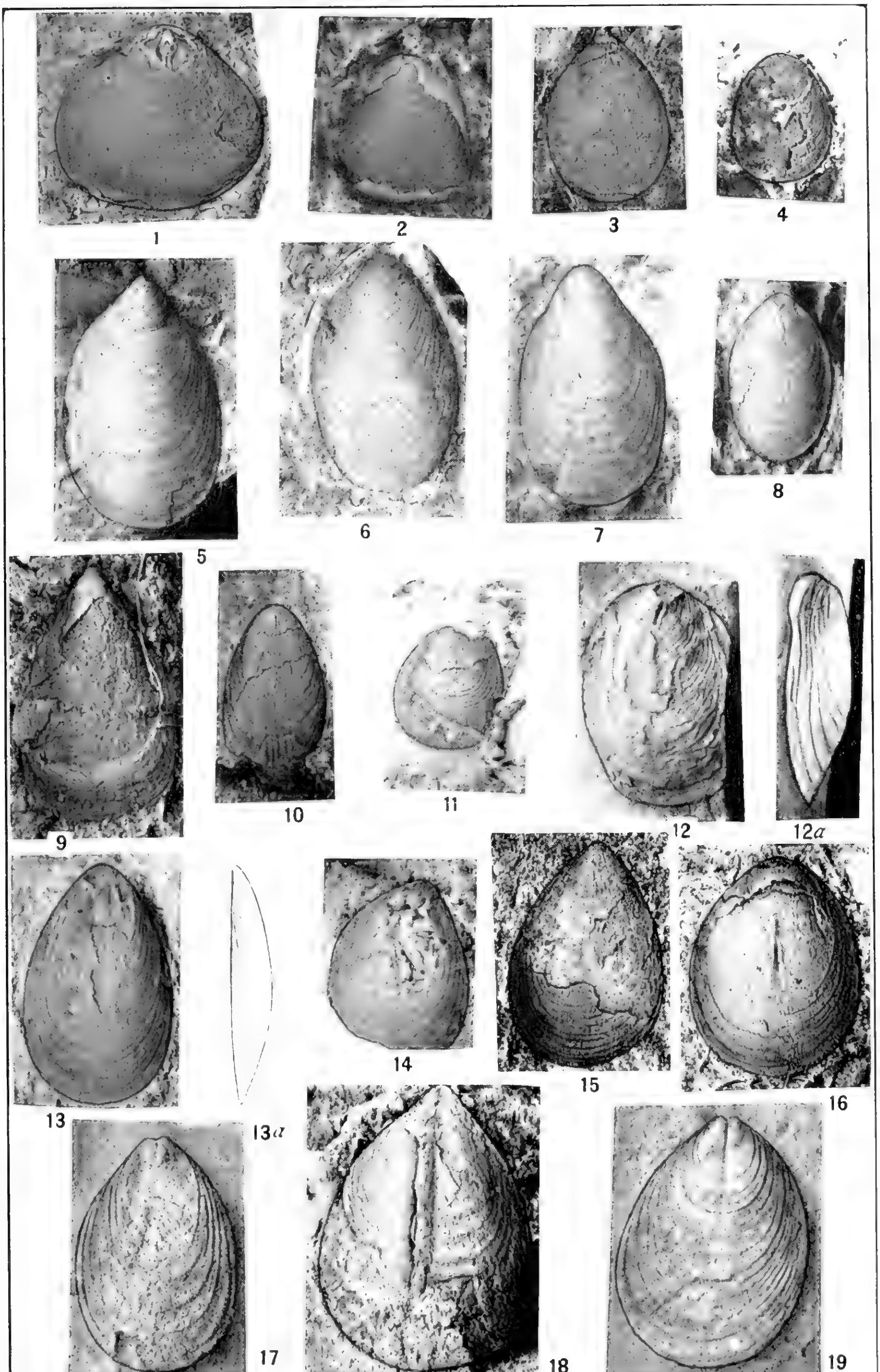
Lingulella siliqua Walcott. (See pl. 109, fig. 1) 495

FIG. 17. (×4.) A ventral ? valve partially flattened on the surface of shaly limestone. U. S. Nat. Mus., Cat. No. 69671.

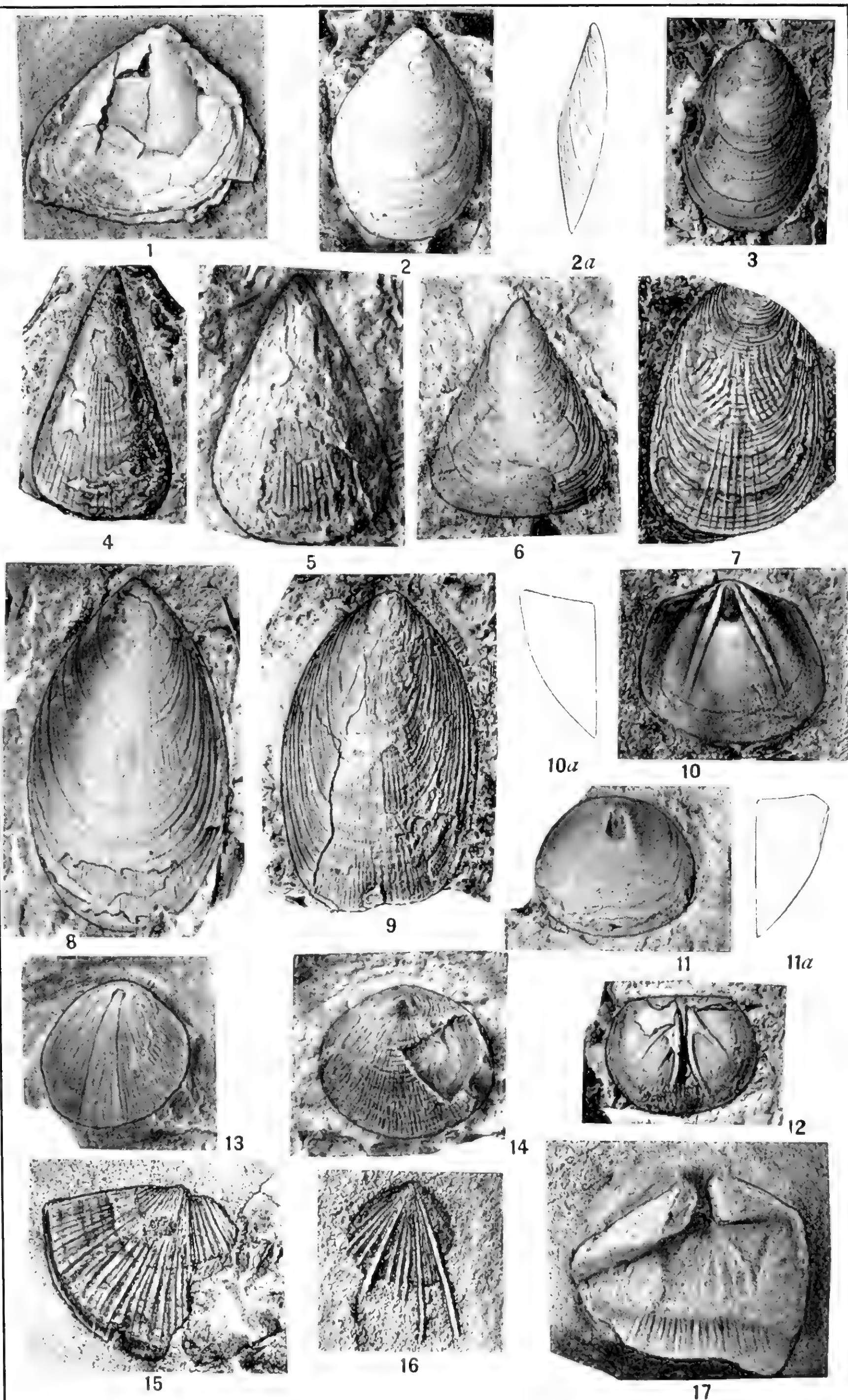
18. (×4.) A small imperfect ventral valve broken out of limestone. U. S. Nat. Mus., Cat. No. 69672.

19. (×4.) A crushed and somewhat broken dorsal valve on surface of limestone. U. S. Nat. Mus., Cat. No. 69673.

The specimens represented by figs. 17-19 are from locality 63x, Upper Cambrian: Ottertail formation; thin-bedded limestones, Wolverine Pass, B. C., Can.



OBOLUS-LINGULELLA.



LINGULELLA-LINGULEPIS-ACROTRETA-NISUSIA.

DESCRIPTION OF PLATE 109

PAGE

Lingulella siliqua Walcott. (See pl. 108, figs. 17-19) 495

FIG. 1. (×4.) A crushed dorsal valve doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 69674.

For locality, see pl. 108, figs. 17-19.

Lingulella remus Walcott 494

FIGS. 2, 2*a*. (×4). Ventral valve and side outline. U. S. Nat. Mus., Cat. No. 69675.

3. (×4.) Dorsal valve and side outline. U. S. Nat. Mus., Cat. No. 69676.

The specimens represented by figs. 2, 2*a*, 3 are from locality 61q, Ozarkian; Chushina formation; gray limestone, Robson Peak District, B. C., Can.

Lingulepis nabis Walcott 489

FIG. 4. (×6.) A small but well preserved ventral valve. U. S. Nat. Mus., Cat. No. 69677.

5. (×6.) Acuminate ventral valve with front margin broken away. U. S. Nat. Mus., Cat. No. 69678.

6. (×6.) A broad ventral valve that may not belong to this species. U. S. Nat. Mus., Cat. No. 69679.

7. (×6.) Partially exfoliated dorsal valve illustrating vascular markings. U. S. Nat. Mus., Cat. No. 69680.

The specimens represented by figs. 4-7 are from locality 16q, Ozarkian: Mons formation, gray limestone; Brisco Range, Sinclair Canyon, B. C., Can.

Lingulella ibicus Walcott. (See pl. 108, figs. 5-8) 491

FIG. 8. (×6.) A ventral valve from the type locality 61q. (See description of figs. 5-8, pl. 108.) U. S. Nat. Mus., Cat. No. 69660.

9. (×6.) A dorsal valve from Sinclair Canyon, locality 16q. (See under description of fig. 7 above). U. S. Nat. Mus., Cat. No. 69681.

Acrotreta atticus Walcott 496

FIG. 10, 10*a*. (×6.) Top, side and back view of a ventral valve. U. S. Nat. Mus., Cat. No. 61682.

11, 11*a*. (×6.) Top, side and back view of a ventral valve. U. S. Nat. Mus., Cat. No. 61683.

12. (×6.) Natural cast of interior of dorsal valve. U. S. Nat. Mus., Cat. No. 61684.

The specimens represented by figs. 10-12 are from locality 61q. (See fig. 2, above.)

Acrotreta discoidea Walcott 497

FIG. 13. (×6.) Top view of ventral valve. U. S. Nat. Mus., Cat. No. 69685.

14. (×6.) Exterior of dorsal valve. U. S. Nat. Mus., 69686.

The specimens represented by figs. 13 and 14 are from locality 61q (see fig. 2, above).

Nisusia spinigera Walcott 498

FIG. 15. (×4.) Exterior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69687.

16. (×6.) Spines on surface costæ. U. S. Nat. Mus., Cat. No. 69688.

17. (×4.) Interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69689.

The specimens represented by figs. 15-17 are from locality 63x, Upper Cambrian: Ottertail formation; limestones, Wolverine Pass, B. C., Can.

DESCRIPTION OF PLATE 110

PAGE

Nisusia burgessensis Walcott 499

FIG. 1. (× 3.) Ventral valve with attached surface spines. U. S. Nat. Mus., Cat. No. 69690.

2. (× 2.) Natural cast of exterior of a compressed ventral valve. U. S. Nat. Mus., Cat. No. 69691.

3. (× 2.) Interior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69692.

4. (× 2.) Outer surface of shell. U. S. Nat. Mus., Cat. No. 69693.

5. (× 6.) A small ventral valve enlarged to illustrate outer surface. U. S. Nat. Mus., Cat. No. 69694.

6. (× 2.) Interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69695.

7. (× 2.) Exterior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69696.

8. (× 2.) Top view of natural cast of interior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69697.

The specimens represented by figs. 1-8 are from locality 35k, Middle Cambrian: Burgess shale, B. C., Can.

Nisusia (*Jamesella*) *oriens* Walcott 500

FIG. 9, 9*a*. (× 2.) Top and side views of a ventral valve with prolonged mesial sinus. U. S. Nat. Mus., Cat. No. 69698.

10, 10*a*. (× 2.) Top and side views of a ventral valve with a broad mesial sinus. U. S. Nat. Mus., Cat. No. 69699.

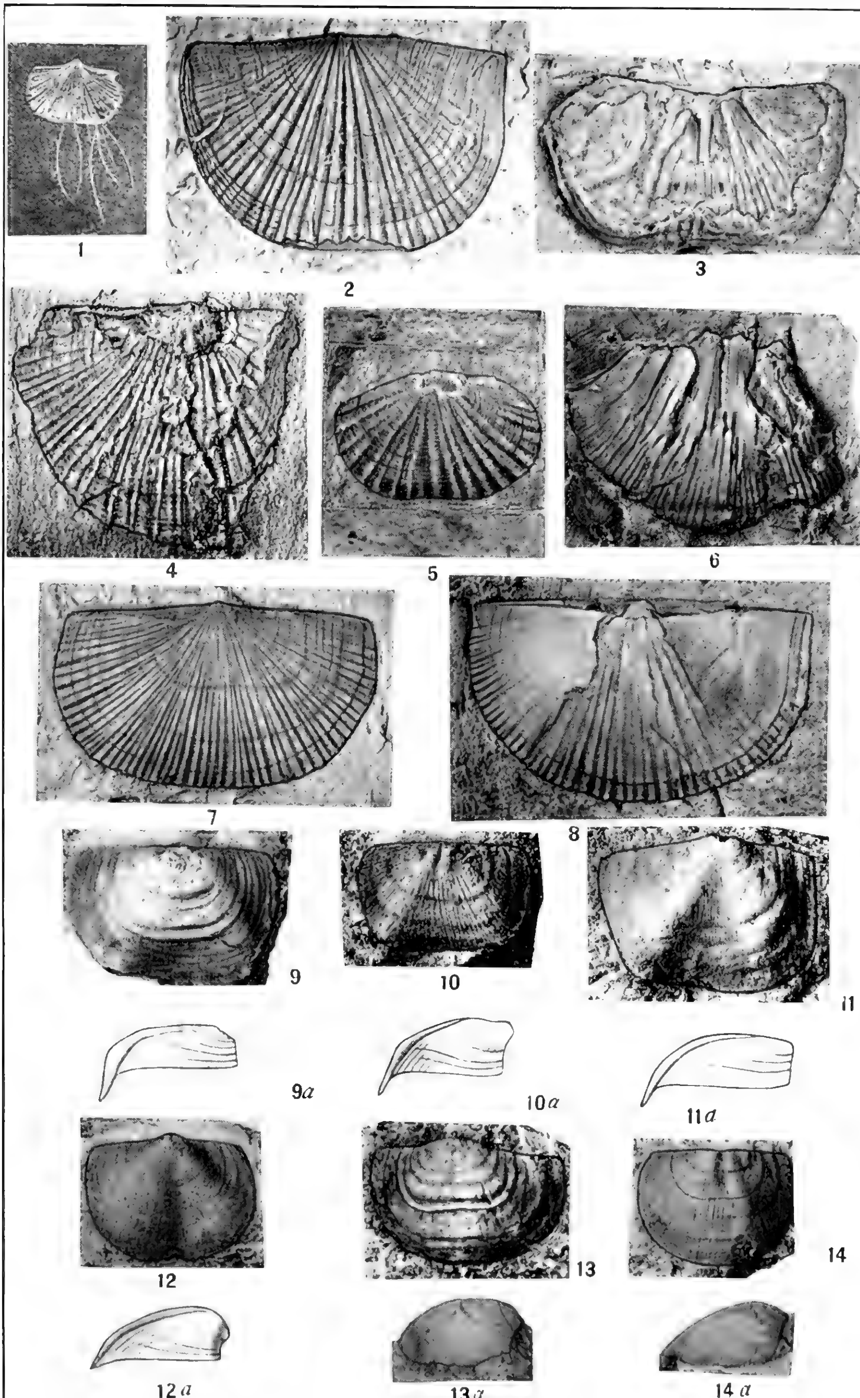
11, 11*a*. (× 2.) Ventral valve with a small dorsal valve beside it. U. S. Nat. Mus., Cat. No. 69700.

12, 12*a*. (× 2.) Top and side view of a ventral valve. U. S. Nat. Mus., Cat. No. 69701.

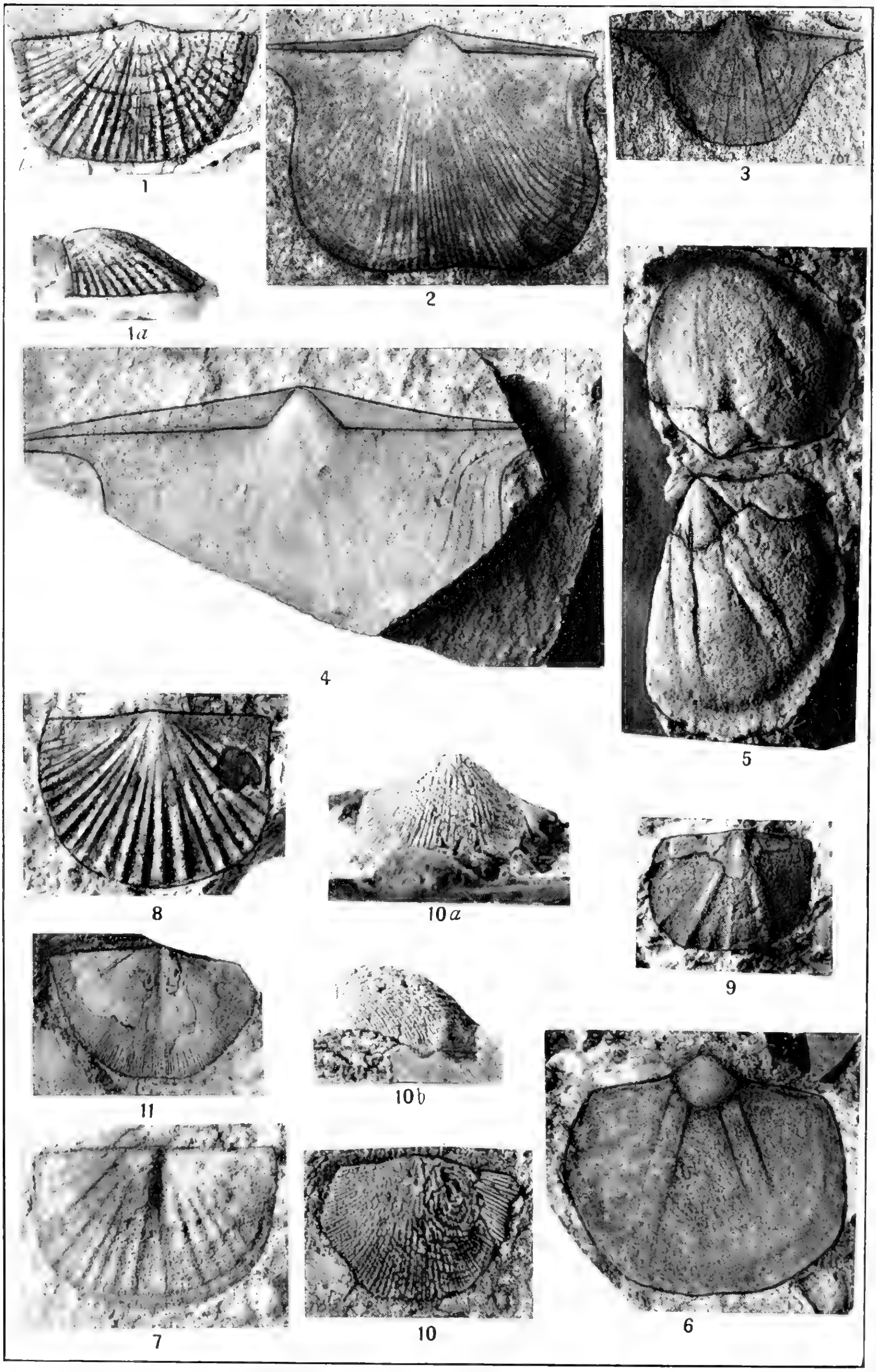
13, 13*a*. (× 2.) Top and side view of a dorsal valve. U. S. Nat. Mus., Cat. No. 69702.

14, 14*a*. (× 2.) Top and side view of a depressed dorsal valve. U. S. Nat. Mus., Cat. No. 69703.

The specimens represented by figs. 9-14*a* are from locality 41b, Lower Cambrian: lower beds of Forteau Point, Forteau Bay, north shore of Straits of Belle Isle, Labrador, Canada.



NISUSIA.



NISUSIA-WIMANELLA-BILLINGSELLA-PROTORTHIS.

DESCRIPTION OF PLATE 111

FIGS. 1, 1*a*. (× 2.) Top and side view. U. S. Nat. Mus., Cat. No. 69704.

The specimens represented by figs. 1 and 1*a* are from locality 14s, Middle Cambrian: Stephen formation; Mount Stephen, above Field, B. C., Can.

FIG. 2. (× 4.) Portion of an exfoliated ventral valve with faint vascular sinuses. U. S. Nat. Mus., Cat. No. 69705.

3. (× 4.) A small ventral valve with acute cardinal angles. U. S. Nat. Mus., Cat. No. 69706.

4. (× 4.) Exfoliated dorsal valve with acute cardinal angle. U. S. Nat. Mus., Cat. No. 69707.

The specimens represented by figs. 2-4 are from locality 61v, Middle Cambrian: Titkana formation; gray shaly limestone, Robson Peak District, Alberta, Can.

FIG. 5. (× 4.) Natural casts of interior of ventral valves. U. S. Nat. Mus., Cat. No. 69708.

6. (× 4.) Natural cast of interior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69709.

7. (× 4.) Partially exfoliated dorsal valve somewhat doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 69710.

The specimens represented by figs. 5-7 are from locality 64l, Upper Cambrian: Lyell formation; gray limestone, Glacier Lake Canyon, Alberta, Can.

FIG. 8. (× 4.) Exterior of dorsal valve. U. S. Nat. Mus., Cat. No. 69711.

9. (× 4.) Partially exfoliated ventral valve showing main sinuses. U. S. Nat. Mus., Cat. No. 69712.

The specimens represented by figs. 8 and 9 are from locality 21j, Ozarkian: Mons formation, hard gray limestone, east of Golden, B. C., Can.

FIGS. 10, 10*a*, 10*b*. (× 4.) Top, side and back view of a small ventral valve. U. S. Nat. Mus., Cat. No. 69713.

11. (× 2.) Partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69714.

The specimens represented by figs. 10, 10*a*, 10*b*, and 11 are from locality 65w, Ozarkian: Mons formation, Clearwater Canyon, Alberta, Can.

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PAGE

Billingsella archias Walcott 501

FIG. 1. (× 4.) Exterior of a ventral valve. U. S. Nat. Mus., Cat. No. 69715.

2. (× 4.) Natural cast of interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69716.

3. (× 4.) Natural cast of interior of a broken ventral valve. U. S. Nat. Mus., Cat. No. 69717.

4. (× 4.) Natural cast of interior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69718.

5. (× 4.) Natural cast of an interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69719.

The specimens represented by figs. 1-5 are from locality 61q, Ozarkian: Chushina formation, Robson Peak District, B. C., Can.

Eoorthis vicina Walcott 512

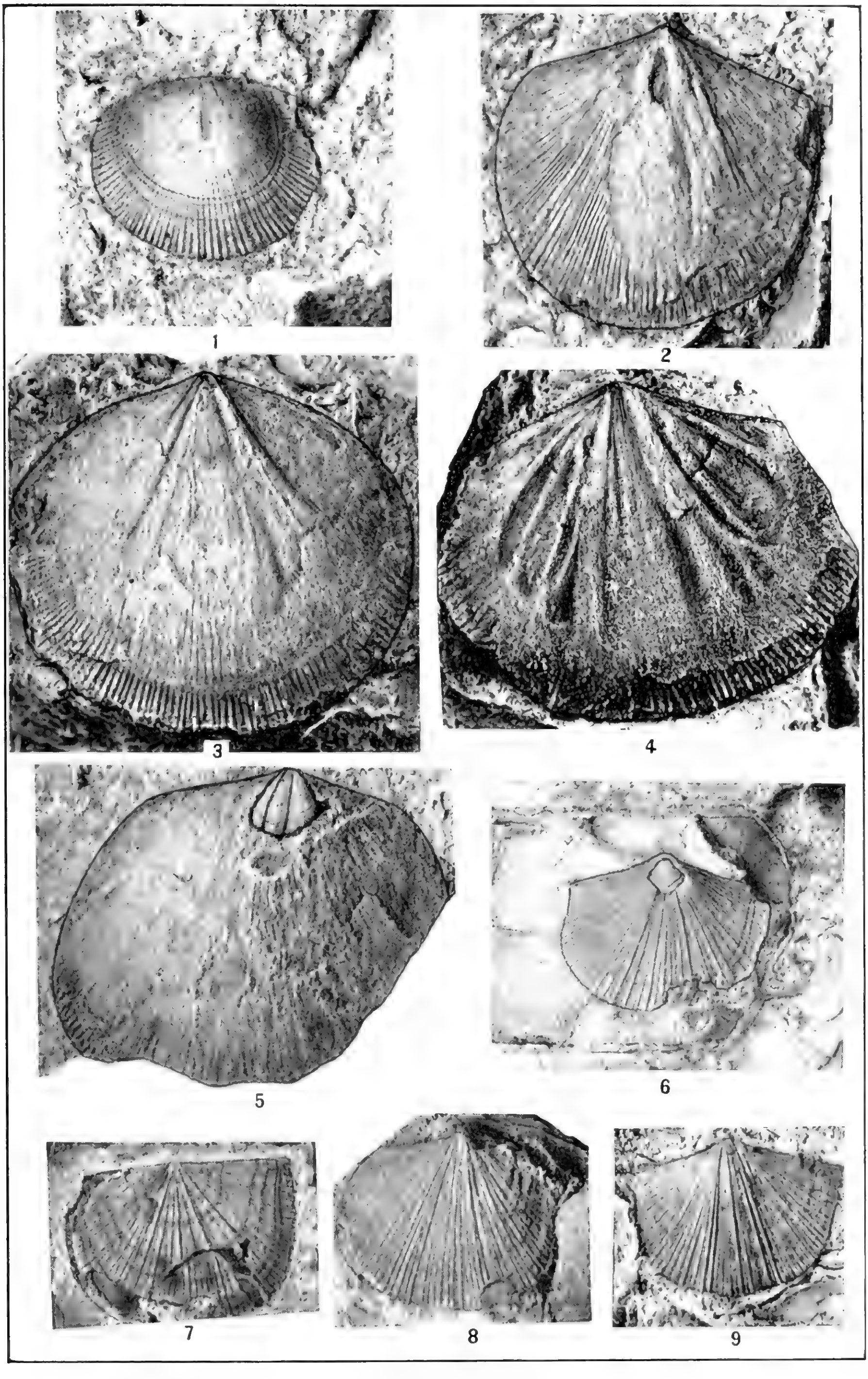
FIG. 6. (× 3.) Exterior of ventral valve. U. S. Nat. Mus., Cat. No. 69720.

7. (× 3.) Exterior of dorsal valve. U. S. Nat. Mus., Cat. No. 69721.

8. (× 3.) Exterior of ventral valve. U. S. Nat. Mus., Cat. No. 69722.

9. (× 3.) Partial cast of interior of ventral valve. U. S. Nat. Mus., Cat. No. 69723.

The specimens represented by figs. 6-9 are from locality 65x, Ozarkian: Mons formation, Clearwater Canyon, Alberta, Can.



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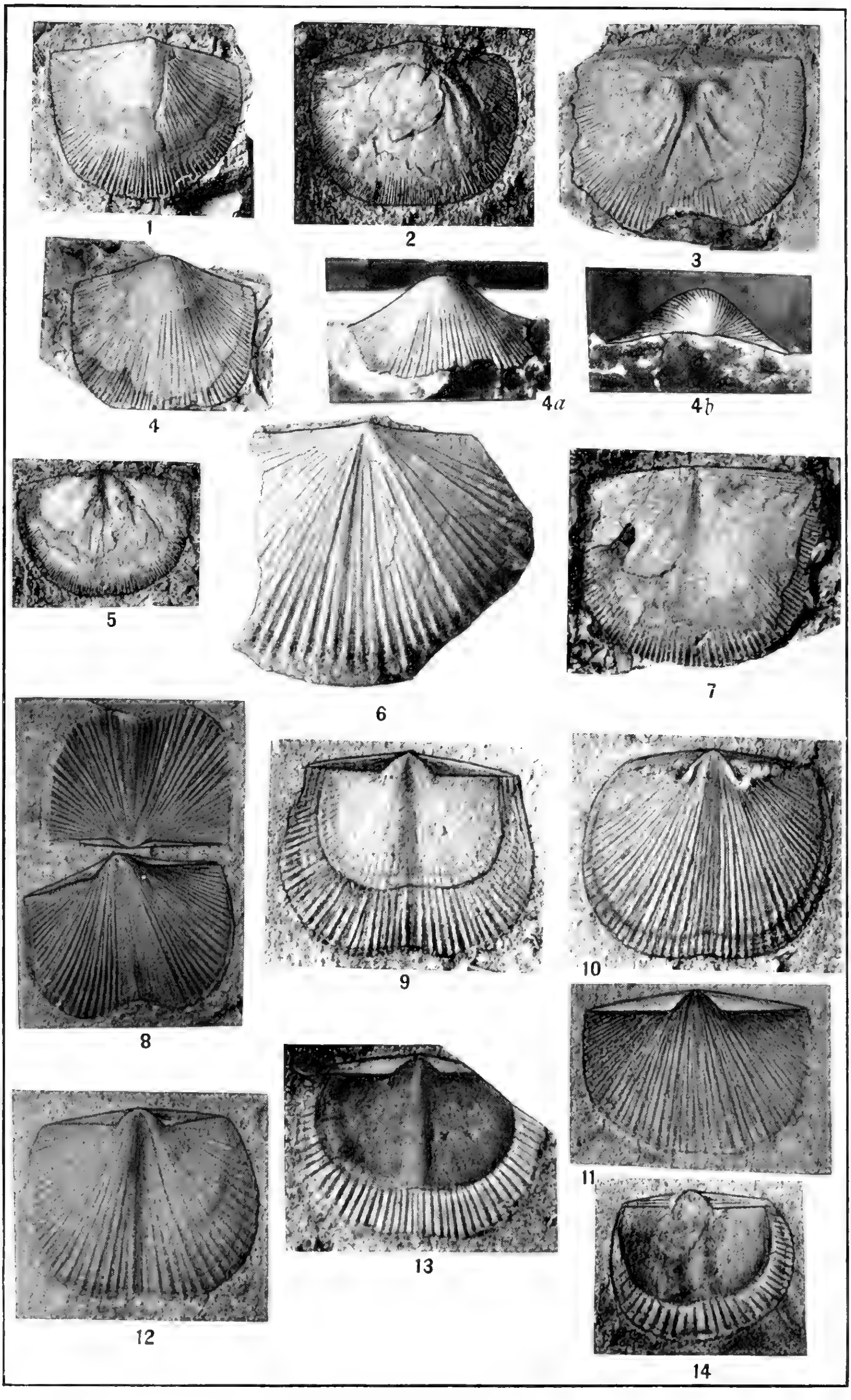


PROTORTHIS-EOORTHIS.

DESCRIPTION OF PLATE 113

PAGE

Protorthis iones Walcott 503

FIG. 1. (× 2.) Partially exfoliated ventral valve. U. S. Nat. Mus., Cat. No. 69724.

2. (× 2.) Natural cast of interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69725.

3. (× 2.) Natural cast of interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69726.

4, *4a*, *4b*. (× 4.) Top, side and back view of a small ventral valve. U. S. Nat. Mus., Cat. No. 69727.

5. (× 2.) Partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69728.

6. (× 4.) Outer surface of a dorsal valve. U. S. Nat. Mus., Cat. No. 69729.

7. (× 2.) Partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69730.

The specimens represented by figs. 1-7 are from locality 65w, Ozarkian: Mons formation, Clearwater Canyon, Alberta, Can.

Eoorthis bellicostata Walcott 505

FIG. 8. (× 3.) Ventral and dorsal valves on surface of shale. U. S. Nat. Mus., Cat. No. 69731.

9. (× 3.) Natural cast of interior of a ventral valve. U. S. Nat. Mus., Cat. No. 69732.

10. (× 3.) Exterior of a compressed ventral valve. U. S. Nat. Mus., Cat. No. 69733.

11. (× 3.) Interior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69734.

12. (× 3.) Dorsal valve. U. S. Nat. Mus., Cat. No. 69735.

13 and 14. (× 3.) Interior of dorsal valves. U. S. Nat. Mus., Cat. Nos. 69736, 69737.

The specimens represented by figs. 8-14 are from locality 35k, Middle Cambrian: Burgess shale, above Field, B. C., Can.

DESCRIPTION OF PLATE 114

PAGE

Eoorthis iophon Walcott (see pl. 119, fig. 14) 508

FIG. 1. (× 4.) Small ventral valve. U. S. Nat. Mus., Cat. No. 69738.

2. (× 4.) Ventral valve showing outline of visceral cavity beneath umbo. U. S. Nat. Mus., Cat. No. 69739.

3. (× 2.) Dorsal valve with acute cardinal angles. U. S. Nat. Mus., Cat. No. 69740.

4. (× 2.) Dorsal valve with broad mesial sinus. U. S. Nat. Mus., Cat. No. 69741.

5. (× 2.) Exterior of dorsal valve. U. S. Nat. Mus., Cat. No. 69742.

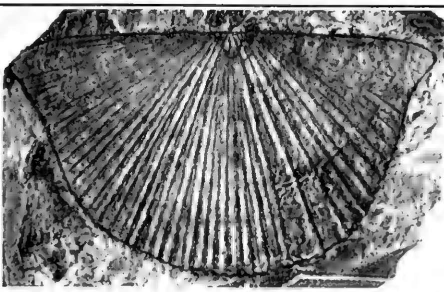
The specimens represented by figs. 1-5 are from locality 65e, with the exception of fig. 3 which is from locality 67w. All are from Ozarkian: Mons formation, Sawback Range, Alberta, Can.

Eoorthis putillus Walcott (see pl. 115, fig. 9) 510

FIG. 6. (× 4.) Ventral and dorsal valves in limestone. U. S. Nat. Mus., Cat. No. 69743.

7. (× 4.) Another group of shells on broken surface of limestone. U. S. Nat. Mus., Cat. No. 69744.

The specimens represented by figs. 6 and 7 are from locality 61q, Ozarkian: Chushina formation; gray limestone, Robson Peak District, B. C., Can.



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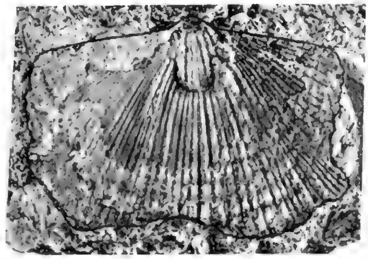

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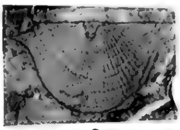

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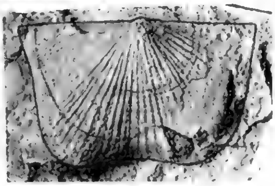

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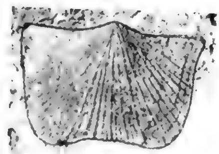

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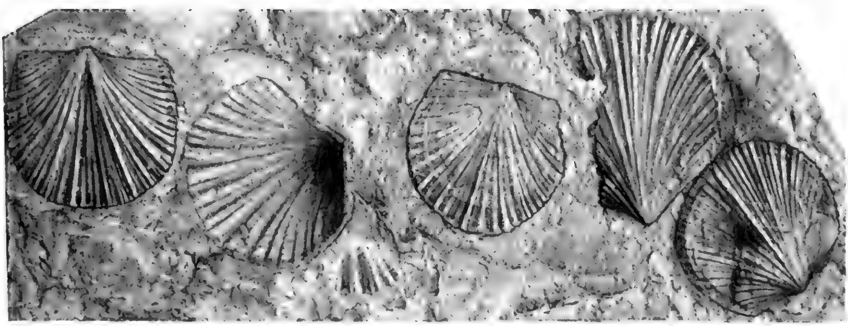

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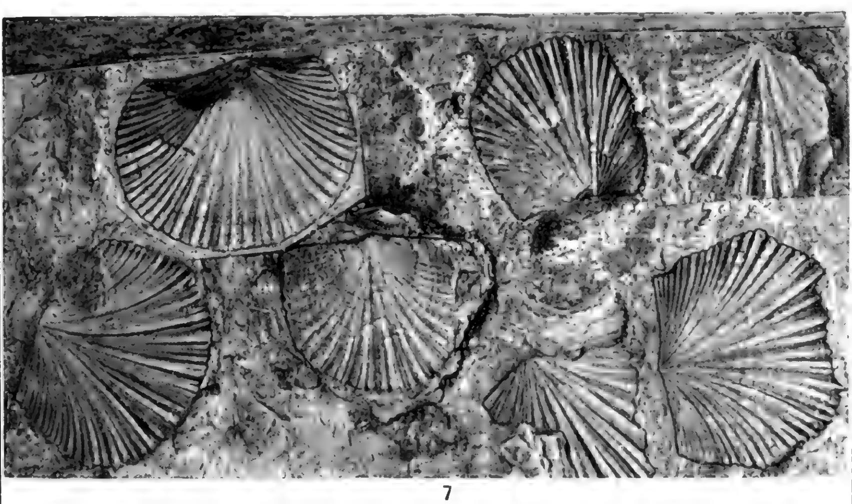

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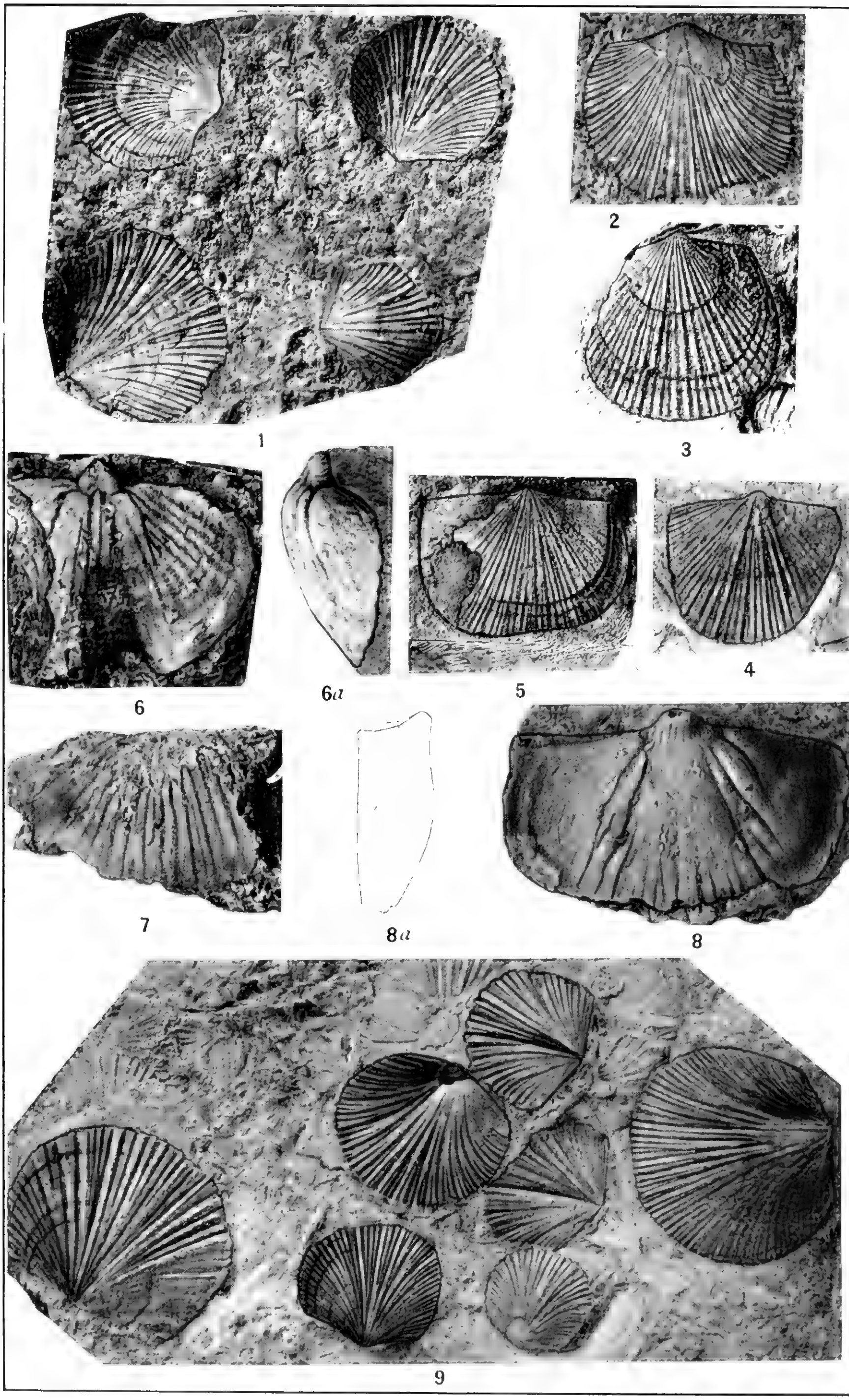


EOORTHIS-FINKELNBURGIA.

DESCRIPTION OF PLATE 115

PAGE

Eoorthis putillus laeviuscula Walcott 511

FIG. 1. (× 4.) Ventral valves. U. S. Nat. Mus., Cat. No. 69745.

2. (× 4.) Dorsal valve associated with specimens shown in fig. 1. U. S. Nat. Mus., Cat. No. 69746.

The specimens represented by figs. 1 and 2 are from locality 67q, Ozarkian: Mons formation; gray limestone, Douglas Lake Canyon Valley, Alberta, Can.

Eoorthis lineocosta Walcott 508

FIGS. 3 and 4. (× 2.) Casts of exterior of ventral valves. U. S. Nat. Mus., Cat. Nos. 69747, 69748.

5. (× 2.) Exterior of a broken dorsal valve. U. S. Nat. Mus., Cat. No. 69749.

The specimens represented by figs. 3-5 are from locality 360a, Ozarkian: Manitou formation; red silicious limestone, Beyer Park, El Paso County, Colorado.

Finkelnburgia noblei Walcott 514

FIGS. 6, 6*a*. (× 3.) Top and side view of a cast of the interior of a broken ventral valve. U. S. Nat. Mus., Cat. Nos. 69750.

7. (× 3.) Portion of the radially striated surface of the interior of the shell. U. S. Nat. Mus., Cat. No. 69751.

8, 8*a*. (× 3.) Top and side views of a cast of a ventral valve. U. S. Nat. Mus., Cat. No. 69752.

The specimens represented by figs. 6-8*a* are from locality 73c, Upper Cambrian: Muav formation; Hermit Creek, Grand Canyon of the Colorado River, Arizona.

Eoorthis putillus Walcott (see pl. 114, figs. 6, 7) 510

FIG. 9. (× 3.) Group of shells in shaly limestone [from a locality ? miles (? km.) distant from locality 61q at Mount Robson]. U. S. Nat. Mus., Cat. No. 69753.

The specimen represented by fig. 9 is from locality 67w, Ozarkian: Mons formation; Sawback Range, Alberta, Can.

DESCRIPTION OF PLATE 116

PAGE

Eoorthis wichitaensis Walcott 513

Fig. 1. (× 4.) Exterior of ventral valve. U. S. Nat. Mus., Cat. No. 69754.

2. (× 4.) Partially exfoliated ventral valve. U. S. Nat. Mus., Cat. No. 69755.

3. (× 4.) Interior of a ventral valve showing strong vascular sinuses. U. S. Nat. Mus., Cat. No. 69758.

4. (× 4.) Exfoliated ventral valve doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 69759.

5. (× 4.) Dorsal valve. U. S. Nat. Mus., Cat. No. 69760.

6. (× 4.) Ventral valve on same surface of limestone as fig. 5. U. S. Nat. Mus., Cat. No. 69761.

7. (× 4.) Exterior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69762.

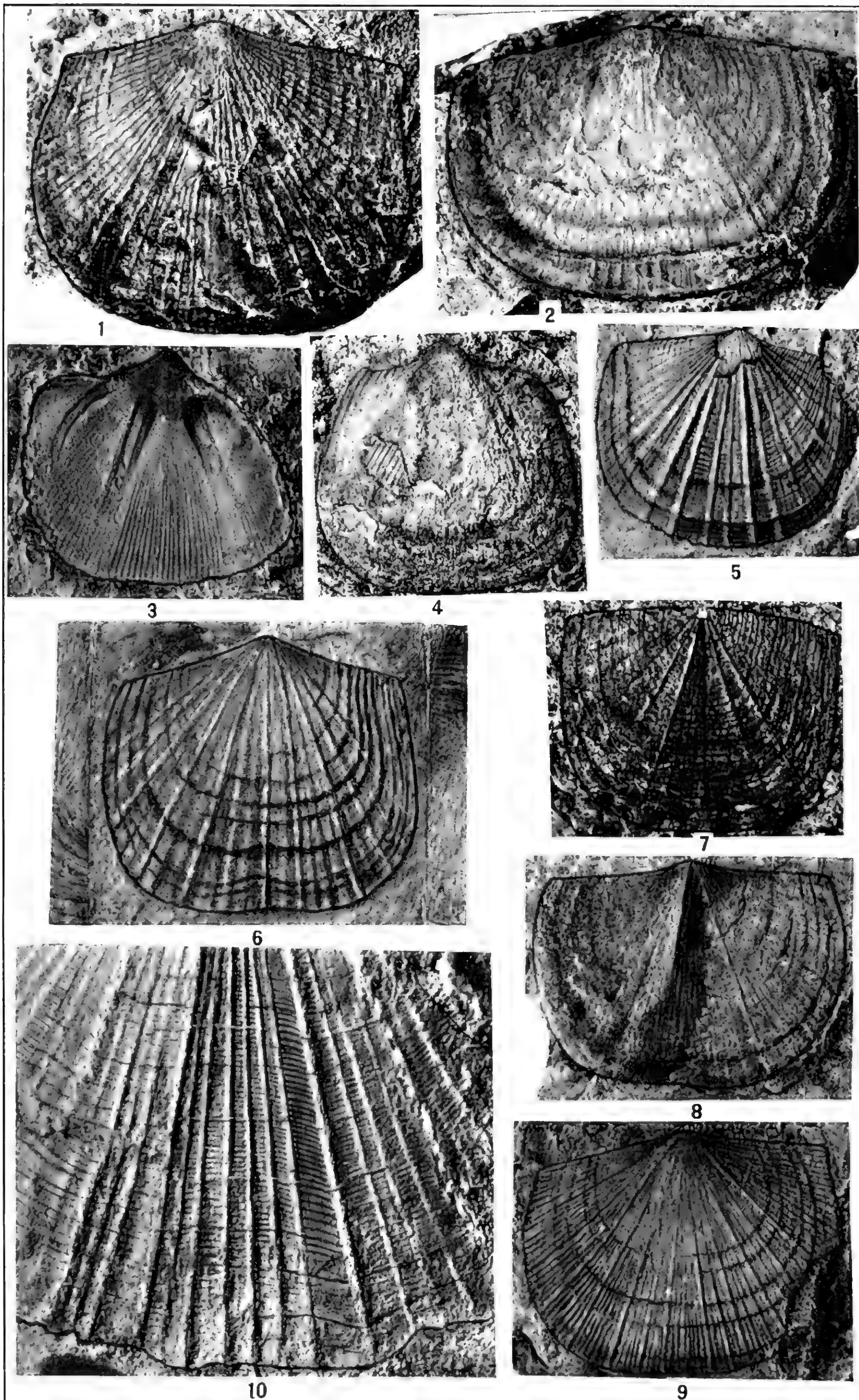
8. (× 4.) A partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69756.

9. (× 4.) Outer surface of a dorsal valve. U. S. Nat. Mus., Cat. No. 69757.

10. (× 8.) Enlargement of surface to show main ribs, intercalated finer ribs or elevated striæ, and concentric lines and striæ of growth. U. S. Nat. Mus., Cat. No. 69763.

The specimens represented by figs. 1, 2, 8 and 9 are from locality 64l, Upper Cambrian: Lyell formation. Head of Glacier Lake Canyon, Alberta, Canada.

Figs. 3-7 and 10 are from locality 64t, Lyell formation, Sawback Range, Alberta, Can.



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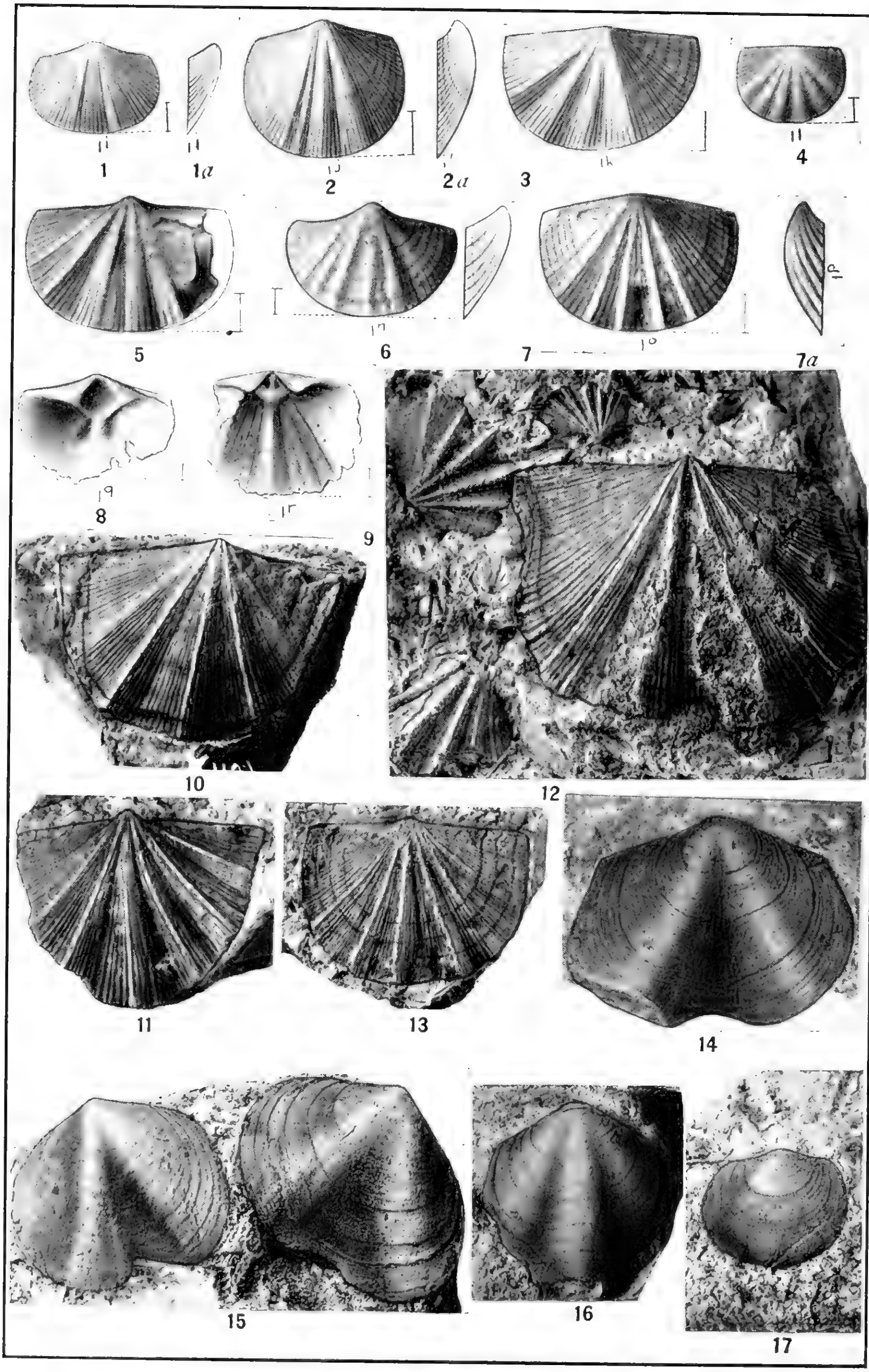


EOORTHIS-SYNTROPHIA.

DESCRIPTION OF PLATE 117

PAGE

Eoorthis fascigera Walcott 507

FIGS. 1, 1*a*, and 2, 2*a*. Top and side views of ventral valves from locality 14k, Upper Cambrian limestone on Wolf Creek, 15 miles (24.2 km.) west-southwest of Sheridan, Sheridan County, Wyoming. U. S. Nat. Mus., Cat. Nos. 52320a and 52320b, respectively.

3 and 4. Exterior of dorsal valves associated with the dorsal valves represented by figures 1 and 2. U. S. Nat. Mus., Cat. Nos. 52320c and 52320d, respectively.

5 and 6. Exterior of small ventral valves. U. S. Nat. Mus., Cat. Nos. 52319a and 52319b, respectively.

7. Exterior and side view of a ventral valve. U. S. Nat. Mus., Cat. No. 52319c.

7*a*. Side view of a young, convex shell. U. S. Nat. Mus., Cat. No. 52319d.

8. Posterior portion of the interior of an abraded ventral valve. U. S. Nat. Mus., Cat. No. 52319e.

9. Interior of an abraded dorsal valve. U. S. Nat. Mus., Cat. No. 52319f.

The specimens represented by figures 5-9 are from locality 168, Middle Cambrian limestones, Tepee Creek, Bighorn Mountains, Wyoming.

Figs. 1 to 9, inclusive, are the same as figs. 1*i* to 1*r*, pl. 96, of Mong. 51, U. S. Geological Survey, 1912.

Eoorthis ochus Walcott 509

FIGS. 10 and 11. (× 3.) Ventral valves with very regular radiating elevated lines and fine strong ribs. U. S. Nat. Mus., Cat. Nos. 69764, 69765.

12. (× 3.) A large dorsal valve with the main radiation ribs broken off. The smaller associated shells have very strong radiating ribs. U. S. Nat. Mus., Cat. No. 69766.

13. (× 3.) A ventral valve with the apex broken down. U. S. Nat. Mus., Cat. No. 69767.

The specimens represented by figs. 10-13 are from locality 16u, Ozarkian: Mons formation, Sinclair Canyon, B. C., Can.

Syntrophia isis Walcott 517

FIG. 14. (× 4.) A ventral valve with a strong mesial sinus. U. S. Nat. Mus., Cat. No. 69768.

15. (× 4.) Two ventral valves that vary slightly in outline. U. S. Nat. Mus., Cat. No. 69769.

16. (× 4.) Dorsal valve. U. S. Nat. Mus., Cat. No. 69770.

17. (× 4.) A young shell with a very slight mesial fold. U. S. Nat. Mus., Cat. No. 69770.

The specimens represented by figs. 15-17 are from locality 65f, Ozarkian: Mons formation, Glacier Lake, Alberta, Can.

DESCRIPTION OF PLATE 118

PAGE

Syntrophia perilla Walcott 519

FIG. 1. (× 4.) Ventral valve with traces of radiating lines on the inner layers of the shell. U. S. Nat. Mus., Cat. No. 69773.

2. (× 4.) A larger, more transverse ventral valve with shell partly exfoliated. U. S. Nat. Mus., Cat. No. 69772.

3. (× 4.) A large dorsal valve. U. S. Nat. Mus., Cat. No. 69774.

4. (× 4.) An elongate dorsal valve. U. S. Nat. Mus., Cat. No. 69775.

5. (× 4.) Dorsal valve. U. S. Nat. Mus., Cat. No. 69776.

6. (× 4.) Ventral valve, U. S. Nat. Mus., Cat. No. 69777.

7. (× 4.) A small dorsal valve. U. S. Nat. Mus., Cat. No. 69778.

The specimens represented by figs. 1-7, with the exception of fig. 2, are from locality 65x, Ozarkian: Mons formation, Clearwater Canyon, Alberta, Can.

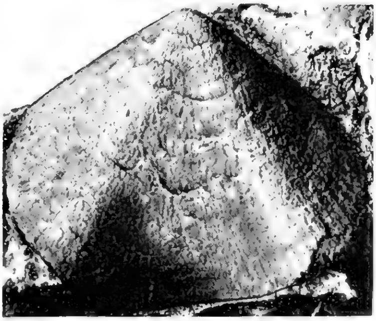
Fig. 2 is from Fossil Mountain, Alberta, Can.

Huenella simon Walcott 521

FIG. 8. (× 4.) A ventral valve with a broad shallow mesial sinus. U. S. Nat. Mus., Cat. No. 69779.

9. (× 8.) Enlargement of surface ribs of fig. 8.

The specimen represented by figs. 8 and 9 is from locality 64z, Ozarkian: Mons formation; Sawback Range, Alberta, Can.



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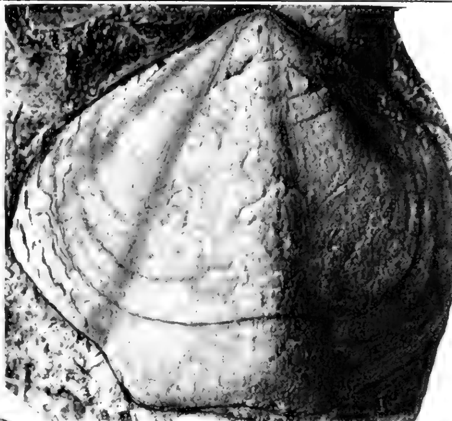

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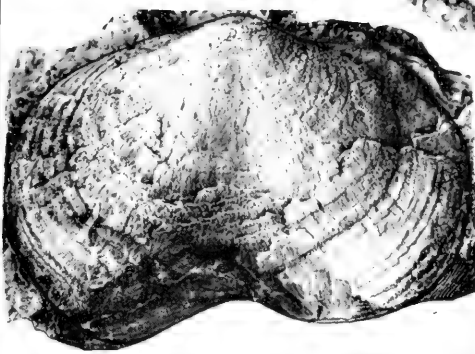

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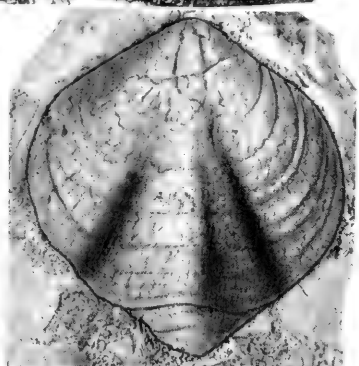

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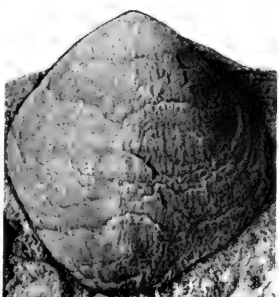

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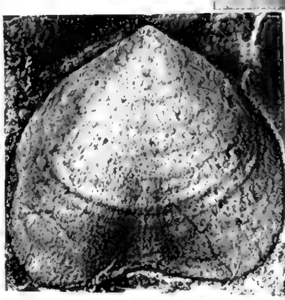

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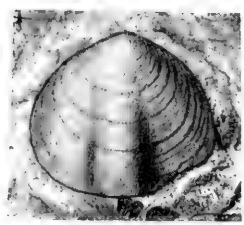

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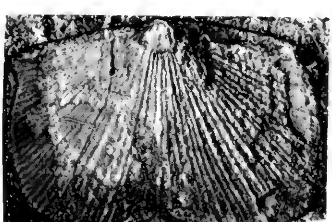

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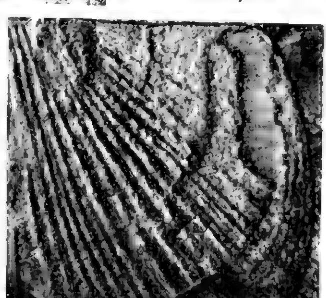

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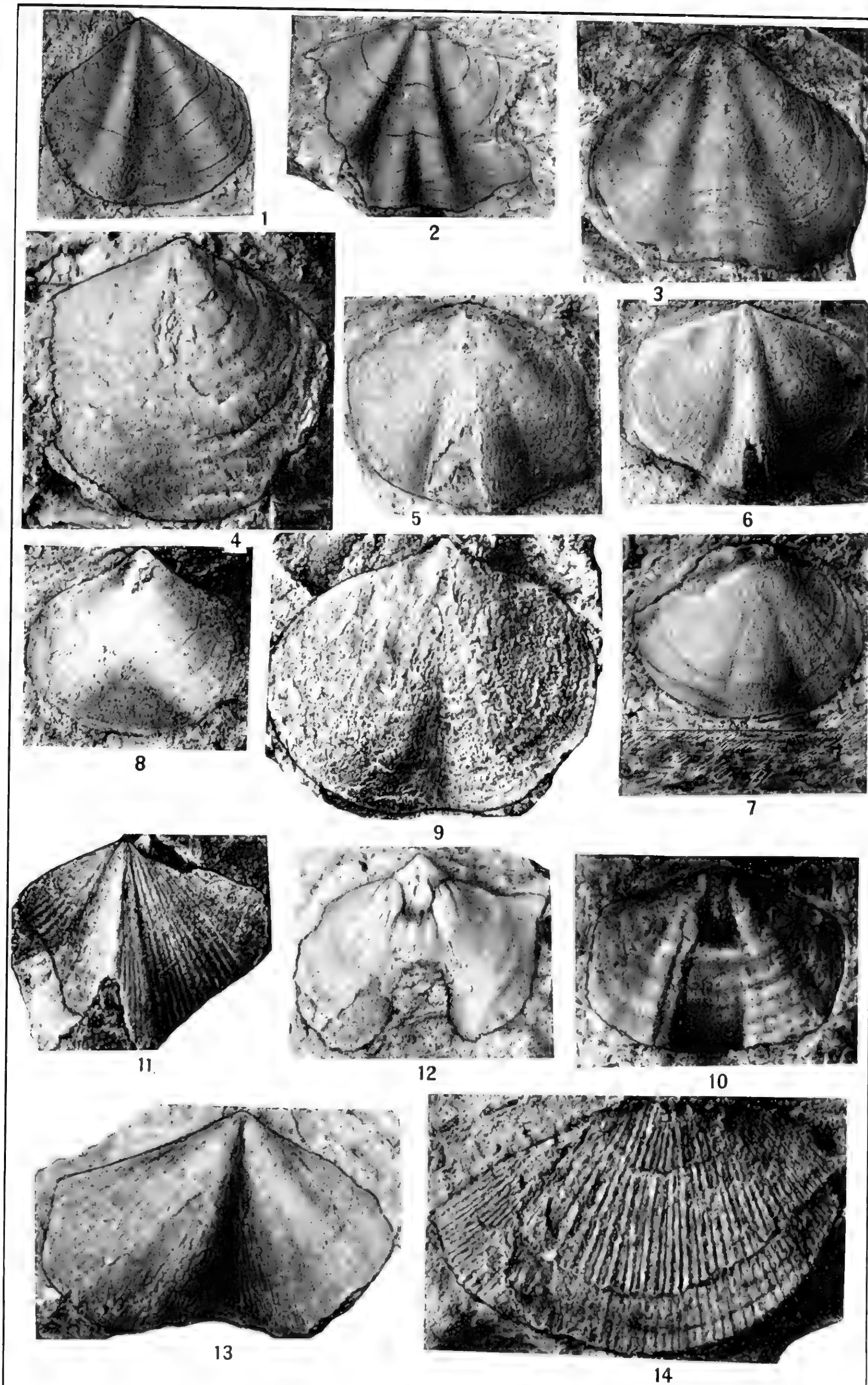
SYNTROPHIA-HUENELLA.



SYNTROPHIA-HUENELLA.

DESCRIPTION OF PLATE 119

PAGE

Syntrophia nisis Walcott.. 517

FIG. 1. (× 4.) Ventral valve with strong ridge on sides of mesial fold. U. S. Nat. Mus., Cat. No. 69780.

2. (× 4.) Dorsal valve with furrow on mesial fold. U. S. Nat. Mus., Cat. No. 69781.

3. (× 4.) Dorsal valve with faint furrow on mesial fold. U. S. Nat. Mus., Cat. No. 69782.

The specimens represented by figs. 1-3 are from locality 66 o, Ozarkian: Mons formation; Fossil Mountain, Alberta, Can.

Syntrophia nonus Walcott.. 518

FIG. 4. (× 4.) Ventral valve with a slight mesial sinus. U. S. Nat. Mus., Cat. No. 69783.

5. (× 4.) Dorsal valve with broad mesial fold. U. S. Nat. Mus., Cat. No. 69784.

6. (× 4.) Dorsal valve with a more sharply elevated mesial fold. U. S. Nat. Mus., Cat. No. 69785.

7. (× 4.) Dorsal valve with a few faint radiating ribs. U. S. Nat. Mus., Cat. No. 69786.

8. (× 4.) Ventral valve. U. S. Nat. Mus., Cat. No. 69787.

9. (× 4.) A large exfoliated ventral valve preserving traces of the vascular sinuses. U. S. Nat. Mus., Cat. No. 69788.

The specimens represented by figs. 4-7 are from locality 66 o, given under *S. nisis* above. Figs. 8 and 9 are from the same locality, but a little lower in the section (66n).

Huenella hera Walcott.. 520

FIG. 10. (× 4.) Interior of a ventral valve showing cast of pseudospondilium. U. S. Nat. Mus., Cat. No. 69789.

The specimen represented by fig. 10 is from locality 64w, Upper Cambrian: Lyell formation; Sawback Range, Alberta, Can.

Huenella juba Walcott.. 521

FIG. 11. (× 4.) Exterior of a broken dorsal valve. U. S. Nat. Mus., Cat. No. 69790.

12. (× 4.) Cast of interior of a ventral valve showing cast of pseudospondilium. U. S. Nat. Mus., Cat. No. 69791.

13. (× 4.) Ventral valve with a broad mesial sinus. U. S. Nat. Mus., Cat. No. 69792.

Eoorthis iophon Walcott (see pl. 114, figs. 1-5)........................ 508

FIG. 14. (× 4.) Enlargement of surface to show strong, fine radiating ribs. U. S. Nat. Mus., Cat. No. 69793.

The specimens represented by figs. 11-14 are from locality 65e, Ozarkian: Mons formation; Sawback Range, Alberta, Can.

DESCRIPTION OF PLATE 120

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Huenella icetas Walcott 520

FIG. 1. (× 4.) Ventral valve. U. S. Nat. Mus., Cat. No. 69794.

2. (× 4.) Exterior surface of a small ventral valve. U. S. Nat. Mus., Cat. No. 69795.

3. (× 4.) A dorsal valve associated with fig. 1. U. S. Nat. Mus., Cat. No. 69796.

The specimens represented by figs. 1-3 are from locality 65e, Ozarkian: Mons formation: Sawback Range, Alberta, Can.

Huenella texana Walcott 522

FIG. 4. (× 4.) A ventral valve partially concealed by the mesial sinus of another specimen.

6. (× 4.) Interior of a ventral valve that occurs on the same weather surface as 4 and 8.

7. (× 4.) Dorsal valve associated with *Huenella weedi* Walcott.

8. (× 4.) Part of a small piece of a thin layer of limestone on which the fossils weather out in relief. Both *H. texana* and *H. weedi* occur scattered irregularly over the surface.

U. S. Nat. Mus., Cat. No. 69797.

Huenella weedi Walcott 522

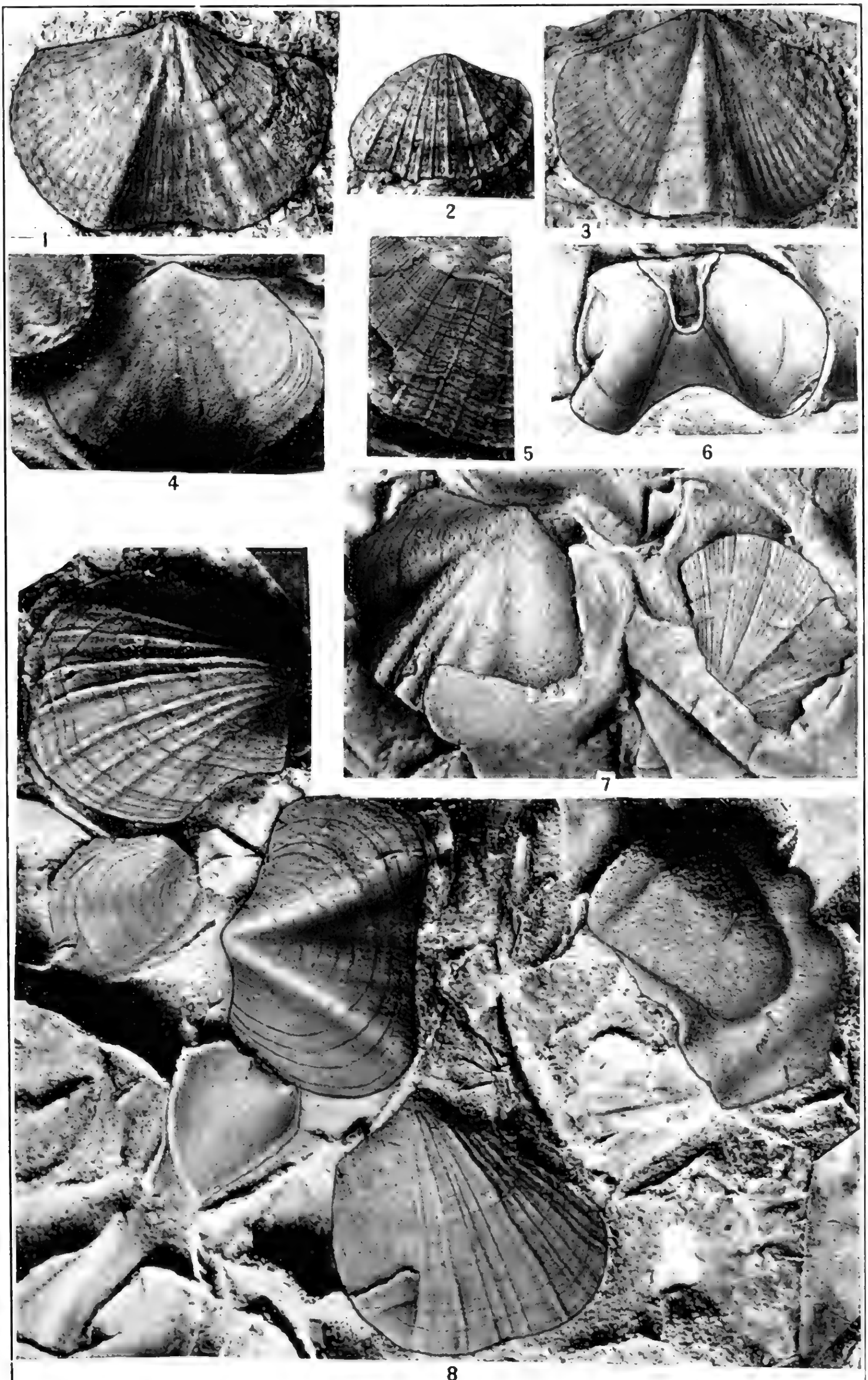
FIG. 5. (× 4.) A small portion of the outer surface of the shell.

7. (× 4.) Dorsal valve.

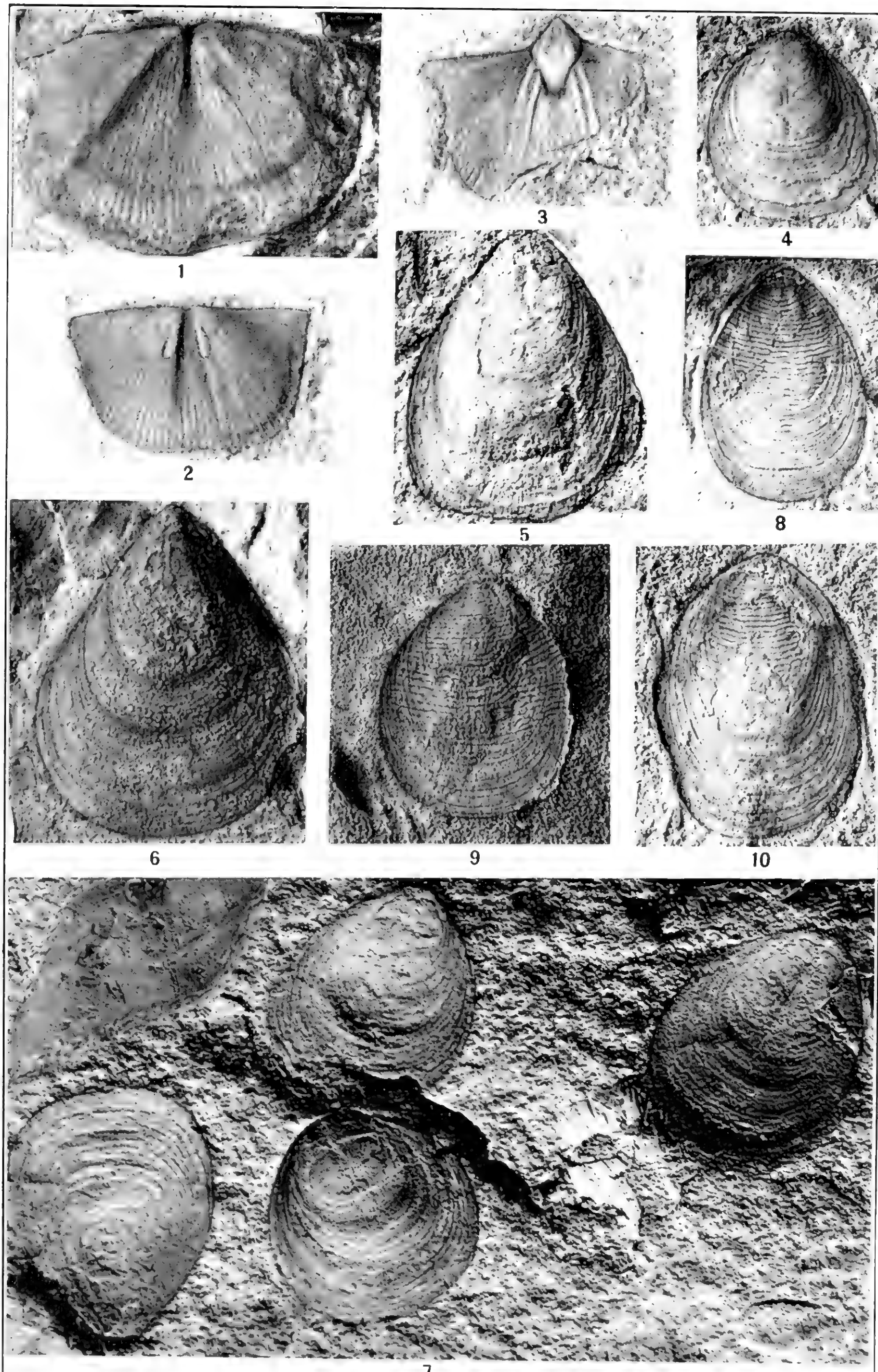
8. (× 4.) Ventral valve associated with *H. texana* Walcott.

U. S. Nat. Mus., Cat. No. 69798.

The specimens represented by figs. 4-8 are from locality 302g, Upper Cambrian; Crowfoot Ridge, Yellowstone National Park, Wyoming.



HUENELLA.



BILLINGSELLA-OBOLUS.

DESCRIPTION OF PLATE 121

PAGE

Billingsella origen Walcott.. 503

FIG. 1. (×4.) Exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 19809.

2. (×4.) An exfoliated dorsal valve showing traces of muscle scars. U. S. Nat. Mus., Cat. No. 69807.

3. (×4.) Natural cast of interior of ventral valve showing visceral area and main vascular sinuses. U. S. Nat. Mus., Cat. No. 69808.

The specimens represented by figs. 1-3 are from locality 17t, Ozarkian: Mons formation, Sabine Mountain, B. C., Can.

Obolus whymperi Walcott.. 487

FIG. 4. (×3.) A small well preserved dorsal valve. U. S. Nat. Mus., Cat. No. 69810.

5. (×3.) A partially exfoliated ventral valve. U. S. Nat. Mus., Cat. No. 69812.

6. (×3.) A ventral valve with some of the inner layers of the shell preserved. U. S. Nat. Mus., Cat. No. 69811.

7. (×3.) Three dorsal valves and a broken ventral valve as they occur on the surface of shaly limestone. U. S. Nat. Mus., Cat. No. 69813.

The specimens represented by figs. 4-7 are from locality 68c, Lower Cambrian: Mt. Whyte formation, Mount Whymper, B. C., Can.

Obolus (Westonia) ollius Walcott.. 487

FIG. 8. (×3.) A flattened ventral valve with the apex broken off. U. S. Nat. Mus., Cat. No. 69814.

9. (×3.) A flattened, slightly distorted dorsal valve showing the elevated transverse lines. U. S. Nat. Mus., Cat. No. 69815.

10. (×3.) A partially exfoliated dorsal valve. U. S. Nat. Mus., Cat. No. 69816.

The specimens represented by figs. 8-10 are from locality 11c, Upper Cambrian: Hardystone Quartzite, Newton, New Jersey.

DESCRIPTION OF PLATE 122

PAGE

Lingulella miltoni Walcott.. 492

FIG. 1. (× 4.) Broad form of ventral valve. U. S. Nat. Mus., Cat. No. 69818.

2. (× 4.) An elongate dorsal valve. U. S. Nat. Mus., Cat. No. 69819.

3. (× 4.) Narrow elongate form of ventral valve. U. S. Nat. Mus., Cat. No. 69820.

4. (× 4.) Broad form of dorsal valve. U. S. Nat. Mus., Cat. No. 69821.

The specimens represented by figs. 1-4 are from locality 61u, Ozarkian: Chushina formation, Mount Robson, B. C., Can.

Lingulella waptaensis Walcott.. 496

FIG. 5. (× 6.) Dorsal valve with a flattened ventral valve turned sideways beneath it. U. S. Nat. Mus., Cat. No. 69822.

6. (× 6.) An uncompressed ventral valve. U. S. Nat. Mus., Cat. No. 69823.

7. (× 6.) A group of ventral and dorsal valves on a piece of hard silicious shale. U. S. Nat. Mus., Cat. No. 69824.

8. (× 6.) Ventral valves on the same piece of shale as those represented by fig. 7. U. S. Nat. Mus., Cat. No. 69824.

The specimens represented by figs. 5-8 are from locality 35k, Middle Cambrian: Burgess shale. Ridge between Mount Wapta and Mount Field, B. C., Can.

Acrothyra gregaria Walcott.. 498

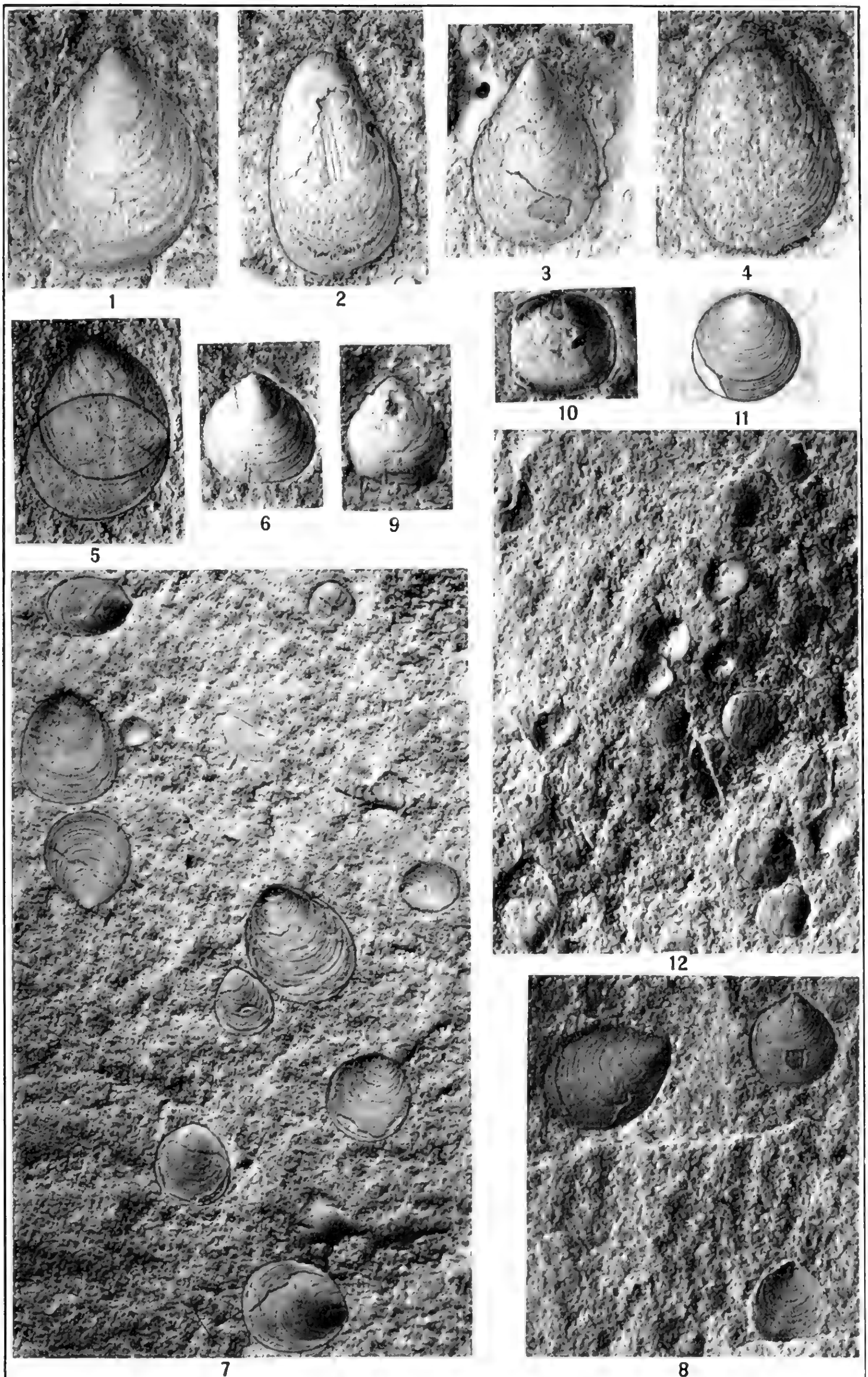
FIG. 9. (× 8.) Partially exfoliated ventral valve showing cast of apical callosity and main vascular sinuses. U. S. Nat. Mus., Cat. No. 69825.

10. (× 8.) Partially exfoliated dorsal valve showing trace of median septum. U. S. Nat. Mus., Cat. No. 69826.

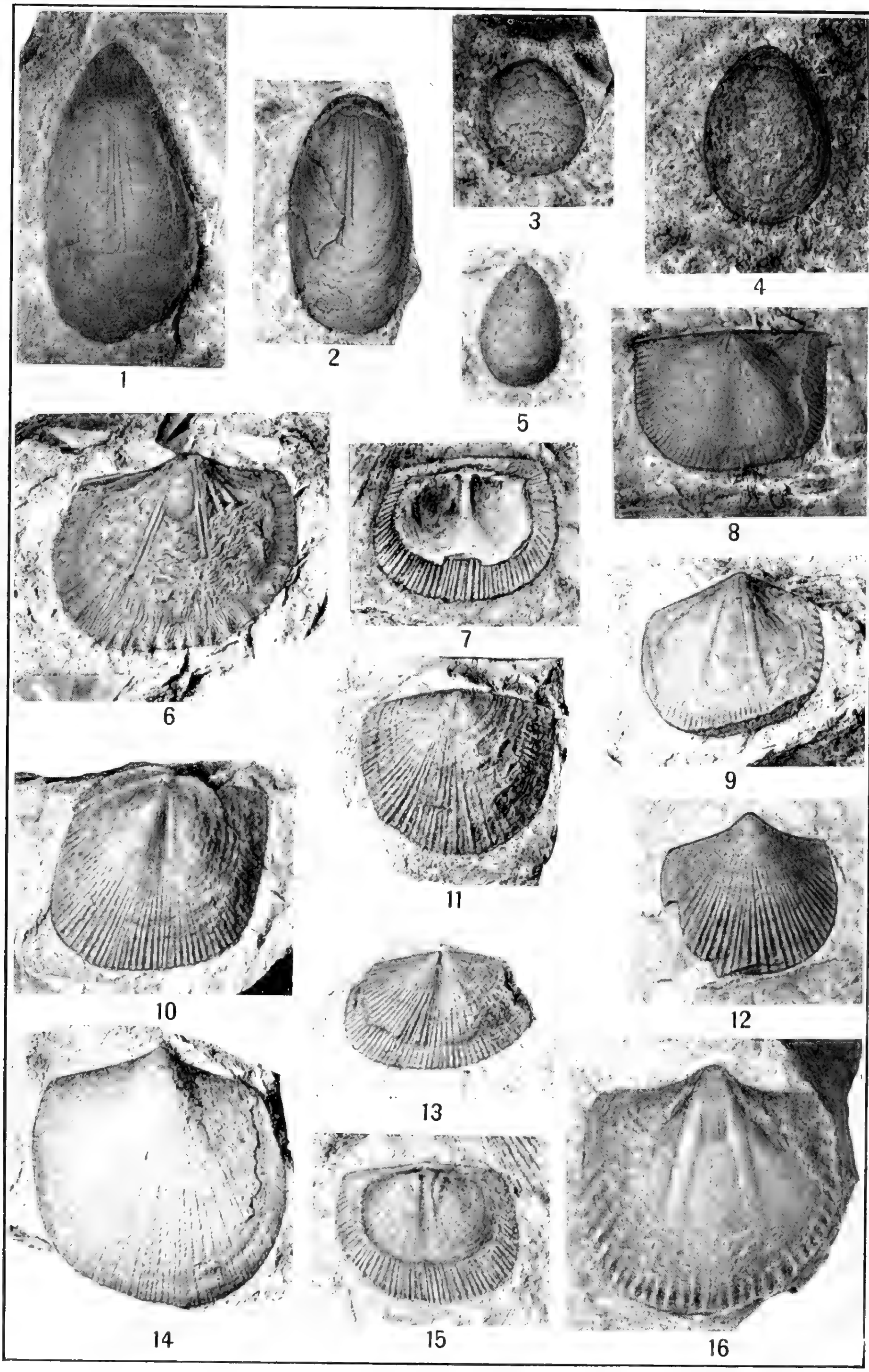
11. (× 8.) Exterior of a dorsal valve. U. S. Nat. Mus., Cat. No. 69827.

12. (× 8.) A group of shells on a piece of hard silicious shale. U. S. Nat. Mus., Cat. No. 69828.

The specimens represented by figs. 9-12 are from locality 35k as above.



LINGULELLA-ACROTHYRA.



LINGULELLA-BILLINGSELLA.

Novaya Zemlaya Brachiopods.

DESCRIPTION OF PLATE 123

PAGE

Lingulella arctica Walcott 524

FIG. 1. (× 3.) An exfoliated ventral valve.

2. (× 3.) A partially exfoliated dorsal valve.

Lingulella cf. *desiderata* Walcott 524

FIGS. 3 and 4. (× 6.) Dorsal valves.

5. (× 6.) Ventral valve.

Billingsella holtedahli Walcott 525

FIG. 6. (× 2.) View of a partially exfoliated ventral valve, preserving part of main vascular sinuses and inner markings of shell.

7. (× 2.) Partial interior of a dorsal valve. See fig. 15.

8. (× 2.) Partly exfoliated dorsal valve.

9. (× 2.) Partly exfoliated ventral valve.

10. (× 2.) Dorsal valve with a shallow median furrow.

11. (× 2.) Dorsal valve with outer surface layer exfoliated.

12. (× 3.) Top view of a small ventral valve.

13. (× 2.) Dorsal valve with outer surface preserved.

14. (× 2.) Exterior of ventral valve with outer surface layer more or less exfoliated.

15. (× 2.) Partially exfoliated dorsal valve. See fig. 7.

16. (× 4.) Partialy exfoliated ventral valve showing cast of vascular sinuses and umbonal cavity.

The specimens represented by figs. 1, 2, 6-16, are from locality 67y, Island of Novaya Zemlya, Russia, west coast of southern island, Gribovii Fjord.

Figs. 3, 4, 5 are from locality 68a, west coast of southern island in mountains 7 km. northwest of the head of Bessimyanni Fjord.

DESCRIPTION OF PLATE 124

PAGE

Billingsella ? oppius Walcott.. 525

FIG. 1. (× 2.) Exterior of dorsal valve.

2. (× 2.) Exterior of ventral valve with shell crushed into umbonal cavity.

3. (× 4.) Exterior of a small dorsal valve that may belong with this species.

4 and 6. (× 2.) Casts of interior of ventral valves.

5. (× 2.) Exfoliated ventral valve doubtfully referred to this species.

7. (× 2.) Exterior surface of dorsal valve.

8. (× 2.) Top and side view of exterior of a ventral valve.

The specimens represented by figs. 1-8 are from locality 67y, Island of Novaya Zemlya, Russia, west coast of southern island, Gribovii Fjord.

Eoorthis sabus Walcott.. 526

FIG. 9. (× 4.) Cast of interior of a small ventral valve.

10. (× 3.) Top view of exterior of a ventral valve.

11. (× 3.) Natural cast of the interior of a dorsal valve.

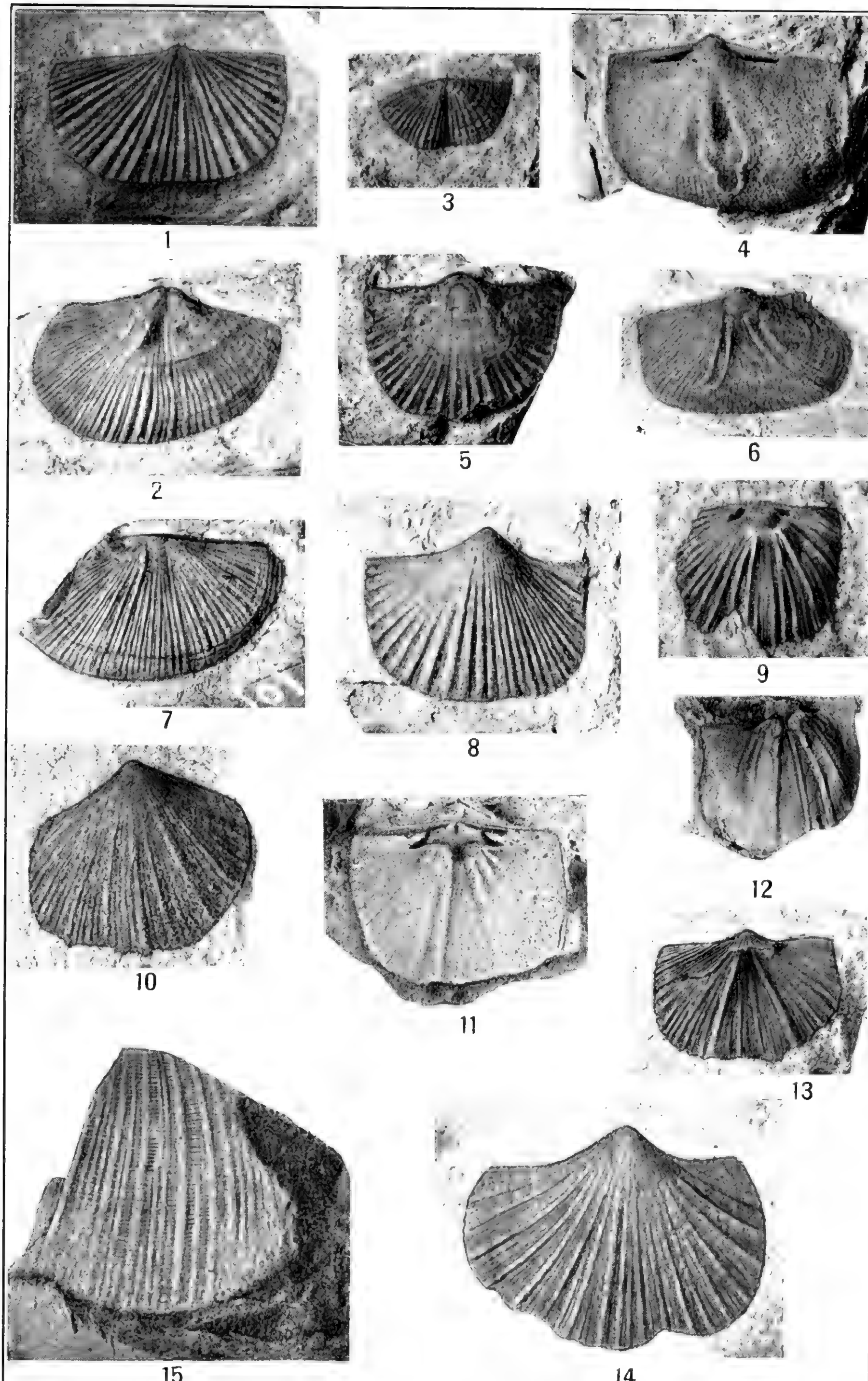
12. (× 2.) View of the cast of a ventral valve.

13. (× 3.) Partly exfoliated dorsal valve having a shallow mesial sinus.

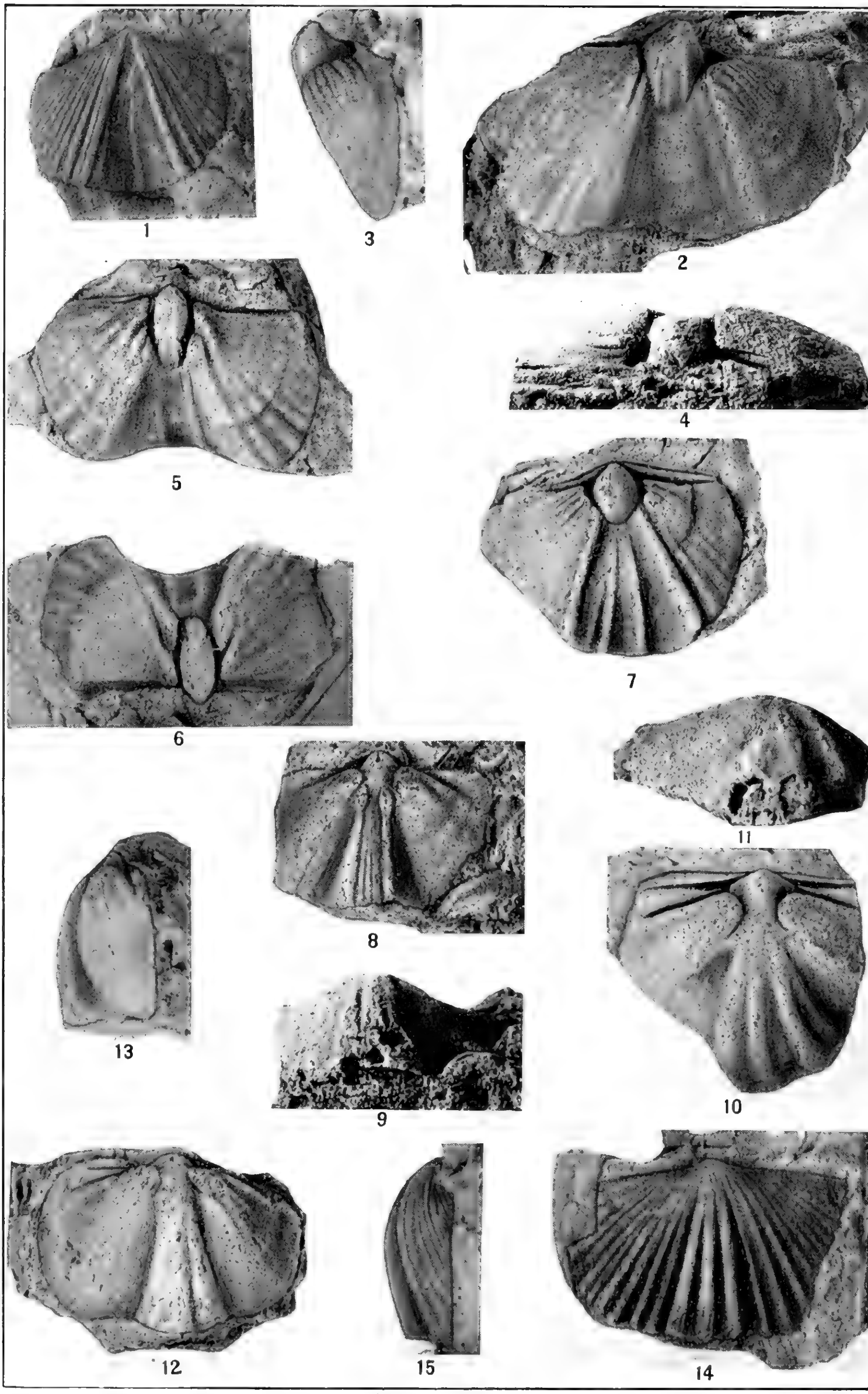
14. (× 3.) One of a small group of shells in an arenaceous matrix.

15. (× 4.) Fragment of a cast of the exterior surface.

The specimens represented by figs. 9-14 are from locality 68a, west coast of southern island, mountains 7 km. northwest of the head of Bessimyanni Fjord. Fig. 15 is from locality 67y, west coast of southern island, Gribovii Fjord, Island of Novaya Zemlya, Russia.



BILLINGSELLA-EOORTHIS.
Novaya Zemlaya Brachiopods.



HUENELLA.
Novaya Zemlaya Brachiopods.

DESCRIPTION OF PLATE 125

PAGE

Huenella triplicata Walcott 526

FIG. 1. (× 3.) Exterior of a ventral valve with one well defined mesial plication in furrow.

2, 3, 4. (× 3.) Top, side and back views of cast of the interior of a ventral valve showing pseudospondilium of medium length, short slight sinuses extending out into the cardinal slopes.

5, 6. (× 3.) Top and half back view of cast of interior of ventral valve with a narrow, long pseudospondilium, base of short vascular sinuses, and two plications in mesial sinus.

7. (× 3.) Cast of the interior of a ventral valve with two strong and one faint plications in mesial furrow, and a relatively short pseudospondilium.

8, 9. (× 3.) Top and front views of a cast of interior of a dorsal valve showing imprint of adductor muscle scars, small pseudospondilium and a minute cardinal process.

10, 11, 12, 13. (× 3.) Top, front and side views of casts of interior of dorsal valves varying somewhat from figs. 8, 9.

14, 15. (× 3.) Top and side view of exterior of dorsal valve with three plications on a rather mesial fold.

The specimens represented by figs. 1-15 are from locality 68a, mountains 7 km. northwest of the head of Bessimyanni Fjord, island of Novaya Zemlya, Russia.

DESCRIPTION OF PLATE 126

PAGE

Ozomia lucan Walcott 531

FIG. 1. (× 3.) Natural cast of the interior of one side of the carapace of a large specimen. U. S. Nat. Mus., Cat. No. 69799.

2. (× 3.) Natural cast of a smaller carapace. U. S. Nat. Mus., Cat. No. 69800.

3, 3*a*. (× 3.) Side and anterior view of a cast preserving the impression of both sides of the carapace. U. S. Nat. Mus., Cat. No. 69801.

The specimens represented by figs. 1-3, and 3*a*, are from locality 66n, Ozarkian: Mons formation, Fossil Mountain, Alberta, Can.

Endoceras (?) *monsensis* Walcott 529

FIG. 4. (× 4.) View of the deeper side of the conch in which the annulations and the lines of the cameræ are clearly defined. U. S. Nat. Mus., Cat. No. 69802.

4*a*. (× 4.) Dorsal or ventral view of fig. 4 specimen.

4*b*. (× 4.) Section of fig. 4 specimen, showing the oval dorsoventral section.

The specimens represented by figs. 4, 4*a*, 4*b*, are from locality 64p, Ozarkian: Mons formation, Glacier Lake Canyon Valley, Alberta, Can.

Ellesmeroceras robsonensis Walcott 527

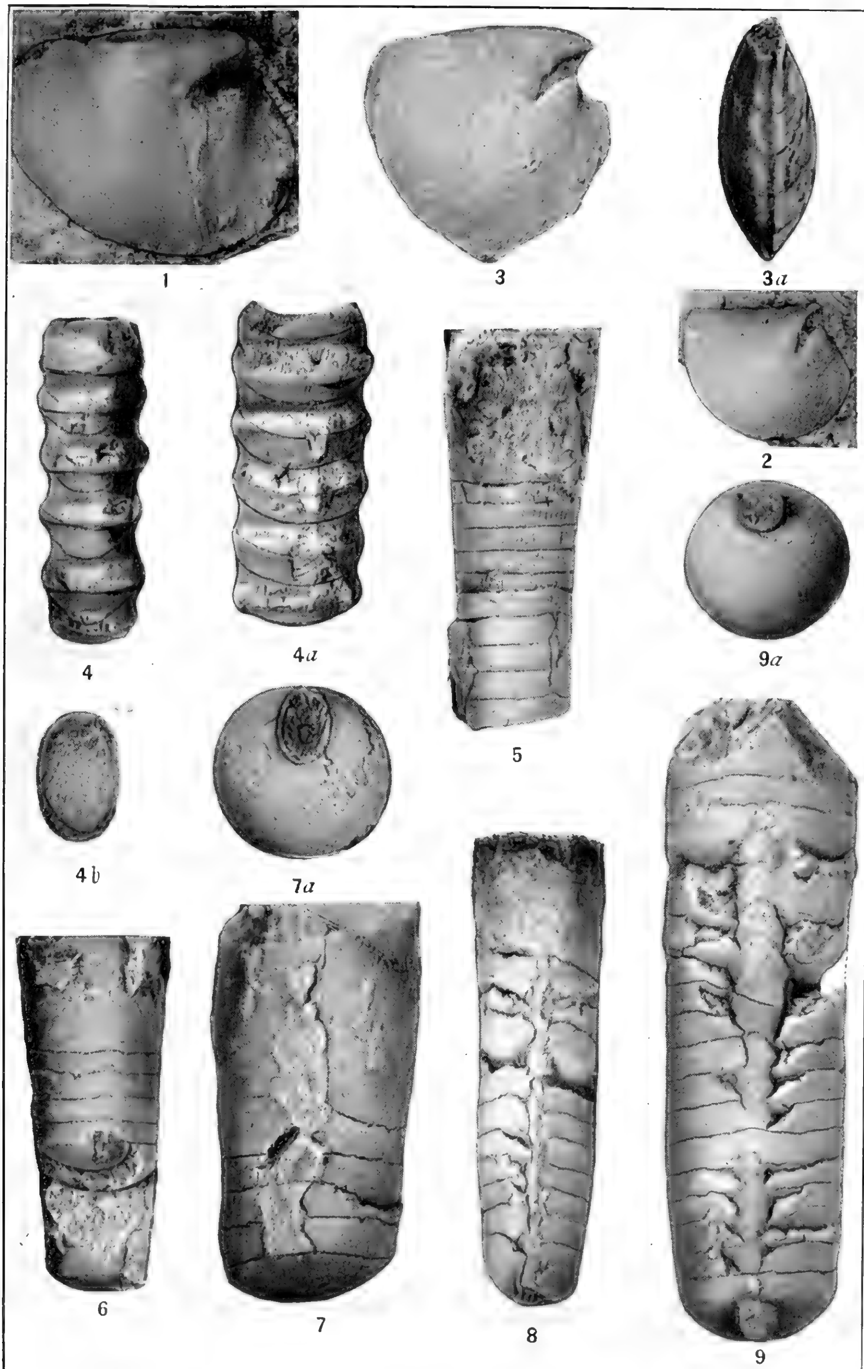
FIGS. 5 and 6. (× 4.) Two views of a fragment of a conch preserving a portion of the living chamber and a number of the sutures separating the septa. U. S. Nat. Mus., Cat. No. 69803.

7, 7*a*. (× 4.) A fragment of a conch preserving a portion of the living chamber, a few septa, and at the end one of the camera with a section of the siphuncle. U. S. Nat. Mus., Cat. No. 69804.

8. (× 4.) Ventral side of a broken conch preserving the living chamber, septa and sutures; the siphuncle shows fairly well. U. S. Nat. Mus., Cat. No. 69805.

9, 9*a*. (× 4.) A finely dissected specimen of the septate middle section of a conch showing the septa of the siphuncle with slightly elevated margin on the sutures, the cameræ, and sutures. Fig. 9*a* illustrates the position of the siphuncle. U. S. Nat. Mus., Cat. No. 69806.

The specimens represented by figs. 5-9*a* are from locality 61q, Ozarkian: Chushina formation, Billings Butte, Mount Robson District, B. C., Can.



OZOMIA-ENDOCERAS-ELLESMEROCERAS.