SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 1



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

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## ABRUPT APPEARANCE OF THE CAMBRIAN FAUNA ON THE NORTH AMERICAN CONTINENT

WITH ONE MAP

BY

CHARLES D. WALCOTT

(PUBLICATION 1940)

CITY OF WASHINGTON
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## ABRUPT APPEARANCE OF THE CAMBRIAN FAUNA ON THE NORTH AMERICAN CONTINENT[1]

By CHARLES D. WALCOTT

(With One Map)

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## INTRODUCTION

In accepting the invitation of the Representatives for Paleontology of the Swedish Committee of the Eleventh International Geological Congress, to take part in the discussion of "The Abrupt Appearance of the Cambrian Fauna," I decided to confine the geological discussion mainly to phenomena observed on the North American Continent and to limit paleontological conclusions to results obtained from studies of material from the oldest fossiliferous Cambrian rocks.

In summing up the Lower Cambrian fauna in 1891 [Walcott,

[1] Read at the Eleventh International Geological Congress, Stockholm, Sweden, August 18, 1910.

1891a, pp. 594-595] I said, when speaking of the "Origin of Fauna":

If we attempt to classify the *Olenellus* fauna by its genesis, an almost impenetrable wall confronts us. That the life in the pre-*Olenellus* seas was large and varied there can be little, if any, doubt. The few traces known of it prove little of its character, but they prove that life existed in a period far preceding Lower Cambrian time, and they foster the hope that it is only a question of search and favorable conditions to discover it. As far as known to me, the most promising area in which to search for the pre-*Olenellus* fauna is on the western side of the Rocky Mountains in the United States and on their eastern (western) slopes in British Columbia. There the great thickness of conformable pre-*Olenellus* zone strata presents a most tempting field for the student collector. Another of the known possible areas is that of New York and Vermont, but the prospect is not as favorable as in the West. Other and better fields may exist in Asia and Africa, but as yet they are unknown, with the exception of the areas described by Baron Richthofen in China [Richthofen, 1882, Vol. 2, pp. 94, 100, and 101] where a great thickness of conformable sedimentary beds exists beneath a horizon that is comparable with the Middle Cambrian of western North America.

With the above thought in mind I have for the past eighteen years watched for geological and paleontological evidence that might aid in solving the problem of pre-Cambrian life. The great series of Cambrian and pre-Cambrian strata in eastern North America from Alabama to Labrador; in western North America from Nevada and California far into Alberta and British Columbia, and also in China,[1] have been studied and searched for evidences of life until the conclusion has gradually been forced upon me that on the North American Continent we have no known pre-Cambrian *marine* deposits containing traces of organic remains, and that the abrupt appearance of the Cambrian fauna results from geological and not from biotic conditions. I do not mean by this to infer that Brooks' hypothesis [Brooks, 1894, pp. 455-479] of the origin of the earlier forms of life in the surface waters of the open ocean is incorrect, but I mean that we have no known record in the strata of the marine life of the period between those earlier open-sea forms and the first records of life found in the Lower Cambrian strata. That such life existed there can be no question. It is the imperfection of the geological record as known to us that is the cause of the present uncertainty as to the pre-Cambrian faunas, and the abrupt appearance of the Cambrian fauna.

It is my present view that the known later Algonkian rocks in-

[1] Willis and Blackwelder, 1907, Vol. 1, pt. 1, pp. 21-44, 99-156, 265-274.

cluded in the Grand Canyon, Llano, and Belt series, and in formations correlated with them [see Van Hise and Leith, 1909, pp. 45, 46], were deposited in fresh- or brackish-water seas to which the marine life of the extra-continental seas very rarely had access. Such access occurred in mid-Beltian time when a protozoan, a crustacean, and a few annelids penetrated and became adapted to the conditions of the Montana sea, and more or less similar forms to the Arizona sea. Other and different forms may have lived in these and other interior bodies of water, but as yet we have no knowledge of them.

On the eastern side of the continent the unconformity between the oldest Cambrian and the known Algonkian rocks is so marked that there is no question of a great stratigraphic and time break between the two systems. The same is true of the Lake Superior, Hudson Bay, and Cordilleran areas. The Algonkian sedimentary rocks of the Atlantic coast region and the central interior continental areas, like most, if not all, of those of the western interior or Cordilleran areas, are of terrigenous origin, and in the absence of a marine fauna are considered as having been deposited in epicontinental seas or lakes of fresh or brackish water.

## PRE-CAMBRIAN ROCKS

With our present information it appears that toward the close of Archean time a period of diastrophism ensued, resulting in an uplift of the North American, and probably other continental masses. It was accompanied by local disturbances that resulted in the profound folding and metamorphism of the Archean complex and the formation of high mountains and uplands. Large areas of low lands existed between the higher lands, and in these the terrigenous sediments began to accumulate in inland seas and lakes and in the marine waters along the shores. Great quantities of eruptive matter were extruded, the agencies of diastrophism continued to exert their influence, but with decreasing energy, and during the latter part of Algonkian time they were still less active. When the continental area that had largely been a land surface since the first great uplift at the close of the Archean began to admit the Cambrian sea, or what is more probable, the sea began to rise, the latter found a surface of relatively low relief, and in some districts great areas of sediment that had been deposited in the inland lakes, so situated that the Cambrian sediments were laid down almost conformably superjacent to them.

In a word, the thought is that the Algonkian period, with its great epicontinental formations, was a period of continental elevation and largely terrigenous sedimentation in non-marine bodies of water, also a period of deposition by aerial and stream processes over considerable areas.

The recent map of the pre-Cambrian rocks of North America by Van Hise and Leith [1909, pl. 1] shows that the distribution of the Algonkian rocks is confined to areas well within the margins of the continental platform. The strata we have to consider on this map are in the areas placed under the Algonkian, including Keewatin areas in Canada and the Lake Superior region. Van Hise and Leith [1909, p. 21] define the Algonkian as including "the major part of the pre-Cambrian sedimentary rocks, though it also contains sediments so deformed and metamorphosed that their stratigraphy cannot be deciphered. The Archean is the basement complex, perhaps including several series or groups upon which the Algonkian rests, so far as known, with unconformity."

The sediments of other Algonkian areas of North America were much like those of the Lake Superior region in having immense quantities of sand and mud, and, more rarely, great thicknesses of calcareous matter.[1]

Briefly, the rocks of the later Algonkian formations may be outlined as follows:

WESTERN NORTH AMERICA

Grand Canyon series, Arizona. [Walcott, 1899, pp. 215-216.]

| | FEET |
|---|---|
| Chuar terrane (composed of fine-grained sandstone, argillaceous and arenaceous shales, and 285 feet in thickness of limestone) | 5,120 |
| Unkar terrane (composed mainly of sandstones with a bed of magnesian limestone 150 feet in thickness and a series of basalt flows 800 feet in thickness | 6,830 |
| Total thickness | 11,950 |

There are no conglomerates except a bed not exceeding 30 feet in thickness at the base.

The Llano series of Texas is much like the Grand Canyon series [Walcott, 1884, pp. 431, 432].

The Belt series of Montana [Walcott, 1899, pp. 201-209; 1906, pp. 2-15, 17-21] and British Columbia, Canada [Walcott, 1906, pp. 21-

[1] For data relating to the description of the Algonkian rocks see Van Hise and Leith, Bull. No. 360, U. S. Geol. Survey.


SIBERIA
BERING STRAIT
A L A S K A
D O M I N I O N
BOUNDARY OF CONTINENTAL
N O R T
GREENLAND
BAFFIN BAY
DAVIS STRAIT
ICELAND
Banks Land
Prince Albert Land
Victoria Land
Wales Land
North Somerset
North Devon
Cockburn Island
Southampton
FOXE CHANNEL
HUDSON STRAIT
HUDSON BAY


MAP OF NORTH AMERICA SHOWING DISTRIBUTION OF PRE-CAMBRIAN ROCKS. (AFTER VAN HISE AND LEITH, 1909.)

26], include in the Belt Mountain section 4,400 feet of limestone and 7,600 feet of arenaceous and siliceous strata [Walcott, 1899, p. 204], and in the Mission Range section about 6,000 feet of calcareous strata and over 18,000 feet of arenaceous and siliceous beds [Walcott, 1906, p. 18].

In the Lake Superior region the Keweenawan system is made up of a great series of mainly igneous rocks in the lower portion, with sedimentary sandstone and siliceous strata above, that form about 15,000 feet of the 50,000 feet in thickness provisionally assigned to this system [Chamberlin and Salisbury, 1906, p. 192].

The eastern or Atlantic Province Algonkian strata are represented in Newfoundland by about 10,000 feet of mainly siliceous sediments, and in Nova Scotia there may be 15,000 feet of similar sediments [Chamberlin and Salisbury, 1906, p. 204].

*Sources of Sediments.*—Of the sources of the sediments of the Algonkian (Proterozoic) formations of the Lake Superior region, Chamberlin and Salisbury consider [1906, Vol. 2, p. 199] "that a large portion of the sediments was produced by *mature decomposition* of older rocks, and this implies that they were not derived by rapid mechanical abrasion such as that which accompanies and follows great elevation and excessive precipitation. The great series of quartzites were derived from the complete decomposition of quartz-bearing rocks, and involved the almost complete separation of the quartz grains from other constituents, while the thick beds of shale arose from the complementary clayey products of decomposition from which most of the basic oxides had been removed by carbonation." These authors consider that the sediments were deposited on the bed of the Algonkian sea [p. 200].

The sources of the sediments of the Algonkian formations of the Cordilleran and Atlantic Provinces appear to have been similar to those described above, and all indicate relatively low elevations and quiet conditions of deposition except in the case of the massive, coarse sandstones in the lower Belt series of northwestern Montana [Walcott, 1906, p. 26].

The Algonkian formations of the Belt, Grand Canyon, Llano, and Avalon series all contain a large amount of bluish-black, red, and green, finely arenaceous, siliceous shales. These often form beds hundreds of feet in thickness, and extend over wide areas. With the exception of *Cryptozoan ? occidentale* Dawson [Walcott, 1906, p. 18] in some of the interbedded limestones there is no evidence of the presence of life in them.

There are also thick masses of limestone interbedded in the Algonkian series. The Blackfoot terrane has over 4,800 feet of calcareous beds. The Siyeh limestone is 4,000 feet thick, and the Newland limestone 2,000 feet. Similar blue, red, and green deposits, if deposited in the ocean, would probably have been accumulated in deep, quiet water [Chamberlin and Salisbury, Vol. 1, 1904, pp. 361-363], but (a) the large amount of calcareous matter; (b) the presence of shrinkage cracks and ripple markings on shales, sandstones, and limestone shales; (c) the presence in calcareous shales of fossils that lived in shallow water [Walcott, 1899, pp. 235-238], indicate that the Algonkian sediments were deposited in relatively shallow water.

In speaking of the climatic significance of red-colored deposits, Barrell [Barrell, 1908, pp. 292 and 293] says:

Turning to the climatic significance of red, it would therefore appear both from theoretical considerations and geological observations that the chief condition for the formation of red shales and sandstones is merely the alternation of seasons of warmth and dryness with seasons of flood, by means of which hydration, but especially oxidation of the ferruginous material in the flood-plain deposits is accomplished. This supplements the decomposition of the source and that which takes place in the long transportation and great wear to which the larger rivers subject the detritus rolled along their beds. The annual wetting, drying, and oxidation not only decompose the original iron minerals but completely remove all traces of carbon. If this conclusion be correct, red shales or sandstones, as distinct from red mud and sand, may originate under intermittently rainy, subarid, or arid climates without any close relation to temperature and typically as fluvial and pluvial deposits upon the land, though to a limited extent as fluviatile sediments coming to rest upon the bottom of the shallow sea. The origin of such sediment is most favored by climates which are hot and alternately wet and dry as opposed to climates which are either constantly cool or constantly wet or constantly dry.

*Origin of Later Algonkian Rocks.*—The question under this heading is as to whether the rocks of the Belt series of Montana, the Grand Canyon series of Arizona, the Llano series of Texas, the Avalon series of Newfoundland, and more doubtfully the Keweenawan series of the Lake Superior region, are of marine or of terrestrial origin.

By referring to the accompanying map of the later Algonkian rocks we find that all of the known areas are within the limits of the outline of the continental platform, even those of Newfoundland and Nova Scotia being 150 miles within that platform. With this in view I will first call attention to the origin of the great series of Tertiary terrestrial non-marine sediments in the western section of the continent, for the solution of that problem has a most important bearing on the probable origin of the Algonkian sediments.

In speaking of the terrestrial formations of the Eocene, Chamberlin and Salisbury [1906, Vol. 3, p. 204], when comparing the sedimentation of the Eocene with the present time, say:

Then as now, temporary and permanent streams were doubtless aggrading their valleys, and building fans and alluvial plains where the appropriate conditions were found, while sheet-floods spread debris washed down from the higher lands on the tracts below. The deformative movements which initiated the modern era probably gave rise to basins here and there, in which lakes were formed, and the flows of lava from the unnumbered vents of the time doubtless sometimes obstructed valleys, ponding the streams and giving rise to lakes. Under these conditions, it is probable that much of the debris which was started seaward by the swift waters of the higher lands found lodgment long before it reached the sea, some of it at the bases of steep slopes, some of it on river plains, and some of it in lakes. The wind also made its contribution. The result was an inextricable combination of fluvial, pluvial, eolian, and lacustral deposits.

Terrestrial formations of Eocene age and of fluvial, pluvial, lacustral, and eolian origin are widespread throughout the western interior, occurring even in proximity to the western coast. Many of them are of limited extent, while others are spread over great areas.

Again, in describing the terrestrial deposits of the Miocene, the above authors say [p. 266]:

The terrestrial Miocene formations (the Truckee Miocene[1] of King) are said to reach a thickness of 4,000 feet (King) at some points in the vicinity of the 40th parallel. In general, they are made up of sandstones, conglomerates, volcanic debris, infusorial earths, and fresh-water limestones, overlain by great thicknesses of volcanic tuffs. The John Day series, the upper portion of which is perhaps Miocene, is also thick (said to be 3,000 or 4,000 feet), and is made up largely of volcanic ash and sand, much of which seems to be eolian.[2]

Other areas of deposition, some of them lakes, existed during the Miocene in Nevada and Montana. In the southwestern part of Nevada, the Miocene beds (Esmeralda formation) described as lacustrine, consist of the usual sorts of clastic rocks, pyroclastic material, and workable coal, the latter showing that the formation is not altogether lacustrine. The formation also carries some sulphur. The remarkable thickness of 14,800 feet (which may include Pliocene beds) is reported for this formation.[3]

In the fresh-water Morrison formation of Colorado Mr. Darton notes the presence of 66 feet of limestone [Darton, N. H., 1905, p. 97] in a section 166 feet in thickness.

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[1] King, Geol. Expl. of the 40th Parallel, Vol. 1, pp. 412, 458.

[2] Merriam, Journ. Geol., Vol. 9, p. 71, and Bull. Dept. Geol., Univ. of Cal., Vol. 2, p. 306.

[3] Turner, Amer. Geol., Vol. 29, p. 268, and 21st Ann. Rept. U. S. Geol. Survey, Pt. 2.

I find in my field notes of 1879, on the Tertiary section at the head of the Upper Kanab Valley in southern Utah, the following on the fresh-water beds:

| | FEET |
|---|---|
| a. Light gray limestone with Physa and Planorbis..... | 125 |
| b. Pink arenaceous marls........................... | 180 |
| c. Light gray limestone........................... | 20 |
| d. Marl ......................................... | 40 |
| e. Pink limestone ................................ | 50 |
| f. Light gray limestone ........................... | 125 |
| g. Pink limestone ................................ | 100 |
| | 625 |
| h. Sandstones with fine conglomerate at the base...... | |

The limestones extend over a considerable area west, north, and east, and were deposited in massive layers in a deep, quiet lake.

The Tertiary sedimentation described above, omitting the eruptive materials, is very similar in many respects to that of later Algonkian time. The sediments of the Algonkian are as a whole more siliceous, but the variation in thickness and character of the various beds [Walcott, 1906, pp. 17-21] is of the same general type.

The sediments of the two widely separated periods of Algonkian and Tertiary time were accumulated within the limits of the great Cordilleran geosyncline, and, with our present knowledge, I think, under essentially similar physical conditions. At the time of the Tertiary deposition there was abundant life, both on the land and in the water, but in Algonkian time only a fragment of the pre-Cambrian life had had the opportunity of adapting itself to the conditions of the inland seas of late Algonkian time.

Dr. Joseph Barrell has given a full review of the evidence favoring the continental origin of most of the Algonkian rocks of the Cordilleran area. He argues that from the presence of mud-cracks in the Belt and Grand Canyon series that many of the formations were deposited on flood plains. He says [1906, p. 566]:

The discussion of these pre-Cambrian deposits but especially of the Montana occurrences, shows how completely in accord is the hypothesis of the dominant flood-plain origin of mud-cracks with the other marks of subaerial deposition in an arid climate. The mud-cracks are confined to just such formations as from other characteristics suggest a flood-plain origin and these formations are usually separated from the deposits of limestone by transitional formations which differ in color, in character, and in the absence of mud-cracks, suggesting the true submarine deposits originating between the shore and the open sea.

Doctor Barrell's view that the limestones are of marine origin is similar to the one that largely influenced me in the past to consider that the Grand Canyon and similar series of Algonkian formations were of marine origin.

## PRE-CAMBRIAN CONTINENTAL SURFACE

In 1892 I published the opinion that the North American continent

> Was larger at the beginning of Cambrian time than during any epoch of Paleozoic time and probably not until the development of the great fresh-water lakes of the lower Mesozoic was there such a broad expanse of land upon the continental platform between the Atlantic and Pacific oceans.
>
> The continent was well outlined at the beginning of Cambrian time; and I strongly suspect, from the distribution of the Cambrian faunas upon the Atlantic coast, that ridges and barriers of the Algonkian continent rose above the sea, within the boundary of the continental plateau, that are now buried beneath the waters of the Atlantic. On the east and west of the continental area the pre-Cambrian land formed the mountain region, and over the interior a plateau existed that at the beginning of, or a little before, Upper Cambrian time was much as it is to-day. Subsequent mountain building has added to the bordering mountain ranges, but I doubt if the present ranges are as great as those of pre-Cambrian time that are now known only by more or less of their truncated bases. The Interior Continental area was outlined then and it has not changed materially since. Its foundations were built in Algonkian time on the Archean basement, and an immense period of continent growth and erosion elapsed before the first sand of Cambrian time was settled in its bed above them. [Walcott, 1892, pp. 562-563.]

When the Californian Cambrian sea began its invasion of the Algonkian land in southwestern California and Nevada there awaited the incoming waters a land surface deeply disintegrated and more or less base-leveled by erosion. As compared with the earlier epoch of the Algonkian it was a featureless continent, the elevations caused by folding and uplift in the geosynclines of the Cordilleran, Lake Superior, and Appalachian areas having been largely degraded. The rising waters of the Cambrian sea met with few marked elevations in the Cordilleran and Appalachian troughs, as is evidenced by the absence of coarse conglomerates and the presence above the basal conglomerates of immense deposits of very fine sandstone and mud rocks in the Lower Cambrian.

The character of the pre-Cambrian surface in the southern Appalachian area is well indicated in the description by Mr. Arthur Keith,

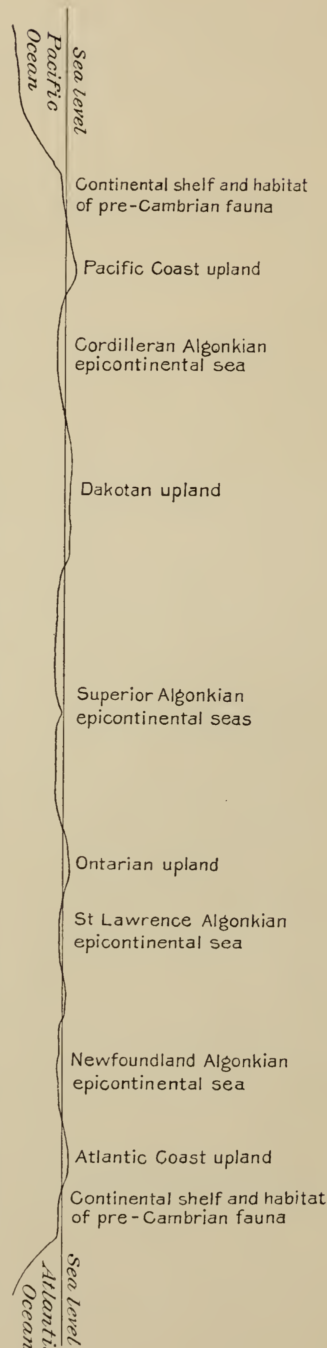


FIG. 1.

Theoretical profile of North American continent on line of Forty-eighth parallel, during part of Algonkian time. The Cordilleran, Superior, St. Lawrence, and Newfoundland epicontinental Algonkian seas are assumed to have been shut off from communication with the oceans during Algonkian time, except an occasional and very brief connection of the Cordilleran lakes with the Pacific Ocean.

of the Cambrian and pre-Cambrian contact in eastern Tennessee, who says[1]:

With the deposition of the Cambrian rocks there came a great change in the physical aspect of this region. The sea encroached on areas which for a long time had been dry land. Erosion of the surface and eruptions of lava were replaced by deposition of sediments beneath a sea. Extensive beds of these rocks were laid down in some areas before other areas were submerged, and the sediments lapped over lavas and plutonic granites alike. The waste from them all was combined in one sheet of gravel and coarse sand, which now appears as shale, sandstone, conglomerate, and rocks derived from them. The thickness of this first formation varies greatly and abruptly in this region, showing that the surface upon which it was laid down was irregular. Subsequent formations of Cambrian age came in a great group of alternating shale and sandstone followed by an immense thickness of limestone and shale. Fossils of Cambrian age, mainly *Olenellus,* are found as far down as the middle of the sandstone group. The strata lying beneath the fossiliferous beds differ in no material respect from those overlying. All are plainly due to the same causes and form part of one and the same group, and all are closely associated in area and structure.

When speaking of the similar contacts in northwestern North Carolina, he says[2]:

Here the sediments lapped over lavas and plutonic granites alike, and the waste from them all was combined in one sheet of gravel and coarse sand which now appears as sandstone, conglomerate, and quartzite. Some of this waste consists of epidote and jasper, the products of alteration in the Linnville metadiabase. It is thus seen that the interval between the Algonkian and Cambrian was at least long enough to permit dynamic movements and chemical changes to effect considerable results, even before the period of erosion and reduction began.

## UNCONFORMITY BETWEEN THE CAMBRIAN AND PRE-CAMBRIAN

In my paper on "The North American Continent during Cambrian Time" attention is called to a series of conformable pre-Cambrian rocks found in the Appalachian and Rocky Mountain troughs [Walcott, 1892, p. 544] that were thought to be conformably beneath the Lower Cambrian sandstone. Mr. Keith's detailed work, as cited above, has proven the presence of a marked unconformity in the southern Appalachian area. During the past ten years, as incidental to my Cambrian work, I have been studying the contact between the Cambrian and pre-Cambrian in the Cordilleran area. From

[1] U. S. Geol. Survey, Geological Atlas, Roan Mountain Folio, No. 151, 1907, p. 4.

[2] U. S. Geol. Survey, Geological Atlas, Cranberry Folio, No. 90, 1903, p. 4.

British Columbia and Alberta, on the main line of the Canadian Pacific Railway, to Arizona and southern California, a distance of over 1,000 miles, I have found evidence of a transgressing Cambrian sea and consequent unconformity between the Cambrian and pre-Cambrian. It may have been the advancing, overlapping Lower Cambrian sea as in southwestern Nevada, the Middle Cambrian sea as in Utah and Idaho, or the Upper Cambrian sea as in Colorado.

The Cambrian rocks may be abruptly unconformable upon the Algonkian [Walcott, 1891, p. 551, fig. 48], or practically conformable as in areas where there has been very little disturbance of the subjacent Algonkian beds [Walcott, 1899, pp. 210-213]. Over the interior of the continent the late Middle Cambrian and Upper Cambrian strata unconformably overlap the Algonkian and Archean [Walcott, 1891, pl. 44, pp. 561-562], and clearly could not have recorded any part of the history of the period indicated by the absence of Lower Cambrian strata or of the sediments deposited in the period represented by the unconformity between the Lower Cambrian and Algonkian strata. I do not know of a case of proven conformity between Cambrian and pre-Cambrian Algonkian rocks on the North American continent. In all localities where the contact is sufficiently extensive, or where fossils have been found in the basal Cambrian beds or above the basal conglomerate and coarser sandstones, an unconformity has been found to exist. Stated in another way, the pre-Cambrian land surface was formed of sedimentary, eruptive, and crystalline rocks that did not in any known instance immediately precede in deposition or origin the Cambrian sediments. Everywhere there is a stratigraphic and time break between the known pre-Cambrian rocks and Cambrian sediments of the North American continent.

## EXTENT OF WITHDRAWAL OF SEAS IN ALGONKIAN TIME

That the present area of the North American continent was higher than the level of the Atlantic and Pacific oceans at the beginning of known Cambrian time is, I think, well established, and with the data available it would appear that all other continental areas were in a similar condition. What diastrophic action caused the withdrawal of the oceanic waters from the continental areas during the great period represented by the non-marine deposition of the later Algonkian sediments and the period of erosion preceding the deposition of the superjacent Cambrian sediments, is unknown. It may have been produced by a sinking of the ocean bed that lowered the shore line of all the continents. It was of world-wide extent and of great duration, and it was during this period that the open-sea fauna, as described by Brooks, probably found its way to the littoral zone and developed in the protected waters along the ancient continental shelves. Of this period we have no known record either in marine sedimentation or in life.

## EVIDENCE OF THE FOSSILS

The evidence afforded by the few traces of pre-Cambrian fossils is inconclusive as far as determining whether their habitat was in marine, brackish, or fresh water.

The fossils from the Chuar group of Arizona [Walcott, 1899, pl. 23, figs. 1-4; pl. 27, figs. 9-13] are not sufficiently characterized to prove their origin or habitat. The *Protozoan, Cryptozoon ? occidentale* Dawson, is very abundant in Arizona, also in the Belt series of Montana, Alberta, and British Columbia. It occurs in limestones similar to those deposited in the fresh-water lagoons of Florida, and similar to the limestones of the lake deposits of the Tertiary formations of the Great Plains region of North America. The fossils of the Beltina zone of Montana and Alberta could as readily have been developed in fresh or brackish waters. There is nothing about the crustacean remains incompatible with their living in fresh water, in fact, the fragments indicate a form more nearly related to the fresh-water *Branchiopoda* with very thin test, rather than the strong *Merostome* (*Eurypterus,* etc.).

The oldest Cambrian fauna now known, with *Nevadia weeksi* and *Holmia rowei* [Walcott, 1910, pp. 257 and 292], is limited to a few forms, but with a careful examination of the region where it occurs in southwestern Nevada it is highly probable that a considerable fauna will be found. The strata in which it occurs were deposited in a depression opening out toward the Pacific ocean, where southwestern California is now located; this depression soon extended northward and presumably connected through to British Columbia and Alberta, as the same species of *Olenellus* occur in the central and upper portions of the Lower Cambrian both in Nevada and Alberta.

I do not know of a Cambrian fauna as old as that of *Nevadia weeksi* on the eastern side of the continent, or on the European continent. It appears to be a portion of the older fauna that is missing everywhere except in southwestern Nevada. I think it was brought in by the advancing Lower Cambrian sea from a sea to the west, the sediments of which are buried beneath later strata or are off the present shore line of the continent beneath the sea.

The theory that life originated and developed in fresh-water ponds and lakes does not appeal to me. More uniform conditions of temperature and environment would be present in the ocean and the sediments of the fresh-water deposits of pre-Cambrian and Cambrian time, if such exist, do not show sufficient evidence of life having existed at the time of their deposition. The Algonkian fossils of the Belt and Grand Canyon series [Walcott, 1899, pp. 227-239] probably came from the marine fauna when a temporary connection existed between the interior fresh- or brackish-water lakes and the ocean.

## RÉSUMÉ

1. Life probably first developed in the open ocean, as outlined by Brooks [1894].

2. The life of the oceans became adapted to littoral and shore conditions in Algonkian time during a period when the relation of all the continents to sea level was essentially the same as at the present time, or the continents may have been still more elevated in relation to the surrounding oceans.

3. The period of Algonkian continental elevation was of sufficient duration to permit of the development along the shores and shelves of the continents of the types of life now found in the basal Cambrian rocks, but the sediments containing the record of this life are probably concealed beneath the present oceans.

4. The known fossils contained in the Algonkian sediments of the Cordilleran geosyncline lived in fresh or brackish waters that were rarely in connection with marine waters on the margins of the Algonkian continent of North America. This will explain the abrupt appearance of a highly specialized crustacean deep down in the Belt series.

5. When the oceanic waters gained access to the Algonkian continental areas at the close of that era they brought with them the littoral fauna which had been developed during the Lipalian sedimentation,[1] and buried its remains in the sands and muds which form the Lower Cambrian deposits.

[1] Lipalian (λειπα + αλς) is proposed for the era of unknown marine sedimentation between the adjustment of pelagic life to littoral conditions and the appearance of the Lower Cambrian fauna. It represents the period between the formation of the Algonkian continents and the earliest encroachment of the Lower Cambrian sea.

6. The apparently abrupt appearance of the Lower Cambrian fauna is therefore to be explained by the absence on our present land areas of the sediments, and hence the faunas of the Lipalian period. This resulted from the continental area being above sea level during the development of the unknown ancestry of the Cambrian fauna.

I fully realize that the conclusions above outlined are based primarily on the absence of a marine fauna in Algonkian rocks, but until such is discovered I know of no more probable explanation of the abrupt appearance of the Cambrian fauna than that I have presented.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 2



# CAMBRIAN
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## II

## No. 2.—MIDDLE CAMBRIAN MEROSTOMATA

WITH SIX PLATES

BY

CHARLES D. WALCOTT

(PUBLICATION 2009)



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## CONTENTS



## ILLUSTRATIONS

## INTRODUCTION

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

## CAMBRIAN MEROSTOMATA

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

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

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

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

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

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

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

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

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

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

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

*Sub-Class MEROSTOMATA*

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

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

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

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

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

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

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

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

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

## Class CRUSTACEA

### Sub-Class MEROSTOMATA (Dana) Woodward

### Order EURYPTERIDA

#### Sub-Order LIMULAVA, new sub-order

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

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

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

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

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

### Family SIDNEYIDAE, new family

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

### Genus SIDNEYIA, new genus

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

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

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

Surface of dorsal shield smooth.

*Genotype*.—*Sidneyia inexpectans*, new species.

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

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

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

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

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

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

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

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

[2] Idem, pp. 216, 217.

## SIDNEYIA INEXPECTANS, new species

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

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

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

*Abdomen.*—The abdomen has twelve segments as shown by fig. 1, pl. 2 and fig. 2, pl. 5. The anterior nine segments form a broad ellipse, the anterior end of which is attached to and merges into the outline of the cephalo-thorax; the length of these segments is about one-eighth of their width; the first segment terminates in a point equally converging from the front and back margins; in the second segment the convergence and curvature is greatest toward the front side and back of this the curvature of the front margin increases until there is a slight backward arching of the posterior margin so as to form a sharp point with the downward arching front margin; posteriorly the tenth and eleventh segments are nearly as long as wide, much narrower than the first nine segments and more than twice as long as the anterior segments from which they extend backward; they appear to be simple, annular rings; the twelfth or terminal segment has a central body, broadly oval in outline, that extends backward from two-thirds to four-fifths of the distance to the posterior margin; at about half its length a wing-like extension continues backward and slightly outward to a transverse margin; on each side of the terminal segment (pl. 3, figs. 2-4), and attached to its anterior side, there is a lateral swimmeret that on the inside overlaps more or less the central terminal section and on the outside margin expands so as to form, with the central terminal section, a broad caudal fin suggestive of that occurring in the Schizopoda and Decapoda; it may be that there are more than one of the lateral swimmerets on each side, but if so they are so pressed in together as not to be distinguished. The anterior margin of each segment extends under the segment in front of it from one-fifth to one-third its length at the center, the underlap gradually narrowing to where it passes from beneath the segment near its outer termination; the anterior segment passes beneath the cephalo-thorax in the same manner.

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

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

The simple form of the third pair of appendages is shown by fig. 1, pl. 5. They have a relatively large basal joint, the anterior inner margin of which is provided with six or more sharp spines that appear to have been used in connection with the basal joints of the fourth and fifth pair of appendages as manducatory organs. This appendage has broad, strong joints in small specimens (pl. 5, fig. 1) and in large specimens it is developed into a peculiarly constructed and complex chelate terminal section; this is formed of twelve or more joints of a forward curving appendage to which are attached on the anterior side long spines carrying numerous smaller spines on the margin opposed to the main body of the appendage (pl. 4, fig. 4). There is also in this specimen a broad appendage of three joints attached to the outer posterior end of the basal joint. The features described are partially illustrated on pl. 4, by figs. 1-4. Fig. 3 illustrates some of the long spines where they are sufficiently separated to show the shorter secondary spines. Another unusual variation is illustrated by fig. 1. In the small specimen illustrated by fig. 2, pl. 2, it looks as though there were two jointed branches extending outward with small spines on their anterior margins. A larger series of specimens will undoubtedly enable us to interpret these chelate appendages more accurately but with our present information it seems probable that in the complex form represented by fig. 1, pl. 4, provision was made for capturing the numerous small phyllopod crustaceans and numerous annelids with which the bottom and adjacent water were abundantly supplied. It may be that the chelate, complex appendages were also used in fighting and that there was a marked difference in those belonging to the male and female.

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

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

*Ventral appendages: Abdominal.*—A number of specimens show more or less of traces of abdominal appendages on the first nine segments of the abdomen. None of these indicates the presence of a jointed appendage in any way comparable with the appendages of the cephalo-thorax, or the abdominal appendages of the trilobite. The appendages appear to be formed of clusters of branchial fringes attached to short lobes that are round or oval in outline and affixed to the ventral surface on each side of the abdomen at the outer edge of its inner third, or they may be of a lamellated structure as shown by fig. 1, pl. 3, fig. 1, pl. 2, fig. 3, pl. 6. What is now known of these branchial clusters recalls very strongly the lamellated branchial fringes occurring in the cephalic portion of the trilobite *Calymene senaria,*[1] and in specimens of *Neolenus serratus* (see pl. 6, figs. 1 and 2) associated with *Sidneyia inexpectans.*

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

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

### Genus AMIELLA, new genus

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

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

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

### AMIELLA ORNATA, new species

(Pl. 5, fig. 4.)

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

Crust thin and compressed in the shale.

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

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

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

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

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

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

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

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

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

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

## DESCRIPTION OF PLATE 2

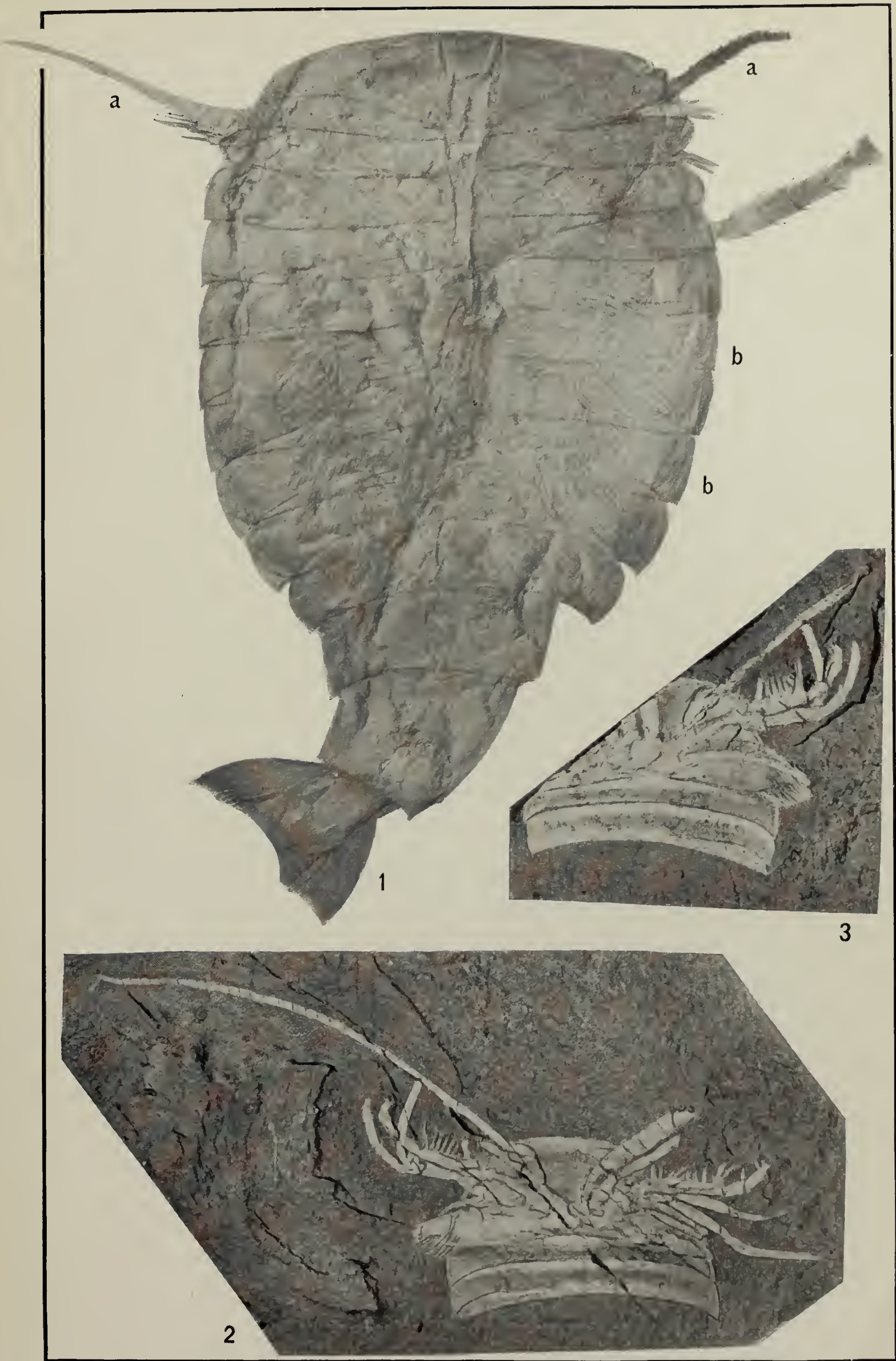


FIG. 1. A large dorsal shield (natural size) flattened and somewhat broken by compression in the shale; an antenna projects out from each side in front of the eye, and, on the right-hand side, probably the fourth appendage of the cephalo-thorax which has been pushed back under the second segment of the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

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

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

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




SIDNEYIA INEXPECTANS

## DESCRIPTION OF PLATE 3



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

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

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

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


SIDNEYIA INEXPECTANS

## DESCRIPTION OF PLATE 4

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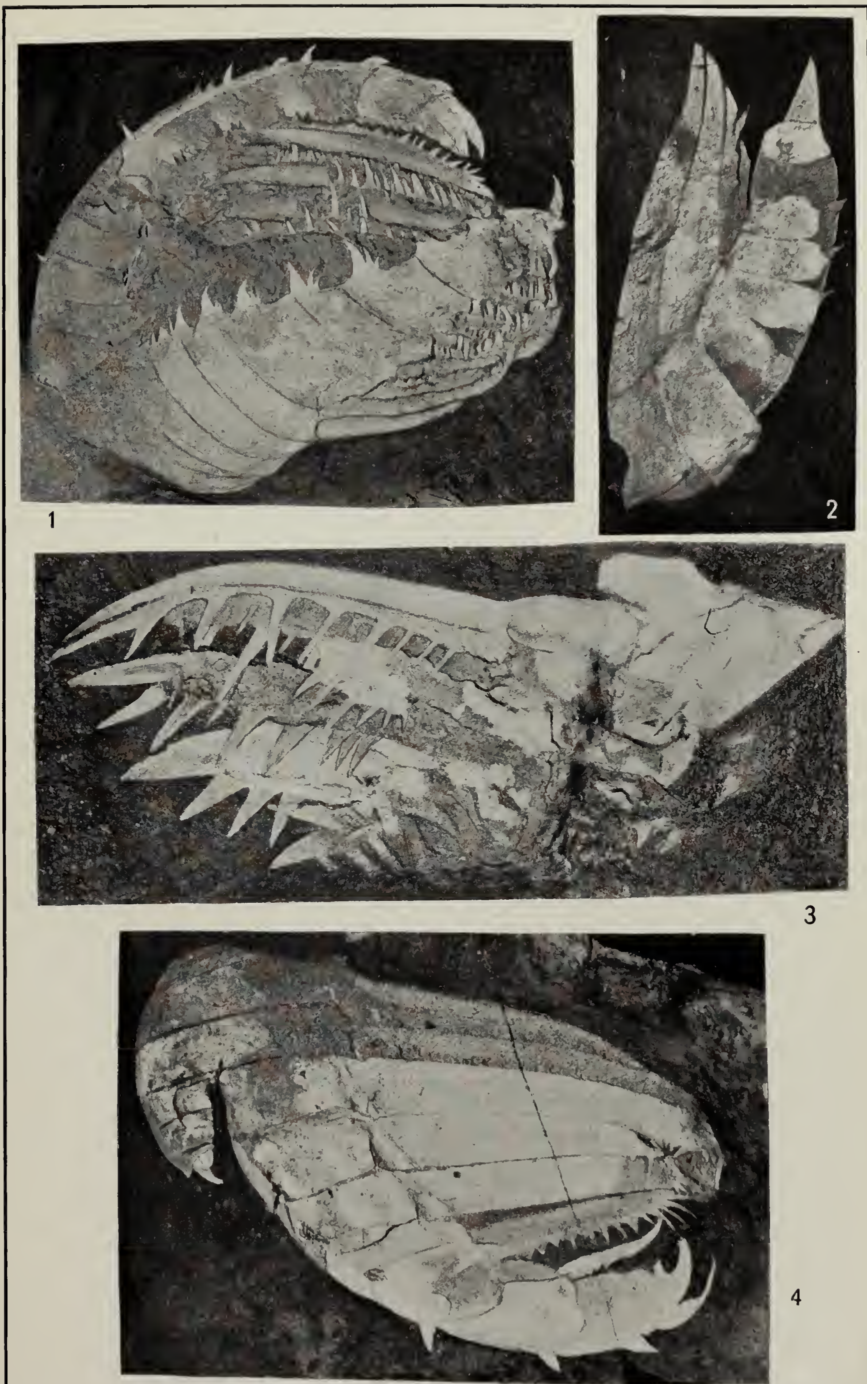
Fig. 1. Outer portion of the third pair of appendages of the cephalo-thorax (× 2). In this there appears to have been a somewhat different development of parts as compared with those seen in figs. 3 and 4. U. S. National Museum, Catalogue No. 57490.

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

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

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




SIDNEYIA INEXPECTANS

## DESCRIPTION OF PLATE 5



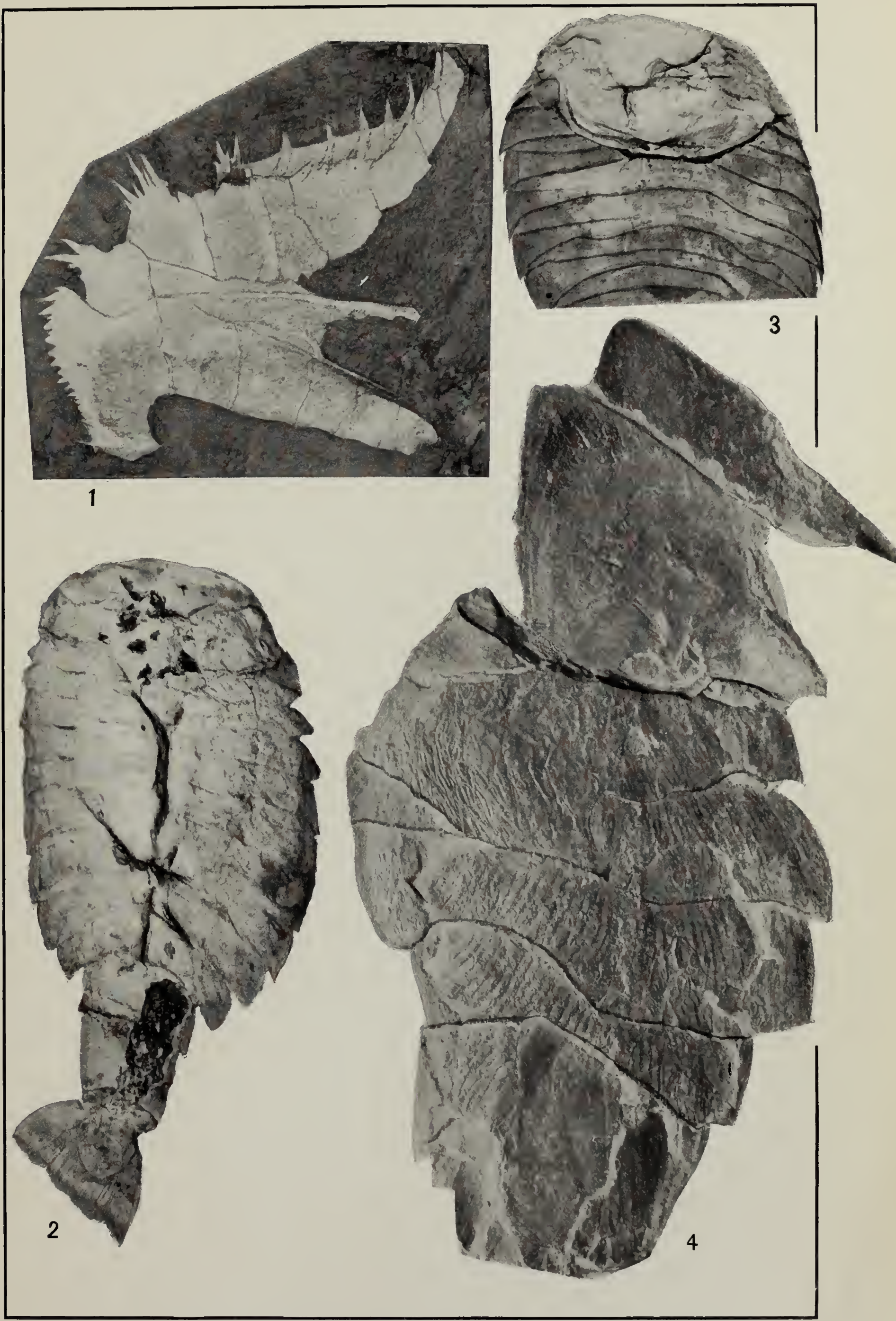
FIG. 1. The third, fourth, and fifth appendages of the cephalo-thorax, showing the gnathobases and something of the proportions of the appendages. × 3. U. S. National Museum, Catalogue No. 57494.

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

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



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




SIDNEYIA INEXPECTANS AND AMIELLA ORNATA

## DESCRIPTION OF PLATE 6

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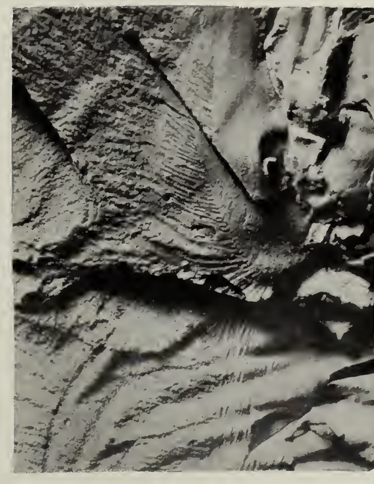
*Neolenus serratus* (Rominger) .......................................... 27

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

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

*Sidneyia inexpectans* Walcott .......................................... 24

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



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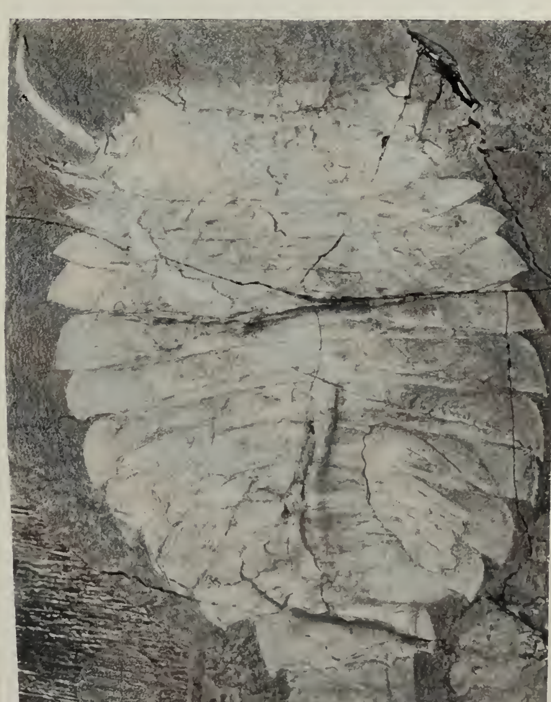

3

NEOLENUS SERRATUS AND SIDNEYIA INEXPECTANS

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

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

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

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

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

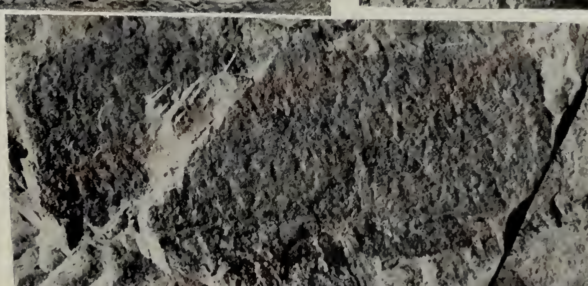
4. A large abdominal segment preserving a portion of the original convexity and tuberculated surface. Natural size. U. S. National Museum, Catalogue No. 57503.

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

1

2

2a



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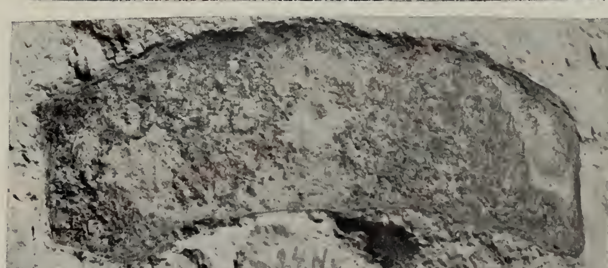

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SIDNEYIA INEXPECTANS AND BELTINA DANAI

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 3



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 3.—MIDDLE CAMBRIAN HOLOTHURIANS AND MEDUSÆ

WITH SIX PLATES

BY

CHARLES D. WALCOTT

(PUBLICATION 2011)



CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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## II

## No. 3.—MIDDLE CAMBRIAN HOLOTHURIANS AND MEDUSÆ

By CHARLES D. WALCOTT

(With Six Plates)

CONTENTS



PLATES

## TEXT FIGURES



## INTRODUCTION

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

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

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

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

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

## HOLOTHURIANS

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

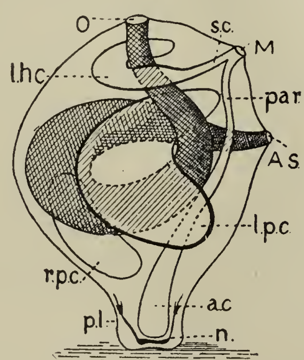


FIG. 2.—Diagrammatic reconstruction of the imagined primitive Pelmatozoic ancestor. (After Lankester, 1900, fig. 7, p. 9.[1]) O = mouth; As = anus; ac = right and left anterior portion of cœlom; rpc and lpc = right and left posterior portion of cœlom; lhc = left hydrocœl; sc = canal connecting lhc and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

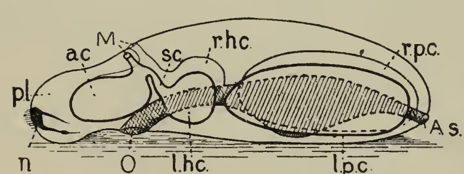


FIG. 3.—Diagrammatic reconstruction of imagined *Dipleurula* ancestor. Anterior end at left of drawing; organs of left side toward observer, and with stronger outline than those of right side. (After Lankester, 1900, fig. 1, p. 4.[1]) O = mouth; As = anus; ac = right and left anterior portion of cœlom;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

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

Among zoologists the theoretically most primitive ancestor of the

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

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

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

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

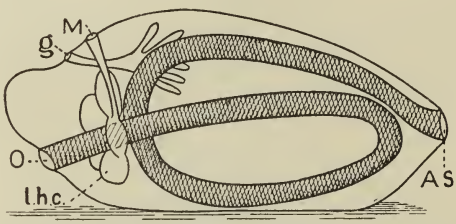


FIG. 4.—Diagrammatic reconstruction of the imagined primitive Holothurian type. (After Lankester, 1900, fig. 16, p. 18.[1]) O = mouth; As = anus; lhc = left hydrocœl; M = hydropore; g = genital opening.

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

[1] See footnote on p. 43.

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

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

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

## Class HOLOTHURIOIDEA Siebold, 1848

### Order ACTINOPODA

#### Family ELDONIIDAE, new family

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

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

#### Genus ELDONIA, new genus

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

---

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

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

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

*Genotype.*—*Eldonia ludwigi,* new species.

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

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

## ELDONIA LUDWIGI, new species

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

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

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

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

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

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

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

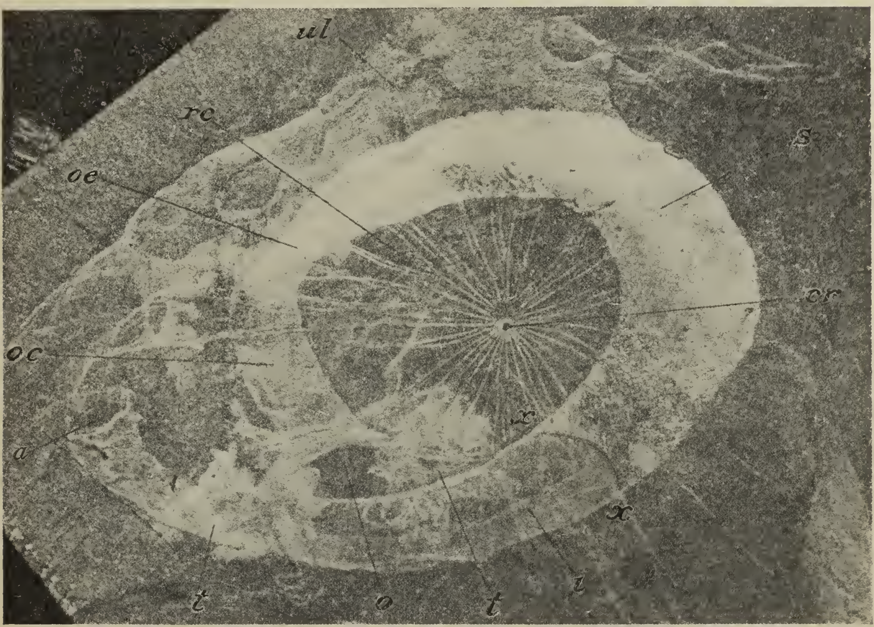


FIG. 5.—*Eldonia ludwigi*, × 2. A specimen flattened in the shale and preserving the alimentary canal, oral aperture and tentacles, water vascular system and traces of the umbrella. U. S. National Museum, Catalogue No. 57537.

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

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

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

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

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

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

The outer opening of the oral chamber is best shown by fig. 5, pl. 9. A number of specimens show that from each side of the flattened opening there is a short projecting arm which supports a cluster of short tentacles, or, if we interpret the short arm as a strong tentacle, with a disk to which are attached digits, the whole tentacle being retractile and capable of being withdrawn into the oral chamber. Some of the specimens suggest a three-lobed disk (text fig. 5). With the material now available it is not perfectly clear how many of the "peltato-digitate" tentacles originally existed. Two only have thus far been seen on each of several beautifully preserved specimens. It may be that five will be found, two of which will be fully developed and three immature or atrophied.

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

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

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

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

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

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

*Dimensions.*—The largest specimen is represented by fig. 3, pl. 12. The right and left sides have been partly folded under and lost, but by taking the average width of the lobed umbrella outside of the alimentary canal the diameter of the umbrella must have been about 12 cm. That the greater number of specimens were smaller is proven by the size of the spiral alimentary canal.

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

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

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

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

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

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

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

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

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

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

[2] BURGESS SHALE

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

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

*Derivation.*—From Burgess Pass, the type locality.

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

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

*Stratigraphic position.*—Above thin bedded, dark gray, and bluish-black limestones of the Stephen formation, and beneath a thin bedded limestone of the Stephen formation; west slope of ridge between Mount Field and Wapta Peak, one mile northwest of Burgess Pass, above Field on the Canadian Pacific Railway, British Columbia, Canada.

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

### Family HOLOTHURIIDÆ

#### Genus LAGGANIA, new genus

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

*Genotype.*—*Laggania cambria,* new species.

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

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

### LAGGANIA CAMBRIA, new species

Plate 13, fig. 1.

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

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

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

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

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

### Genus LOUISELLA, new genus

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

*Genotype.—Louisella pedunculata,* new species.

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

### LOUISELLA PEDUNCULATA, new species

Plate 13, fig. 4.

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

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

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

### Family SYNAPTIDÆ[2]

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

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

---

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

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

**Genus MACKENZIA, new genus**

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

*Genotype.—Mackenzia costalis,* new species.

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

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

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

---

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

### MACKENZIA COSTALIS, new species

Plate 13, figs. 2 and 3.

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

Surface smooth so far as determined.

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

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

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

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

## SCYPHOMEDUSÆ

### Order RHIZOSTOMÆ

#### Family Undetermined

#### Genus PEYTOIA, new genus

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

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

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

(b) Margin of bell cleft into lappets,

(c) Absence of tentacles, and

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

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

*Genotype.—Peytoia nathorsti,* new species.

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

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

### PEYTOIA NATHORSTI, new species

Plate 8, figs. 1 and 2.

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

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

No traces of a concentric muscle band.

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

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

*Observations.*—The three specimens of this species occur in partings of the siliceous shale in association with annelids and crustaceans that indicate that they were deposited on the bottom in quiet water, and were not left on a beach between tides. The subumbrella disk had considerable substance to it, as it has left a very clear impression and the lobes still retain a slight convexity.

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

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

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

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

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

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

## DESCRIPTION OF PLATE 8

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

PAGE

*Peytoia nathorsti* Walcott........................................ 56

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

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

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

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

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

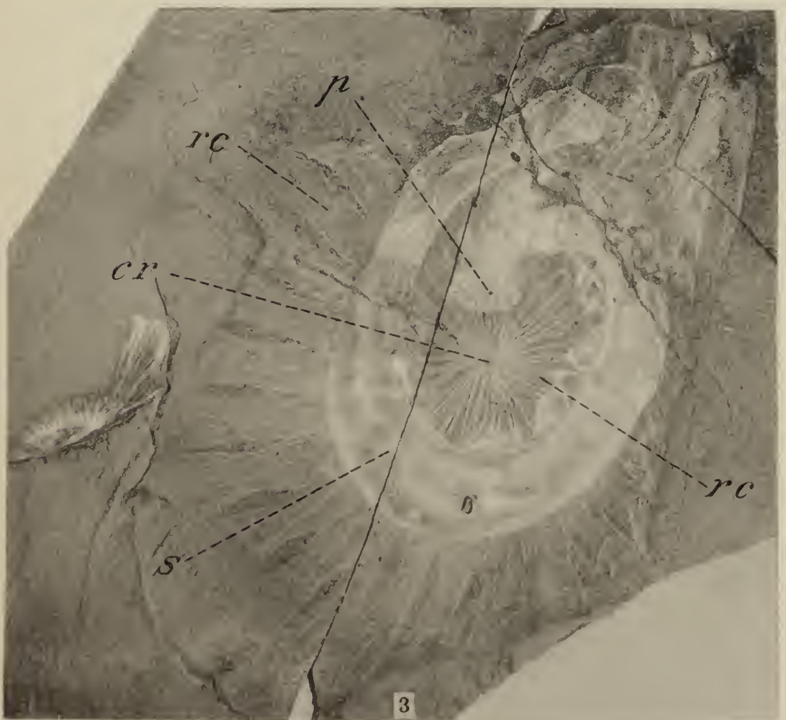
FIG. 3. An individual preserved as a thin film in the shale. Natural size. U. S. National Museum, Catalogue No. 57540.

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

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.






MIDDLE CAMBRIAN MEDUSA AND HOLOTHURIAN

## DESCRIPTION OF PLATE 9

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

PAGE

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

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

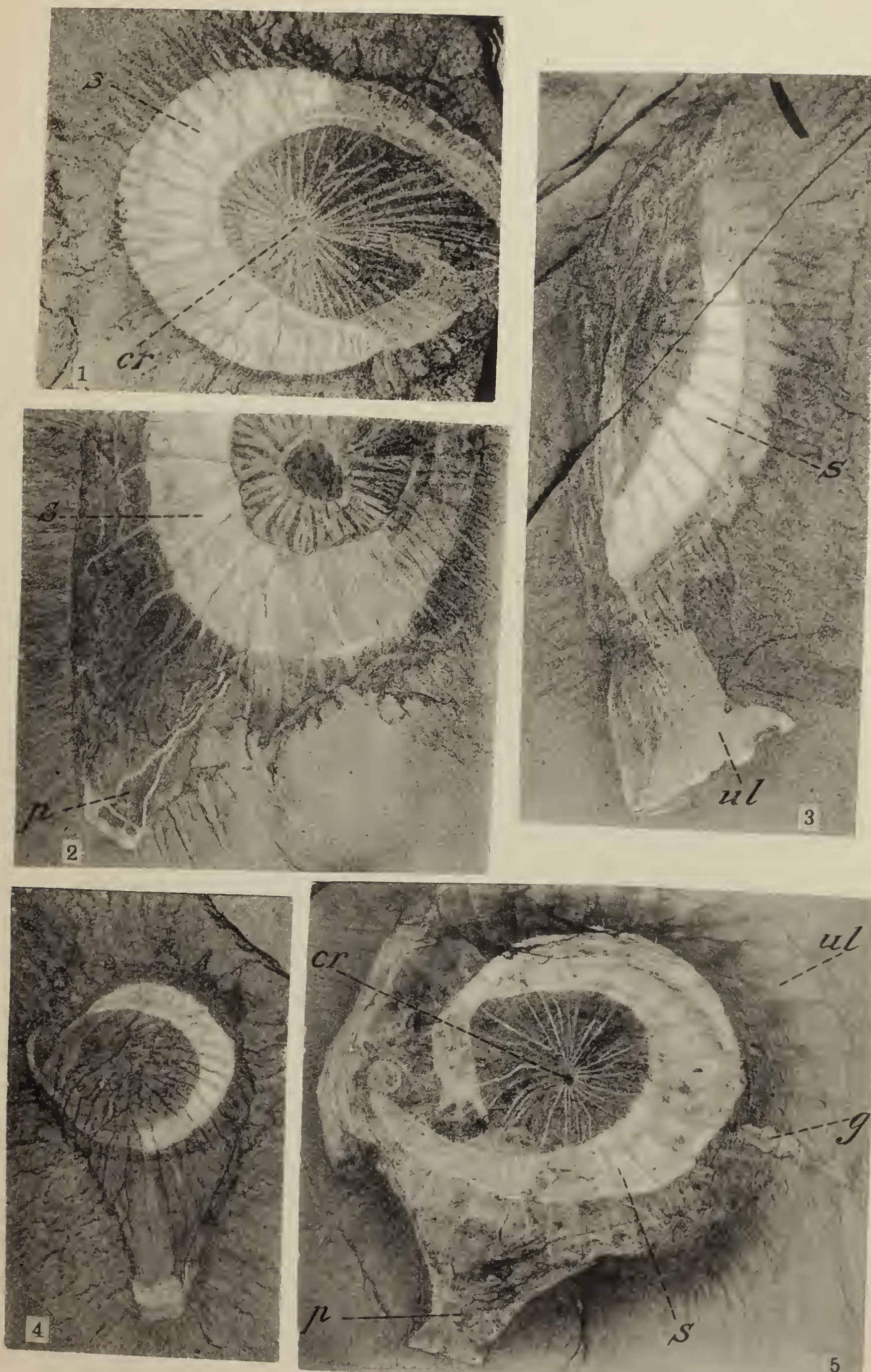
2. An individual (× 2) showing the stomach (s), radial canals, and what appears to be the umbrella at (p). U. S. National Museum, Catalogue No. 57542.

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

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

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN HOLOTHURIAN

## DESCRIPTION OF PLATE 10

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

PAGE

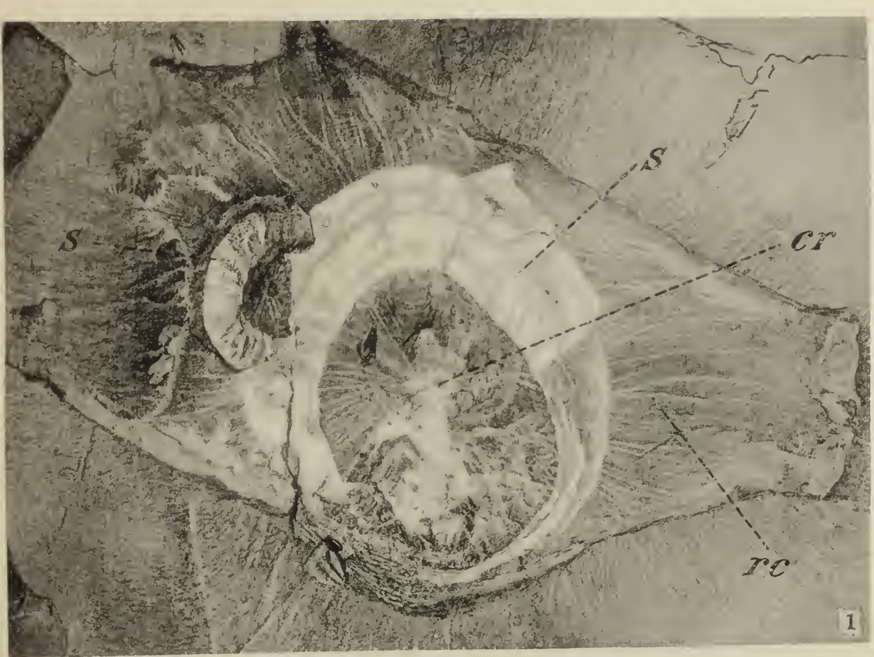
*Eldonia ludwigi* Walcott (see also text fig. 5 and pls. 8-9 and 11-12).... 46

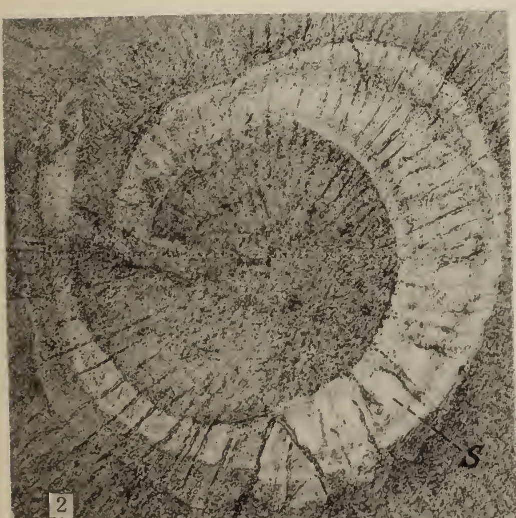
FIG. 1. A large individual very much compressed and distorted. The central ring (cr), radial canals (rc), and stomach (s) are indicated. A second specimen that lies under the large specimen is shown on the left by the convoluted stomach. Natural size. U. S. National Museum, Catalogue No. 57546.

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

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.





MIDDLE CAMBRIAN HOLOTHURIAN

## DESCRIPTION OF PLATE 11

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

PAGE

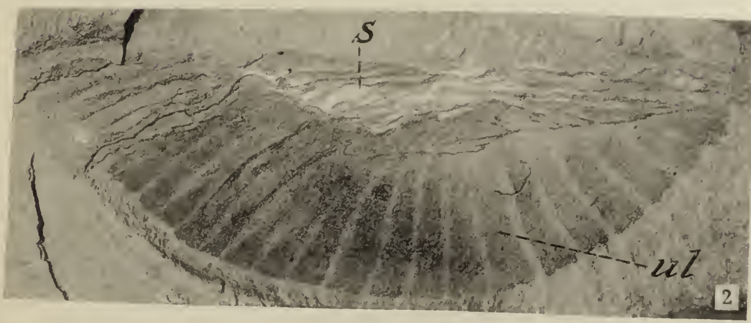
*Eldonia ludwigi* Walcott (see also text fig. 5 and pls. 8-10 and 12)...... 46

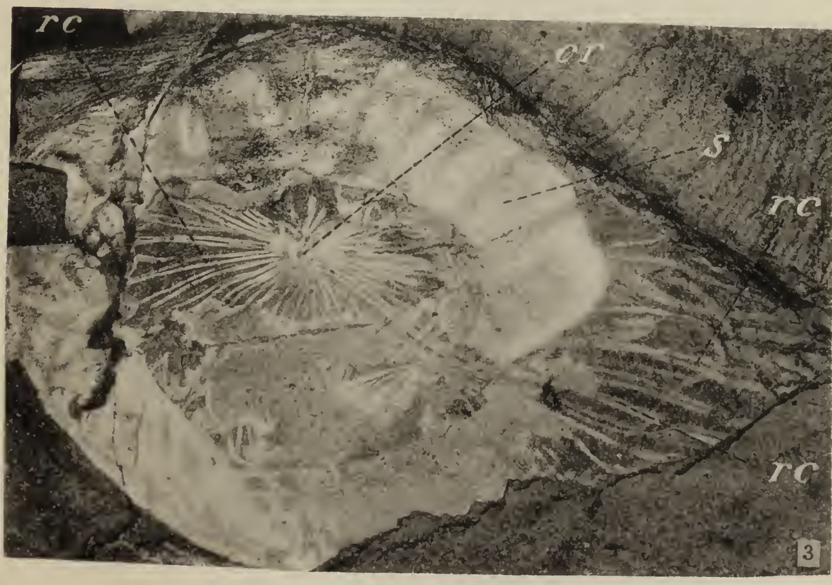
FIG. 1. An individual flattened in the shale, showing the lobate character of the umbrella. × 2. U. S. National Museum, Catalogue No. 57549.

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

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.


MIDDLE CAMBRIAN HOLOTHURIAN

## DESCRIPTION OF PLATE 12

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

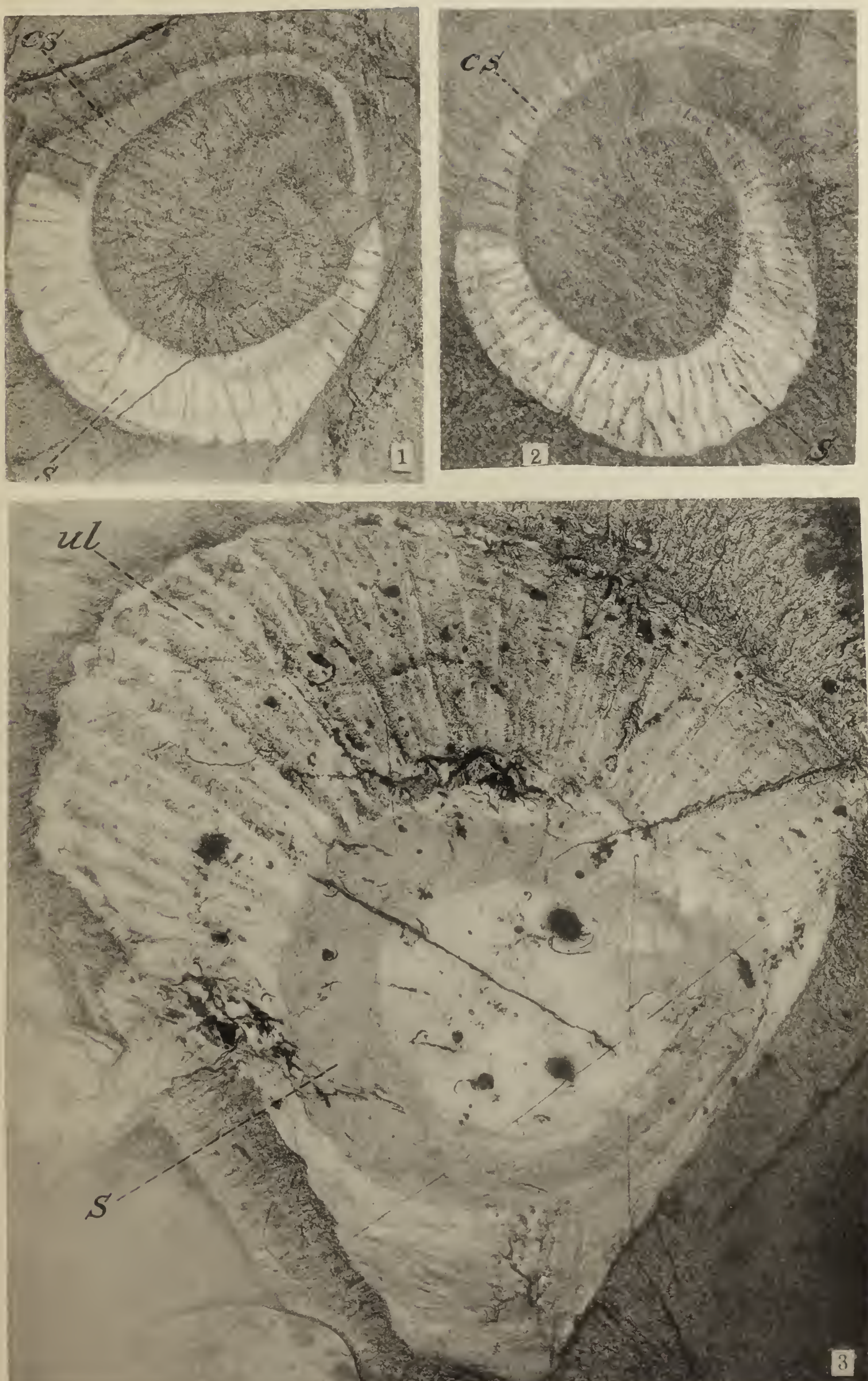
PAGE

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

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

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN HOLOTHURIAN

## DESCRIPTION OF PLATE 13

PAGE

*Laggania cambria* Walcott .......................................... 52

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

*Mackenzia costalis* Walcott .......................................... 55

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

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

*Louisella pedunculata* Walcott .......................................... 53

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

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian; dark siliceous shales in the Burgess shale of the Stephen formation on the west slope of the ridge between Mount Field and Wapta Peak, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.


MIDDLE CAMBRIAN HOLOTHURIANS

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 4



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 4.—CAMBRIAN FAUNAS OF CHINA

With Four Plates

BY

CHARLES D. WALCOTT

(Publication 2012)



CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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# CAMBRIAN GEOLOGY AND PALEONTOLOGY

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(With Four Plates)

CONTENTS



ILLUSTRATIONS



## INTRODUCTION

This is the third preliminary paper on the Cambrian faunas of China.[1] It includes the description of a few new species from the collection made by Mr. Eliot Blackwelder of the Carnegie Institution of Washington Expedition to China in 1903-04; a larger number of species are from collections made in Manchuria by Dr. Joseph P. Iddings, who very kindly offered to make a collection for the Smithsonian Institution in the Province of Liau-tung, where Baron Richthofen collected the Cambrian trilobites described by Dr. Wilhelm Dames[2] and the Cambrian brachiopods described by Dr. Emanuel Kayser.[3] Other species are included, see list on pages 72-73.

In the revision of the new material from Liau-tung, Shan-tung, and Shan-si, it became necessary to study the references of the

[1] Proc. U. S. National Museum, Vol. 29, 1905, pp. 1-106.
Idem, Vol. 30, 1906, pp. 563-595.

[2] China, by Richthofen, vol. 4, pp. 3-33.

[3] Idem, pp. 33-36.

species and genera. This resulted in the founding of several new genera and the changing of the generic reference of a number of the species described in the first two preliminary papers. The changes made are shown in the accompanying list, the first column giving the preliminary generic references and the second column the genera to which the species are now referred:

## LIST OF NAMES CHANGED

| *Former generic reference.* | *Present generic reference.* |
|---|---|
| *Agnostus koerferi* Monke, 1903 | = *Agnostus douvillei* Bergeron |
| *Agraulos abaris* Walcott, 1905 | = *Inouyia abaris* (Walcott) |
| *Agraulos acalle* Walcott, 1905 | = *Inouyia ? acalle* (Walcott) |
| *Agraulos agenor* Walcott, 1905 | = *Levisia agenor* (Walcott) |
| *Agraulos armatus* Walcott, 1906 | = *Inouyia ? armatus* (Walcott) |
| *Agraulos (?) capax* Walcott, 1906 | = *Inouyia capax* (Walcott) |
| *Agraulos divi* Walcott, 1905 | = *Inouyia divi* (Walcott) |
| *Agraulos (?) melie* Walcott, 1906 | = *Inouyia melie* (Walcott) |
| *Agraulos regularis* Walcott, 1906 | = *Inouyia ? regularis* (Walcott) |
| *Amphoton* Lorenz, 1906 | = *Dolichometopus* Angelin |
| *Amphoton steinmanni* Lorenz, 1906 | = *Dolichometopus deois* Walcott |
| *Anomocare bergioni* Walcott, 1905 | = *Anomocarella bergioni* (Walcott) |
| *Anomocare bianos* Walcott, 1905 | = *Coosia ? bianos* (Walcott) |
| *Anomocare bigsbyi* Walcott, 1906 | = *Anomocarella bigsbyi* (Walcott) |
| *Anomocare biston* Walcott, 1905 | = *Anomocarella biston* (Walcott) |
| *Anomocare ? butes* Walcott, 1905 | = *Anomocarella butes* (Walcott) |
| *Anomocare commune* Lorenz, 1906 | = *Anomocarella chinensis* (Walcott) |
| *Anomocare daunus* Walcott, 1905 | = *Coosia ? daunus* (Walcott) |
| *Anomocare decelus* Walcott, 1905 | = *Coosia decelus* (Walcott) |
| *Anomocare eriopia* Walcott, 1906 | = *Ptychoparia (Emmrichella) eriopia* (Walcott) |
| *Anomocare limbatum* Angelin | = *Coosia (?) limbatum* (Angelin) |
| *Anomocare speciosum* Lorenz, 1906 | = *Anomocarella speciosum* (Lorenz) |
| *Anomocare tatian* Walcott, 1905 | = *Anomocarella tatian* (Walcott) |
| *Anomocare temenus* Lorenz, 1906 | = *Anomocarella temenus* (Walcott) |
| *Anomocare temenus* Walcott, 1905 | = *Anomocarella temenus* (Walcott) |
| *Anomocarella ? bura* Walcott, 1905 | = *Lisania bura* (Walcott) |
| *Anomocarella carme* Walcott, 1905 | = *Coosia carme* (Walcott) |
| *Anomocarella contigua* Walcott, 1906 | = *Anomocarella albion* Walcott |
| *Arionellus agonius* Walcott, 1905 | = *Lisania agonius* (Walcott) |
| *Arionellus ajax* Walcott, 1905 | = *Lisania ajax* (Walcott) |
| *Arionellus alala* Walcott, 1905 | = *Lisania alala* (Walcott) |
| *Bathyuriscus asiaticus* Lorenz, 1906 | = *Dolichometopus deois* Walcott |
| *Bradoria bergeroni* Walcott, 1905 | = *Aluta bergeroni* (Walcott) |
| *Bradoria enyo* Walcott, 1905 | = *Aluta enyo* (Walcott) |
| *Bradoria eris* Walcott, 1905 | = *Aluta eris* (Walcott) |
| *Bradoria fragilis* Walcott, 1905 | = *Aluta fragilis* (Walcott) |
| *Bradoria sterope* Walcott, 1905 | = *Aluta sterope* (Walcott) |
| *Bradoria woodi* Walcott, 1905 | = *Aluta woodi* (Walcott) |

| | |
|---|---|
| *Calymene ? sinensis* Bergeron, 1899 | =*Blackwelderia sinensis* (Bergeron) |
| *Conocephalites subquadratus* Dames, 1883 | =*Anomocare subquadratus* (Dames) |
| *Conocephalites typus* Dames, 1883 | =*Ptychoparia typus* (Dames) |
| *Craniella* ?? sp. Walcott, 1905 | =*Discinopsis sulcatus* Walcott |
| *Damesella* Walcott, 1905 | =*Stephanocare* Monke |
| *Damesella chione* Walcott, 1905 | =*Stephanocare richthofeni* Monke |
| *Damesella sinensis* Walcott, 1905 | =*Stephanocare ? sinensis* (Bergeron) |
| *Dicellocephalus ? sinensis* Bergeron, 1899 | =*Stephanocare ? sinensis* (Bergeron) |
| *Dikelocephalus ? baubo* Walcott, 1905 | =*Ptychaspis baubo* (Walcott) |
| *Dikelocephalus ? brizo* Walcott, 1905 | =*Ptychaspis brizo* (Walcott) |
| *Dorypygella* Walcott, 1905 | =*Teinistion* Monke |
| *Dorypygella alastor* Walcott, 1905 | =*Blackwelderia alastor* (Walcott) |
| *Dorypygella alcon* Walcott, 1905 | =*Teinistion alcon* (Walcott) |
| *Dorypygella typicalis* Walcott, 1905 | =*Teinistion typicalis* (Walcott) |
| *Hoeferia* Redlich, 1901 | =*Redlichia* Cossman, 1902 |
| *Liostracus megalurus* Dames, 1883 | =*Anomocare megalurus* (Dames) |
| *Menocephalus adrastia* Walcott, 1905 | =*Levisia adrastia* (Walcott) |
| *Menocephalus belenus* Walcott, 1905 | =*Lisania belenus* (Walcott) |
| *Menocephalus* sp. Walcott, 1905 | =*Anomocare* sp. (Walcott) |
| *Obolus* (*Lingulepis*) *eros* Walcott, 1905 | =*Lingulella* (*Lingulepis*) *eros* (Walcott) |
| *Obolus* (*Lingulepis ?*) sp. undt., Walcott, 1906 | =*Lingulella* (*Lingulepis ?*) sp. undt. (Walcott) |
| *Olenoides ? cilix* Walcott, 1905 | =*Blackwelderia cilix* (Walcott) |
| *Olenoides leblanci* Bergeron, 1899 | =*Blackwelderia sinensis* (Bergeron) |
| *Orthis linnarssoni* Kayser, 1883 | =*Eoorthis linnarssoni* (Kayser) |
| *Orthis* (*Plectorthis*) *agreste* Walcott, 1906 | =*Eoorthis agreste* (Walcott) |
| *Orthis* (*Plectorthis*) *doris* Walcott, 1905 | =*Eoorthis doris* (Walcott) |
| *Orthis* (*Plectorthis*) *kichouensis* Walcott, 1906 | =*Eoorthis kichouensis* (Walcott) |
| *Orthis* (*Plectorthis*) *linnarssoni* Walcott, 1905 | =*Eoorthis linnarssoni* (Kayser) |
| *Orthis* (*Plectorthis*) sp. undt., Walcott, 1906 | =*Eoorthis* sp. undt. (Walcott) |
| *Plectorthis kayseri* Walcott, 1905 | =*Eoorthis kayseri* (Walcott) |
| *Plectorthis pagoda* Walcott, 1905 | =*Eoorthis pagoda* (Walcott) |
| *Ptychoparia ? batia* Walcott, 1905 | =*Chuangia batia* (Walcott) |
| *Ptychoparia ? bromus* Walcott, 1905 | =*Ptychoparia* (*Emmrichella*) *bromus* (Walcott) |
| *Ptychoparia ceus* Walcott, 1905 | =*Liostracina krausei* Monke |
| *Ptychoparia granulosa* Walcott, 1905 | =*Ptychoparia granosa* Walcott |
| *Ptychoparia comus* Walcott, 1906 | =*Anomocarella comus* (Walcott) |
| *Ptychoparia constricta* Walcott, 1905 | =*Ptychoparia* (*Emmrichella*) *constricta* (Walcott) |
| *Ptychoparia dryope* Walcott, 1905 | =*Conocephalina ? dryope* (Walcott) |
| *Ptychoparia inflata* Walcott, 1906 | =*Inouyia ? inflata* (Walcott) |

| | |
|---|---|
| *Ptychoparia* (?) *maia* Walcott, 1906 | = *Conocephalina maia* (Walcott) |
| *Ptychoparia mantoensis* Walcott, 1905 | = *Ptychoparia* (*Emmrichella*) *mantoensis* (Walcott) |
| *Ptychoparia nereis* Walcott, 1906 | = *Anomocare ? nereis* (Walcott) |
| *Ptychoparia tellus* Walcott, 1905 | = *Lonchocephalus tellus* (Walcott) |
| *Ptychoparia tenes* Walcott, 1905 | = *Anomocarella tenes* (Walcott) |
| *Ptychoparia theano* Walcott, 1905 | = *Ptychoparia* (*Emmrichella*) *theano* (Walcott) |
| *Ptychoparia titiana* Walcott, 1905 | = *Inouyia titiana* (Walcott) |
| *Ptychoparia undata* Walcott, 1906 | = *Anomocarella undata* (Walcott) |
| *Ptychoparia vesta* Walcott, 1906 | = *Conocephalina vesta* (Walcott) |
| *Ptychoparia* sp. undt., Walcott, 1906 | = *Conocephalina* sp. undt. (Walcott) |
| *Ptychoparia* (*Liostracus*) *intermedia* Walcott, 1906 | = *Solenopleura intermedia* (Walcott) |
| *Ptychoparia* (*Liostracus*) *subrugosa* Walcott, 1906 | = *Anomocarella subrugosa* (Walcott) |
| *Ptychoparia* (*Liostracus*) *thraso* Walcott, 1905 | = *Anomocarella thraso* (Walcott) |
| *Ptychoparia* (*Liostracus*) *toxeus* Walcott, 1905 | = *Anomocarella toxeus* (Walcott) |
| *Ptychoparia* (*Liostracus*) *trogus* Walcott, 1905 | = *Anomocarella trogus* (Walcott) |
| *Ptychoparia* (*Liostracus*) *tutia* Walcott, 1905 | = *Anomocarella tutia* (Walcott) |
| *Ptychoparia* (*Proampyx*) *burea* Walcott, 1905 | = *Proampyx burea* (Walcott) |
| *Shantungia* Lorenz, 1906 | = *Chuangia* Walcott |
| *Shantungia* Walcott, 1905 | = *Shantungia* Walcott |
| *Shantungia buchruckeri* Lorenz, 1906 | = *Chuangia nitida* Walcott |
| *Solenopleura abderus* Walcott, 1905 | = *Menocephalus abderus* (Walcott) |
| *Solenopleura acantha* Walcott, 1905 | = *Menocephalus acantha* (Walcott) |
| *Solenopleura acidalia* Walcott, 1905 | = *Menocephalus acidalia* (Walcott) |
| *Solenopleura belus* Walcott, 1905 | = *Conocephalina belus* (Walcott) |
| *Stephanocare sinensis* Monke, 1903 | = *Blackwelderia sinensis* (Bergeron) |
| *Syntrophia orientalis* Walcott, 1905 | = *Huenella orientalis* (Walcott) |

The following is a list of the species described or figured in this paper, with page and plate and figure references to the plates accompanying this paper. The list includes not only the new species from China, but the old species which have been made the types of new genera (*Ptychoparia* (*Emmrichella*) *theano, Inouyia capax, Lisania bura, Chuangia batia,* and *Levisia agenor*) ; three new species from Alabama (*Coosia superba, Coosa robusta,* and *Anomocare convexa*), *Coosia superba* being the type of that genus; and the type of the genus *Anomocare* (*Anomocare læve*).

*Micromitra* (*Paterina*) *lucina* Walcott, p. 73, pl. 14, fig. 1.
*Lingulella manchuriensis* Walcott, p. 74, pl. 14, figs. 2, 2a.
*Lingulella marcia* Walcott, p. 74, pl. 14, figs. 3, 3a.

*Acrotreta venia* Walcott, p. 75, pl. 14, figs. 4, 4a.
*Orthotheca glabra* Walcott, p. 75, pl. 14, figs. 5, 5a.
*Albertella pacifica* Walcott, p. 76, pl. 14, fig. 6.
*Stephanocare ? monkei* Walcott, p. 77, pl. 14, fig. 7.
*Ptychoparia granosa* Walcott, p. 77, pl. 14, fig. 8.
*Ptychoparia* (*Emmrichella*) *theano* (Walcott), p. 79, pl. 14, figs. 9, 9a.
*Ptychoparia kochibei* Walcott, p. 78, pl. 14, figs. 10, 10a.
*Crepicephalus convexus* Walcott, p. 79, pl. 14, figs. 11, 11a.
*Pterocephalus ? liches* Walcott, p. 80, pl. 14, fig. 12.
*Inouyia capax* (Walcott), p. 80, pl. 14, fig. 13.
*Inouyia ? thisbe* Walcott, p. 81, pl. 14, fig. 14.
*Agraulos sorge* Walcott, p. 82, pl. 15, fig. 1.
*Lisania bura* (Walcott), p. 82, pl. 15, fig. 2.
*Chuangia batia* (Walcott), p. 84, pl. 15, figs. 3, 3a.
*Chuangia fragmenta* Walcott, p. 84, pl. 15, fig. 4.
*Chuangia nais* Walcott, p. 84, pl. 15, fig. 5.
*Chuangia nitida* Walcott, p. 85, pl. 15, fig. 6.
*Levisia agenor* (Walcott), p. 86, pl. 15, fig. 7.
*Anomocare ephori* Walcott, p. 90, pl. 15, figs. 8, 8a.
*Anomocare lisani* Walcott, p. 90, pl. 15, figs. 9, 9a-b.
*Anomocarella hermias* Walcott, p. 92, pl. 15, fig. 10.
*Anomocarella macar* Walcott, p. 92, pl. 15, figs. 11, 11a-b.
*Coosia superba* Walcott, p. 94, pl. 16, figs. 1, 1a.
*Coosia robusta* Walcott, p. 97, pl. 16, figs. 2, 2a.
*Asaphiscus iddingsi* Walcott, p. 99, pl. 16, fig. 3.
*Bathyuriscus manchuriensis* Walcott, p. 97, pl. 16, fig. 4.
*Solenopleura chalcon* Walcott, p. 83, pl. 16, fig. 5.
*Anomocare læve* Angelin, p. 87, pl. 17, figs. 1, 1a-c.
*Anomocare convexa* Walcott, p. 87, pl. 17, figs. 2, 2a-d.
*Anomocarella smithi* Walcott, p. 92, pl. 17, figs. 3, 3a.
*Levisia richardsoni* Walcott, p. 86, pl. 17, figs. 4, 4a.
*Levisia nasuta* Walcott, p. 87, text figs. 7, 7a; pl. 17, fig. 5.

The memoir on the Cambrian faunas of China is now well advanced and will probably be printed and distributed the latter part of the year 1911.

## BRACHIOPODA

### MICROMITRA (PATERINA) LUCINA, new species

Plate 14, fig. 1

Ventral valve, depressed subconical, with a minute beak curving over and concealing the pseudo-deltidium. The cardinal slope is bent abruptly backward and downward so as to form a narrow false area on each side of a wide, open, triangular space.

Dorsal valve transverse, gently convex, with the nearly straight posterior margin shorter than the greatest width of the valve; beak minute, marginal; false area unknown.

Surface marked by concentric, slightly irregular, rounded lines and ridges of growth that may or may not be grouped in bands of varying width. A dorsal valve shows a few fine, faint, radiating ridges.

A ventral valve 3 mm. in width has a length of 2.75 mm. and a height of 1 mm. A dorsal valve with a width of 2.5 mm. has a length of 2 mm. and a height of 0.5 mm. at the beak.

*Observations.*—In form the ventral valve of this species is not unlike that of *Micromitra sculptilis* (Meek) except that it is not as elevated and its surface is quite different. It is associated with *M. sculptilis* and the two varieties of *Micromitra* (*Iphidella*) *pannula*,—*ophirensis* and *maladensis*.

*Formation and locality.*—Middle Cambrian: Fu-chóu series; (35n and 35r) limestones and (36d) shales near the base just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### LINGULELLA MANCHURIENSIS, new species

Plate 14, figs. 2, 2a

This species and *Lingulella marcia* belong to a group of small, elongate, oval shells that are represented in the Rocky Mountain Province Cambrian fauna by *Lingulella manticula* (White) and in the Atlantic Province fauna by *L. atava* (Matthew), *L. collicia* (Matthew), *L. ferruginea* (Salter), *L. nanno* (Walcott), and a number of similar forms. *Lingulella manchuriensis* appears to be most nearly related to *L. similis* (Walcott). It differs in the broader, more rounded posterior half of the ventral valve.

The average length of the ventral valve is 3 mm. among the large number of shells that occur in both limestone and shale.

*Formation and locality.*—Middle Cambrian: (35p) Fu-chóu series; shales about 80 feet (24 m.) above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### LINGULELLA MARCIA, new species

Plate 1, figs. 3, 3a

This species is one of the small forms allied to the group of similar shells mentioned under *L. manchuriensis*. It differs from the latter species in being relatively broader in outline, with the sides of the valves less uniformly arched, and in having a more broadly rounded frontal margin.

Interiors of the ventral valve indicate that the area was relatively shorter than that of *L. similis* (Walcott). Most of the shells in the limestone are less than 2 mm. in length; a few ventral valves in the shale are 3 to 5 mm. long.

*Formation and locality.*—Middle Cambrian: (35q and 36h) Fu-chóu series; about 200 feet (61 m.) above the white quartzite; also in shales about 130 feet (40 m.) above the white quartzite; collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

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A form flattened in the shale of locality 36f, which is much higher, but in the same section as the locality represented by *L. marcia,* has the outline of the latter species and is tentatively referred to it. This gives an extended stratigraphic range for the species, but not so great as that of *L. similis* (Walcott) which occurs in both the Middle and Upper Cambrian.

### ACROTRETA VENIA, new species

Plate 14, figs. 4, 4a

*Acrotreta venia* is closely related to *A. shantungensis* Walcott. It differs in having a slightly less elevated ventral valve and a more distinct and broader flattening of the posterior side and margin. The faintly defined false area and apex of the valve curve slightly over the porterior margin. The dorsal valve does not show the median depression of the dorsal valve of *A. shantungensis.* Of the American Pacific Province species of *Acrotreta,* it most nearly approaches *A. idahoensis* (Walcott) in the external form of the valves. The vascular markings on the interior of the dorsal valve differ in detail as may be seen by comparing them.

*Formation and locality.*—Middle Cambrian: (35q) Fu-chóu series; about 200 feet (61 m.) above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### ORTHOTHECA GLABRA, new species

Plate 14, figs. 5, 5a

Form an elongate, slender, rounded tube, with the dorsal face less convex than the sides and ventral face. Transverse section round, except for the slightly flattened dorsal side. Operculum unknown. Shell rather thick, and with a smooth surface.

The largest specimen in the collection has a length of 5 mm.

*Observations.*—This species is distinguished from other Chinese forms by its rounded tube and smooth surface. It is the representative in form of the American *Orthotheca communis* Billings.[1]

*Orthotheca glabra* occurs abundantly in association with *Hyolithes cybele* Walcott, in the *Dorypyge richthofeni* zone of Manchuria. Some of the shells have a long, slender terminal section to the tube that is more or less slightly curved. It is so slender and round that it suggests the tube of *Hyolithellus*.[2]

*Formation and locality.*—Middle Cambrian: (C71) massive cliff making limestone in the central portion of the Ki-chóu formation, 4 miles (6.4 km.) southwest of Tung-yü; and (C72) thin green gray limestone interbedded with ocherous and green clay shales, overlying the massive oolite in the Ki-chóu formation, 4 miles (6.4 km.) east of Fang-lan-chön; both in Shan-si, China.

Collected by Eliot Blackwelder.

Also (35n) Middle Cambrian: Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### ALBERTELLA PACIFICA, new species

Plate 14, fig. 6

Of this form only one fragment of the pygidium was found in the collection from Manchuria. This is so characteristic that I do not hesitate to identify it as the pygidium of an *Albertella* although stratigraphically it occurs at a higher horizon in the Middle Cambrian than the American species of the genus.

A pygidium illustrated by M. Barrande as *Paradoxides desideratus* Barrande[3] may possibly belong to a species of *Albertella*. The axial lobe of the pygidium has seven rings and a terminal section and the pleural lobes have lateral spines.

*Formation and locality.*—Middle Cambrian: (36f) Fu-chóu series; about 1000 feet (305 m.) above the white quartzite, collected in a

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[1] Tenth Ann. Rept. U. S. Geol. Survey, 1891, pl. 77, figs. 3, 3a-g.

[2] Idem, pl. 79, fig. 1a.

[3] Barrande, 1852, Systême Silurien du Centre de la Bohême, Vol. 1, pl. 12, fig. 15.

low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### STEPHANOCARE ? MONKEI, new species

Plate 14, fig. 7

*Stephanocare* sp. MONKE, 1903, Jahrb. König. Preuss. Geol. Landesanst. und Bergakad., Vol. 23, Pt. 1, p. 144, pl. 8, figs. 1, 1a, 2-4. (Described and discussed.)

Doctor Monke doubtfully refers a cephalon, two pygidia, and a free cheek to *Stephanocare*. Similar pygidia occur on the platy limestones collected by Mr. Blackwelder and as they are clearly distinct from any described species I give them the specific name of *S. ? monkei* in recognition of the most excellent work done by Doctor Monke on this interesting fauna. The generic reference is in doubt as we have no entire specimens of *Stephanocare richthofeni* Monke and of this species for comparison.

*Formation and locality.*—Middle Cambrian: (C6) thin slabby limestone in the upper shale member of the Kiu-lung group, 2.5 miles (4 km.) southwest of Yen-chuang, Sin-t'ai District, Shan-tung, China.

Collected by Eliot Blackwelder.

### PTYCHOPARIA GRANOSA, new species

Plate 14, fig. 8

*Ptychoparia granulosa* WALCOTT, 1905, Proc. U. S. National Museum, Vol. 29, p. 78. (Species described as below. This species is believed to be congeneric with Hall and Whitfield's species; since the name *granulosa* is therefore preoccupied for *Ptychoparia, granosa* is proposed.)

Not *Crepicephalus* (*Loganellus*) *granulosus* HALL and WHITFIELD, 1877, Geol. Expl. Fortieth Parallel, Vol. 4, p. 214, pl. 2, figs. 2, 3.

The gently convex central portions of the cephalon, exclusive of the free cheeks, are all that is known of this species. These indicate a rather broad, semicircular cephalon, with small free cheeks, wide fixed cheeks, narrow, short, convex glabella, and narrow, flattened frontal rim; glabella marked by three pairs of faintly impressed but clear glabella furrows; frontal space between the glabella and rim broader than the frontal rim and slightly convex; palpebral ridge narrow, clearly defined, and merging into a rather small eye lobe.

Surface finely granulose.

*Formation and locality.*—Lower Cambrian: (C17) ferruginous limestone nodules in the brown sandy shales at the top of the Man-t'o shale, at Ch'ang-hia, Shan-tung, China.

Collected by Eliot Blackwelder.

### PTYCHOPARIA KOCHIBEI, new species

Plate 14, figs. 10, 10a

The cephalon of *P. kochibei,* in outline, wide fixed cheeks, broad frontal limb, and broadly rounded front margin of the gabella, is similar to the cephalon of *Ptychoparia granosa* Walcott (pl. 14, fig. 8). It differs in having a more pronounced swelling of the frontal limb in front of the glabella, more tumid fixed cheeks, and in surface characters. The surface of *P. granosa* is thickly studded with minute tubercles, while that of *P. kochibei* is smooth or possibly finely punctate; its frontal limb is also marked by fine, irregular, sometimes inosculating, rounded ridges that extend from in front of the glabella and palpebral ridges to the groove within the flattened frontal rim (pl. 14, fig. 10a).

The thorax has fourteen transverse segments with a narrow axial lobe and wide pleural lobes. The pleural furrow starts on the inner front side of the pleural lobe of each segment and, widening nearly to the width of the segment, begins to narrow at the point of geniculation and terminates near the posterior margin at the somewhat abrupt falcate termination of the pleura.

Pygidium small; the axial lobe is crossed by two furrows that serve to outline two transverse rings and a terminal section; two anchylosed segments are outlined on the pleural lobes on each side of the axial lobe by furrows that curve gently backward toward the faintly defined border.

Surface finely punctate or slightly roughened by minute depressions.

*Observations.*—This is the only Chinese species of *Ptychoparia* of which we have the entire dorsal shield; all the other species are represented by the separated parts. In outline the dorsal shield is not unlike that of *Ptychoparia kingi* (Meek),[1] and it may be considered as the Chinese representative of that species.

The specific name is given in honor of the former Director of the Geological Survey of Japan, Doctor Kochibe.

*Formation and locality.*—Middle Cambrian: (35n, 35r, and 36e) Fu-chôu series; limestones and shales interbedded with limestones

[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 193.

near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### EMMRICHELLA, new subgenus of PTYCHOPARIA

This subgenus differs from *Ptychoparia* in its smooth glabella and larger palpebral lobe; from *Liostracus,* in having an arched or nearly flat frontal limb and rim and more convex cranidium; from *Conocephalina,* in its smoother glabella and wider fixed cheeks; and from *Anomocare,* in its smoother glabella, usual absence of distinct palpebral ridge, proportionately shorter eye lobes, and glabella.

*Genotype.—Ptychoparia theano* Walcott.[1] (pl. 14, figs. 9, 9a.)

*Observations.*—This subgenus is characterized by a nearly smooth surface on the glabella and fixed cheeks, rather large palpebral lobes, and narrow postero-lateral limbs. Unfortunately, no entire specimens of the cephalon and thorax are known, and the pygidia referred to it may or may not belong to the species to which they are tentatively assigned. Only when a thorough study is made of all the material within the Conocephalinæ will it be possible to make even a fairly adequate grouping of the species.

Of the species of this subgenus from China, *P.* (*E.*) *theano* (Walcott, *P.* (*E.*) *bromus* (Walcott), and *P.* (*E.*) *eriopia* (Walcott) have the posterior, elongate palpebral lobe. In *P.* (*E.*) *mantoensis* (Walcott) and *P.* (*E.*) *constricta* (Walcott) the palpebral lobe is much like that of *Ptychoparia* in its position.

*Stratigraphic range.—Ptychoparia* (*Emmrichella*) *mantoensis* and *P.* (*E.*) *constricta* occur at the summit of the Lower Cambrian; *P.* (*E.*) *eriopia* and *P.* (*E.*) *theano,* at the base of the Ch'ang-hia formation of the Middle Cambrian; and *P.* (*E.*) *bromus,* at about the same horizon in the Kiu-lung formation.

### CREPICEPHALUS CONVEXUS, new species

Plate 14, figs. 11, 11a

The cranidium of this species differs from that of *C. damia* (Walcott) in its shorter frontal lobe, flatter frontal rim, and proportionately longer glabella. The associated pygidium has a proportionately shorter axial lobe and its sides curve outward instead of inward.

*Formation and locality.*—Middle Cambrian: (35r) Fu-chóu series; limestones near the base of the series just above the white quartzite,

[1] Walcott, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 82.

collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### PTEROCEPHALUS ? LICHES, new species

Plate 14, fig. 12

This species is represented by four specimens of the pygidium. It is quite unlike the pygidium referred to *P. busiris* Walcott and with the discovery of entire specimens of the dorsal shield it may be found that the generic reference is incorrect.

The pygidia average 4 mm. in length and are finely preserved in the compact limestone matrix.

*Formation and locality.*—Middle Cambrian: (35n) Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### Genus INOUYIA, new genus

The species referred to this genus are represented only by the cranidium. This in the genotype has a swollen, tumid frontal limb, small palpebral lobes, a convex and more or less subrectangular glabella, strong dorsal furrows about the glabella, and clearly marked glabellar furrows.

Surface apparently smooth, but with a strong lens it has a slightly roughened appearance caused by a shallow, irregular pitting.

*Genotype.*—*Agraulos ? capax* Walcott[1] (pl. 14, fig. 13).

The swollen frontal limb, small palpebral lobes, and convex glabella at once suggest *Agraulos* (see pl. 15) and in fact all of the species now referred to *Inouyia* with the exception of *I. titiana* (Walcott) were at first referred to *Agraulos*. My reasons for separating them and creating the genus *Inouyia* are that the tumidity of the frontal limb is so pronounced as to become a marked feature and the glabella is more rectangular in the typical species. To these should be added the general effect of the cranidium when compared directly with the cranidium of *Agraulos ceticephalus* (Barrande).[2] I think it quite probable that when entire specimens of the dorsal

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[1] Walcott, 1906, Proc. U. S. Nat. Mus., Vol. 30, p. 580.

[2] Système Silurien du Centre de la Bohême, Vol. 1, 1852, pl. 10, figs. 1-21. Barrande referred the species to the genus *Arionellus*, a synonym of *Agraulos*.

shield of the various species are available for comparison other differences will be found to exist between *Inouyia* and *Agraulos*.

In grouping the Chinese species under *Inouyia* some are found to be close to *Agraulos,* notably *I. abaris* (Walcott), *I. acalle* (Walcott), and *I. regularis* (Walcott), and it is probable that with more complete specimens of the species they will be referred to a subgenus intermediate between *Inouyia* and *Agraulos*.

The wide fixed cheeks of *Inouyia capax* are confined to this species, as all other species referred to *Inouyia* have relatively narrow fixed cheeks. The large eye of *I. ? inflata* (Walcott) and relatively narrow frontal limb serve to place it apart from the other species.

I am not at all satisfied with the arrangement of species under *Inouyia* but in dealing with such fragmentary specimens much must be left to future discovery and closer work.

Attention is also called to *Ellipsocephalus hoffi* Barrande[1] as in that species the frontal limb is convex and the glabella subrectangular.

The generic name is given in recognition of Dr. Kinos Ka Inouye, Director of the Imperial Geological Survey of Japan.

### INOUYIA ? THISBE, new species

Plate 14, fig. 14

This species is represented by two broken specimens of the cranidium. These show that the glabella is much like that of *Inouyia titiana* (Walcott), also the fixed cheeks and palpebral lobes. It differs in the transverse swelling of the frontal limb. In *I. ? thisbe* the frontal limb rises with a slight slope in front of the glabella, and curves gently downward to the margin without a trace of a frontal border as in *Inouyia inflata* (Walcott). In *I. titiana* the frontal limb is abruptly convex and there is an almost flattened border.

The surface of *I. ? thisbe* is distinctly punctate and in this respect resembles *Agraulos dryas*.

The type specimen of the cranidium has a length of 5.5 mm.

*Formation and locality*.—Middle Cambrian: (C28) thin bedded oolitic limestone at the base of the Ch'ang-hia limestone, just above the shales in the face of the cliff one mile (1.6 km.) east-southeast of Ch'ang-hia, Shan-tung, China.

Collected by Eliot Blackwelder.

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[1] Barrande, 1852, Systême Silurien du Centre de la Bohême, Vol. 1, pl. 10, figs. 26, 27.

## AGRAULOS SORGE, new species

Plate 15, fig. 1

This species is represented by a single specimen of the central portions of the cephalon. Among the Chinese species referred to *Agraulos* it may be compared with *A. dryas* Walcott, from which it is readily distinguished by its broader, less convex glabella and its almost smooth, instead of strongly punctate, surface.

*Agraulos sorge* appears to have had a strong occipital spine that projected upward and backward from the occipital ring; only the base of the spine is preserved.

Surface slightly roughened by a minute, irregular, shallow pitting.

*Formation and locality.*—Middle Cambrian: (35n) Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by Eliot Blackwelder.

## Genus LISANIA, new genus

Cranidium subquadrate in outline, exclusive of postero-lateral limbs. Glabella with slightly converging sides, broadly rounded in front and curving gently down to a narrow furrow separating it from the frontal border, without distinctly marked glabellar furrows; occipital furrow distinct; occipital segment strong. Fixed cheeks narrow; palpebral lobe above the eye nearly one-third the length of the cephalon; palpebral ridge usually defined to the edge of the dorsal furrow beside the glabella. Frontal border slightly convex and separated from the fixed cheeks and glabella by a narrow, shallow but distinct furrow.

The associated free cheeks have a strong genal spine, and associated pygidia a strong central axis marked by three or four transverse rings and a terminal section.

Surface smooth or slightly roughened by very fine shallow pits.

*Genotype.*—*Anomocarella bura* Walcott[1] (pl. 15, fig. 2).

*Observations.*—This genus is founded to receive four species that do not appear to fall within any described genus. From *Pagodia* it differs in having a longer eye lobe, narrower free cheeks, flatter frontal margin. *Pagodia* occurs with the Upper Cambrian fauna, *Lisania* with the Middle Cambrian fauna. From *Chuangia* (pl. 15, figs. 3-6) it differs in its narrower frontal border, narrower fixed

[1] Walcott, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 56.

cheeks, and quite unlike associated pygidium. The three genera, *Lisania, Pagodia,* and *Chuangia,* all have a strong, nearly smooth glabella and a narrow frontal margin and do not appear to come within the limits of *Agraulos, Anomocare, Ptychoparia, Coosia,* or *Solenopleura.*

The species referred to the genus are all small and unfortunately only represented by cranidia and associated free cheeks and pygidia. It may be that when entire specimens of the dorsal shield are found other marked differences will appear between the three genera, *Lisania, Pagodia,* and *Chuangia.*

The generic name is taken from Li San, the Chinese assistant of both Dr. Bailey Willis and Dr. Joseph P. Iddings.

The species referred to the genus *Lisania* are:

*L. agonius* (Walcott), Kiu-lung group, Middle Cambrian.
*L. ajax* (Walcott), Kiu-lung group, Middle Cambrian.
*L. alala* (Walcott), Ch'ang-hia limestone, Middle Cambrian.
*L. ? belenus* (Walcott), Ch'ang-hia limestone, Middle Cambrian.
*L. bura* (Walcott), Ch'ang-hia limestone, Middle Cambrian.
*L. cf. bura* (Walcott), Ch'ang-hia limestone, Middle Cambrian.

## SOLENOPLEURA CHALCON, new species

Plate 16, fig. 5

Only one specimen of the cranidium of this species is known. In form it is nearest to *Solenopleura beroe* Walcott. It differs in having a proportionately narrower glabella, more convex free cheeks, more rounded frontal rim, and in the presence of a depression dividing the frontal limb on the median line of the glabella. Its tuberculated surface is much like that of *S. beroe.*

*Formation and locality.*—Middle Cambrian: (35r) Fu-chóu series; limestones near the base just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

## Genus CHUANGIA, new genus

This genus is proposed for a group of Upper Cambrian trilobites in which the cephalon has a truncato-conical or subquadrangular glabella; a narrow, concave frontal limb; and, so far as known, a smooth test.

The associated pygidium is large, with a strong axis, broad pleural lobes, and few indications of segments.

The general form of the glabella is much like that of some species of *Anomocare* (pl. 17) but the frontal limb is quite different. The latter suggests *Pagodia lotos* Walcott but the frontal limb of the latter is absorbed by the rounded frontal rim. In *Chuangia* the frontal limb and rim meet to form an angle and the rim does not rise above the upward sloping surface of the frontal limb.

*Genotype.*—*Chuangia batia* Walcott[1] (pl. 15, figs. 3, 3a). Three other species are known from the Upper Cambrian formations of China: *Chuangia nitida, C. nais,* and *C. fragmenta.*

### CHUANGIA FRAGMENTA, new species

Plate 15, fig. 4

Only a fragment of the cephalon of this species is known. This suggests the glabella of *Chuangia batia,* but the narrow fixed cheeks serve to distinguish it. The surface is smooth to the unaided eye, and slightly pitted or punctate under a strong lens. The fragment of the cephalon has a length of 16 mm.

*Formation and locality.*—Upper Cambrian: (C61) a dense black limestone in the uppermost limestone member of the Kiu-lung group, 3 miles (4.8 km.) southwest of Yen-chuang, Sin-t'ai District, Shantung, China.

Collected by Li San.

### CHUANGIA NAIS, new species

Plate 15, fig. 5

This is a large species that is represented by a part of the central portions of the cephalon. Glabella subquadrangular, moderately convex, narrowing slightly toward its broadly rounded front; without glabellar furrows so far as can be determined; occipital furrow shallow, rather broad, and nearly transverse; occipital ring gently convex, and slightly wider toward the center; dorsal furrow shallow and clearly defined.

Fixed cheeks about two-thirds the width of the glabella, nearly flat between the glabella and the palpebral lobes, and sloping downward in front to the frontal rim, and back to the posterior furrow;

[1] Walcott, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 75.

palpebral lobe small; palpebral ridge narrow, low, and situated so as to cross the fixed cheek obliquely where the downward slope to the front is most marked; postero-lateral limbs long, with a strong furrow within the strong rounded rim; the front of the glabella passes into the broad groove that merges into the upward sloping, narrow frontal limb; frontal rim rounded and marked by rather strong striæ parallel to the front border.

Surface smooth to the unaided eye; a strong lens shows a slight, irregular pitting where the outer surface is intact. The type specimen of the cephalon has a length of 20 mm.

*Observations.*—This species was at first confused with *Chuangia batia*. It differs from the latter in the form of the glabella, and the size of the palpebral lobes and frontal limb. The same features distinguish it from *Chuangia nitida* and *C. fragmenta*.

*Formation and locality.*—Upper Cambrian: (C64) upper limestone member of the Kiu-lung group, 2.7 miles (4.3 km.) southwest of Yen-chuang, Sin-t'ai District, Shan-tung, China.

Collected by Eliot Blackwelder.

## CHUANGIA NITIDA, new species

Plate 15, fig. 6

Only the central portions of the moderately convex cephalon of this species is known. Within the facial sutures the outline is subquadrangular, exclusive of the short postero-lateral limbs. Glabella slightly convex, truncato-conical, with a very slight trace of short, slightly oblique posterior glabellar furrows; the latter are shown more distinctly on the cast of the interior; occipital furrow shallow and clearly defined; occipital ring slightly convex and rather broad toward the center; dorsal furrow shallow at the sides of the glabella.

Fixed cheeks about one-half the width of the glabella, gently convex; palpebral ridges strong, low, and passing obliquely backward to the rim of a rather large palpebral lobe; the latter is a little longer than one-third the length of the cephalon. The frontal limb is represented by the short concave space in front of the glabella which forms a sharp angle in uniting with the frontal limb.

Surface slightly pitted when seen through a strong magnifying glass. Length of cephalon, 7 mm.

*Observations.*—This species is much smaller than the type species, *Chuangia batia*. It differs from the latter in its narrower frontal limb, larger palpebral lobes, and more elongate glabella. From *Chuangia nais* and *C. fragmenta* it differs in its longer palpebral lobes and in the outline of the glabella.

*Formation and locality.*—Upper Cambrian: (C11) crystalline limestone 60 feet (18 m.) above the base of the uppermost limestone member, 2.1 miles (3.4 km.) southwest of Yen-chuang, Sin-t'ai District, Shan-tung, China.

Collected by Eliot Blackwelder.

### Genus LEVISIA, new genus

This genus is proposed to include a group of small trilobites represented by *Agraulos agenor* Walcott.[1] The cranidium is strongly convex; glabella truncato-conical, tumid, and with only a trace of glabellar furrows; occipital ring narrow at the sides, broadening rapidly toward the center, convex, and extending backward into an obtuse spine. Frontal limb very narrow and passing almost without any line of demarcation into the rather broad, slightly convex frontal margin of the cephalon. Fixed cheeks tumid, about half as wide as the glabella and with small palpebral lobes midway of their length. Postero-lateral limbs rather short and marked by a deep, narrow, intermarginal posterior furrow that separates a narrow, rounded margin.

*Genotype.*—*Agraulòs agenor* Walcott[1] (pl. 15, fig. 7). A second species, *Levisia adrastia* (Walcott)[2] has the same generic characters. Its surface has the same pitting and in addition a few relatively large, scattered granules.

### LEVISIA RICHARDSONI, new species

Plate 17, figs. 4, 4a

Two species of this genus occur with an Upper Cambrian fauna in the boulders of the conglomerate at Point Lévis, opposite Quebec, Canada. The first I shall give the name of *Levisia richardsoni* in recognition of the fine collecting work done by Mr. J. Richardson under the direction of Sir William E. Logan.

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[1] Walcott, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 44.

[2] Idem, p. 61.

**LEVISIA NASUTA, new species**

Plate 17, fig. 5 and text figs. 7 and 7a.

The second Canadian species associated with *Levisia richardsoni* is *Levisa nasuta.* The glabella of this species is very convex; fixed cheeks narrow and merging anteriorly into the bluntly pointed frontal limb and margin. A dorsal view of the cranidium is given on plate 17, figure 5, and the accompanying text figures show a front and side view of the specimen represented on plate 17.

7 7a

*Levisia nasuta,* new species.

FIGS. 7, 7a.—Side and front views, × 10. U. S. National Museum, Catalogue No. 57600.

**Genus ANOMOCARE Angelin**

*Anomocare* ANGELIN, 1854, Paleontologia Scandinavica, Edition of 1878, p. 24.

For the purpose of comparison a cranidium, free cheek, and pygidium of *Anomocare læve* are illustrated by figs. 1, 1a-c, pl. 17; also an entire dorsal shield of *Anomocare convexa,* new species (figs. 2, 2a-d, pl. 17), from the Middle Cambrian strata of Alabama.

*Genotype.—Anomocare læve* Angelin (1854, edition of 1878, p. 25).

**ANOMOCARE CONVEXA, new species**

Plate 17, figs. 2, 2a-d

Dorsal shield large, elliptical in outline; axial lobe narrow and convex; cephalon semicircular in outline with the genal angles produced into spines. The facial sutures cut the posterior margin a short distance within the genal angles and extend inward with a slight curvature and forward to the base of the palpebral lobe; arching around the palpebral lobe, they extend downward and slightly forward a short distance and then with a broad sweep curve inward, cutting the anterior margin on a line with the outer edge of the palpebral lobe. Cranidium with a large glabella, concave frontal limb, relatively narrow fixed cheeks, and elongate, narrow postero-lateral limbs. Glabella moderately convex, with the sides gradually converging to its broadly rounded front margin; it is marked by four pairs of short furrows that penetrate obliquely inward and backward from the sides; the two posterior lobes outlined by the oblique furrows are roughly subtriangular in outline, the furrows penetrating nearly one-third of the distance toward the center. The second pair appears to be represented by rather prominent, slightly convex tubercles, and extends about one-fourth the distance across the glabella. Viewed with a transverse light, the second pair of lobes appears to be a forward extension of the posterior pair of lobes, since the furrows back of them are not quite so deep as the more oblique furrow just inside of the inner postero-lateral margin of the second pair of furrows; the third pair of lobes extends obliquely inward and backward about one-third of the distance across the glabella; the fourth pair is outlined posteriorly by a rather deep furrow that increases in width from the outer margin inward for a short distance so as to form a shallow, triangular area. The anterior margin of the fourth pair of glabellar lobes is just back of a pit which occurs on the side of the glabella opposite the inner end of the palpebral ridge. On very finely preserved specimens a narrow, gently arched ridge appears to represent the extension of the palpebral ridges on the fixed cheeks. There is also a transverse furrow just within the anterior margin of the glabella. The glabellar furrows and lobes described indicate that the glabella is formed by the union of five or possibly six of the original segments of one of the ancestral forms of this trilobite.[1] The occipital ring is separated from the glabella by a furrow that is rather broad and deep on each side, and narrow, shallow, and arching slightly forward across the center; occipital ring slightly convex, broad across the central portions, narrowing and terminating directly in the line of the posterior intermarginal furrow of the fixed cheeks. Fixed cheeks about half as wide as the glabella, nearly flat within the palpebral lobe and ridge, and sloping gently down into the postero-lateral limb. They are interrupted in front by the strong palpebral ridges which extend backward from a point opposite the anterior pair of glabellar furrows

[1] Walcott, Smithsonian Misc. Coll., Vol. 53, 1910, pp. 237-238.

and merge into the arched palpebral lobes; in front of the palpebral ridge the cheeks descend rapidly and merge into the frontal limb; the postero-lateral limb is long and almost entirely made up of the rounded, narrow posterior rim, strong intermarginal furrow, and a narrow area between the furrow and the facial suture. Palpebral lobe of medium length; in a cephalon 18 mm. in length it has a length of 4 mm.; it is narrow and raised a little above the surface of the fixed cheeks. Frontal limb broad and strongly concave in large cephalons, becoming less so in smaller; in front of the glabella it slopes rather rapidly downward and then upward with a gentle curve to the thin, rounded edge. Free cheeks gently convex, but become slightly concave toward the outer margin in the larger specimens. The genal angles are extended into short spines.

Thorax with eleven nearly transverse segments; axial lobe convex and a little more than one-half the width of the pleural lobes. It is strongly defined by a sharp angle where the segments pass into the pleural lobes. Each segment arches forward slightly at the center, also at the sides just before joining the pleural portion of the segment; the pleural lobe of each segment is transverse for about one-half its length, and then it curves gently down toward the falcate termination. The pleural grooves start just within the front rim of each segment next to the axial lobe, and, widening, continue with a nearly uniform width for about two-thirds of the distance outward, and then narrow, disappearing some little distance within the termination of the segment.

Pygidium large, moderately convex, with a narrow, strongly convex axial lobe and broad, slightly flattened margin; axial lobe five-sixths of the length of the pygidium, convex and narrowing gradually from the anterior margin to its termination; it is crossed by from five to six shallow, transverse furrows that outline from six to seven slightly convex rings and a terminal section; from the axial lobe the surface of the pleural lobes slopes at first gently and then quite rapidly down for about two-thirds of their width and then very gradually out to the margin. They are marked by five or six broad furrows and rather broad, flattened ridges that are the continuation on the pleural lobe of the transverse rings on the axial lobe; the posterior margin curves more or less inward toward the median line so as to give a more or less indented outline to the otherwise rounded curve of the sides and posterior margin of the pygidium.

Surface under a strong lens shows numerous pits or pores; the free cheeks and the cranidium in front of the glabella and palpebral ridges are beautifully marked by irregular radiating ridges that branch quite irregularly and are united by irregular cross-ridges so as to give an anastomosing effect.

*Dimensions.*—The dimensions are shown by the figures on pl. 17, figs. 2 and 2a.

*Observations.*—The cranidium of this species is much like that of *Anomocare læve* (pl. 17, fig. 1). Each has a broad, more or less concave frontal limb and margin marked by radiating ridges, large eyes, and an elongate glabella marked by five short lobes on each side.

The pygidium in each species is of the same type and the surface has the same punctate character in each.

*Anomocare convexa* is associated with several other species of *Anomocare.*

*Formation and locality.*—Middle Cambrian: (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in argillaceous shales, Coosa Valley, east of Center, Cherokee County, Alabama.

Collected by A. M. Gibson, 1884; and Cooper Curtice, 1885.

## ANOMOCARE EPHORI, new species

Plate 15, figs. 8, 8a

This species is represented by specimens of the cranidium and associated pygidia that are referred to it. It is closely related to *Anomocare flava* Walcott. It differs in details of frontal limb and border, glabella, and fixed cheeks. It has a less deeply impressed line between the frontal limb and border than that of *A. flava.*

*Formation and locality.*—Middle Cambrian: (35r) Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niańg-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

## ANOMOCARE LISANI, new species

Plate 15, figs. 9, 9a-b

This fine species is represented by numerous specimens of fragments of the cephalon, segments of the thorax, and entire pygidia. They are all compressed in a fine, argillaceous shale and usually only a faint impression remains. The cranidium is not unlike that of

*Coosia limbatum* (Angelin); it differs in having a slightly convex or rounded frontal limb and proportionately narrower glabella. The pygidium is quite different in outline; the rounded indented posterior margin of *A. limbatum* is represented by a deep notch that gives a bilobed appearance to the very broad margin; the axial lobe is also longer and broader than that of *A. limbatum*. The doublure of the pygidium extends close up to the termination of the furrows of the pleural lobe. The pleural lobes of the thoracic segments have a narrow, strong furrow that extends from the inner, anterior margin diagonally across nearly to the posterior margin of the backward curving, slightly falcate ends of the segment.

The stratigraphic position of this species is about 250 feet (79 m.) above the zone of *Anomocare latelimbatum* Angelin.

The specific name is given in recognition of the excellent work done by Li San, who assisted Professors Willis and Iddings in their collecting.

*Formation and locality*.—Middle Cambrian: (35q) Fu-chóu series; about 200 feet (61 m.) above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### Genus ANOMOCARELLA Walcott

*Anomocarella* WALCOTT, 1905, Proc. U. S. National Museum, Vol. 29, p. 54. (Genus characterized.)

*Anomocarella* was proposed to include species from the Middle Cambrian of China, that differ from *Anomocare* in the absence of glabellar furrows and the presence of a relatively narrow, flattened frontal rim. The sides of the glabella are parallel, palpebral lobes of medium size, and palpebral ridges more or less clearly defined. The associated pygidium has a narrow, conical axis, marked by several transverse furrows which extend out on the pleural lobes and more faintly on the sloping rim.

*Genotype*.—*Anomocarella chinensis* Walcott.

*Observations*.—The type of this genus has ten segments in the thorax with a broad pleural furrow that starts near the inner anterior margin of a segment, broadens very rapidly and extends out beyond the geniculation before gradually narrowing to a point. In *Anomocarella smithi* (pl. 17, figs. 3, 3a) there are twelve segments in the thorax with the same type of pleural furrow.

### ANOMOCARELLA HERMIAS, new species

Plate 15, fig. 10

This species is represented by specimens of the cranidium that have an unusually large and long palpebral lobe. This character is sufficient to distinguish it from other described species. The surface appears to be minutely punctate or marked by minute, shallow pits.

*Formation and locality.*—Middle Cambrian: (35n) Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### ANOMOCARELLA MACAR, new species

Plate 15, figs. 11, 11a-b

Of the Chinese species of *Anomocarella*, the cranidium of this species may be compared with that of *A. tatian* (Walcott) in that the frontal limb curves more abruptly down toward the frontal margin than in most species of the genus, and the frontal margin also bends downward to a greater degree. The outline of the glabella and fixed cheeks is almost similar in the two species. The associated pygidia are more elongate than those referred to *A. tatian* and have a greater number of segments in the axial and pleural lobes.

*Formation and locality.*—Middle Cambrian: (35n) Fu-chóu series; limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### ANOMOCARELLA SMITHI, new species

Plate 17, figs. 3, 3a

Dorsal shield of medium size, elongate-elliptical in outline, convex, with the axial lobe strongly defined and convex. Cephalon semicircular in outline, with the genal angles extended into short, sharp spines; a narrow, flattened border extends across the front of the cranidium and continues along the free cheeks until it passes into the genal spines; the posterior margin is narrow and distinctly defined by a strong, rounded furrow that terminates in the dorsal furrow beside the glabella. Cranidium with the front broadly rounded, narrow fixed cheeks, small antero-lateral limbs, and narrow postero-lateral limbs, the greater part of which is taken up by the strong intermarginal furrow. Glabella without traces of transverse furrows except a short, slight indentation indicating a posterior pair of furrows; the glabella is separated from the fixed cheeks by a very narrow, strong dorsal furrow; the frontal limb is about the same width as the frontal margin, and extends almost directly downward from the dorsal furrow in front of the glabella to the sharp angle made by its union with the frontal margin; fixed cheeks about one-third the width of the glabella opposite the palpebral lobes, gently convex, and merging into the anterior and posterior limbs; occipital ring separated from the glabella by a strong rounded furrow, it is convex, broad along the center portions, and narrow toward the dorsal furrow. Palpebral lobe small, elevated, and about one-fourth tne length of the cephalon; a low ridge extends from its anterior end forward and inward to the dorsal furrow beside the glabella. Free cheeks small, gently convex, and bordered by a flattened rim that is continued posteriorly into a spine; they are separated from the cranidium by the facial sutures which cut the posterior margin a short distance within the genal angles and extend with a slight sigmoid curve inward and forward to the base of the palpebral lobes; curving around these they extend with a slight outward curvature to the angle formed by the union of the frontal limb and margin, and then curve slightly inward across the margin.

Thorax with twelve rather narrow, nearly transverse segments; axial lobe convex, with the segments slightly rounded and separated from the pleural lobes by the obtuse angle formed by the union of the two lobes; pleural lobes a little wider than the axial lobe and flattened for about half their width, or to the geniculation, where each segment curves downward and slightly backward; pleural furrow relatively broad; it starts near the inner anterior edge of the pleural segment and extends along the center of the segment to the geniculation, where it gradually narrows to a point near the end of the flattened falcate termination of the segment.

Pygidium small; the subconical convex axis is marked by three shallow transverse furrows that outline three rings, and a terminal section that terminates within a short distance of the posterior margin of the pygidium; pleural lobes marked by the extension of the transverse furrows on the axial lobe and the faintly indicated, rather narrow border.

Surface slightly roughened by shallow pits or a network of very minute, irregular ridges, the interspaces of which give a pitted appearance.

*Dimensions.*—There are nine entire specimens of the dorsal shield exclusive of the free cheeks. The average length is 15 mm. The different parts have the following dimensions:

| | mm. |
|---|---|
| *Cephalon:* | |
| Length | 6.5 |
| Width at posterior margin | 9 |
| Length of glabella and occipital ring | 5 |
| Width of glabella at base | 3.5 |
| *Thorax:* | |
| Length | 7.5 |
| Width at first segment | 8 |
| Width at last segment | 5 |
| *Pygidium:* | |
| Length | 2 |
| Width at anterior margin | 4.5 |

*Observations.*—This species is the only one of the genus *Anomocarella* of which we have specimens showing the cephalon, thorax, and pygidium, with the exception of the compressed dorsal shield of *Anomocarella chinensis.* The cranidium differs from that of the type of the genus, *A. chinensis*, in having a relatively smaller palpebral lobe, and twelve segments, instead of eight, in the thorax.

*Formation and locality.*—Middle Cambrian; (90x) Conasauga formation; in and attached to the outer surface of siliceous nodules in argillaceous shales, Coosa Valley, east of Center, Cherokee County, Alabama.

Collected by A. M. Gibson, 1884; and Cooper Curtice, 1885.

### Genus COOSIA, new genus

The description of the genotype *Coosia superba* and the observations accompanying it may be taken as the description and discussion of the genus.

*Genotype.*—*Coosia superba* Walcott.

### COOSIA SUPERBA, new species

Plate 16, figs. 1, 1a

Dorsal shield large, elongate-elliptical in outline; axial lobe of medium width, conical, and narrowing from the cephalon gradually to the middle of the pygidium where it disappears.

Cephalon semicircular in outline, moderately convex, genal angles unknown. The facial sutures cut the posterior margin some distance within the outer margin and extend inward and forward with a slight sigmoid flexure to the base of the palpebral lobe; arching about this they extend downward and with a gentle outward curve across the frontal limb and then curve inward across the broad frontal margin. Cranidium with a rather large, subconical, moderately convex glabella that shows very slight traces of lateral furrows. Occipital ring separated from the glabella by a furrow that is rather shallow and nearly transverse; occipital ring slightly convex and of nearly uniform width. Fixed cheeks narrow, about one-fourth or less of the width of the glabella; posteriorly they merge into the large subtriangular postero-lateral limbs which are marked by a shallow, intermarginal posterior furrow; anteriorly the fixed cheeks pass gently down and merge into the frontal limb. Palpebral lobe small, less than one-fifth the length of the cephalon; it is continued in a low ridge diagonally across the fixed cheek to the antero-lateral margin of the glabella. Frontal limb less than one-half the width of the broad, gently convex, frontal border; in front of the glabella it slopes gently downward to a shallow furrow that serves to distinguish it from the frontal border. Free cheeks unknown.

Thorax with twelve rather narrow, slightly convex segments with pleural lobes that arch slightly backward; axial lobe of each segment moderately convex and unmarked, so far as known, by any tubercles or spines; at a clearly defined dorsal furrow it unites with the pleural lobe which is about one-third wider than the axial lobe; the pleural furrows originate at the anterior inner side of the pleural segment and extend outward subparallel to the anterior margin about one-half the length of the pleural portion of the segment; the deepest portion of the furrow is just within the narrow anterior border which is about one-fourth the width of the segment; the exterior half of the segment is gently convex and terminates in a rather bluntly rounded end which may possibly be continued backward as a very short spine or point.

Pygidium large, moderately convex, with a short, convex axial lobe and very broad, campanulate margin; axial lobe about one-half the length of the pygidium, marked by two shallow, transverse furrows that are continued out on the gentle downward slope of the pleural lobes, outlining two segments marked by short, shallow, narrow furrows; the outer portions of the pleural lobes are nearly flat or rising slightly toward the postero-lateral margins; the semicircular outline of the pygidium is interrupted toward the median axis by a slight inward curvature.

Surface slightly roughened, but not pitted or punctate so far as can be determined. The outer half of each pleura is marked by imbricating lines subparallel to the margins of the pleura. Similar lines also occur on the flattened border subparallel to the margin of the pygidium.

*Dimensions.*—The dimensions are as shown by figure 1 of plate 16.

*Observations.*—This fine species represents a small group of species that occur in the Cambrian rocks of northern Alabama in the United States and in the Middle Cambrian rocks of the province of Shan-tung, China. The cephalon is not unlike that of *Anomocare* and *Anomocarella*. It differs from the former in having small palpebral lobes and a broad, slightly convex frontal border, and from the latter in the character of its frontal border. The thoracic segments of *Coosia* are unlike those of both of the two genera mentioned in having short, slightly marked, pleural furrows. The pygidium of *Anomocarella* is quite unlike that of *Coosia;* but the pygidium of *Anomocare* has the broad, flattened margin seen in *Coosia superba*.

Of the Chinese species referred to *Coosia*, *C. carme* (Walcott)[1] appears to be the most nearly related. *Coosia decelus* (Walcott)[1] has a somewhat similar frontal limb and border. Unfortunately the palpebral lobes and posterior portions of the cranidium are unknown. *Coosia bianos* (Walcott)[1] has a somewhat similar frontal limb, but with the fragments available for comparison it is impossible to make indentifications of value; the same is true of the associated pygidium, of which only the central portion is known; this indicates, however, a comparatively broad margin. *Coosia daunus* (Walcott),[1] although having a similar frontal limb and form of glabella, undoubtedly belongs to a different genus or subgenus; this is indicated by its very strongly pitted surface.

A second species from Alabama, *C. robusta* (pl. 16, figs 2, 2a), is illustrated for comparison as it has a well preserved cranidium and the pygidium is proportionately more elongate than that of *C. superba*.

Another form that is very close to this species is *Anomocare limbatum* Angelin. It differs materially, however, in having the very large eye-lobe characteristic of *Anomocare læve* (pl. 17, fig. 1), the type of the genus *Anomocare*. I think that in all probability with the securing of entire specimens of *A. limbatum* the species will be found to have characters intermediate between *Coosia* and *Anomocare*. For the present, however, I will refer it to the genus *Coosia*, subgenus undetermined.

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[1] Referred in 1905 to the genus *Anomocarella*.

*Formation and locality.*—Middle Cambrian: (91) Conasauga (Coosa) shales, at Cedar Bluff, Cherokee County, Alabama; (16) limestones in Conasauga (Coosa) shales, Blountsville Valley, Blount County, Alabama; and (107) limestone in Bull Run, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, Knox County, Tennessee.

Collected by A. M. Gibson and Cooper Curtice.

### COOSIA ROBUSTA, new species

Plate 16, figs. 2, 2a

Of this species the cranidium and pygidium are known. The cranidium differs from that of *C. superba* (pl. 16, fig. 1) in having a proportionately more elongate glabella, more convex frontal border, and narrower postero-lateral limbs.

The pygidium differs in being more elongate, in having a proportionately longer axial lobe, and less flattened pleural lobes.

*Formation and locality.*—Middle Cambrian: (107) limestone in Bull Run, northwest of Copper Ridge, 11 miles (17.6 km.) northwest of Knoxville, Knox County, Tennessee.

Collected by Cooper Curtice.

### BATHYURISCUS MANCHURIENSIS, new species

Plate 16, figs. 4

This species is founded on numerous specimens of the cranidium, free cheeks, thoracic segments, and pygidia that are compressed in a fine argillaceous shale. Unfortunately, there are no entire specimens of the dorsal shield.

As restored by combining the free cheeks and cranidium, the cephalon is semicircular in outline and moderately convex. It is bordered by a narrow, slightly rounded margin that is separated by a sharply defined narrow furrow from the glabella and the slope of the free cheeks. The posterior border is very narrow, elevated, and separated from the fixed cheek by a strongly defined furrow; the palpebral lobes are narrow and a little less than one-fourth the length of the cephalon. Genal angles extended into short, sharp, backward curving spines. The cranidium is broad at the base, narrowing toward the front; the antero-lateral limbs are very small and disappear where the palpebral lobe touches the dorsal furrow; the postero-lateral limbs and narrow fixed cheeks merge into each other so as to form transversely subtriangular areas, with the narrow palpebral lobes on their front outer margins.

Glabella large, subquadrangular in outline, and separated from the fixed cheeks by clearly defined dorsal furrows; its sides are nearly parallel or slightly diverging; front broadly rounded, almost transverse; surface marked by five pairs of furrows, the posterior of which extends obliquely across the posterior portion nearly to the center and separates a small triangular lobe on each side; the next two anterior pairs of furrows are short and extend inward at right angles to the side of the glabella; the next pair is nearly opposite the front end of the palpebral lobe; the anterior furrows are short and extend obliquely inward subparallel to the front margin of the glabella. Occipital ring narrow at the sides, widening toward the center where it is marked by a small sharp node a little back of the transverse center. Free cheeks large and surmounted on the inner side by a narrow eye lobe. The facial sutures cut the posterior margin a little within the genal angle and extend obliquely inward and slightly forward to the base of the eye lobes; curving over and around the eye lobes, they extend forward and downward, cutting the front margin on a line with the posterior base of the eye lobe. Number of thoracic segments unknown. Single specimens of the segments show that the axial lobe was nearly as wide as the pleural lobes, that it was moderately convex, and that a small node occurs at the center of each segment near the posterior margin; also that on the outer side of each segment a rounded transverse node is outlined from the main body of the segment by a slightly oblique transverse furrow; pleural lobes nearly flat out to the geniculation where they curve gently downward; each pleura has a furrow that is broad at its inner end next to the axial lobe and gradually narrows to the geniculation, where it terminates within the somewhat broadly rounded outer extremity; in well-preserved specimens a rounded ridge starts near the inner end of the pleural furrow and extends outward one-fourth of the length of the furrow.

The associated pygidia are semicircular, with the anterior margin almost transverse in the compressed specimens. The axial lobe is large and quite distinctly marked; it is divided by three transverse furrows into three rings and a terminal section that ends just within the outer border; a small node occurs near the posterior margin at the center of each ring; five anchylosed segments are outlined on the pleural lobes by furrows that progressively curve more and more backward from the first to the posterior one which adjoins the terminal segment; the furrows all terminate within the narrow, slightly flattened border.

The casts of the outer surface indicate that it was smooth or minutely granulose.

*Observations.*—This species appears to be quite distinct from any that has been described. The quadrangular glabella with nearly parallel sides distinguishes it from *Bathyuriscus howelli* Walcott and *B. productus* (Hall and Whitfield).

*Formation and locality.*—Middle Cambrian: (36g) (36h) and (350) Fu-chóu series; shales about 130 feet (40 m.) above the white quartzite on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

### ASAPHISCUS IDDINGSI, new species

Plate 16, fig. 3

Dorsal shield longitudinally oval in outline, moderately convex. Cephalon semicircular in outline; a little more than one-third of the entire length of the dorsal shield; bordered by a nearly flat or slightly rounded margin that passes at the genal angle into a moderately strong genal spine; within the genal spine a rounded posterior border is separated from the fixed cheek by a rounded, clearly defined furrow; the interborder furrow is shallow and rounded. Cranidium moderately convex and roughly subquadrate in outline; the frontal limb is slightly convex and, with the anterior portion of the glabella and the front margin, forms a gentle slope that is broken only by the slight dorsal furrow in front of the glabella and the shallow intermarginal furrow; the frontal limb merges on the sides into the fixed cheeks which are a little less than one-half the width of the glabella; posteriorly the fixed cheeks merge into relatively small postero-lateral limbs; palpebral lobe narrow and extended in front as a low ridge that crosses the fixed cheek to the dorsal furrow near the antero-lateral angle of the glabella; that portion of the palpebral lobe above the eye is about one-fourth the length of the cephalon.

Glabella large, slightly narrower in front than at the occipital furrow; sides nearly straight and slightly converging, frontal margin broadly rounded; surface marked by very faint impressions of three pairs of glabellar furrows, which can only be seen where the surface is very perfectly preserved. Occipital ring about as wide as the frontal margin and separated from the glabella by a shallow furrow that terminates on the side slightly in advance of the posterior intermarginal furrow. Free cheeks about as wide opposite the eye as the fixed cheeks; eye lobe about one-fourth the length of the cephalon. Postero-lateral angle continued backward into a moderately strong spine. The facial sutures cut the posterior margin just within the genal angle and extend obliquely inward with a slightly sigmoid curvature to the base of the eye lobes; curving over and around the eye lobes, they pass forward and a little outward, cutting the frontal margin obliquely.

Thorax with nine segments; axial lobe moderately convex, slightly narrower than the pleural lobes in compressed specimens; on the outer side of each segment a low rounded node or ridge is separated from the main body of the segment by a slightly oblique furrow transverse to the segment; pleural lobes slightly convex, nearly flat out to the geniculation where they curve slightly downward and backward; each pleura has a well-defined furrow starting near the inner anterior margin and extending backward to the center of the pleura at the geniculation, where it curves slightly backward and terminates on the broadly rounded, slightly falcate end of the pleura.

Pygidium roughly semicircular in outline, one-fourth the length of the dorsal shield; anterior margin nearly transverse at the axial lobe and curving slightly backward to conform to the curvature of the last thoracic segment; axial lobe moderately convex and tapering gradually toward its posterior section which is just within the nearly flat marginal border; it is divided by four transverse furrows into four rings and a terminal section; three anchylosed pleural segments are outlined on the pleural lobes by furrows that curve backward and terminate on the inner margin of the doublure; this line is continued forward on the pleural lobes of the thorax, terminating on each side opposite the posterior end of the facial suture.

Surface of specimens preserved in the limestone nearly smooth or marked by very minute shallow pits.

*Dimensions.*—A dorsal shield 30 mm. in length has the following dimensions:

| | mm. |
|---|---|
| *Cephalon:* | |
| Length | 11.0 |
| Length of eye lobe | 3.5 |
| Width at posterior margin | 20.0 |
| Width of glabella at posterior margin | 6.0 |
| *Thorax:* | |
| Length | 12.0 |
| Width at fourth segment | 19.0 |
| Width of axial lobe at first segment | 5.5 |
| Width of axial lobe at ninth segment | 4.0 |
| *Pygidium:* | |
| Length | 7.0 |
| Width at union with thorax | 12.0 |

*Observations.*—Fragments of this species are quite abundant in the limestones and interbedded shales. A few entire specimens are found in a fine argillaceous shale a short distance above the white quartzite at the base of the section, and it is from the best specimens of these that the above description was drawn, together with specimens of the cranidium in the limestone.

In general outline and appearance *Asaphiscus iddingsi* approaches the type of the genus, *A. wheeleri* Meek.[1] *Asaphiscus iddingsi* has a genal spine, a longer eye lobe, a proportionately shorter cephalon, and nine, instead of eight, segments in the thorax.

*Formation and locality.*—Middle Cambrian: (35r) (36e) Fu-chóu series; shales interbedded with limestones near the base of the series just above the white quartzite, collected in a low bluff on the shore of Tschang-hsing-tau island, east of Niang-niang-kung, Liau-tung, Manchuria, China.

Collected by J. P. Iddings and Li San.

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[1] Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, pl. 31, fig. 3.

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FIG. 1. Summit view of a ventral valve. × 6. U. S. National Museum, Catalogue No. 57559.

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FIG. 2. View of a ventral valve. × 8. U. S. National Museum, Catalogue No. 57560.

2a. View of a partially exfoliated dorsal valve. × 8. U. S. National Museum, Catalogue No. 57561.

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FIG. 3. View of an exfoliated ventral valve, showing vascular markings and cast of concentric lines of growth. × 8. U. S. National Museum, Catalogue No. 57562.

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4a. Anterior portion of a dorsal valve, showing median ridge and central muscle scars. × 8. U. S. National Museum, Catalogue No. 57565.

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5a. A minute, slender, broken specimen. × 8. U. S. National Museum, Catalogue No. 57567.

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FIG. 7. Pygidium doubtfully referred to this genus. × 2. It is associated with *Stephanocare sinensis* (Bergeron). U. S. National Museum, Catalogue No. 57601.

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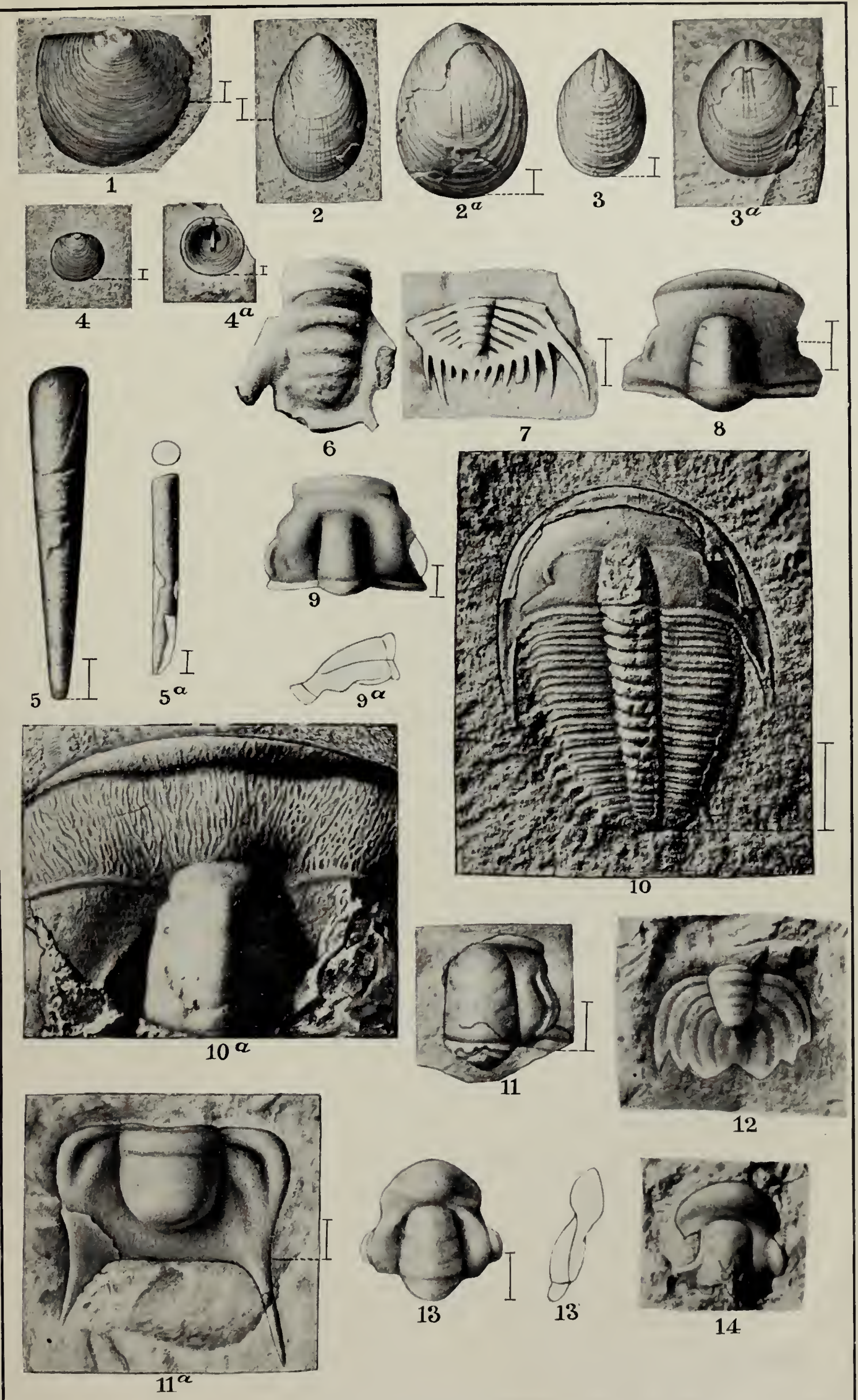
FIG. 8. Dorsal view of a cranidium. × 3. U. S. National Museum, Catalogue No. 57602.

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FIGS. 9 and 9a. Top view and side outline of cranidium. ×4. The type specimen of the species and subgenus. U. S. National Museum, Catalogue No. 57603.

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FIG. 14. Dorsal view of the type specimen of the species. ×3. U. S. National Museum, Catalogue No. 57574.

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[1] By error a figure of the cranidium of *Inouyia melie* = *Agraulos ? melie* Walcott 1906 was put on the plate instead of the cranidium of *Inouyia capax*.

## DESCRIPTION OF PLATE 15

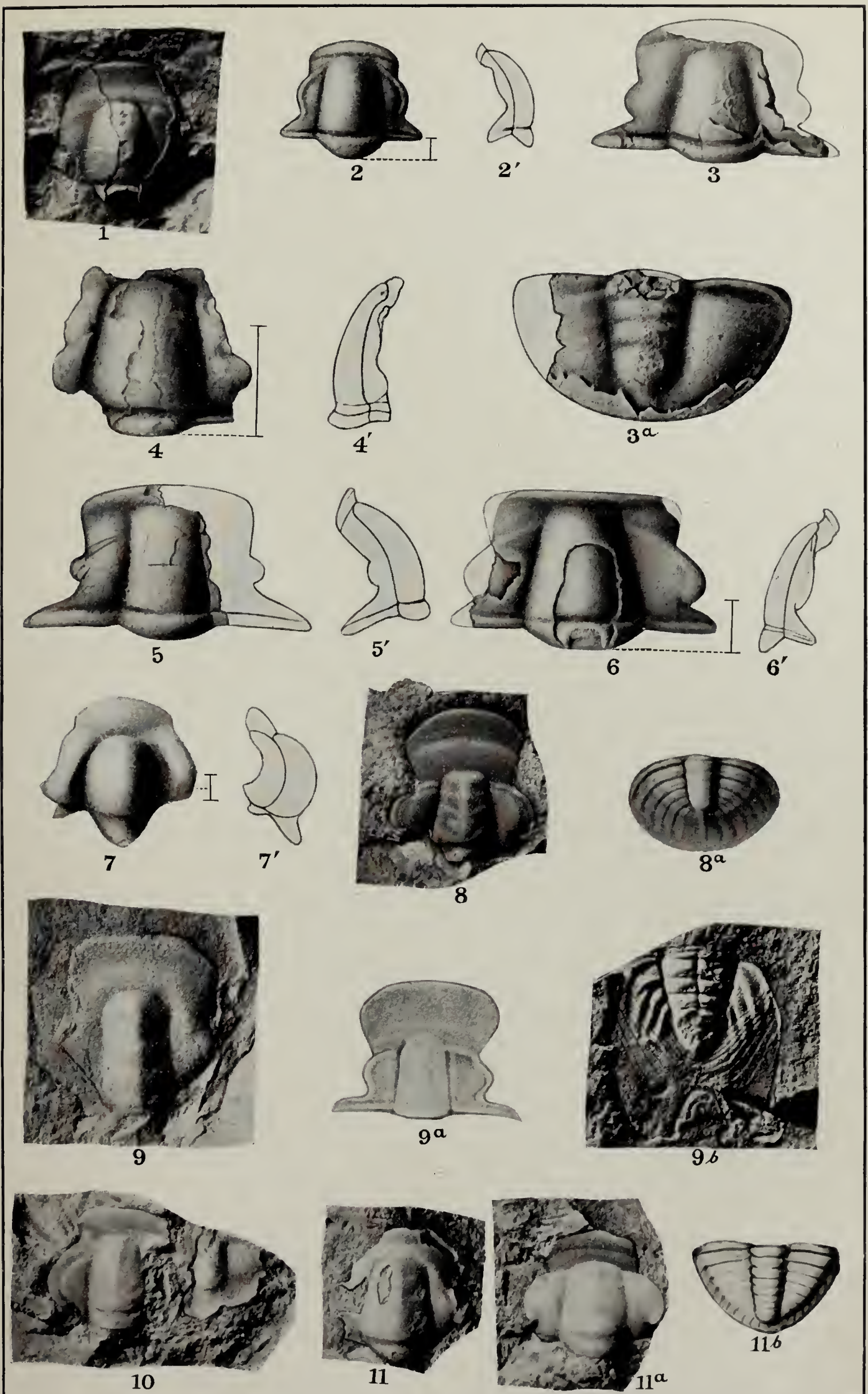


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FIG. 10. The cranidium with a portion of the pygidium on the same piece of rock. × 4. U. S. National Museum, Catalogue No. 57582.

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FIG. 11. A broken cranidium. Natural size. U. S. National Museum, Catalogue No. 57583.

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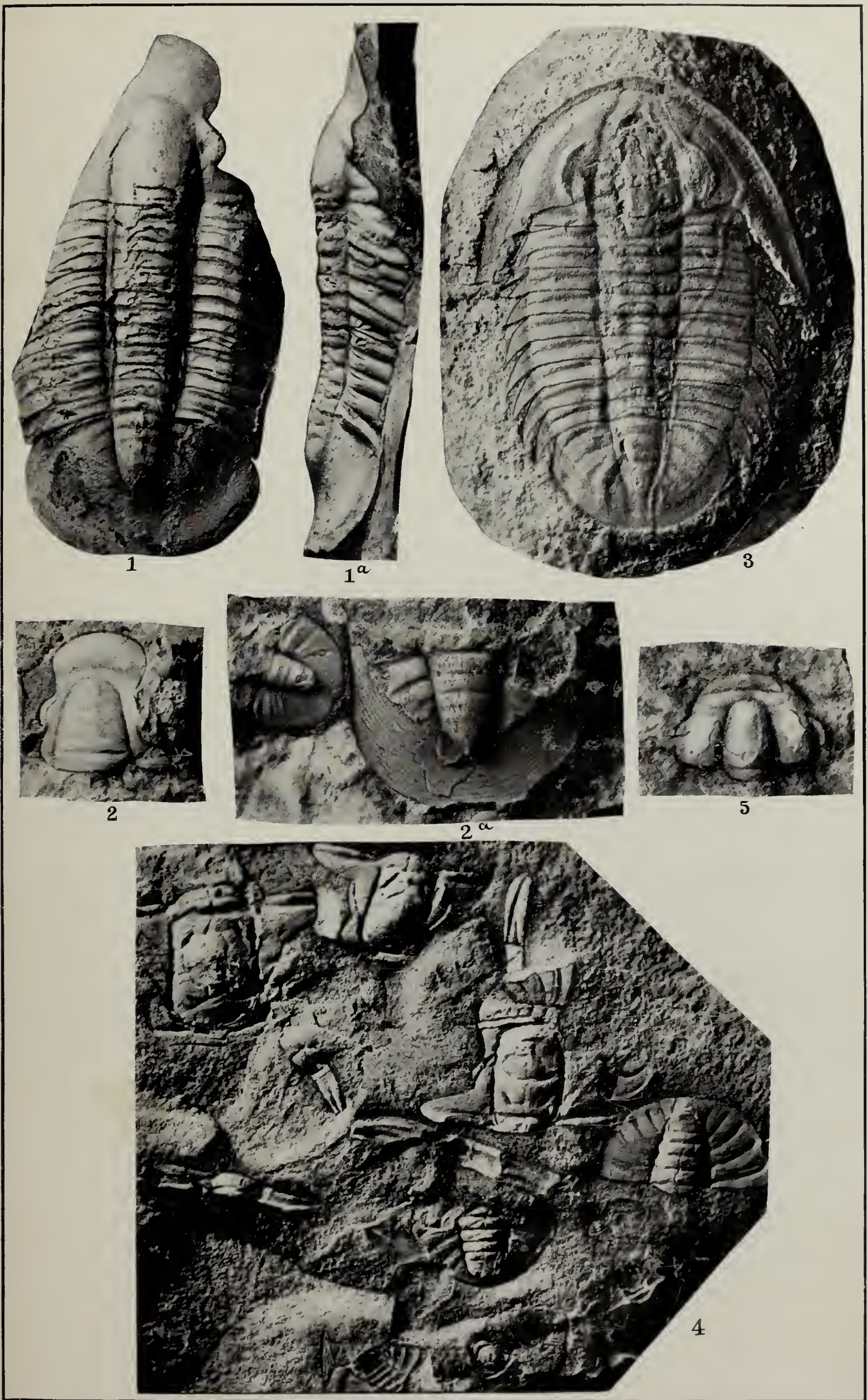


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FIGS. 1 and 1a. Dorsal and side view of an unusually perfect cranidium. Natural size. U. S. National Museum, Catalogue No. 57592.

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From locality (8w) Middle Cambrian: Paradoxides forchhammeri zone, Andrarum, Province of Christianstad, Sweden.

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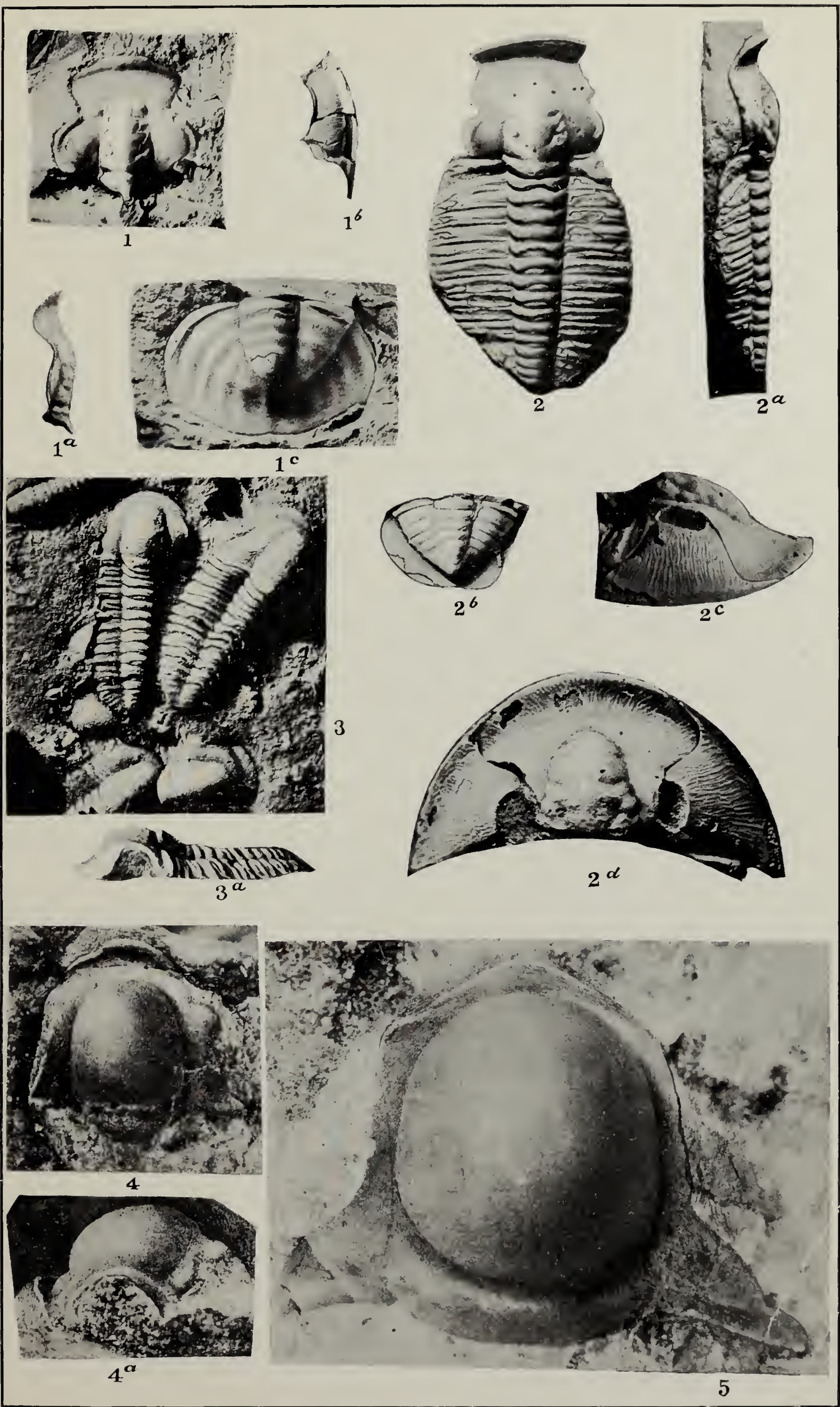
FIG. 5. Dorsal view of cranidium (× 10), the type specimen of the species and genus. U. S. National Museum, Catalogue No. 57600. (See text figures for side and front views.)




CAMBRIAN FAUNAS OF CHINA

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 5



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 5.—MIDDLE CAMBRIAN ANNELIDS

With Six Plates

BY

CHARLES D. WALCOTT

(Publication 2014)



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PUBLISHED BY THE SMITHSONIAN INSTITUTION
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(With Six Plates)

CONTENTS

## ILLUSTRATIONS



## INTRODUCTION

This is the third paper on Middle Cambrian fossils from the Burgess shale member of the Stephen formation of British Columbia. The first was on the Merostomata[1] and the second on the Holothurians and Medusæ.[2] We now have for consideration the annelids. As a rule the annelids have been known only by trails and borings in the muds and sands deposited in the various periods between the Pre-Cambrian Algonkian and the present, and only under very exceptional conditions have any traces of the actual animal been preserved. The most noted discoveries are those in the Upper Jurassic Solenhofen lithographic shales of Bavaria and the Eocene shales of Monte Bolca. Another discovery that has long escaped the attention of authors is that made by Dr. E. O. Ulrich and described by him in 1879.[3] These fossils appear to be true segmented Polychætous annelids from the Ordovician shale at Cincinnati, Ohio.

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[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911.
[2] Idem, No. 3.
[3] Journ. Cincinnati Soc. Nat. Hist., Vol. 1, 1879, pp. 87-91, pl. 4, figs. 1-4.

## CAMBRIAN ANNELIDS.

I have often searched the fine shales of the pre-Cambrian and Cambrian strata for remains of annelids but it was not until the summer of 1910 that anything more than trails and borings were found.

The annelids of the Burgess shale, like the holothurians and Medusæ, are pressed flat so that the animal is represented by only a thin film. Fortunately this is darker than the shale and usually shiny, and the contents of the animal are often preserved as a glistening silvery surface, even to the fine details of structure. How clearly the specimens exhibit both external and internal characters is shown by the plate figures which are reproduced from photographs made by reflected light. As it was impossible to bring out all the characters through light falling from one direction, the photographs were touched up by pencil, but not to such an extent as to introduce interpretation of structure not shown by the fossil.

*Classification.*—I have followed very largely the classification of Parker and Haswell's Text-Book of Zoology, Vol. 1, London, 1910.

The Class Chætognatha is represented by one genus and species, *Amiskwia sagittiformis*. The Class Chætopoda by six genera of the sub-class Polychæta as follows: *Miskoia, Aysheaia, Canadia, Worthenella, Pollingeria, Wiwaxia,* and *Selkirkia;* and the Class Gephyrea by four genera: *Ottoia, Banffia, Pikaia,* and *Oesia.*

The list of families, genera, and species may be found in the table of contents.

*Relations to living annelids.*—The discovery of this remarkable group of annelids in the Burgess shale[1] member of the Stephen formation opens up a new point of view on the development of the Annulata. The fact that from one very limited locality there have been collected eleven genera belonging to widely separated families points clearly to the conclusion that the fundamental characters of all the classes had been developed prior to Middle Cambrian time. No examples of the Class Hirudinea have been recognized, but the segmentation of the Chætopoda is present in *Ottoia* and *Banffia,* annelids which otherwise are true Gephyreans. To a certain extent these two genera serve to link the Chætopoda and Hirudinea.

I should not be at all surprised to find representatives of the Archi-Annelida in the Burgess shale. Thus far the annelids collected were incidental to other fossils rather than a direct object of search.

[1] Smithsonian Misc. Coll., Vol. 57, No. 3, 1911, p. 51.

As in the case of the holothurians the annelids go to prove that the Cambrian fauna was highly developed and differentiated in pre-Cambrian Lipalian time.[1]

## ANNULATA

### Class CHÆTOGNATHA

#### AMISKWIDÆ, new family

Chætognatha allied by external form to *Sagitta*. Body divided into a head, trunk, and tail. One pair of lateral fins. An interior septum occurs between the head and body, but none is shown between the body and tail.

One genus, *Amiskwia*.

#### AMISKWIA, new genus

As there is but one species the generic and specific descriptions will be combined under the species.

*Genotype.—Amiskwia sagittiformis,* new species.

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

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

*Observations.—Amiskwia* resembles *Sagitta* superficially, but differs from the latter genus in the form of the head, the presence of strong tentacles, the absence of a hood about the head, the strong single pair of lateral fins, and the absence of a posterior septum.

Generic name derived from Amiskwi, name of a river west of Mount Burgess, British Columbia, Canada.

#### AMISKWIA SAGITTIFORMIS, new species

Plate 22, figs. 3 and 4

Body cylindrical and divided into a broadly elongate oval head, a cylindrical body, and an expanded tail. The head, expanding from the neck, contracts to a bluntly pointed anterior end, from the rounded angles of which project a pair of strong tentacles. The lateral fins of the body are a little more than one-third the length of

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[1] Smithsonian Misc. Coll., Vol. 57, No. 1, 1910, p. 14.

the body and quite prominent. The tail is expanded and slightly transverse at the posterior margin.

The enteric canal and traces of other internal organs show quite clearly. In the head (fig. 3) a triangular-shaped area is outlined in front, and back of it a quadrate space. Posterior to the latter are two elongate oval spaces; from the outer side of the left of these three short hooks curve inward; these were undoubtedly beside the mouth. The enteric canal begins between the bases of the two oval spaces and terminates a little beyond the center of the tail. The anus doubtless existed at this point. A transverse, somewhat irregular line at the base of the oval spaces, indicates a thin septum separating the head and body cavities.

*Dimensions.*—The largest specimen has a length of 20 mm. Other proportions are shown by figures 3 and 4, which represent the body flattened on the shale.

*Observations.*—The living representatives of this beautiful little annelid are pelagic and very active swimmers; this fact and its association in the shale with small free swimming phyllopod crustaceans indicate very clearly that it was active and free swimming. Only three entire specimens were found.

*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.

## Class CHÆTOPODA

### SUB-CLASS POLYCHÆTA

### MISKOA, new order

Polychæta with similar segments and parapodia throughout the length of the body; retractile proboscis; straight enteric canal. Body not distinctly specialized into sections.

#### MISKOIDÆ, new family

Body elongate, slender; with numerous uniform segments; anterior end with rows of strong setæ about the mouth. Surface of anterior portion with numerous papillæ. Parapodia abundant, branched. Proboscis elongate, retractile. Enteric canal straight, with enlargement in anterior portion.

*Observations.*—The long retractile proboscis with the mouth at its base (fig. 1) suggests the Class Gephyrea as does the large body cavity surrounding the enteric canal, but the presence of distinct segments and parapodia brings *Miskoia preciosa* under the marine Polychæta. The constriction of the intestinal canal also suggests the Polychæta.

### MISKOIA, new genus

The generic and specific description is united under the description of the species as there is but one species known.

*Genotype.—Miskoia preciosa,* new species.

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

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

Generic name derived from Misko, the name of a pass and creek south of Park Mountain and Lake O'Hara, British Columbia, Canada.

### MISKOIA PRECIOSA, new species

Plate 18, figs. 1-5

Body elongate, slender. A specimen 26 cm. in length is 1 cm. in width at the widest part as it lies flattened in the shale. The body may be roughly divided into three sections: (1) The anterior, with the mouth and proboscis as shown in figs. 1 and 3; (2) the central, which is more or less expanded (fig. 2); (3) the slender, terminal section (fig. 5).

The anterior section merges into the central section so gradually that no definite line of demarcation can be drawn. There is a swelling posteriorly and a slight contraction anteriorly that at the end may be a simple opening fringed with fine strong setæ (fig. 1), or an expanded opening (fig. 3) with the setæ radiating from it. When the proboscis is protruded (fig. 1) the sides of the anterior section are nearly parallel, and when the proboscis is retracted the sides bulge outward. Usually the proboscis appears to have been cast off, in which case the body may contract between the mouth and the expanded central section. The central section may be considerably expanded or only a little larger, as shown by fig. 2, which is a portion of the specimen of which fig. 1 is the anterior and fig. 5 the posterior section.

The posterior section is a little more than one-third the entire length of the animal. Posteriorly it grows smaller and terminates in a rounded end.

*Surface.*—The surface of the anterior and central sections is marked by numerous distinct, annular, impressed lines that divide it into many segments or metameres. In a specimen 26 cm. in length the annular lines average two to the millimeter along the anterior half of the body (fig. 3), while the posterior half is apparently smooth (fig. 5). Numerous fine setæ occur on the posterior end of the body. The smooth surface may be due to the condition of preservation, as some specimens of the anterior half show no traces of annular rings or segmens. From the mouth backward for a distance equal to four or five times the diameter of the flattened body the surface is thickly studded with elongated papillæ, as shown on the left side of figure 1. The papillæ appear to be arranged in longitudinal rows.

*Parapodia.*—Small, branching parapodia fringe the side of the body on several specimens (figures 4 and 5). There appear to be two, three, or even more divisions of some of the podia.

*Proboscis.*—A single specimen shows the proboscis protruded (fig. 1). It is slender and expanded toward the outer end where the surface is covered with numerous fine papillæ. The posterior half has many fine setæ extending obliquely forward. In fig. 3 the proboscis appears to have been retracted within the body and more or less crowded in on itself.

*Mouth and anus.*—The mouth is circular and surrounded by rows of strong setæ (figs. 1 and 3). No teeth have been seen. The anus is probably terminal as the enteric canal may be traced to within a very short distance of the posterior end of the body.

*Enteric canal.*—This canal is a rather large, elongated tube that extends from the mouth to the anus. It appears to be straight with an expansion at about the anterior third (fig. 2) that is quite marked in several specimens. In some examples the canal appears to be constricted by annular lines that divide it into segments two to three times as long as the segments of the body. There is a suggestion in one specimen that the body cavity was divided into a series of chambers by delicate muscular bands, but to be conclusive such an interpretation should be substantiated by evidence from other specimens.

*Observations.*—This beautiful annelid was first recognized from the specimen illustrated on pl. 18, figs. 1, 2 and 5. It was found by Mrs. Walcott in splitting a slab of shale that had been slid down the mountain side and carried by pack animal to the Burgess Pass camp. We were all greatly interested and every one was on the alert to find other specimens. About ten days after the anterior half of the specimen represented by figs. 1 and 2 was found Mrs. Walcott called my attention to another "straight worm" she had found in a slab that had been blasted out of the ledge and taken to camp after the first discovery of the long annelid. I compared the two specimens and found that the break across them was on the same angle and that they fitted together to form the entire animal. Part of the second find is shown by fig. 5. The two parts united are 26 cm. in length. Subsequently several fragmentary specimens were found, but nothing equal to the specimen so strangely and fortunately saved by a most unusual combination of circumstances.

There are a number of unsolved questions relating to this annelid on which I will not now speculate, as the collection of 1911 may give further material for study.

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

### AYSHEAIDÆ, new family

Polychæta with a slender fusiform body with many segments, large, strong, segmented parapodia attached to alternating groups of segments, setæ on parapodia as hoops or jointed spines. Head small with two and probably four tentacles.

*Observations.*—It would be hazardous to define a family of living Polychæta from the data afforded by *Aysheaia pedunculata,* but it would be still more so to identify this strongly marked form with any of the described families. The peculiar segmentation of the body and the attachment of the large parapodia on alternating groups of segments are unusual. While it is not impossible, it is not probable that a Cambrian annelid of this type would belong to any of the families of recent annelids.

### AYSHEAIA, new genus

Of this genus there is but one species and one specimen known. The generic and specific descriptions are combined under the species.

*Genotype.—Aysheaia pedunculata,* new species.

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

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

Generic name derived from Ayshea, the name of a mountain peak north of Wapta glacier, British Columbia, Canada.

### AYSHEAIA PEDUNCULATA, new species

Plate 23, figs. 8 and 9

Body elongate, slender. Segments numerous and clearly defined by lines on which many minute shallow pits occur, several of the lines having 13 pits on the exposed side of the body. Head small; a central narrow longitudinal section has a rounded lobe on each side of its posterior half that suggests large eyes; the anterior end appears to have two short, slender tentacles projecting forward. Parapodia large and attached in such a manner as to have two lines of pits and three segments between each pair of parapodia, and one line of pits and two segments between the lines of pits which merge into the anterior and posterior outline of each parapodia or foot. Hook-like and straight, jointed setæ are attached to the parapodia. Traces of a small enteric canal occur in the posterior half of the body.

*Dimensions.*—Length of specimen preserving 10 parapodia on the left side 33 mm. Width as flattened in the shale 3 to 4 mm. One parapodia is 3 mm. in length. Each one appears to be drawn in towards the body.

*Observations.*—The unique specimen representing this species is flattened and slightly distorted in the shale. The head is not as distinct as the body and some of the posterior portion is missing. In the hope of finding other specimens during the season of 1911 further discussion on its structure will be deferred. This species is associated with *Ottoia prolifica* (pl. 29, figs. 1-5).

*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.

### CANADIDÆ, new family

Polychæta with a slender body formed of long segments bearing setiferous parapodia with dorsal and ventral bundles of setæ. Head small with two strong tentacles.

One genus, *Canadia.*

*Observations.*—For comparison with recent annelids we turn to the Aphroditidæ,[1] Amphinomidæ, and Palmyridæ, but in none of these do we find the slender body, narrow segments combined with the small parapodia, and great development of setæ without scales on the dorsal surface.

### CANADIA, new genus

The description and illustrations of *Canadia spinosa* will serve to indicate this genus. The other species express, in variations in size and position of the bundles of setæ, characters that for this preliminary study are considered to be of specific value.

*Genotype.—Canadia spinosa,* new species.

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

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

*Observations.*—Five species are referred to *Canadia: C. spinosa, C. setigera, C. sparsa, C. dubia,* and *C. irregularis.* Of these the first two are illustrated on pl. 23. The other three species will be illustrated in a final paper on this fauna.

Generic name derived from Canada.

### CANADIA SPINOSA, new species

Plate 23, figs. 4-7

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

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

[1] See Dr. E. Ehlers beautiful memoir on the annelids of the Blake expedition. Mem. Mus. Comp. Zool., Vol. 15, 1887.

*Observations.*—This beautiful species recalls in its dorsal aspect the recent *Palmyra aurifera*[1] and *Chlœia euglochis* Ehlers.[2] The latter has almost the same grouping of setæ on the parapodia.

The species is represented by a number of specimens, but none exhibit the detailed structure of the head.

*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.

### CANADIA SETIGERA, new species

Plate 23, figs. 1-3

This species differs from *C. spinosa* in being more elongate, slender, and with much smaller bundles of finer setæ. Its characters are well illustrated by figs. 1 and 3. A series of 36 specimens indicate that the elongate forms represented by figs. 1 and 2 are connected by numerous gradations with the form represented by 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

### CANADIA SPARSA, new species

A slender form with only two strong setæ on each very short parapodia. Finer setæ may occur, but they are not shown on the one specimen which, in size and distance of the parapodia, resembles the specimen represented by fig. 2, pl. 23.

*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.

### CANADIA DUBIA, new species

This species is proposed to include a small chætiferous annelid not over 10 mm. in length. One specimen shows a bundle of very fine setæ on each side near the head.

*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] Challenger Rept. Zoology, Vol. 12, 1885, pl. 9, fig. 1.

[2] Mem. Mus. Comp. Zool., Vol. 15, 1887, pl. 1, fig. 1.

### CANADIA IRREGULARIS, new species

A small slender species not over 20 mm. in length. The setæ are irregular in size and appearance and suggest partially worn macerated specimens of the slender forms of *C. setigera*.

*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.

### SELKIRKIA, new genus

Polychætous annelids with a slender, straight, or slightly curved tube. Probably chitinous. A number of tubes of *Selkirkia major* show the animal projecting from the end as illustrated by fig. 6, pl. 19. It is divided into segments or sections and more or less provided with short spines at the base of the anterior or end section. A number of short-jointed appendages indicate a rather large head.

*Genotype.*—*Selkirkia major* (Walcott).

Two other species *S. fragilis* and *S. gracilis* are referred to this genus on account of the form of the tubes; they are clearly not to be referred to *Hyolithes*.

*Stratigraphic range.*—The stratigraphic range in limited to a band of dark siliceous shale about 4 feet in thickness forming a part of the Burgess shale member of the Stephen formation at locality (35k) near Burgess Pass, and on the slope of Mount Stephen it was found extending through 50 feet or more of the coarse siliceous shales.

*Geographic distribution.*—On the slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway; and on the slope of Mount Stephen 2300 feet above Field; both in British Columbia, Canada.

Generic name derived from Selkirk, name of mountain range, British Columbia, Canada.

### SELKIRKIA MAJOR (Walcott)

Plate 19, fig. 6

*Orthotheca major* Walcott, 1908, Canadian Alpine Journal, Vol. 1, p. 246, pl. 1, fig. 11.

This species was founded on a long, slender, delicate tube that is known only as it occurs flattened on the surface of the shale. The apical end is broken off on all the specimens in the collection. The tube is usually so completely flattened that the fine concentric lines and fine ridges that give an annulated appearance to it have disappeared; often the tubes appear to be longitudinally striated as the result of lateral compression. Some tubes appear to be slightly constricted near the aperture and also a little thickened. The tubes were thin and easily compressed and flattened. They may have been calcareous, but from their bright, almost shiny, luster they were more probably chitinous or parchment-like.

*Dimensions.*—The largest flattened tube has a length of 68 mm., with a width of 12 mm. at the larger end, and of 8 mm. at the smaller. A more slender tube 64 mm. long is 9 mm. wide at the large end and 2 mm. at the smaller. The larger number of tubes have a transverse diameter of from 5 to 7 mm. at the larger end.

*Animal.*—Ten specimens show more or less of the animal projecting from the tube. It fills the end of the tube and is divided into sections a little longer than wide that are faintly indicated by slight successive contractions, and the presence of somewhat more prominent spines or hooks. The spines appear to have been arranged in concentric rows over all parts of the surface of the body except the terminal section. A specimen that is not illustrated shows a conical terminal section with several small-jointed appendages about its posterior end. My present impression is that the terminal section represents the head and the appendages a circle of gills. From the fact that the animal projects so much more from some tubes than it does from others, it seems that it was retractile and could withdraw into its tube. No traces of an operculum have been seen. With the somewhat formidable series of spines to protect it an operculum would scarcely have been necessary.

*Observations.*—On pl. 19, fig. 7, there is inserted for comparison with *Selkirkia major* a photograph of a specimen of *Hyolithes carinatus* Matthew showing the triangular tube, operculum, and, for the first time among the Hyolithidæ, the curved supports of the fins of a pteropod.

The discovery of the animal that lived in one of the tubes that has been classed with the pteropods removes one more doubtful form from the latter to the annelids, and with it will probably go *Hyolithellus* and other tube-like shells that have none of the distinctive external characters of *Hyolithes* and its allies.

In these preliminary notes I do not care to mention further the relations of the various Paleozoic tube-like fossils that have been referred to the Pteropoda and Annelida, except to call attention to a discussion of the subject by Dr. G. F. Matthew,[1] who concludes that *Hyolithes* and allied forms should be classed with the annelids, along with *Hyolithellus* and other slender tubes.

During the field season of 1911 we hope to add something more to the information about the animal of *Selkirkia*.

*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; and (14s) about 2300 feet (701 m.) above the Lower Cambrian and 2700 feet (823 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; both in British Columbia, Canada.

### SELKIRKIA FRAGILIS, new species

Plate 19, fig. 8

A thin tube that when flattened has a diameter at the larger end of from 2.5 to 3 times its length; the slender proximal end is curved. The largest specimen has a length of 25 mm. This species differs from *Selkirkia gracilis* (fig. 9), and *S. major* (fig. 6) in its greater proportional diameter at the aperture.

*Formation and locality.*—Middle Cambrian: (14s) about 2300 feet (701 m.) above the Lower Cambrian and 2700 feet (823 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, Canada.

### SELKIRKIA GRACILIS, new species

Plate 19, fig. 9

A number of fine specimens of this species have been found in the same layers of shale with *S. major,* but unfortunately none of them show any traces of the animal. The tube is very thin and, unlike *S. major,* retains the slender, more or less curved proximal end. A comparison of fig. 9 with figs. 6 and 8 shows how this flattened tube differs in form from *S. major* and *S. fragilis.*

The largest tube has a length of 47 mm. and a width of 10 mm. at the aperture.

[1] Trans. Roy. Soc., Canada, 2d ser., Vol. 5, sec. 4, 1899, p. 103.

*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; and (14s) about 2300 feet (701 m.) above the Lower Cambrian and 2700 feet (823 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; both in British Columbia, Canada.

### WIWAXIDÆ, new family

Body oval; covered with dorsal ribbed scales and strong, elongate spines.

One genus, *Wiwaxia*.

### WIWAXIA, new genus

The generic and specific descriptions are united under the description of the species.

*Genotype.*—*Wiwaxia corrugata* (Matthew).

*Stratigraphic range.*—The stratigraphic range is limited to a band of dark siliceous shale about 4 feet in thickness forming a part of the Burgess shale member of the Stephen formation at locality (35k) near Burgess Pass, and on the slope of Mount Stephen it was found in the trilobite beds of locality (14s).

*Geographic distribution.*—On the slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet above Field on the line of the Canadian Pacific Railway; also on the slope of Mount Stephen 2300 feet above Field; both in British Columbia, Canada.

Generic name derived from Wiwaxy, name of several small mountain peaks north of Lake O'Hara, British Columbia, Canada.

### WIWAXIA CORRUGATA (Matthew)

Plate 21, figs. 1-4

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

*Orthotheca corrugata* WALCOTT, 1908, Canadian Alpine Journal, Vol. 1, No. 2, p. 246, pl. 1, fig. 11.

This fine species is represented by a number of specimens of nearly the entire dorsal surface, which appears to have been covered by scales. The best example of what was probably the entire dorsal outline is illustrated by fig. 2, the anterior end being at the left or next to the side of the plate. The scales, as on the recent Aphroditidæ and Polynoidæ, radiate or point from the axis of the body backward and outward along the sides. An example of a recent annelid covered with dorsal scales is furnished by *Iphionella cimex* De Quatref,[1] and dorsal spines are a distinctive character on *Lætmonice producta willemœsii,*[2] *L. producta wyvilli,*[3] *and Lætmonice aphrodites.*[4] The form, size, and surface markings of the scales and spines of *Wiwaxia* are well shown by the illustrations on pl. 21. In fig. 4 the slender cylindrical proximal extension of the end of the scale and also of the dorsal spines is well shown; this extension probably continued down into the sac from which the scale began its growth. The spines are probably modified scales, but they may correspond to the dorsal spines of the recent annelids referred to above. A very fine surface ornamentation consisting of minute, irregularly outlined, transversely oblong spaces also occurs on the scales. The scattered scales and spines are often very abundant. It was one of the spines that Dr. G. F. Matthew described under the name of *Orthotheca corrugata.*[5] It is hoped that specimens showing the ventral surface of the animal will be found in the near future.

*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; and (14s) about 2300 feet (701 m.) above the Lower Cambrian and 2700 feet (823 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; both in British Columbia, Canada.

### POLLINGERIA, new genus

The generic and specific characters known are given under the description of the species.

*Genotype.*—*Pollingeria grandis,* new species.

*Stratigraphic range.*—The stratigraphic range is somewhat greater than that of *Wiwaxia corrugata,* with which it is associated in some layers. The scales have been found extending up from the Phyllopod bed (page 130) through about 30 feet of shale.

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[1] Challenger Rept. Zool., Vol. 12, 1889, pl. 9, fig. 4.

[2] Idem, pl. 6, fig. 3.

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

[4] Idem, pl. 7, fig. 4.

[5] Trans. Roy. Soc., Can., 2d ser., Vol. 5, sec. 4, 1899, p. 42, pl. 1, fig. 3.

*Geographic distribution.*—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.

Generic name derived from Pollinger, name of mountain of President range, British Columbia, Canada.

### POLLINGERIA GRANDIS, new species

Plate 21, figs. 7, 8, and 9

This is a much larger form than *Wiwaxia corrugata.* One specimen that has the anterior end broken off measures 12 cm. in length, with a width midway of 7 cm. Individual scales vary in length from 10 to 15 mm. The scales are thin, smooth, elongate, and variable in outline as shown by figs. 7-9. They occur in great numbers scattered on the surface of partings of the shale, but in only one example are they grouped together to indicate the size and form of the dorsal surface. Nothing is known of the body of the annelid.

One of the curious facts connected with the scales is that a considerable proportion of them have been traversed by a minute annelid, the trail of which curves and coils about within the area of the scale. This indicates that there was some animal matter attached to the scale which the minute annelid was seeking.

The scales of this species are so radically different from those of *Wiwaxia* that they do not fall within that genus. There are no dorsal spines so far as known.

The presence of two or three other species of annelids is shown by the presence of scales that vary materially from those of *Pollingeria grandis* and *Wiwaxia corrugata.*

*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.

### WORTHENELLA, new genus

As this genus has but one known species the description of the latter will sufficiently define the genus.

*Genotype.*—*Worthenella cambria,* new species.

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

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

*Observations.*—The generic name is given in recognition of the fine work of Prof. A. H. Worthen, formerly State Geologist of Illinois.

**WORTHENELLA CAMBRIA, new species**

Plate 22, fig. 2

Body slender, elongate, and formed of 46 or more segments and a small head. The segments, as flattened in the shale, have a length of about one-half the diameter, which indicates that when uncompressed the diameter and length of each segment were about the same. Each segment has an annular median furrow that serves to divide it into two narrow rings with a groove between them.

The head is not well-preserved, but it appears to be formed of a large posterior segment and one or two anterior segments. A small shiny spot in front suggests an eye. The head appears to have been conical in form and provided with one or more pairs of tentacles and a pair of palps, the latter being represented by the long filament-like organs extending back from the ventral side of the head. The tentacles are represented by short, faint, jointed appendages extending forward from the front of the head.

The anterior 34 segments of the body show on their inner or ventral side, as compressed on the shale, strong parapodia divided into two filamentous branches. The parapodia of the next posterior 8 segments are longer and more compact. This description of the parapodia is subject to revision as the details of structure are not clear.

*Enteric canal.*—A very narrow dark line that extends close to the ventral or inner margin of the body from the head nearly to the posterior end, may represent a slender enteric canal.

*Measurements.*—The only specimen in the collection has a length of about 60 mm.

*Observations.*—Of this species there is only one specimen and its matrix. The characters described are readily seen by reflected light. The presence of small oval and round scale-like objects on the shale suggests that they may have belonged to the annelid and been detached. If so, with our present information *Worthenella cambria* is considered to represent an annelid belonging to the order Polychæta. It does not appear to fall within the limits of any of the recent families of the order. It may be that in the collections of

1911 material will be discovered that will give much better data for determining its family relations.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, west slope of 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, Canada.

## Class GEPHYREA—Quatrefages

### Class II.—GEPHYREA.

" The Gephyrea are marine Annulata devoid of any trace of segmentation in the adult condition, without parapodia, and either without setæ or with only a limited number; with either an invaginable anterior body region or introvert, at the extremity of which is the mouth surrounded by tentacles, or with a long, highly retractile proboscis representing the pre-oral lobe of the larva, and having the mouth situated at the base. The anus is sometimes terminal and posterior, sometimes anterior and dorsal. There is an extensive cœlome filled with a corpusculated fluid, and not divided by septa. The ventral nerve-cord is not made up of a series of ganglia. There is, as a general rule, only a single pair of nephridia. The sexes are separate; the ovaries and testes simple masses of cells; the nephridia act as reproductive ducts. The larva is a trochophore." [1]

The genus Ottoia is tentatively referred to the Gephyrea, since, while it possesses certain characters of the Gephyrea, it has others that do not come clearly within the class. The segmentation of the body serves to withdraw it from Gephyrea, but in so ancient a form this character is to be anticipated. The proboscis is similar in function to that of some of the Gephyrea and Polychæta where the buccal region is "*everted*" and may be withdrawn into the buccal region.[2] The proboscis and mouth of *Ottoia* also suggest the sucker-like mouth and proboscis of some of the Hirudinea (leeches). The exterior appearance of the body of *Ottoia* is also not unlike that of some of the leeches that have a slender body, finely marked segmentation, and a retractile proboscis with the mouth at the end. The absence of parapodia removes *Ottoia* from the Polychæta, and the presence of segments is not sufficient to place it with the Hirudinea.

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[1] Parker and Haswell, Text-Book of Zoology, Vol. 1, London, 1910, pp. 491-492.

[2] See Cambridge Natural History, Vol. 2, London, 1896, pp. 249-250.

ORDER?

With our present information it is not practicable to make a reference of *Ottoia* to any of the existing orders of the Gephyrea. The presence of an anterior, retractile, or introvertible proboscis, and the elongate cylindrical shape of the body is essentially similar to some of the Sipunculoidea, but the direct enteric canal, and more or less distinct segmentation is unknown in that order. In this tentative study the ordinal classification will be omitted.

### OTTOIDÆ, new family

Body cylindrical, elongate; with numerous segments that vary in width posteriorly. Hooks about the mouth and also at the posterior end. Proboscis papillose, introvertible, and with mouth at anterior end. Enteric canal direct from mouth to anus, or possibly with some slight convolutions.

The genus *Ottoia* is referred to this family, and also, though tentatively, *Banffia*.

### OTTOIA, new genus

The description of the species *O. prolifica* includes all the known essential characters of the genus.

*Genotype.*—*Ottoia prolifica,* new species.

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

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

*Observations.*—The position of *Ottoia* among the annelids is discussed under the class Gephyrea to which it is tentatively referred (page 127).

Generic name derived from Otto, name of a creek north of President Range, British Columbia, Canada.

### OTTOIA PROLIFICA, new species

Plate 19, figs. 1-5

Body elongate, tapering at each end when not contracted. It is divided by annular lines into many segments that average seven in a distance of 5 mm., except toward the posterior end where they are about twice as long (fig. 5). At the anterior end there is a band of minute hooks arranged in five or six concentric rings (figs. 1, 2, 4, and 5). At the posterior end there is a concentric row of stronger hooks as shown by figs. 1 and 3.

The proboscis is strong, retractile, and papillose. In fig. 4 it is extended nearly to its full length; in figs. 1 and 5 partially contracted, and in fig. 2 apparently broken off.

There are no traces of parapodia or openings on the surface except at the ends of the body.

Enteric canal small and extending the entire length of the body from the mouth to the posterior end (fig. 2). The mouth is at the base of the proboscis in front of the bands of hooks (fig. 2). The anus appears to have been at the posterior end, as indicated by the termination of the enteric canal in figs. 1 and 2.

The average length of adult specimens is from 8 to 10 cm. One 9 cm. in length is 2 cm. across its widest part as it is flattened in the shale. Other specimens are more contracted, shorter, and proportionally broader (fig. 1).

*Observations.*—There is a large series of this species in various conditions of preservation. Some show the annular lines and bands with great distinctness (figs. 1 and 3) and others are apparently smooth (fig. 2). The proboscis may be protruded (fig. 4), partially pushed out (fig. 5), or absent (fig. 2). Bands of longitudinal muscles are suggested by the lines near the inner curve of fig. 1, and concentric muscles by the annular bands.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, west slope of 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, Canada.

### OTTOIA MINOR, new species

Plate 22, figs. 5 and 6

This species differs from *Ottoia prolifica* in its proportionally more slender form when elongated (fig. 5), and straighter outline both when elongated and contracted (fig. 6). The hooks are also much finer and extend farther back on the anterior end. The annular lines and interspaces are also finer and more irregular.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, west slope of 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, Canada.

### OTTOIA TENUIS, new species

This species is based on a small slender annelid that has a slender proboscis; its anterior end has a band of hooks and the posterior end a long whip-like appendage that is longer than the body. The body, exclusive of the caudal appendage, is from 25 to 30 mm. in length in the four specimens collected. One 30 mm. long has a width of 2 to 2.5 mm. as it flattened in the shale.

*Ottoia tenuis* differs from *O. prolifica* and *O. minor* in its slender body and long posterior appendage.

*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.

### BANFFIA, new genus

The description of the type species includes all that is known of the genus.

*Genotype.*—*Banffia constricta,* new species.

*Stratigraphic range.*—The stratigraphic range is through about 110 feet of shale or from the lower Phyllopod bed,[1] where it occurs in a hard siliceous shale, up through to nearly the summit of the Burgess shale where the shale is coarser-grained, steel gray in color on fresh surface, and weathering to a dirty buff color.

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

*Observations.*—The reference of this genus to the Gephyrea is tentative. With its elongate body and annular lines it resembles *Ottoia,* and in the absence of interior structure the evidence is too incomplete to refer it elsewhere.

Generic name derived from Banff, name of town on Canadian Pacific Railway, Alberta, Canada.

### BANFFIA CONSTRICTA, new species

Plate 21, figs. 5 and 6

Body elongate, constricted midway. The anterior and larger section is elongate-spatulate in outline and the posterior section a narrow ellipse truncated at the ends. The constriction between the

[1] Phyllopod bed is the name now given to a stratum of shale about 5 feet in thickness in the Burgess shale in which many Phyllopod crustaceans occur.

two sections reduces the diameter at that point, of a specimen flattened in the shale, to one-half the cross section of the anterior portion.

Surface of anterior section marked by fine, transverse, slightly imbricating lines that serve to define narrow segments. On a specimen 55 mm. in length there are 4 lines in a distance of 5 mm.; in one 10 mm. long, 7 to 8 in 5 mm.

The posterior section has more and stronger lines than the anterior section. The distance between them varies according to the extent to which the annelid was drawn up or contracted. The distance also varies in different parts of the section, but usually they are farther apart near the ends. On a posterior section 35 mm. in length the lines on the posterior third are 1 mm. apart and on the central and anterior portion .5 mm. distant. On one specimen two rather strong hooks occur at the posterior end. No traces of a mouth or anus have been observed. One fragment shows a small enteric canal.

*Dimensions.*—The largest specimen of the half dozen in the collection has a length of 8 cm. A fragment of another indicates a length of 10 cm.

*Observations.*—This interesting species occurs in a somewhat coarser sediment than the annelids *Ottoia prolifica* and *Miskoia preciosa* with the result that the more delicate parts have not been preserved. It is hoped that the collections of 1911 may afford better specimens.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, west slope of 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, Canada.

### PIKAIDÆ, new family

Polychæta with a slender, many segmented, mobile body; small head, with well-developed eyes; parapodia on the anterior segments. Enteric canal straight; mouth and anus at the ends of the body.

One genus, *Pikaia*.

### PIKAIA, new genus

The description of the genus and species is united under the species.

*Genotype.*—*Pikaia gracilens,* new species.

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

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

Generic name derived from Pika, name of a mountain peak northwest of Laggan, Alberta, Canada.

### PIKAIA GRACILENS, new species

Plate 20, figs. 1 and 2

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

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

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

*Observations.*—This was one of the active, free-swimming annelids that suggest the Nephthydidæ of the Polychæta. I am unable to place it within any of the families of the Polychæta, owing to the absence of parapodia on the body segments back of the fifth. As compressed in the shale the study of a number of specimens of the posterior portion of the body leads me to think that it may have been flattened and thus been a much more effective aid in swimming.

*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.

### OESIA, new genus

Polychæta with thin, translucent, irregular tube having an enlarged head region. Segments numerous and more or less distinctly shown for the entire length. Enteric canal small and extending the length of the body. Hooks of anterior region very small.

Compared with recent annelids *Oesia* resembles some of the Maldanidæ.[1] In the absence of the details of head structure, setæ, etc., it is not practicable to compare the genera, although *Nicomache japonica*[2] looks as though it might appear very much like *Oesia disjuncta* if it were flattened out on a smooth surface.

*Genotype.*—*Oesia disjuncta,* new species.

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

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

Generic name derived from Oesa, name of a lake east of Lake O'Hara, British Columbia, Canada.

### OESIA DISJUNCTA, new species

Plate 20, figs. 3-5

All this is known of this species is illustrated by the figures on Pl. 20. It appears to have been a form that lived in an irregular tube that was so thin the annelid shows through it. The segmentation is shown by fig. 3, and the enteric canal in the three specimens illustrated and several others in the collection. The variation in appearance is very great. No two specimens are alike. Traces of minute hooks at the anterior end have been observed on one specimen.

The largest specimen has a length of 10 cm., with a relatively small head.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation, west slope of 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, Canada.

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[1] Challenger Rept. Zool., Vol. 12, 1885, pls. 46 and 47.

[2] Idem, pl. 46, fig. 5.

## DESCRIPTION OF PLATE 18

Legend:

e=enteric canal. pr=parapodia.
m=mouth s=setæ.
p=papillæ.

PAGE

*Miskoia preciosa* Walcott........................................ 114

FIG. 1. (× 2.) Anterior portion of a specimen 26 cm. in length. The extruded proboscis is 5.5 cm. in length. The proboscis is broken midway by a slight displacement of the shale. The enteric canal is shown extending inward from the base of the proboscis. U. S. National Museum. Catalogue No. 57616.

2. (× 2.) Portion of the body of the specimen of figure 1, beginning 6 cm. back of the mouth or anterior end, showing the enlargement of the enteric canal.

3. (× 2.) Anterior end of a body 9 cm. in length in which the proboscis appears to have been withdrawn. Setæ about the mouth, annular lines, and segments finely shown. U. S. National Museum, Catalogue No. 57617.

4. (× 2.) Portion of a body showing the parapodia on left side. U. S. National Museum, Catalogue No. 57618.

5. (× 2.) Nine (9) centimeters in length of terminal portion of annelid, the anterior portion of which is represented by figure 1. The parapodia are finely shown on the left side.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian: dark siliceous shales in the 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.


MIDDLE CAMBRIAN ANNULATA

## DESCRIPTION OF PLATE 19



FIG. 1. (× 2.) A small specimen enlarged to show the hooks about the mouth, proboscis, and posterior end, also the distinct annular lines and segments. U. S. National Museum, Catalogue No. 57619.

2. (Natural size.) An adult annelid showing the enteric canal and mouth, with the proboscis broken off. U. S. National Museum, Catalogue No. 57620.

3. (× 2.) Posterior end of a small specimen in which the annular lines and hooks are very distinct. U. S. National Museum, Catalogue No. 57621.

4. (× 3.) Enlargement of a proboscis, belt of hooks, and a portion of the anterior end of the body. The outlines of the enteric canal are clearly defined as well as the belt of hooks and the papillæ on the proboscis. U. S. National Museum, Catalogue No. 57622.

5. (Natural size.) Adult annelid preserving very distinctly the annular lines and segments, ring of hooks, and proboscis. U. S. National Museum, Catalogue No. 57623.



FIG. 6. (× 3.) A flattened tube with the anterior portion of the animal projecting from it. U. S. National Museum, Catalogue No. 57624.



FIG. 7. (× 2.) Ventral view of shell, operculum and fin or arm supports. This is one of a number of specimens showing the curved fin supports. U. S. National Museum, Catalogue No. 57625.

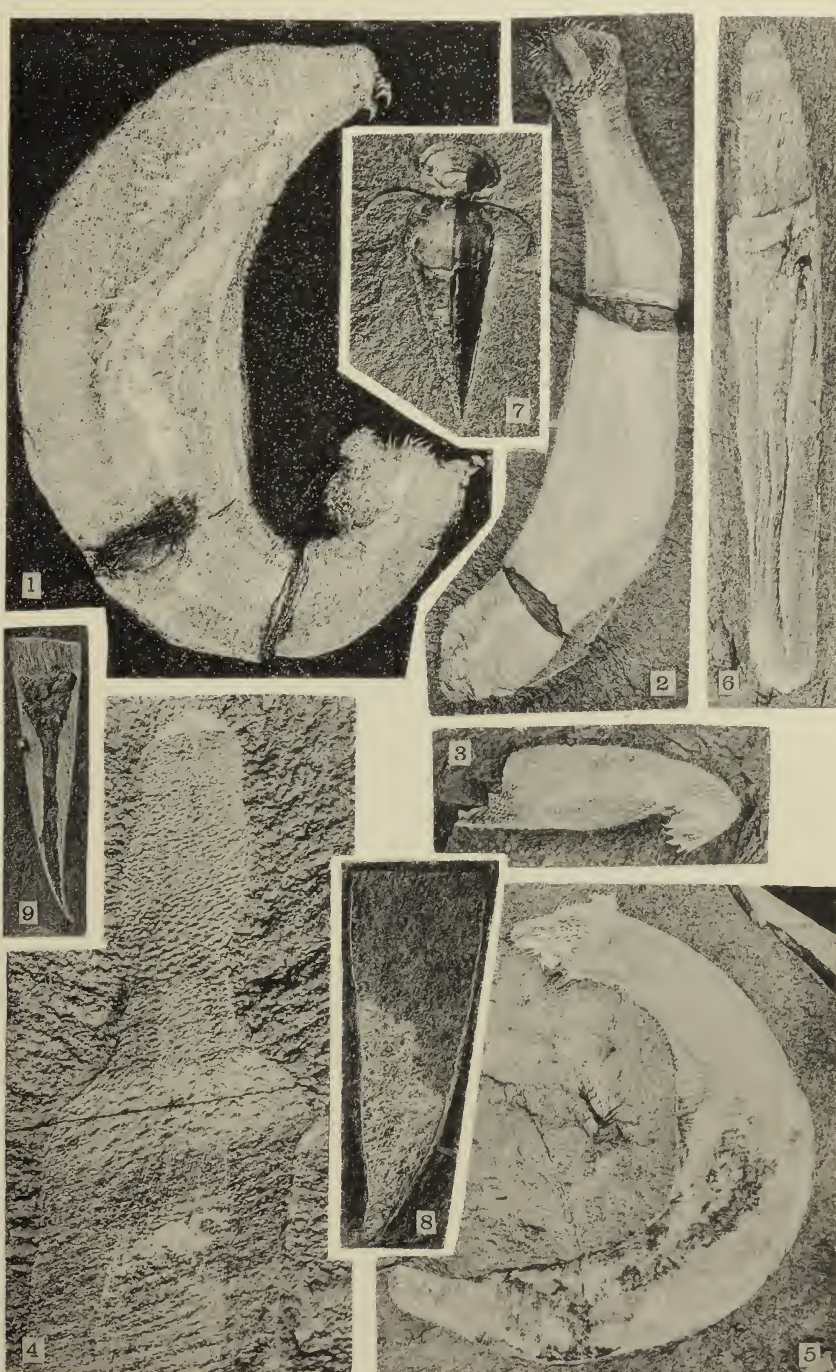


FIG. 8. (× 2.) Typical form of the tube as it is flattened in the shale of locality (14s) Middle Cambrian: about 2300 feet (701 m.) above the Lower Cambrian and 2700 feet (823 m.) below the Upper Cambrian, in the Ogygopsis zone of the Stephen formation, at the great "fossil bed" on the northwest slope of Mount Stephen, above Field on the Canadian Pacific Railway, British Columbia, Canada. U. S. National Museum, Catalogue No. 57626.



FIG. 9. (Natural size.) Type specimen, flattened in the shale. U. S. National Museum, Catalogue No. 57627.

With the exception of fig. 8, all of the specimens illustrated on this plate are from locality (35k) Middle Cambrian: dark siliceous shale in the 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.




MIDDLE CAMBRIAN ANNULATA

## DESCRIPTION OF PLATE 20

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*Pikaia gracilens* Walcott.......................................... 132

FIG. 1. (× 2.) A specimen flattened in shale, that shows the head, parapodia, segmentation, and outline of enteric canal. U. S. National Museum, Catalogue No. 57628.

2. (× 2.) Fragments of a portion of the body. U. S. National Museum, Catalogue No. 57629.

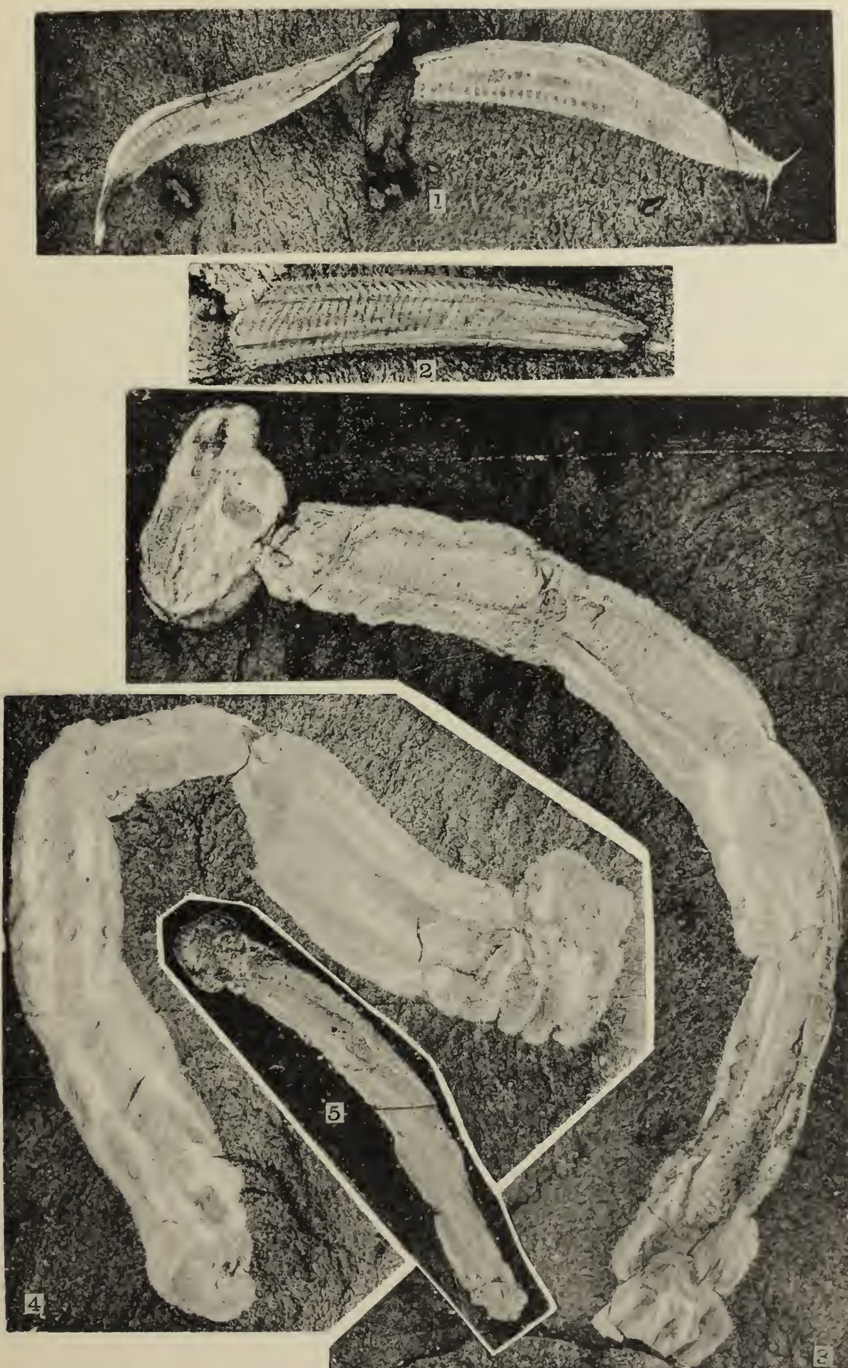
*Oesia disjuncta* Walcott.......................................... 133

FIG. 3. (× 2.) Specimen showing annulations and enlarged anterior end. U. S. National Museum, Catalogue No. 57630.

4. (× 2.) Specimen with irregular sections. U. S. National Museum, Catalogue No. 57631.

5. Natural size. A nearly straight specimen with relatively small anterior end. U. S. National Museum, Catalogue No. 57632.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian: dark siliceous shales in the 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.




MIDDLE CAMBRIAN ANNULATA

## DESCRIPTION OF PLATE 21

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*Wiwaxia corrugata* (Matthew) .......... 123

FIG. 1. (× 2.) Portion of the dorsal surface with numerous scales and five of the dorsal spines. U. S. National Museum, Catalogue No. 57633.

2. (× 2.) Dorsal surface. The arrangement of the scales indicates that the anterior end was on the left side where the outline is slightly incurved. U. S. National Museum, Catalogue No. 57634.

3. (× 1.25.) A specimen crushed down so as to displace scales and spines. U. S. National Museum, Catalogue No. 57635.

4. (Natural size.) Scattered scales and spines on surface of shale. U. S. National Museum, Catalogue No. 57636.

*Banffia constricta* Walcott .......... 130

FIG. 5. (Natural size.) A small specimen showing the two sections of the body. U. S. National Museum, Catalogue No. 57637.

6. (Natural size.) Anterior section and constriction with a portion of the posterior section. U. S. National Museum, Catalogue No. 57638.

*Pollingeria grandis* Walcott .......... 125

FIG. 7. (× 2.) One of the larger scales. U. S. National Museum, Catalogue No. 57639.

8. (× 2.) Scale furrowed by minute annelid. U. S. National Museum, Catalogue No. 57640.

9. (× 2.) Scales differing in form. U. S. National Museum, Catalogue No. 57641.

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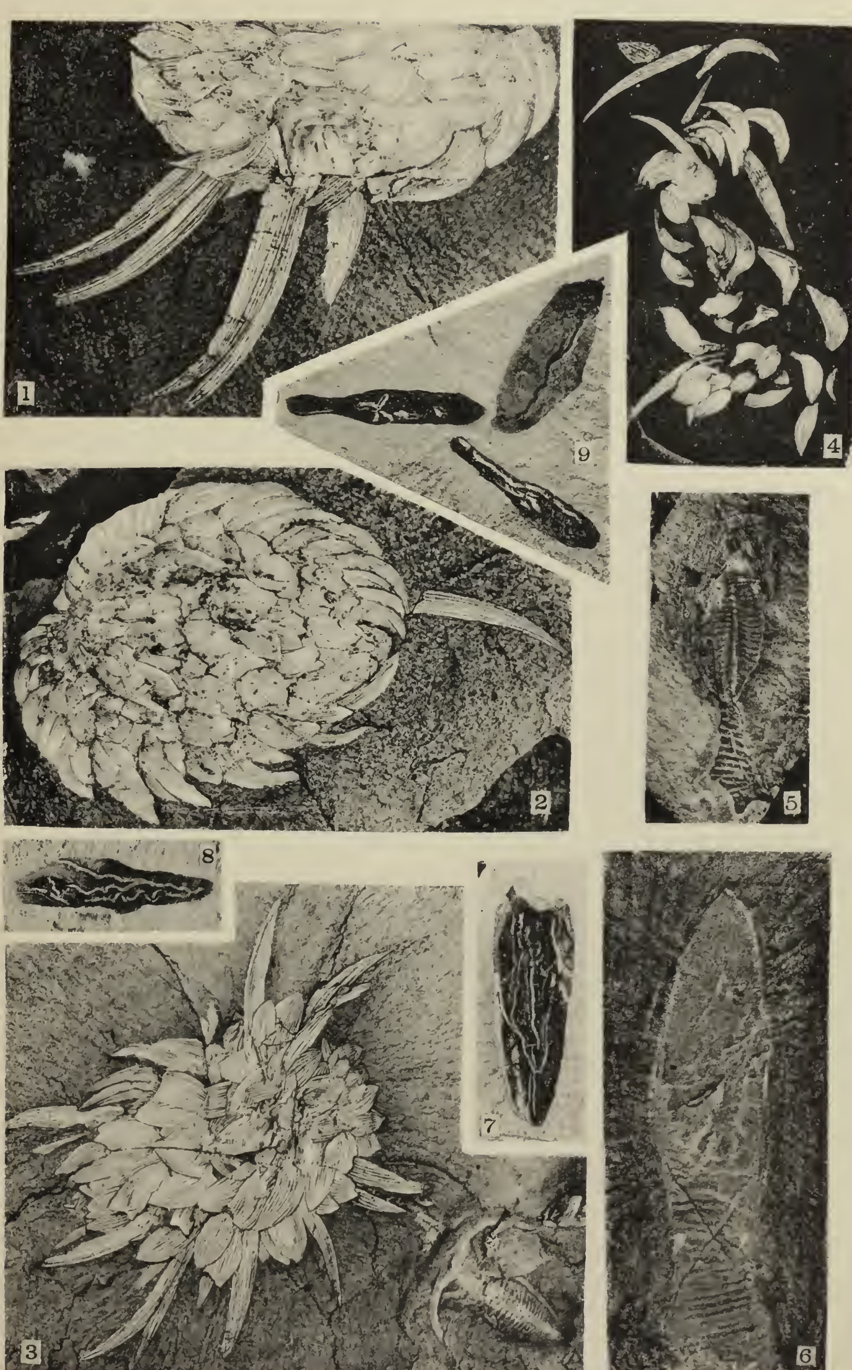


MIDDLE CAMBRIAN ANNULATA

## DESCRIPTION OF PLATE 22

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*Planolites* sp. ?

Fig. 1. (Natural size.) Portion of a trail associated with *Ottoia prolifica* (pl. 19) illustrating a very common type of trail in the Burgess shale. U. S. National Museum, Catalogue No. 57642.

*Worthenella cambria* Walcott.......................................... 126

Fig. 2. (× 2.) The type specimen as it occurs flattened on shale. U. S. National Museum, Catalogue Nos. 57644 and 57645.

*Amiskwia sagittiformis* Walcott.......................................... 112

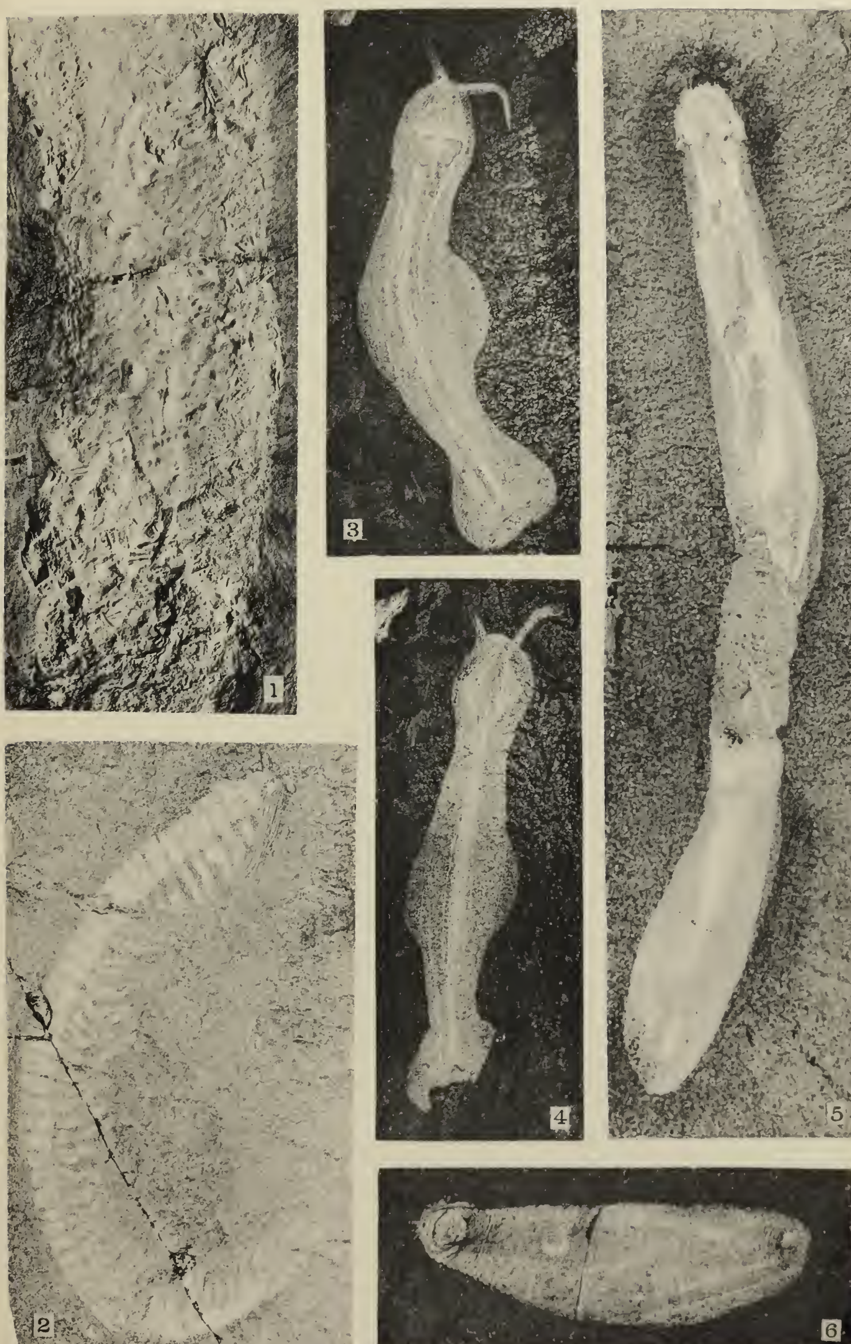
Figs. 3 and 4. (× 3.) Flattened specimens described in the text. U. S. National Museum, Catalogue Nos. 57644 and 67645.

*Ottoia minor* Walcott.......................................... 129

Fig. 5. (× 2.) An elongated specimen that occurs flattened on the shale. U. S. National Museum, Catalogue No. 57646.

6. (× 2.) A small contracted specimen. U. S. National Museum, Catalogue No. 57647.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian: dark siliceous shales in the 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.




MIDDLE CAMBRIAN ANNULATA

## DESCRIPTION OF PLATE 23

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*Canadia setigera* Walcott ........................................ 119

Fig. 1. (× 2.) A slender flattened specimen showing bundles of setæ and one of the tentacles of the head on the left end. U. S. National Museum, Catalogue No. 57648.

2. (× 2.) Posterior portion of a slender specimen. U. S. National Museum, Catalogue No. 57649.

3. (× 3.) A specimen that is contracted more than those represented by figures 1 and 2. This brings the parapodia with their bundles of setæ nearer each other. U. S. National Museum, Catalogue No. 57650.

*Canadia spinosa* Walcott ........................................ 118

Fig. 4. (× 2.) Lateral view of a specimen flattened in the shale. U. S. National Museum, Catalogue No. 57651.

5. (× 3.) Anterior portion and head from the ventral side. U. S. National Museum, Catalogue No. 57652.

6. (× 2.) Ventral view of anterior portion and head showing segments of body, parapodia, and bundles of setæ. U. S. National Museum, Catalogue No. 57653.

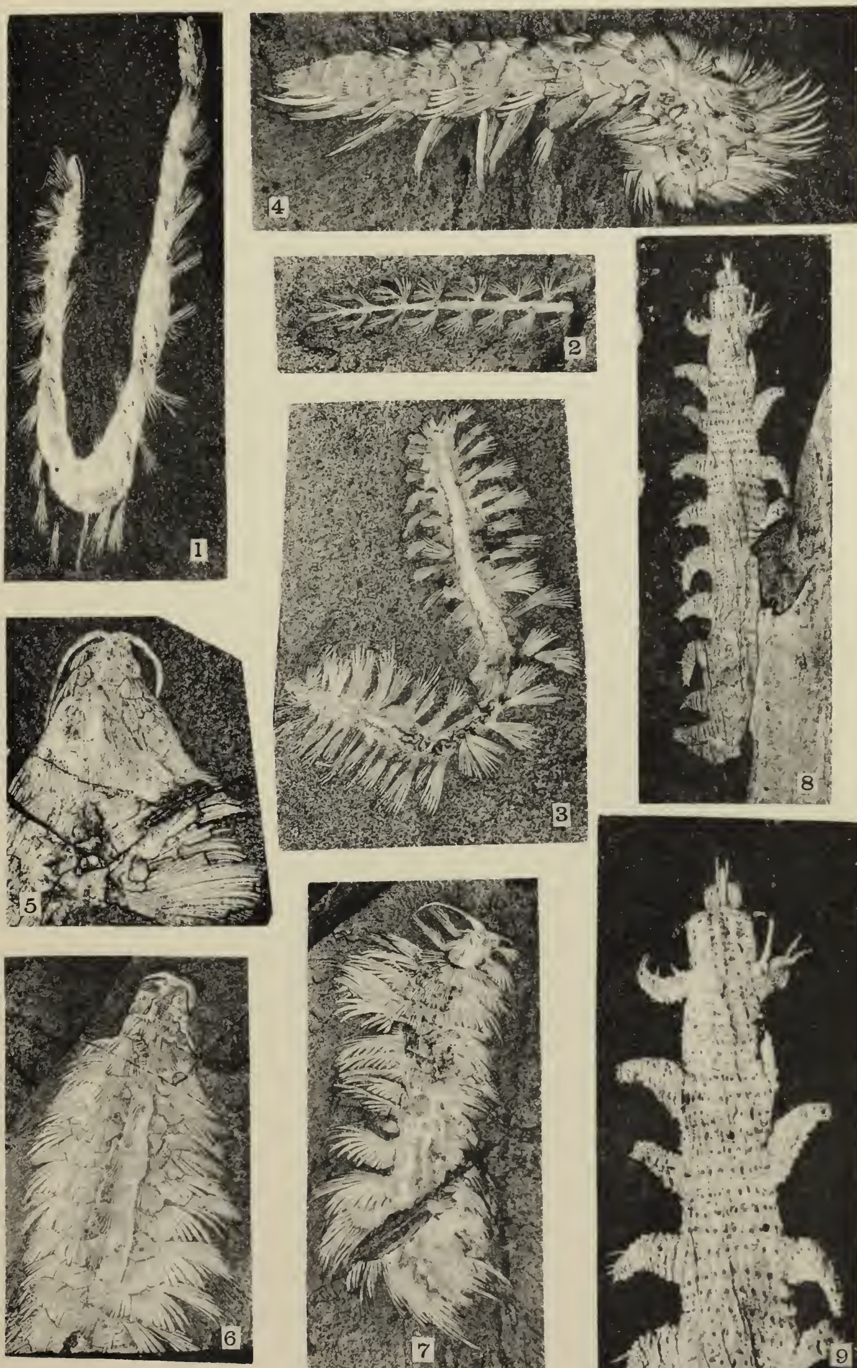
7. (× 2.) Dorsal view showing dorsal setæ and bundles of projecting ventral setæ; also the head and tentacles. U. S. National Museum, Catalogue No. 57654.

*Aysheaia pedunculata* Walcott ........................................ 117

Fig. 8. (× 2.) The type specimen as it occurs lying beside a specimen of *Ottoia prolifica*. (See pl. 19.) U. S. National Museum, Catalogue No. 57655.

9. (× 4.) Anterior portion of fig. 8, enlarged to show more detail.

All of the specimens illustrated on this plate are from locality (35k) Middle Cambrian: dark siliceous shales in the 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.



MIDDLE CAMBRIAN ANNULATA

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 6



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 6.—MIDDLE CAMBRIAN BRANCHIOPODA, MALACOSTRACA, TRILOBITA, AND MEROSTOMATA

WITH PLATES 24 TO 34

BY

CHARLES D. WALCOTT

(PUBLICATION 2051)



CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
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PLATES



## INTRODUCTION

This is the fourth preliminary paper based on collections from the Burgess shale member of the Stephen formation in British Columbia. The first paper described two genera of the Merostomata,[1] *Sidneyia* and *Amiella;* the second, the holothurians and medusæ, and the third the annelids.[2]

This paper includes all of the crustaceans of the subclasses Branchiopoda, Malacostraca, and Merostomata that occur in the collections of 1909 and 1910. A brief note is also given of some new features in the appendages of the Trilobita, and a few unusual forms of trilobites are noted by brief descriptions and simple illustrations. The few traces of the Ostracoda will not be noticed, and many details of structure of species are omitted, both in description and illustration, as I am planning to follow these preliminary notes with a paper on the Burgess shale fauna that shall include the results of a study of the present collections and those of the field seasons of 1911-1912.

*Correction.*—By oversight figures 2-4 of my paper on Middle Cambrian Holothurians and Medusæ, also the text references to Lankester's Treatise on Zoölogy, were credited to Lankester[3] instead of to F. A. Bather, the author of the section on the Echinodermata. Doctor Bather calls my attention to a paper by him in which he discusses the theoretical ancestor of the echinoderm.[4] Doctor Bather

[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pp. 17-40, pls. 2-7.

[2] Idem, No. 3, pp. 41-68, pls. 8-13, and No. 5, pp. 109-144, pls. 18-23.

[3] Idem, No. 3, pp. 43-45.

[4] What is an Echinoderm? Journal of the City of London College Science Society, Vol. 8, 1901, pp. 1-25.

also informs me that Chapter XIII, which includes the Holothurioidea, was written by E. S. Goodrich, as stated in a footnote on page 218, Part III, of Lankester's Treatise on Zoölogy. This was also overlooked in citing from that portion of the treatise. Due credit will be given in the final paper on the subject of the Burgess shale fauna.

## HABITAT

The crustaceans now found in the Burgess shale lived in quiet, relatively shallow waters swarming with life and readily accessible to the fauna of the open sea. In the preliminary study of the fauna I have distinguished 56 genera in collections from a block of shale not over 6 by 40 feet in area and 7 feet 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 *Microdiscus*, are not abundant, although their tests almost make up calcareous shales a few feet below the base of the Burgess shale.

The compact, smooth, exceedingly fine-grained siliceous Burgess shale was deposited from relatively quiet, muddy water. At intervals this condition must have continued 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 at the surface of the mud has already been spoken of.[1]

Owing to faulting and alteration of the shales by shearing the area available for collecting is limited to about 120 feet of outcrop on a steep slope of the mountain. This condition limits our information as to the original extent of this remarkable mud deposit. It was probably laid down in a small bay or lagoon in close connection with the shallow Middle Cambrian sea.

## CHARACTER OF THE SHALE

Mr. E. S. Larsen, Jr., of the United States Geological Survey, examined sections of the shale and from his notes the following is taken:

> The microscopic examination of the thin section of the rock shows that it is very fine-textured—so fine that much of the material shows aggregate polarization. It is made up largely of white mica, which occurs in minute shreds or scales arranged parallel to the cleavage of the rock. Kaolinite is

[1] Smithsonian Misc. Coll., Vol. 57, No. 3, 1911, p. 42.

rather abundant and a very few minute grains of quartz, small prisms of apatite, and a few crystals of pyrite can be recognized. Numerous dark brown to black streaks arranged parallel to the cleavage represent carbonaceous matter. There is a system of parallel veinlets less than a millimeter across, which are normal to the slaty cleavage; fractures through the centers of these veins show small grains of calcite and blotches of cupriferous pyrite. The surfaces of a system of later fractures are irregular and are coated with carbonates. Sections of the veinlets mentioned are made up in large part of an isotropic mineral which is nearly colorless in the thin section. In the hand specimen it is pale green. It has an index of refraction of about 1.62 and preliminary chemical tests indicate that it is near the chlorites in composition. A further study of the mineral is being made. In the center of the veinlets are irregular crystals of calcite and a little pyrite.

A chemical analysis of the slate was made by Mr. George Steiger in the laboratory of the United States Geological Survey and is given under No. 1 of the following table. Analyses of several somewhat similar rocks and of a sericite are also given.

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| $SiO_2$ | 54.49 | 55.80 | 60.28 | 57.96 | 55.00–67.00 |
| $Al_2O_3$ | 25.60 | 27.72 | 22.61 | 24.70 | 11.00–23.00 |
| $Fe_2O_3$ | 0.89 | 3.07 | 2.53 | 1.27 | 0.52– 7.00 |
| FeO | 2.00 | .... | 0.45 | 0.62 | 0.46– 9.00 |
| MgO | 1.18 | 0.53 | 1.35 | 2.16 | 0.88– 4.57 |
| CaO | 1.90 | 0.14 | 0.13 | 2.30 | 0.33– 5.20 |
| $Na_2O$ | 0.28 | 1.51 | 0.54 | 6.95 | 0.50– 3.97 |
| $K_2O$ | 6.67 | 5.62 | 5.73 | 2.56 | 1.76– 5.27 |
| $H_2O-$ | 0.33 | .... | 0.60 | 0.04 | |
| $H_2O+$ | 3.91 | 4.03 | 3.62 | 1.06 | 2.82– 4.09 |
| $TiO_2$ | 0.72 | .... | 0.69 | 0.88 | |
| $ZrO_2$ | none | | | | |
| $CO_2$ | 1.54 | | | | |
| C | not det. | .... | 0.97 | | |
| $P_2O_5$ | 0.08 | .... | 0.03 | | |
| $SO_3$ | none | | | | |
| S | 0.24 | | | | |
| MnO | none | .... | tr. | | |
| BaO | none | .... | 0.04 | | |
| SrO | none | | | | |
| CuO | tr. | | | | |
| | 99.83 | 98.42 | 99.57 | 100.50 | |
| Less O | .09 | | | | |
| | 99.74 | | | | |

1. Middle Cambrian shale from British Columbia.

2. Sericite. Dürrberg. Quoted by Dana, System of Mineralogy, 6th edition, p. 618, analyses 41.

3. Mansfield slate (Lower Huronian). Crystal Falls District, Michigan. U. S. Geological Survey Monograph 36, p. 59.

4. Kata-biotite-orthoclase gneiss. Corundum-bearing. Waldheim, Saxony. Quoted from Grubenman, "Die Kristallinem Schiefer," 2nd edition, 1910, p. 158.

5. Range of composition of commercial slate of aqueous sedimentary origin according to Dale, U. S. Geological Survey Bulletin 275, p. 36.

The analysis shows a remarkable similarity to analysis 2, which is of the mineral sericite from Dürrberg; after deducting the calcite and pyrite from the slate analysis the similarity is still more striking. Analysis 3, which represents the Mansfield slate of Lower Huronian age from the Crystal Falls District, Michigan, is somewhat higher in silica and lower in aluminum but is otherwise very similar. Analysis 4 represents a kata-biotite-orthoclase gneiss, corundum-bearing, from Saxony, and differs from analysis 1 chiefly in its lower water content and in the relation between the soda and the potash. The fifth column gives the range of composition of commercial slates of aqueous sedimentary origin as given by Dale. The slate from British Columbia is outside of these limits in many respects; the silica is a little lower, the aluminum is high, the soda low, and the potash high. In general, this rock, as compared with other slates, phyllites, and related schists, is noteworthy for its low content in silica, its high aluminum and potash, and its poverty in all other oxides except water. The excess of potash over soda is especially remarkable.

The composition of the slate and its microscopic texture show that it was derived from a very fine, highly aluminous sediment, whose material must have consisted of the very finest suspended matter which had been leached unusually free from iron, magnesia, lime, etc., and which consisted largely of kaolinite and quartz.

It is interesting to note that Analysis 2 of the sericite is so similar to the Burgess shale, owing to the fact that where the Burgess shale is compressed and metamorphosed at the western end of the Burgess Pass beneath Mount Burgess it is to all appearances a sericite-schist. Owing to the Burgess shale member of the Stephen formation being overlain and underlain by massive limestones it is very frequently metamorphosed and cleaved into schists or soft calcareous or siliceous slates.

## MODE OF OCCURRENCE

With the exception of *Marrella splendens* and *Hymenocaris perfecta*, *Agnostus,* and *Microdiscus,* the fossils are irregularly distributed and of relatively rare occurrence. They are pressed flat even in layers where there are no visible traces of lamination of the rock.

For convenience of reference I shall call the lower portion of the Burgess shale,[1] in which so many beautifully preserved fossils occur,

[1] Smithsonian Misc. Coll., Vol. 57, No. 3, 1911, p. 51.

the phyllopod bed, as it contains a large, unique, and fine series of phyllopod remains. It has a thickness of 7 feet, 7 inches, and is capped by a layer of coarse, bluish, dirty-gray shale weathering to a yellowish ochre-brown on the edges, that averages 18 inches in thickness. The phyllopod bed may be subdivided as follows from the top downward:

| | ft. | in. |
|---|---|---|
| 1. Bluish-gray siliceous shale with partings of dirty gray-colored shale | 1 | 9 |
| 2. Dirty-gray shale | 0 | 8 |
| 3. Bluish-gray shale in compact layers 3 to 4 inches thick | 1 | 0 |
| 4. Dirty-gray shale | 0 | 2 |
| 5. Bluish-gray, tough, brittle shale | 0 | 2 |
| Great *Eldonia ludwigi* layer. | | |
| 6. Compact layer of bluish-gray hard rock that splits more or less evenly | 0 | 8 |
| 7. Alternating dirty and bluish-gray shale | 0 | 9 |
| Great *Hymenocaris perfecta* bed. | | |
| 8. The same character as No. 6: Compact layer of bluish-gray hard rock that splits more or less evenly | 0 | 8 |
| 9. Dirty-gray, earthy shale | 0 | 2 |
| 10. The same character as No. 6: Compact layer of bluish-gray hard rock that splits more or less evenly | 1 | 4 |
| This is one of the most important fossil-bearing layers—sponges, annelids, holothurians, and crustaceans. | | |
| 11. Dark, dirty-gray, earthy shale | 0 | 1.5 |
| 12. Bluish-gray, tough, brittle shale | 0 | 1.5 |
| This is the great *Marrella splendens* layer. | 7 | 7 |

Below No. 12 the layers of shale are arenaceous, irregular, and not favorable for preserving fine fossils.

In making the collections of 1910 and 1911 over 150 cubic yards of rock were quarried and split up. Frequently, however, many square feet of surface of the shale would be opened without exposing a desirable specimen.

Layer No. 12 is of great interest. It was a slab of this carried down by a snow slide that Mrs. Walcott and I found in 1909 on the trail from Burgess Pass to Summit Lake. It contains *Marrella splendens* in great numbers, and of the annelids it has yielded the only specimens of *Miskoia preciosa* and *Amiskwia sagittiformis,* and most of those of *Pikaia gracilens, Wiwaxia corrugata,* and *Canadia spinosa.* Among the crustaceans the only specimens of *Opabinia regalis, Molaria spinifera, Yohoia tenuis, Y. plena, Mollisonia gracilis,* and *M. ? rara* were found in it, and *Burgessia bella, Waptia* *fieldensis,* and *Naraoia compacta* are of more or less frequent occurrence.

Layer No. 10 gave many beautiful specimens, including several fine sponges and sertularians. Of the annelids, *Ottoia prolifica, O. minor, Selkirkia major, S. gracilis, Oesia disjuncta, Pollingeria gracilis, Wiwaxia corrugata, Worthenella cambria, Asheaia pedunculata, Canadia spinosa,* and *C. setigera* are present, and among the holothurians, *Laggania cambria, Mackenzia costalis,* and *Louisella pedunculata.* The medusa *Peytoia nathorsti* also appeared at this horizon. The crustaceans include *Marrella, Burgessia, Waptia, Nathorstia transitans, Naraoia compacta, Bidentia difficilis, Emeraldella brocki, Leanchoilia superlata, Hymenocaris perfecta, H. obliqua, H. ? circularis, H. ovalis, H. ? parva, Tuzoia retifera Fieldia lanceolata, Hurdia victoria, H. triangulata,* and *Odaraia alata.* Among the trilobites *Neolenus serratus* is found with its antennæ, caudal rami, branchiæ, and legs finely preserved.

No. 8 gave many plates of the annelid *Pollingeria grandis* and several specimens of the large *Odaraia alata.* In the dirty-gray layer of No. 9 the large *Anomalocaris gigantea* occurred.

In layer No. 5 the pelagic holothurian *Eldonia ludwigi* was abundant over a limited area, and also *Marrella splendens* and *Hymenocaris perfecta.*

Above No. 5 the scattered valves of *Hymenocaris perfecta* and more or less imperfect annelids (*Ottoia prolifica, Pollingeria grandis,* and *Banffia grandis*) were occasionally found, along with sponges, brachiopods, and fragments of trilobites. The small gastropod *Scenella varians* is found throughout the phyllopod bed and often its depressed conical shell, with the apex up, occurs in great numbers.

The mode of occurrence and limited area of the fauna indicate that we have only a portion of a crustacean fauna that was already developed early in Cambrian time and whose descendants swarmed in the Silurian and Devonian seas.

## CLASSIFICATION

The classification used is partly that of Dr. W. T. Calman as outlined in Lankester's Treatise on Zoölogy, Part VII, 1909, and such additions as I have found it necessary to make in describing the many unique forms from the Burgess shale. All of the genera described in this paper fall under the subclasses Branchiopoda, Malacostraca, Trilobita, and Merostomata, and existing orders.

*Table of Classification*

Class Crustacea
Sub-Class Branchiopoda
  Order Anostraca Calman
  Family Opabinidæ, new family
    Genus *Opabinia,* new genus
    Genus *Leanchoilia,* new genus
    Genus *Yohoia,* new genus
    Genus *Bidentia,* new genus
  Order Notostraca Calman
  Family Naraoidæ, new family
    Genus *Naraoia,* new genus
  Family Burgessidæ, new family
    Genus *Burgessia,* new genus
  Family (Undetermined)
    Genus *Anomalocaris* Whiteaves
  Family Waptidæ, new family
    Genus *Waptia,* new genus
Sub-Class Malacostraca
  Order Hymenocarina Clarke
  Family Hymenocaridæ Salter
    Genus *Hymenocaris* Salter
  Family (Undetermined)
    Genus *Hurdia,* new genus[1]
    Genus *Tuzoia,* new genus
    Genus *Odaraia,* new genus
    Genus *Fieldia,* new genus
    Genus *Carnarvonia,* new genus
Sub-Class Trilobita
  Order (Undetermined)
  Family Marrellidæ, new family
    Genus *Marrella,* new genus
  Family (Undetermined)
    Genus *Nathorstia,* new genus
  Order Hypoparia Beecher
  Family (Undetermined)
    Genus *Mollisonia,* new genus
    Genus *Tontoia,* new genus

[1] No attempt has been made to indicate the family relations of the large forms represented by the genera *Hurdia, Tuzoia,* and *Odaraia.* With our present knowledge of them they might possibly be referred to the Hymenocaridæ of Salter.

Sub-Class Merostomata
- Order Aglaspina, new order
- Family Aglaspidæ Clarke
  - Genus *Molaria,* new genus
  - Genus *Habelia,* new genus
  - Genus *Emeraldella,* new genus
- Order Limulava Walcott
- Family Sidneyidæ Walcott
  - Genus *Sidneyia* Walcott

## STRATIGRAPHIC DISTRIBUTION

The several genera of the four subclasses (with the exception of the group of malacostracans represented by genera other than *Hymenocaris* and the trilobitic genera *Mollisonia* and *Tontoia*) have approximately the known vertical range in the Cambrian noted in the diagram on page 156.

In addition to representatives of the subclasses Branchiopoda, Malacostraca, Trilobita, and Merostomata, mentioned in this paper, I have added in the table genera of the Merostomata that occur in the Lower Cambrian and Algonkian, respectively, and of the Ostracoda in the Lower Cambrian, in order to present an outline of the lowest known stratigraphic position of the five subclasses of Crustacea. With the exception of the Branchiopoda all of these are known to have representatives in later Paleozoic formations.

The subclass Merostomata is represented by *Beltina*[1] in the pre-Cambrian; by *Amiella*[2] in the upper part of the Lower Cambrian, by the latter genus and *Habelia, Molaria, Emeraldella,* and *Sidneyia*[3] in the Middle Cambrian Burgess shale; and by *Aglaspis*[4] and *Strabops*[5] in the Upper Cambrian.

The Phyllocarida is first known in the Lower Cambrian by *Isoxys,*[6] a genus that is represented in the Burgess shale. *Hymenocaris* is well distributed in the lower half of the Middle Cambrian and the order Hymenocarina continues on up into the Ordovician, Silurian, and Devonian.

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

[2] Smithsonian Misc. Coll., Vol. 57, No. 3, 1911, p. 28.

[3] Idem, p. 27.

[4] Sixteenth Ann. Rept. New York State Museum, 1863, pp. 181 and 182, pl. 11, figs. 7-16.

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

[6] Tenth Ann. Rept. U. S. Geol. Survey, 1891, pp. 625 and 626, pl. 80, figs. 10 and 10a.


Stratigraphic Distribution of Earliest Representatives of Each of the Five Subclasses of the Crustacea.

The oldest known representative of the Ostracoda is *Indiana dermatoidea* from the Lower Cambrian.[1] Several genera of ostracods range up through the Middle and Upper Cambrian. A fine, small species occurs in the Burgess shale.

The Trilobita begins with *Nevadia* deep down in the Lower Cambrian[2] and predominates in all later Cambrian faunas.

I do not know of any genera of the Branchiopoda in the Cambrian other than those described in this paper from the Burgess shale and the single specimen of *Protocaris* from the upper part of the Lower Cambrian.[3]

That a large and varied crustacean fauna preceded and followed that of the Burgess shale is certain, and large additions to our information of it will undoubtedly be forthcoming in the near future.

## STRUCTURAL FEATURES

*Exoskeleton.*—Among the Anostraca there is no true shell, the external cuticle being little more than a membrane that is thicker in the cephalic region and on the telson, if the latter is present. Among the notostracans the carapace varies from the simple form seen in *Burgessia* (pl. 27) to the double shield of *Naraoia* (pl. 28). The malacostracans all have a strong bivalve carapace, as shown on plates 31-34.

The carapace of *Marrella* (pl. 25, fig. 1) is most interesting. The eyes on the anterior margin, the large antennules (?), and the great posterior dorsal spines indicate a great modification of and advance over the simple primitive shield resulting from a fold of the cuticle of the fifth segment of the head. The shield of *Burgessia* (pl. 27, figs. 1-3) is simple, and that of *Naraoia* (pl. 28, fig. 4) simple over the head and more complex over the thorax.

In *Waptia* (pl. 27, figs. 4 and 5) the shield has passed nearly to the bivalve stage of the Hymenocarina. It appears to be a transition between the simple bent shield of *Burgessia* and the bivalve carapace of *Hymenocaris* (pl. 31).

The bivalve carapaces of *Tuzoia* and *Carnarvonia* are so similar to the carapace of living forms of the Nebaliacea that there is little question of the intimate relationship between them. The reticulated surface on the large carapaces of *Carnarvonia* (pl. 33, fig. 1) and

[1] Tenth Ann. Rept. U. S. Geol. Survey, 1891, p. 626, pl. 80, figs. 1 and 1a. The genus *Indiana* Matthew is described in the Canadian Record of Science, Vol. 8, 1902, p. 460.

[2] Smithsonian Misc. Coll., Vol. 53, No. 6, 1911, pp. 249 and 258.

[3] Tenth Ann. Rept. U. S. Geol. Survey, 1891, p. 629, pl. 81, fig. 6.

*Tuzoia* (pl. 33, fig. 2), also approximates in pattern and size that of *Nebaliopsis typica* Sars.[1]

The merostomes *Sidneyia*,[2] *Amiella*,[3] *Habelia* (pl. 29), *Molaria* (pl. 29), and *Emeraldella* (pl. 30), have a compact cephalic shield and well-defined thoracic and abdominal segments and telson that are similar in character to the dorsal shield of the trilobite.

*Labrum*.—The labrum or hypostoma of *Sidneyia*,[2] *Emeraldella* (text fig. 8, p. 204), and *Marrella* (pl. 26, fig. 2) is clearly shown in a number of specimens, also that of *Burgessia* (pl. 27, fig. 2), but in the other species it has not been seen nor has the lower lip (labium or metastoma) been observed in any species.

*Segmentation*.—The following table gives the number of cephalic, thoracic, and abdominal segments so far as known. The eyes are considered as representing a segment, which gives six segments in the cephalic region.

*Table of Cephalic, Thoracic, and Abdominal Segments.*

| Genera. | Cephalic segments. | Thoracic segments. | Abdominal segments. |
|---|---|---|---|
| BRANCHIOPODA. | | | |
| Opabinia | ? | 16 | 1 |
| Leanchoilia | 4[1] | 9 | ? |
| Yohoia | 6 | 8 | 4 |
| Bidentia | ? | 11 | 1 |
| Naraoia | 6[2] | 17-19 | 3 |
| Burgessia | 6 | 8 | 30+ |
| Anomalocaris | .. | ? | 12+ |
| Waptia | 6 | 8 | 6 |
| MALACOSTRACA. | | | |
| Hymenocaris | 6 | 8 | 6 ? |
| TRILOBITA. | | | |
| Marrella | 6 | 24 | 1 |
| MEROSTOMATA. | | | |
| Sidneyia | 5 | 9 | 3 |
| Habelia | 6 ?[2] | 11 | 2 |
| Emeraldella | 3 | 11 | 3 |
| Molaria | 6[2] | 8 | 2 |

[1] All that have been seen on imperfect specimens.
[2] The eyes are considered in this table as representing a cephalic segment.

In the table the telson has been included as an abdominal segment and the caudal rami are considered as attachments of the terminal segment.

*Appendages*.—So far as can be determined from the specimens now available for study the normal number of cephalic appendages

[1] Challenger Rept., 1887, Vol. 19, Pt. 56, pl. 3, figs. 1, 5, and 6.

[2] Smithsonian Misc. Coll., Vol. 57, 1910, pls. 2-7.

[3] Idem. pl. 5.

of the Branchiopoda and Malacostraca is six if we consider the stalked eyes as representing the first pair.

Eyes = first
Antennules = second
Antennæ = third
Mandibles = fourth
Maxillulæ = fifth
Maxillæ = sixth

The stalked eyes are distinctly shown for *Opabinia* (pl. 28, fig. 1), *Waptia* (pl. 27, fig. 4), and *Yohoia* (pl. 29, fig. 9), and for *Hymenocaris* by specimens not illustrated. *Burgessia* (pl. 27) and *Marrella* (pl. 25, figs. 4 and 5) have sessile eyes and five pairs of cephalic appendages. The sessile eyes, as in the trilobite, probably represent a segment of the cephalic shield.

The character of the several thoracic appendages is described under each species. So far as determined, the stalked eyes, antennules, and antennæ are not very unlike those of recent crustaceans of the same orders, and the mandible, maxillula, and maxilla also have the same fundamental structure with modifications to meet the needs of each genus and species.

The thoracic appendages appear to be based on the typical crustacean limb having a protopodite bearing an exopodite and endopodite. There are no recognized modifications of this that would indicate a simpler form. An epipodote (gill) is attached to the protopodite in *Marrella* (pl. 26, fig. 4), *Opabinia* (pl. 27, fig. 6), and *Molaria* (pl. 29, fig. 3).

The number of thoracic appendages is indicated in the table (p. 158) which gives the number of thoracic segments. Each of these thoracic segments is considered to have had a pair of attached appendages although, as in the case of *Apus,* the posterior segments may possibly have had more than one pair of appendages.

Simple, bifid abdominal appendages only appear on the abdominal segments of *Anomalocaris* (pl. 34, fig. 3). The caudal rami of the abdominal segment vary greatly in form and structure in the crustaceans from the Burgess shale. The female of *Opabinia* appears to have two unsegmented, expanded rami. *Waptia* (pl. 27, figs. 4 and 5) and *Yohoia* (pl. 29, figs. 8, 11, and 14) have two expanded rami with rudimentary segmentation. *Hymenocaris* (pl. 31, figs. 3 and 5) and *Odaraia* (pl. 34, fig. 2) have several cercopods attached to the last abdominal segment, and the trilobite *Neolenus* (pl. 24, figs. 1 and 1a) has two long, slender, jointed rami.

Most of the Branchiopoda are provided with strong, broad, setiferous swimming exopodites that probably also served in *Marrella* (pls. 25 and 26), *Opabinia* (pl. 27, fig. 6, and pl. 28, fig. 1), and *Leanchoilia* (pl. 31, fig. 6) to bring food to the mouth.

In a future paper I expect to illustrate and describe in detail the appendages of each species so far as the material will permit.

*Alimentary canal.*—This has been preserved in a number of species. In *Opabinia* (pl. 28, fig. 1), *Marrella* (pl. 26, fig. 6), and *Burgessia* (pl. 27, figs. 1 and 2), it is straight from the head to its posterior end and expands more or less in the cephalic region. The size of the canal varies from the head to the anus as in *Opabinia* (pl. 28, fig. 1) and *Marrella* (pl. 25, fig. 6 and pl. 26, fig. 6) but how much this may be due to flattening in the shale is uncertain. In *Burgessia* (pl. 27, figs. 1 and 2) the canal is large at the point where the hepatic tubes join it, and tapers to its posterior end. It is rounded as though retaining its contents in a fossil state. This is also true of the slender rounded canal of *Hymenocaris* (pl. 31, fig. 2). In *Burgessia* the hepatic tubes enter it back of the maxillæ. The stomach is indicated by the expansion of the anterior end of the alimentary canal. It is also outlined by a slight contraction of the canal (pl. 27, fig. 1).

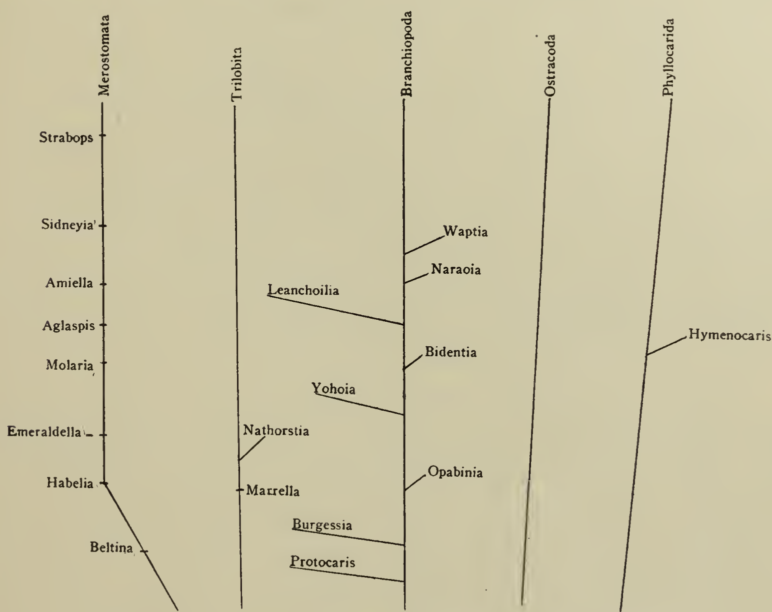
*Hepatic cæca.*—The hepatic cæca are beautifully preserved in the shield of *Burgessia* (pl. 27, figs. 1-3), *Naraoia* (pl. 28, fig. 4), and *Molaria* (pl. 29, fig. 3). In *Burgessia* they reach their greatest development, the branches showing in fine detail on the dark shale. No definite structure has been detected in the dorsal spines of *Marrella* (pl. 26, fig. 1) that could certainly be referred to as the glands, but the fact that the spines have a relatively large central canal suggests that they may have contained them.

Among recent crustaceans the hepatic cæca are branched in some copepods, Corycæidæ and Asterocheridæ, but none have the beautiful structure found in *Burgessia*. We called the latter the "Kidney crab" in camp on account of the shape of the cæca, but as the cæca open directly into the alimentary canal they could hardly function as kidneys.

## ORIGIN OF MIDDLE CAMBRIAN CRUSTACEAN FAUNA

The Cambrian crustacean fauna suggests that five (p. 156) main lines or stems (Branchiopoda, Malacostraca, Ostracoda, Trilobita, and Merostomata) were in existence at the beginning of Cambrian time and that all of them had already had their inception in Lipalian time or the period of pre-Cambrian marine sedimentation of which no known part is present on the existing continents.[1]

The known stratigraphic position of the various genera is shown by the diagram on page 156. In this 13 genera are found only at one limited horizon (phyllopod bed) in the Middle Cambrian. The five subclasses are represented as having had a long line of crustacean ancestors, a view that if correct would manifestly necessitate a prolonged pre-Cambrian period for the development of the crustacean fauna now found in the Burgess shale. As the trilobites are




THEORETICAL LINES OF DESCENT OF CAMBRIAN CRUSTACEA

probably derived from the same stock as the Branchiopoda, the lines of probable descent of the various genera of the latter in the Burgess shale are projected backward into the pre-Cambrian. It may be that some of the genera of the Branchiopoda in the table were developed in early Cambrian time, but of this we have no evidence.

A suggested scheme of descent of the genera in the table and other Cambrian genera, with the exception of the genera of the Trilobita, is shown in the above diagram.

The Lower Cambrian formations have only been searched in a

[1] Smithsonian Misc. Coll., Vol. 57, No. 1, 1910, p. 14.

2

very superficial manner in those parts of North America where they are well developed and finely exposed for the collection of fossils. This leads me to think that it is only a question of time and detailed work to bring to light a large and varied crustacean fauna. This almost certainly existed, as proven by the occurrence of *Beltina* in the pre-Cambrian of the Rocky Mountains.[1]

Bernard's very interesting and valuable study of *Apus*[2] is replete with suggestions and inferences bearing on the evolution of the Crustacea from a browsing carnivorous annelid with its first 5 segments (head) bent so that its mouth faced ventrally and posteriorly, and using its parapodia for pushing food into its mouth. He concludes that the modern representative of this crustacean-annelid is *Apus*. With Bernard's theory in mind I have examined the Burgess shale annelidan and crustacean fauna to ascertain if there was an annelid that could be considered as representing his hypothetical crustacean-annelid, and nearer to it in structure than *Apus*. I found specimens of *Canadia spinosa* Walcott laterally flattened in the shale with the head bent down, so that the mouth faces posteriorly,[3] also that 14 out of 24 specimens have the head bent under and out of sight beneath the flattened body. Possibly these annelids and the crustaceans were derived from the same general type of animal.

Among the crustaceans *Marrella splendens* (pls. 25 and 26) has an *Apus*-like form, but it is evidently a more highly developed form than *Apus*. This is shown among other characters by its carapace, long jointed legs, and fewer segments.[4] *Burgessia bella* (pl. 27, figs. 1-3) has a simple carapace, few thoracic segments, and many abdominal segments, if those of the telson-like extension of the body are considered as belonging to the abdominal region. The eight thoracic segments serve to separate *Burgessia* from *Apus* and other genera of the Apodidæ and at the same time bring it near to the Phyllocarida as represented by *Nebalia*. On the other hand, the simple *Lepidurus*-like carapace, sessile eyes, and hepatic glands in the

[1] C. D. Walcott, 1899, Pre-Cambrian Fossiliferous Formations; Bull. Geol. Soc. America, Vol. 10, pp. 238-239, pls. 25 and 26.

[2] The Apodidæ. Nature Series, London, 1892.

[3] Smithsonian Misc. Coll., Vol. 57, No. 5, 1911, pl. 23, fig. 4.

[4] Dr. Austin H. Clark considers that a comparison should be made between *Marrella* and the Trilobita. He suggests that the cephalon is comparable with that of *Acidaspis*, the two anterior spines being the genal spines and the posterior spines the same as the occipital spines or processes of *Acidaspis*. The terminal plate he takes to be the pygidium, and the feathery organ (m) the last cephalic appendage.

carapace serve to place *Burgessia* in the Branchiopoda under the order Notostraca.

Among the anostracans *Opabinia regalis,* in its elongate many-segmented body, phyllopod-like swimming exopodites and insignificant or rudimentary ambulatory endopodites, small head, and slender body, is very suggestive of an annelidan ancestor.

These comparisons raise the question as to the relations of the Branchiopoda, Leptostraca (representing the Malacostraca), Trilobita, and Merostomata. With the data afforded by the Burgess shale fauna the inter-relationship of the four so-called subclasses is found to be very intimate.

In *Opabinia* (pl. 27, fig. 6, and pl. 28, fig. 1) and *Leanchoilia* (pl. 31, fig. 6) the typical branchiopod is clearly present.

In *Waptia* (pl. 27, figs. 4 and 5) the Leptostraca is very near at hand as developed in *Hymenocaris* (pl. 31, figs. 1 and 2).

In *Marrella* (pls. 25 and 26) the trilobite is foreshadowed, and *Nathorstia* (pl. 28, fig. 2) is a generalized trilobite as the trilobite appears to be a specialized branchiopod, adapted largely for creeping on the bottom. The trilobite gives some conception of a possible form between the Branchiopoda and the Aglaspidæ of the Merostomata.

Such forms as *Habelia* (pl. 29, fig. 6), *Molaria* (pl. 29, figs. 1-5), and *Emeraldella* (pl. 30, fig. 2) serve to fill in the gap between the Branchiopoda and the Merostomata as represented by *Sidneyia*[1] and later the Eurypterida. *Sidneyia* is now known to have a pair of jointed biramous appendages on each of the anterior 9 segments of the body. The inner division or endopodite is a jointed leg adapted for creeping close to the bottom and the outer branch is a lamellated branchial lobe (see Smithsonian Misc. Coll., vol. 57, No. 2, 1911, pl. 6, fig. 3, and pl. 7, fig. 1; and text fig. 10 of this paper, p. 206).

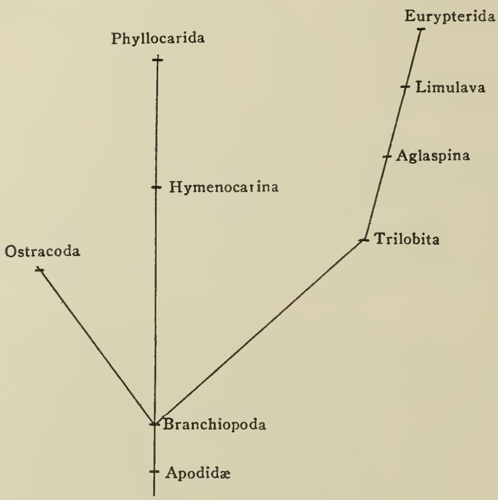
In the following diagram the attempt is made to show the relations of Cambrian crustaceans to a theoretical ancestral stock which for convenience is correlated with the Apodidæ. From this stock it is assumed that the Branchiopoda came, and from the Branchiopoda stock three distinct branches were developed prior to or during Cambrian time. Of these the one of greatest interest in the present connection is that on the right of the diagram. In this line of descent it is assumed that the Trilobita are directly descendent from the Branchiopoda and forms grouped under the order Aglaspina derived from the Trilobita. The order Limulava is considered as being inter-

[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, p. 22.

mediate between Aglaspina and the Eurypterida, and that the two orders Limulava and Aglaspina serve to connect the Trilobita and the Eurypterida.

From the Eurypterida we pass to the Xiphosura. It is thought that the Phyllocarida, as represented by the group of forms included under the Hymenocarina, came from the Branchiopoda, but on a different line of descent from the Trilobita and the orders grouped under the Merostomata.

The ostracods are assumed to have been derived from the Branchiopoda but on a different line of descent from the Trilobita and Phyllocarida.




Theoretical Evolution of Cambrian Crustacea from the Branchiopoda

I will not attempt further to discuss the various lines of descent of the genera in this preliminary notice, as in the spring of 1913 much more material may be available for study. The outline diagram (p. 161) indicates my present view, though this is tentative pending study and comparison with living forms. Any speculation on the origin of the various invertebrate groups based on the faunas found in the Cambrian must necessarily be very defective, as the pre-Cambrian development extended far back into pre-Cambrian time.

## RELATION TO RECENT CRUSTACEANS

That the Burgess shale crustacean fauna was a tremendous surprise to me and that it will be to all paleozoologists is evident to any one acquainted with what was known of the early Paleozoic

Crustacea and the theoretical views concerning its development. The highly organized merostome *Sidneyia inexpectans*[1] removed the origin of the Merostomata far back into pre-Cambrian time and seemed to link the problematic *Beltina* of the Algonkian Belt terrane with the merostomes of Ordovician and Silurian time, and through them with the living Ziphosuridæ. That Branchiopoda of the order Anostraca lived in Cambrian time is not so surprising, but that they should be almost perfectly preserved, and closely allied to the living forms, certainly is unexpected. *Opabinia regalis* (pl. 27, fig. 6, and pl. 28, fig. 1) is much like *Thamnocephalus platyurus* Packard,[2] and *Burgessia* (pl. 27, figs. 1-3) has the dorsal shield and somewhat similar cephalic region of *Lepidurus*.

*Hymenocaris* (pl. 31) may be compared with *Nebalia*, and *Carnarvonia* (pl. 33) and *Tuzoia* (pl. 33) with the reticulated carapace of *Nebaliopsis typica* Sars.[3]

The group of forms represented by *Nathorstia* (pl. 28, fig. 2), *Naraoia* (pl. 28, fig. 4), *Yohoia* (pl. 29, figs. 7-14), and *Bidentia* (pl. 30, fig. 1) does not appear to have any living representatives.

Viewed as an ancestral fauna of the living Crustacea the Burgess shale fauna foreshadows the Branchiopoda in both its orders, Anostraca and Notostraca; the Ostracoda by the family Indianidæ[4]; the Malacostraca by the Phyllocarida; and the Merostomata by Aglaspina and Limulava.[5]

## SURVIVAL OF THE BRANCHIOPODA

The recent Polyartemidæ and Apodidæ are animals that by their remarkable adaptation to conditions are practically immune to agencies that, during geologic time, have destroyed whole races of invertebrate animals. When they became adapted to living in intermittent ponds that depended on rainfall and that might be fresh, brackish, or saline, is unknown. Their wide geographic distribution and the great vitality of their eggs indicate great age, and the discovery of their probable ancestors in such forms as *Opabinia* (pl. 27, fig. 6, and pl. 28, fig. 1) and *Burgessia* (pl. 27), in association with a large and

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[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pp. 19-28, pls. 2-7.

[2] U. S. Geog. and Geol. Surv. Territories, 12th Ann. Rept., Pt. 1, 1883, pp. 353-355. Text-fig. 23.

[3] Challenger Rept. 1887, Vol. 19, Pt. 56, pl. 3, figs. 1, 5, and 6.

[4] Name proposed in MSS. by Ulrich and Bassler.

[5] This was referred to as a subfamily of the Eurypterida in 1911, but its characters are such that it now seems desirable to consider its typical genus as representing a family of the Merostomata.

varied Middle Cambrian fauna, proves that in that early time they were capable of flourishing in the midst of active and powerful enemies. This was owing undoubtedly to their great power of reproduction and active movements.

Bernard[1] attributes the preservation of the Apodidæ in geologic time to the isolated manner of life of the animals. This may be true since Carboniferous time, but I doubt if it was so during the long, early Paleozoic ages. The evidence for the existence of a land surface since early Carboniferous time with continuing streams or ponds is found in the presence in Lower Carboniferous strata of fresh-water shells that were undoubtedly the ancestors of the living fresh-water genera *Physa*[2] and *Ampullaria*.[3] It may be that the descendants of the Cambrian Branchiopoda became adapted to fresh-water conditions in Devonian time after the disappearance of the large group of merostomes that reached its greatest development and almost disappeared in Silurian time.

That the smaller and more delicate forms of the Branchiopoda have not been found in Ordovician, Silurian, and later rocks is no proof that they did not exist side by side with the thick shell-covered crustaceans that have only left traces here and there in the sediments.

## Class CRUSTACEA

### Sub-Class BRANCHIOPODA

### Order ANOSTRACA Calman[4]

#### OPABINIDÆ, new family

Carapace absent; paired eyes pedunculate; antennæ unknown, frontal appendage (proboscis) flexible, prehensile in male, bifid in female. Trunk limbs 16 pairs, the terminal joints of the feet broad and spatulate as in the Thamnocephalinæ. Abdomen a simple plate, with two caudal, unsegmented furcal rami on the female.

The Opabinidæ differ from the most nearly allied family, Thamnocephalinæ Packard, in having a simple plate-like unsegmented abdomen.

#### OPABINIA, new genus

The generic and specific descriptions are united under the description of the species.

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[1] The Apodidæ. Nature Series, London, 1892, p. 9.

[2] Walcott, Monogr. U. S. Geol. Survey, Vol. 8, 1884, p. 262.

[3] Idem, p. 261.

[4] As defined in Lankester's Treatise on Zoölogy, London, 1909, Pt. 7, p. 53.

*Genotype.—Opabinia regalis,* new species.

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

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

The generic name is derived from Opabin, the name of a pass between Mount Hungabee and Mount Biddle, southeast of Lake O'Hara, British Columbia, Canada.

### OPABINIA REGALIS, new species

Plate 27, fig. 6, and plate 28, fig. 1

Body elongate, moderately wide, and divided into a small head section, a trunk of 16 somites, and a broad telson. The base of the head is formed of an elongated portion about as wide as long when flattened in the shale; in front of this the head narrows where the base of a large stalked eye is attached on each side. In front there is a short section from which a strong central appendage extends directly forward as viewed from above (fig. 1, pl. 28) and curves upward from the front lower side of the head when seen in profile (fig. 6, pl. 27). The appendage is narrow, wrinkled, and more or less flexible; near the anterior end it expands to form a base of attachment of a number of small, slightly incurved, short claws or spines.

The eyes are at the end of a strong, short stalk and traces of the reticulated surface of the compound eye remain on the matrix of the specimen illustrated by figure 1, plate 28.

The 16 somites of the post-cephalic body (thorax) are very uniform in appearance and size except that the posterior somites gradually decrease in size and width. Their arrangement is finely shown in profile view by figure 6, plate 27.

The terminal somite is a broad, elongate, spatulate lobe with a short point on each postero-lateral rounded angle. Between the points there is a transverse line that may mark a division of the telson and the presence of a post-anal plate.

*Appendages.*—The anterior, central cephalic appendage has been mentioned. It suggests the appendage of the male of the species. Reference to the possible presence of the female in the collection will be spoken of later.

None of the heads of the four specimens show traces of antennules, antennæ, mandibles, or maxillæ. If these appendages were large they have been broken off; if small they may be concealed beneath the crushed and flattened large posterior section of the head.

The thoracic legs are shown both in side view (fig. 6, pl. 27) and from below on a flattened specimen (fig. 1, pl. 28). They appear to be of a uniform character on all the 16 somites except the two anterior pairs, which may be smaller and have narrower terminal joints. The legs are formed of two or three rather strong, short joints followed by broad, flat, elongate-oval lobe-like joints (f, fig. 6, pl. 27). The gills are shown as oval lobes on the upper portion of the leg (br, fig. 6, pl. 27). The terminal elongate swimming joint or fin is shaped much like that of the common *Branchipus vernalis* Verrill. A strongly setiferous lobe occurs above the large terminal joint, but its relations to it are not clear. Another feature difficult to interpret is that of the groups of short, longitudinal lines shown in figure 1, plate 28. My present view is that they are groups of strong setæ attached to one or more of the lobe-like middle joints of the leg. I obtained an almost similar effect by pressing flat between glass plates a specimen of the recent *Branchinecta paludosa* (O. F. Müller).

The details of structure of the leg cannot be determined, but judging from the material available for examination they follow somewhat closely the leg of *Thamnocephalus* as illustrated by Packard.[1]

*Interior structure.*—The alimentary canal is readily traced from the head back to the posterior portion of the terminal lobe between the two points (fig. 1, pl. 28). Parts of the canal are convex and presumably contain portions of the matter in the canal at the time of the death of the animal.

A very beautiful specimen showing some details of the interior has recently been worked out, but with the chance of getting more satisfactory specimens before a more complete review of the Burgess shale fauna is prepared I will not attempt to interpret its somewhat confused structure.

*Dimensions.*—The four specimens in the collection have the following longitudinal dimensions in millimeters:

| | Length. | Proboscis. | Head. | Trunk. | Telson. |
|---|---|---|---|---|---|
| No. 1 ........ | 86 | 24 | 9 | 44 | 9 |
| No. 2 ........ | 78 | 16 | 10 | 45 | 7 |
| No. 3 ........ | 72 | 20 | 8 | 37 | 7 |
| No. 4 ........ | .. | 24 | 9 | 51 | Broken |

[1] U. S. Geog. and Geol. Surv. Territories, 12th Ann. Rept., Pt. 1, 1883, pl. 14.

Compared with recent species of the Anostraca, *Opabinia regalis* is from three to four times as large, since the former average from 10 to 24 mm. in length.

*Female.*—There are two associated specimens that I have referred to the female of this species. One has a length of 61 mm. and the other of 52 mm., exclusive of any frontal appendages. The female differs from the male in having two slender caudal appendages or rami; and in having a slender bifid frontal appendage instead of the strong appendage of the male. The character of the frontal appendage is more or less doubtful as it is turned under and back on the side of the body. I hope that we will find in the collections of the summer of 1912 specimens that will add much to our knowledge of all parts of both the male and female of this species.

*Observations.*—Compared with recent forms *Opabinia regalis* has many outward characters of *Thamnocephalus platyurus* Packard.[1] The proboscis, form of head, body segments, and expanded terminal segment or telson are very suggestive of *Thamnocephalus.* So far as can be determined the structure of the thoracic legs is essentially similar, but this of course is subject to revision. After flattening specimens of *Branchinecta* and *Branchipus* between plates of glass and studying them, I am greatly surprised that any distinct characters of the appendages are preserved in the fossils in a recognizable condition.

The frontal appendage is referred to as the proboscis. It is united directly with the front of the head; it was flexible and provided with a central canal that may be traced from its base out to the expanded end, which has a circle of small, curved claw-like spines attached to it. The function of the proboscis and its terminal spines is unknown; it appears to be adapted to the gathering of food and conveying it to a mouth beneath the head, but it was probably used by the male to seize the female.

If we consider the appendage-bearing somites as the thorax, the abdomen is confined to the one elongated expanded somite I have referred to as the telson. This does not show evidence of segmentation unless there is a post-anal plate, which is very doubtful. None of the specimens of the male show any traces of caudal appendages.

*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] U. S. Geog. and Geol. Surv. Territories, 12th Ann. Rept., Pt. 1, 1883, pp. 353-355, text fig. 23.

### OPABINIA ? MEDIA, new species

This species was not recognized until after the plates illustrating the crustaceans from the Burgess shale had been completed.

It differs from *Opabinia regalis* (pl. 27, fig. 6) (a) in being much smaller, (b) in having a proportionately smaller head, and (c) in having fewer segments, 12 or 14. The frontal appendage is not clearly shown, but it is small compared with that of *O. regalis.*

The appendages of the thorax have an expanded setiferous terminal joint, and there are traces of a small, broad, lanceolate gill or flabellum toward the basal part of the leg.

The two largest specimens each have a length of about 38 mm. The specimens of this species are not well preserved, but the characters are sufficiently clear to distinguish the species from *O. regalis* A thorough search will be made for better specimens during the season of 1912.

*Formation and locality.*—Middle Cambrian: $\left(\frac{35k}{10}\right)$ Burgess shale member of the Stephen formation (about 75 feet above the phyllopod bed near the base of the shale) 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.

### LEANCHOILIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Leanchoilia superlata,* new species.

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

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

The generic name is derived from Leanchoil, the name of a railway station on the Canadian Pacific Railway, 17 miles southwest of Field, British Columbia, Canada.

### LEANCHOILIA SUPERLATA, new species

Plate 31, fig. 6 (lower specimen)

Body elongate, with clearly defined head shield and nine strong body segments up to the point where the posterior part of the body is broken off. The anterior pointed end of the head is broken off in such a manner that the presence of a frontal appendage is suggested. The large opening on the side of the head indicates a large pedunculated eye comparable with that of *Opabinia regalis* (pl. 28, fig. 1).

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

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

The size and proportions of the type and only example of the species are shown by the lower specimen of figure 6, plate 31.

*Observations.*—This is one of the rare species in the collection. The anterior half was found after a dynamite blast and later the matrix showing the posterior portion and part of the anterior was picked out of the débris. Working as we often did with cold rain or snow falling, fragments once lost trace of were rarely recovered.

The large natatory, distal joints of the thoracic legs are much like those of *Opabinia regalis* (fig. 6, pl. 27), also the large eye. For the present the species is placed in the family Opabinidæ, although I fully realize that the reference is of the most tentative character.

*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.

### YOHOIA, new genus

The description of *Yohoia tenuis* embodies the characters of the genus.

*Genotype.*—*Yohoia tenuis,* new species.

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

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

The generic name is derived from Yoho, the name of the beautiful Yoho Valley, east of Mounts Wapta and Field.

*Observations.*—Two species have been referred to the genus, *Y. tenuis* and *Y. plena*. Both are elongate, slender, and have a small cephalic carapace, eight thoracic and four abdominal segments, with expanded caudal rami on the posterior segment.

**YOHOIA TENUIS, new species**

Plate 29, figs. 7-13

Body elongate, slender. Head short and without a carapace. Thorax with eight segments. Abdomen with four segments, the posterior bearing a pair of expanded caudal rami.

Head sub-quadrangular in outline, composed of five coalesced segments, the posterior four of nearly equal width and the anterior narrow. The segmentation of the head is very plainly shown on some specimens (fig. 12) and not on others (fig. 10). I have inclined at times to consider that there was a cephalic carapace, but finally decided that if present it was very small and thin and not to be recognized as a true carapace. The eyes are small, pedunculated, and rarely seen, since they appear, in side view, to be in a niche between the first and second segments of the head. As seen from above, on a specimen from which the edge of the test has been removed, they are small, round, bright spots (fig. 9).

The thorax is composed of eight segments that, with triangular-shaped pleurons on each side, clearly separate the thoracic segments from the four cylindrical segments of the abdomen. The two expanded rami attached to the posterior abdominal segments were thin and readily distorted by compression in the shale.

*Appendages.*—The first pair (antennules) appear to be short and blunt as they project beyond the anterior end of the head (fig. 13, side view; fig. 9, top view). The second pair (antennæ) have several joints (three are shown beyond the margin of the head) with a terminal group of three long, slender, curved spines (fig. 13). These probably represent the claspers of the male. The third, fourth, and fifth cephalic appendages show as small jointed legs hanging below the head.

The appendages of the thorax are not very well preserved. They indicate a leg much like that of *Waptia fieldensis* (pl. 27, fig. 5), composed of broad joints, the last provided with numerous long setæ.

No appendages or setæ have been observed on the four abdominal segments.

Very little is known of the interior structure, except the presence of a slender, straight alimentary canal. One specimen, as viewed from above (fig. 9), suggests a division into two lobes of the interior of the head.

*Dimensions.*—The largest specimen has a length of 24 mm. The other dimensions as the animal is flattened in the shale are shown by the figures on plate 29.

*Observations.*—This species is associated with *Waptia fieldensis* (pl. 27, figs. 4 and 5) and has the same type of body and expanded caudal rami. It differs in the absence of a carapace; in having four instead of six abdominal segments; and so far as known a different form of antennæ.

*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.

### YOHOIA PLENA, new species

Plate 29, fig. 14

This species has a proportionately larger head, thicker body with shorter segments, and the caudal rami are more expanded than in the associated *Yohoia tenuis.* A somewhat similar form from about 75 feet higher in the Burgess Shale $\left(\frac{35k}{10}\right)$ is represented by two imperfect specimens.

Specimens of this species reach a length of 24 mm., but most of them are about half as long.

*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.

### BIDENTIA, new genus

The description of the genus is included with that of the type species.

*Genotype.*—*Bidentia difficilis,* new species.

*Stratigraphic range.*—The stratigraphic range is limited to a band of gray siliceous buff-weathering shale forming a part of the upper portion of the Burgess shale member of the Stephen formation.

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

The generic name is derived from Bident, the name of one of the mountain peaks east of the "Valley of the Ten Peaks," south of Laggan, Alberta, Canada.

### BIDENTIA DIFFICILIS, new species

Plate 30, fig. 1

Body elongate, with well-marked head, thoracic segments, and expanded caudal rami. Head short and, as pressed flat on the shale, semicircular with the straight side jointed to the thorax. In figure 1 I have dotted the approximate outline of the head. Thoracic segments short and of nearly equal length; there appear to be eleven that have attached appendages. Abdomen with one segment and a pair of expanded rami. The latter are pressed together in figure 1; in another specimen, not illustrated, they are more flattened out.

*Appendages.*—The only appendages of the head shown by figure 1 are the strong antennæ (a′). They have a thick, jointed basal portion with two long jointed branches. The latter may be the claspers of the male.

The thoracic limbs are obscure owing to the great pressure and flattening they have undergone. Those best preserved along the central segments show a large, broad lanceolate terminal segment fringed with long setæ on the posterior margin; gill lobes are indicated on the upper portion of the leg.

*Dimensions.*—The largest specimen has a length of 45 mm. exclusive of the telson which is about 10 mm. long.

*Observations.*—At first I placed this species with *Emeraldella brocki* (pl. 30, fig. 2), but further study of the specimen illustrated and one other led to its separation as the type of a new genus and species. It differs from *E. brocki* in having an abdomen of one segment bearing two expanded caudal rami that form a natatory appendage similar to that of *Waptia fieldensis* (pl. 27, figs. 4 and 5). The systematic position of the genus is doubtful. It is probably a form nearer the Merostomata than the Branchiopoda.

*Formation and locality.*—Middle Cambrian: $\left(\frac{35k}{10}\right)$ Burgess shale member of the Stephen formation (about 75 feet above the phyllopod bed near the base of the shale), 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.

### Order NOTOSTRACA Calman[1]

### NARAOIDÆ, new family

Carapace large, with hepatic cæca in anterior portion; eyes pedunculate. Head with 5 ? pairs of appendages. Thorax with 17 to 19 segments. Abdomen with 2 to 3 segments. Thoracic appendages leg-like, with setiferous fringes and probably gills attached to the basal joints.

One genus, *Naraoia*.

### NARAOIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Naraoia compacta*, new species.

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

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

The generic name is derived from Narao, the name of a group of small lakes in Cataract Brook canyon, above Hector on the Canadian Pacific Railway, British Columbia, Canada.

### NARAOIA COMPACTA, new species

Plate 28, figs. 3 and 4

General outline of dorsal carapace elongate oval. It is divided into two subequal parts forming the cephalic carapace and a posterior or thoracic carapace. When flattened on the shale and not distorted, the two parts are subequal in size and outline. The anterior part is distorted in figure 4, but the posterior part has nearly the natural outline of a specimen when flattened out. It has a slight inward arching at the median line where the abdomen passes from beneath it. The

[1] As defined in Lankester's Treatise on Zoölogy, London, 1909, Pt. 7, p. 53.

carapace was very thin and is now frequently wrinkled and folded in a manner resembling pressed and dried specimens of the carapace of the recent *Lepidurus glacialis.*

The two parts of the carapace appear to be attached along the longitudinal median line to the dorsal surface of a number of the segments of the head and thorax. The line between the two parts of the carapace appears to be at about the third thoracic segment of the body. There is nothing in the appearance of the cephalic carapace to indicate how many segments are coalesced in it, but on one specimen of a posterior part 14 segments are faintly indicated. Whether these are only the impressions of the underlying segments or represent coalesced segments I am not prepared to state.

The body is slender and composed of several cephalic segments, probably 5, and 17 to 19 thoracic segments. Three of the latter appear beneath the anterior part of the carapace, 14 beneath the posterior part, and two extend beyond the posterior edge of the carapace. An abdomen is indicated by two small segments and a short, slender-jointed telson-like extension (fig. 4).

*Appendages.*—In the head of *Burgessia bella* (pl. 27, fig. 3) the cephalic appendages are all anterior to the lateral canals connecting the hepatic cæca and alimentary canal. Specimens of *Naraoia compacta* show the hepatic tubes, and anterior to it the outline of four divisions or segments of the central axis of the head. What may be the outer end of a simple straight antenna projects from the side of the carapace, and seventeen legs extend from beneath the carapace in figure 4. Of these, three are referred to that portion of the bodv beneath the anterior part and 14 to the posterior part of the carapace. The legs have long, slender joints, all of which except the distal have a strong fringe of fine setæ. The legs terminate in a minute, slightly curved claw. I have not seen a flabellum or gill in position, but considerable evidence of their presence along the side of the body is furnished by faint outlines showing through the carapace.

*Interior structure.*—The large hepatic cæca are beautifully shown in the sides of the anterior half of the carapace (fig. 4) also the canal connecting with the alimentary canal. The latter canal is finely shown in the thorax, where it extends to the posterior segment a little back of the posterior margin of the carapace, where the slender telson joins the body.

*Observations.*—This species furnishes another interesting addition to the group of Middle Cambrian Branchiopoda from the Burgess shale. It is essentially *Burgessia*-like (pl. 27, figs. 1-3) with the addition of the posterior half of the carapace extended back over the thorax. The hepatic cæca and legs are of the same type. Nothing is yet known of the eyes and labrum, and only a suggestion of the cephalic appendages.

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

### BURGESSIDÆ, new family

Carapace forming a dorsal shield; paired eyes sessile; body with fourteen pairs of appendages of which five are cephalic, eight thoracic, and one abdominal, as now known; many segments, thirty or more, in the abdominal (telson) extension of the body. Labrum relatively large and attached to the anterior reflected edge of the carapace. Thoracic appendages leg-like and with small branchial lobes.

One genus, *Burgessia*.

*Observations.*—Anticipating that there will be many more specimens available for study in the near future, I will not attempt to correlate the Burgessidæ with any described faimly of the Notostraca. I suspect that *Burgessia bella* is the representative of an irregular order that, like the Leptostraca, does not fall strictly within the definition of the subclass to which it is referred.

### BURGESSIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Burgessia bella,* new species.

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

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

The generic name is derived from Burgess, the name of a mountain and pass near the fossil bed from which *Burgessia bella* was collected, British Columbia, Canada.

### BURGESSIA BELLA, new species

Plate 27, figs. 1-3, and plate 30, figs. 3 and 4

Carapace large, semicircular in outline when pressed flat, with a rounded notch at the posterior side where the thorax appears from beneath the carapace. The test is very thin and it has often been wrinkled and distorted in the shale. Ten specimens show it pressed down sideways so as to give the outline of a bivalve carapace (figs. 3 and 4, pl. 30).

The thorax is slender and composed of 8 rather short segments that bear appendages.

The abdomen is composed of one segment that is about the size of the last thoracic segment; it is followed by a long, slender, many-jointed telson-like extension that tapers gradually to a very fine, thread-like extremity. An abdomen of one segment has a telson 21 mm. in length attached to a body 12 mm. long, and composed of over thirty segments.

*Eyes.*—The paired eyes are shown on three specimens. In one a slight convexity still remains and in all a minute, round, bright dot indicates the eye a short distance within the anterior margin of the carapace.

*Labrum.*—A narrow labrum is outlined in a number of specimens between what appear to be two branches of the alimentary canal. In figure 1, plate 27, the labrum is on the under side and only the broad anterior end (stomach) of the alimentary canal is shown. In figures 2 and 3, plate 27, the labrum lies over the stomach and causes it to appear forked. It is shown more definitely in other specimens.

*Appendages.*—Many specimens have two slender, short-jointed antennæ projecting out from in front of the carapace (fig. 2, pl. 27). Others show a second shorter, smaller pair that is nearer the median line and probably represents the antennules. Several specimens have two or three very slender jointed appendages projecting from beneath the carapace posterior to the antenna. A flattened specimen of the under side of the head shows the basal joints of the first five pairs of appendages (fig. 3, pl. 27). An antenna may be traced to the second joint. The third shows only an obscure inner joint; the fourth has two long slender joints (1 and 2) and the fifth two rather broad joints. (Traces of the cephalic appendages are shown by fig. 2, pl. 27.) Where what may be the terminal joints of the third to fifth appendages project beyond the carapace, they are very delicate, slender, and one at least ends in two fine filaments.

The first five pairs of appendages are in front of the large tubes (cl, fig. 1) coming in from each side.

The thoracic legs have at least seven joints, the last pointed and curved slightly with a delicate terminal spine or claw. The three inner joints are larger than the outer and have a flattened triangular expansion of the inner side that gives a nodelike appearance to the leg when flattened so as to bring this feature in profile. These triangular expansions also show on the fourth and fifth joints of some specimens. One specimen shows on seven pairs of legs, small, elongate, oval bodies attached near the first joint to the outer side of the leg. These bodies left but slight impression on the rock and are rarely seen. They appear to represent the gills.

A pair of minute, jointed, setiferous appendages projecting from beneath the first abdominal segment suggests the presence of a simple phyllopodan natatory leg. The remaining thirty or more segments of the abdomen and telson are limbless so far as can be determined from many specimens.

*Interior structure.*—The thin carapace has preserved and now shows most beautifully the large hepatic cæca. The position and connection of these is finely shown at (kd) by figures 1 and 2, plate 27. The alimentary canal is large, expanded in the head as a stomach (st, fig. 1), and extending directly through the body from the front of the head to the first abdominal segment where it presumably terminated at the anus.

*Dimensions.*—The average length of the larger specimens of the carapace is about 10 mm. Some are 12 mm. and many 6 to 8 mm. The proportions of carapace, thorax, and abdomen are fairly well shown by figure 1, except that the long, thin abdomen continues backward until it exceeds the entire length of head and thorax about 3 to 2, or by actual measurement in one example, 21 mm. to 12 mm. for the head and body respectively.

*Observations.*—The very delicate carapace resembles that of the recent *Lepidurus* and like the latter takes many forms when flattened by pressure. An illustration of the deformation of the carapace of *Burgessia* is given by figures 3 and 4, plate 30. I at first thought that the latter represented quite a different form from *Burgessia bella*, but with the examination of many specimens a fine series was selected, showing gradations between the typical specimens on plate 27, figures 1 and 2, and the crushed side views shown by figures 3 and 4, plate 30. I had selected many specimens to be photographed but decided to illustrate only five in this preliminary paper as many interesting points have come up that more material may throw light on.

Among living Branchiopoda the Apodidæ furnish the most suggestive examples for comparison with *Burgessia bella*. The absence of abdominal segments with appendages is a marked distinction, also the presence of eight pairs of thoracic legs. The long slender abdominal section points to the disappearance of appendages such as occur in the Apodidæ and the diminution in size of the abdominal segments and probably to the ultimate disappearance of most of them.

*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.

### Family (undetermined)

### Genus ANOMALOCARIS Whiteaves

### ANOMALOCARIS GIGANTEA, new species

Plate 34, fig. 3

Practically all that is known of this species is illustrated by figure 3 of plate 34 (natural size), which gives a side view of the abdomen of the species. Nothing is known of the carapace or of the details of the appendages more than that for each segment there are two strong pointed appendages that appear to be composed of two joints; the long, narrow, sharp distal joint, and a short, broad proximal joint.

One specimen found in association with the other fragments indicates, if it belongs to the same species, that the abdomen terminated in a short, strong, slightly curved telson.

This species differs from *Anomalocaris canadensis* Whiteaves[1] in its greater size and more compact abdominal segments.

It is hoped that more perfect material will be found at the Burgess Pass locality that will enable us more clearly to determine this species, also to discover the nature of its carapace and that of the other described species of *Anomalocaris* which occur on the slope of Mount Stephen at nearly the same horizon about six miles away.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

### WAPTIDÆ, new family

A transition form between the Branchiopoda and Malacostraca with a small carapace covering more or less of the cephalic and thoracic region. Abdominal region with 6 segments the last of which bears a pair of fin-like rami or a slender telson.

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[1] Canadian Alpine Journal, Vol. 1, No. 2, 1908, pl. 2, fig. 3a.

Thorax with 8 segments bearing more or less foliaceous jointed appendages that carry a small scale-like exopodite, or it may be an epipodite.

Eyes pedunculated.

One genus, *Waptia,* is referred to this family.

### WAPTIA, new genus

The generic description is included with that of the type species.

*Genotype.—Waptia fieldensis,* new species.

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

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

Generic name derived from Mount Wapta, a mountain above the fossil bed in which the type specimens of the genus and species were found.

### WAPTIA FIELDENSIS, new species

Plate 27, figs. 4 and 5

Carapace about one-third the length of the body. Seen from the side it is broadly oval in outline with the upper side slightly curved. From above, when flattened out, it is narrowed toward the front and projects into broad lobes separated by a forward curving toward the median line. In figure 5 the carapace has been pushed forward and turned over so as nearly to reverse its true position. In figure 4 it has been compressed laterally so as to give the posterior parts a wing-like appearance. The test was so delicate that only a few specimens show even approximately the original outlines.

Body long and slender. It is divided into a head, trunk or thorax, abdomen, and tail.

The head cannot be clearly described as it is largely concealed by the carapace. The presence of appendages indicates that 5 segments are combined to form it.

The trunk or body is formed of eight short segments, nearly equal in size, each bearing a pair of appendages.

The abdomen has six long, sharply defined segments with short spines on the posterior margin. The caudal rami are expanded into rather broad lobes that overlap slightly so as to form a strong caudal fin.

The eyes are situated on each side just beyond the antennæ (fig. 4). When pressed flat they show a crescentiform outline at the end of a short strong peduncle.

*Appendages.*—The antennæ are long and slender with rather long joints. Between the antennæ in one specimen a pair of short lobe-like appendages occur that for the present I shall consider as the antennules. They are not shown in the specimens illustrated. The first pair of leg-like appendages seen show six joints to where they are lost beneath the carapace (m, fig. 5). The next posterior four have fine curved spines on the terminal joint with short joints carrying strong setæ on their back margin. The posterior six pairs have all the joints heavily fringed with setæ and the terminal joint apparently has two or more narrow, elongate, lobe-like prolongations. Pressed down on the basal joint there is a lance-shaped, short, flat lobe that may be the exopodite or possibly the epipodite. The large, broad, setiferous, outer joints of the six posterior pairs of legs were undoubtedly natatory in their action, and the basipodite also probably carried branchiæ on the epipodite. On one specimen such lobes are shown on three of the legs. No traces of any appendages have been seen on the posterior six segments of the body.

*Alimentary canal.*—This may be traced as a small, straight canal from the head back to the point where the caudal rami unite with the posterior segment.

*Dimensions.*—The largest specimen in the collection has a length of nearly 65 mm. Its proportions, in side view, are shown by figure 5, plate 27.

*Observations.*—This is one of the most beautiful and graceful of the remarkable group of crustaceans from the Burgess shale. It occurs in relative abundance but unfortunately I have not yet found a specimen showing clearly the arrangement of the various appendages beneath the anterior portion of the body.

*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.

## Sub-Class MALACOSTRACA

### Order HYMENOCARINA Clarke

#### Family HYMENOCARIDÆ Salter

#### Genus HYMENOCARIS Salter

*Hymenocaris* SALTER, 1853, Rept. British Assoc. Adv. Sci. for 1852. On the Lowest Fossiliferous Beds of North Wales, p. 58. (Genus briefly described. Genotype = *Hymenocaris vermicauda* Salter.)

*Hymenocaris* SALTER, 1866, Mem. Geol. Survey Great Britain, Vol. 3, p. 293, pl. 2, figs. 1-4, pl. 5, fig. 25. (Description of genus slightly changed and illustrations given of type species.)

*Hymenocaris* ETHERIDGE, 1881, Mem. Geol. Survey Great Britain, Vol. 3, 2d ed., p. 484. (Reprint of description by Salter, 1866.)

The generic description by Salter (1866) is as follows:

Carapace ample, semi-oval, narrowed towards the front, curved downward at the sides, but not angularly bent along the dorsal line; no external eyes; antennæ?; abdomen as long or longer than the carapace, of nine transverse segments, the last with three pairs of unequal lanceolate appendages.

The illustrations accompanying the description by Salter show the general form of the carapace and abdomen. These taken in connection with seven specimens of the carapace, two of which have several segments of the abdomen attached to them (in the collection of the United States National Museum), enable me to identify the genus and add materially to the description of Salter.

On one of the specimens of the carapace [Salter, 1866, pl. 2, fig. 3] two antennæ are shown, otherwise no traces of the appendages of the head or body are mentioned.

*Hymenocaris perfecta* (pl. 31, fig. 2) shows the antennæ to be jointed, while the antennæ noted by Salter for *Hymenocaris vermicauda* were unjointed.

The genus and its type species have been referred to by authors many times during the past fifty years, and Salter's diagrammatic figure has been copied into nearly all text-books in which the fossils of the Cambrian system are illustrated.

In addition to those described in this paper there are a number of American species of *Hymenocaris* known. These include *H. argentea* (Walcott)[1] from the Middle Cambrian of Utah, and several undescribed species from the Middle Cambrian of the Cordilleran province of western North America.

The valves of the carapace of *Isoxys acutangula*[2] (Walcott) are abundant in the lower portion of the Burgess shale, and there are also fragments of the carapace of a very large form that possibly may be related to *Hurdia victoria* (pl. 32, fig. 9).

### HYMENOCARIS PERFECTA, new species

Plate 31, figs. 1-6 (upper specimen)

The form and outline of the carapace are shown as flattened on the shale by figure 1 on side view and somewhat roughly from dorsal view by figure 2. Several specimens show seven abdominal segments

[1] Bull. U. S. Geol. Survey, No. 30, 1886, p. 146, pl. 8, fig. 5.
[2] Canadian Alpine Journ., Vol. 1, No. 2, 1908, pl. 2, fig. 5.

extending beyond the carapace. The terminal segment has from two (fig. 4) to six (fig. 5) cercopods attached to it.

A strong adductor muscle scar (adm, figs. 1 and 2) is shown on many specimens.

A pair of small pedunculated eyes project in front of the carapace, one showing on each side of a pair of minute antennules.

*Appendages.*—Head. Several specimens show a pair of minute, jointed antennules projecting forward from between the large jointed antennæ (fig. 2). The antennæ are large and are composed of a single stem of short joints; they may, however, be straight, unjointed, and long (fig. 2, pl. 31). I have not illustrated a specimen showing the antennules and eyes, as they were not observed until after the plates were made up.

The specimen illustrating the thoracic legs and head appendages (fig. 1) is unfortunately not so good as one which was found and cleaned of calcareous deposits after the plates were finished and before this description was written. This specimen shows three cephalic legs. The two anterior are slender (mandible and maxillula), and the posterior maxilla is large and formed of short strong joints. There are eight pairs of thoracic legs. The distal portions of these are finely shown in figure 1. The broad, setiferous joints of the exopodite are also shown near the carapace. In other specimens they extend out over the legs so as nearly to conceal them. Traces of oval gills (epipodites) are shown for three legs on the outer side of what appears to be the second joint of the leg.

*Interior structure.*—The alimentary canal may be traced from the anterior part of the body back to the posterior abdominal segment where it terminates between two larger cercopods of the type represented by figures 1 and 2. One specimen, not illustrated, appears to have a considerable enlargement of the canal in the head portion.

*Dimensions.*—The valves of the carapace average from 40 to 60 mm. in length, with other proportions as shown by figure 1.

*Formation and locality.*—Middle Cambrian: (35k) Extending through about 25 feet of the 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.

#### HYMENOCARIS ? CIRCULARIS, new species

Plate 32, fig. 4

This is a much smaller species than the other species of this genus from the Burgess shale and I am not sure that it should be referred to the genus. All that is known of its appendages is shown by figure 4. A number of specimens of the valves in the collection average 5 to 8 mm. in length.

*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.

### HYMENOCARIS OBLIQUA, new species

Plate 32, figs. 1-3

This form differs in the form of the carapace from *H. perfecta*, as may be seen by comparing figures 1-3, plate 32, with figure 1, plate 31.

*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.

### HYMENOCARIS OVALIS, new species

Plate 32, figs. 5 and 6

The outline of a valve of the carapace is illustrated by figure 5, which is 15 mm. in length. A laterally compressed carapace and abdomen are represented by figure 6. These two figures illustrate all that is known of the 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.

### HYMENOCARIS ? PARVA, new species

Plate 32, fig. 7

This small species is represented by two specimens. At first it was placed with *H. ? circularis* (pl. 32, fig. 4), but later it was found to differ in its appendages. The specimen illustrated by figure 7 has the carapace crushed down so as to appear broad oval in outline, but another specimen has a nearly straight dorsal margin. The abdomen is pushed over on to the carapace. The antennæ project from the left side.

*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.

**Family (undetermined)**

**HURDIA, new genus**

The generic description is included with that of the type species.

*Genotype.—Hurdia victoria*, new species.

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

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

The generic name is derived from Hurd, the name of a mountain northeast of Leanchoil on the Canadian Pacific Railway, British Columbia, Canada.

**HURDIA VICTORIA, new species**

Plate 32, fig. 9

Of this species only the valves of the carapace are known. The illustration (pl. 32. fig. 9) shows the natural size and proportion of a right valve. A larger specimen has a length of 13.5 cm.

The test was quite thin and readily compressed and distorted, which causes considerable variation in the outlines of the valve.

A faintly outlined reticulation of the surface is shown on several specimens.

The only nearly related form known to me is *Hurdia triangulata.*

*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.

**HURDIA TRIANGULATA, new species**

Plate 34, fig. 1

The left valve illustrating this species is slightly distorted by compression, but it outlines the average form. The largest specimen of a single valve in the collection has a length of about 10 cm. with a depth of 6 cm.

This species differs from *Hurdia victoria* in having a valve proportionately shorter and deeper.

*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.

### TUZOIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Tuzoia retifera,* new species.

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

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

The generic name is derived from Tuzo, the name of one of the mountains of the "Valley of the Ten Peaks" south of Laggan, Alberta, Canada.

### TUZOIA RETIFERA, new species

Plate 33, fig. 2

Of this genus and species only one specimen is known. Its large size, form, and reticulated surface serve to distinguish it from all other known forms. The figure on plate 33 shows very clearly that the test was thin, as it has been crowded and wrinkled near the longitudinal center.

The reticulated surface marking is not unlike that of the carapace of the recent *Nebaliopsis typica* Sars.[1]

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

### ODARAIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Odaraia alata,* new species.

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

*Geographic distribution.*—On the slope of the ridge between Wapta Peak and Mount Field, north of Burgess Pass, and about 3800 feet

[1] Challenger Rept., Vol. 19, Pt. 56, 1887, pl. 3, figs. 1, 5, and 6.

above Field on the line of the Canadian Pacific Railway, British Columbia, Canada.

The generic name is derived from Odaray, the name of a peak west of Lake O'Hara and south of Hector, on the Canadian Pacific Railway, British Columbia, Canada.

**ODARAIA ALATA, new species**

Plate 34, fig. 2

Several specimens of the valves of this large fine species occur in the collection, but unfortunately all of them are more or less crushed and distorted. The one illustrated on plate 34 (natural size) indicates that the test of the carapace was very thin and readily wrinkled and broken. This specimen has, projecting from under the posterior margin of the valve, portions of three of the posterior segments of the abdomen with one of the large cercopods attached and one crowded under and out of place.

There is no probability of this genus or species being confused with any described form.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

**FIELDIA, new genus**

The generic description is included with that of the type species.

*Genotype.*—*Fieldia lanceolata,* new species.

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

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

The generic name *Fieldia* is derived from Field, the name of a mountain rising above Burgess Pass northeast of Field, British Columbia, Canada.

**FIELDIA LANCEOLATA, new species**

Plate 32, fig. 8

This species is so distinctly characterized by the long slender form of its valves that it is not apt to be confused with any other species. It is further characterized by five narrow longitudinal bands.

The numerous small appendages projecting outside of the carapace on the lower side indicate that the body had many segments and appendages, but with only one specimen for study I shall not attempt at this time to discuss it, as it is possible that other specimens will be discovered during the field season of 1912.

*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.

### CARNARVONIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Carnarvonia venosa*, new species.

*Stratigraphic range.*—The stratigraphic range is limited to a band of gray, buff-weathering siliceous shale forming the upper part of the Burgess shale member of the Stephen formation.

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

The generic name *Carnarvonia*, is derived from Carnarvon, the name of a mountain of the President Range, northwest of Field, British Columbia, Canada.

### CARNARVONIA VENOSA, new species

Plate 33, fig. 1

The figure on plate 33, of the two valves united and pressed flat on the shale, illustrates all that is known of this genus and species. The size and proportions are shown by the figure.

The reticulated surface, adductor muscle scars, and vascular markings on the shell are beautifully shown on the specimen and in this illustration.

*Formation and locality.*—Middle Cambrian: $\left(\frac{35k}{10}\right)$ Burgess shale member of the Stephen formation (about 75 feet (22.8 m.) above the phyllopod bed near the base of the shale), 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.

## Sub-Class TRILOBITA

### NOTES ON SOME APPENDAGES OF THE GENERA NEOLENUS AND PTYCHOPARIA

We now have from the Burgess shale specimens of a Middle Cambrian trilobite (*Neolenus serratus* (Rominger)), showing the character of its antennæ, legs, branchiæ, and caudal appendages, and another (*Ptychoparia cordilleræ* (Rominger)) with a full series of branchial appendages. Also there are five Ordovician forms, three from the Trenton limestone (*Calymene senaria, Ceraurus pleurexanthemus,* and *Asaphus platycephalus*) and two from the Utica shale (*Triarthrus becki* and *Trinucleus concentricus*), which preserve the antennæ, legs, and branchiæ.

A review of these shows a surprising uniformity of structure of the antennæ, legs, and branchiæ in genera separated by great intervals in the stratigraphic series, and distinguished by marked variations in the external form of the dorsal shield.

At first[1] I was inclined to consider that the trilobite was a highly organized crustacean approaching the merostomes, but with the data now available I join with Burmeister[2] and Bernard[3] in considering that the trilobite is more closely related to the branchiopod crustaceans. Burmeister wrote in 1843:[4]

> The trilobites were a peculiar family of Crustacea, nearly allied to the existing Phyllopoda, approaching this latter family most nearly in its genus *Branchipus,* and forming a link connecting the Phyllopoda with the Pœcilopoda.
>
> In order, however, to estimate fairly the affinity of the trilobites with the Phyllopoda, we must not lose sight of the important fact that the trilobites differ not only from the Phyllopoda, but from all other existing families of Crustacea in the varying numerical proportion of their thoracic rings; a peculiarity neither exhibited at present as a characteristic of any natural family among the Crustacea, nor in any of the heterogeneous Articulata. This peculiarity occurs, it is true, among the Aspidostraca (a group of the second great division of the crustaceans), but only in a modified form, the difference in the numerical proportion being always reducible to one fundamental number. This law is apparently not observed in the case of the trilobites.
>
> It would seem then that the relation existing between the trilobites and the existing Crustacea is one rather of analogy than affinity, so that the whole group may be considered as a separate division, corresponding with the Aspidostraca in the formal variation presented from the typical character, but

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[1] The Trilobite, New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zoöl. at Harvard College, Vol. 8, 1881, pp. 208-211.

[2] The Organization of Trilobites. London, 1846, p. 46.

[3] The Systematic Position of the Trilobites. H. M. Bernard, Quart. Journ. Geol. Soc., London, Vol. 50, 1894, pp. 411-432; and Vol. 51, 1895, pp. 352-359.

[4] Burmeister, "The Organization of Trilobites," 1846, pp. 46-47.

not to be looked on as a nearly allied or similar group to this or to other tribes.

Putting out of the question the important difference exhibited in the numerical proportion of the thoracic rings just alluded to, this analogy to the Aspidostraca might certainly have been considered as very close—all the other relations of organization, so far as they can be traced, corresponding very accurately—if it were not for the structure of the extremities. These, indeed, which are hard, horny, and articulated in a sub-division of the present Aspidostraca, were probably entirely absent in this form in Trilobites; but in other respects all the typical characters of the two groups will be found to correspond.

Bernard[1] concluded that—

*Apus,* on account of its richer segmentation, the absence of pleuræ 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.

In 1895, with the new evidence afforded by the trilobite *Triarthrus becki,* he concluded[2] 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 caudal rami on *Neolenus* (pl. 24, figs. 1 and 1a) still further accentuates the conclusion of Bernard that the trilobites were derived from the same stock as *Apus.* This is further strengthened by the presence in the Middle Cambrian of a form like *Nathorstia transitans* (pl. 28, fig. 2), which is essentially a trilobite, but its setiferous thoracic appendages relate it closely to *Opabinia regalis* (pl. 27, fig. 6).

*Neolenus serratus* (Rominger).—A number of specimens of this species show the antennæ, jointed thoracic legs, and caudal rami. One of the specimens is illustrated by figure 1, plate 24. In this the caudal rami have been displaced and dragged back, bringing a portion of the ventral surface of the abdomen. Figure 1a shows the caudal rami in their normal position. I have already illustrated the filamentous branchial thoracic appendage of this species.[3] The resemblance between these branchiæ and the branchiæ or gills of the branchiopod *Waptia fieldensis* (pl. 27, figs. 4 and 5) is very striking.

[1] The Systematic Position of the Trilobites, 1894, Pt. 1, pp. 429-430.

[2] Idem, 1895, Pt. 2, p. 356.

[3] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pl. 6, figs. 1 and 2.

*Ptychoparia cordilleræ* (Rominger).—A small specimen, with the dorsal shield exfoliated (pl. 24, fig. 2), shows an antenna and a long series of the setiferous or filamentous exopodites. A specimen recently worked out shows narrow, elongate, fringe-like appendages attached to the setiferous branchial appendages that are similar in appearance to the abdominal branchial appendages of *Sidneyia*.[1]

In the near future I wish to review the conclusions published in my paper of 1881,[2] and those that have been entertained regarding *Triarthrus becki* and the new material from the Burgess shale.

## DESCRIPTIONS OF NEW GENERA AND SPECIES

### Order (undetermined)

### MARRELLIDÆ, new family

Carapace strong, small, subquadrangular and with two postero-lateral spines comparable with the lateral lobes of the carapace of Apodidæ. Eyes sessile. Head with five pairs of appendages. Thorax with 24 pairs of appendages. Abdomen a single plate-like telson. Thoracic leg with jointed leg-like endopodite, a jointed setiferous exopodite, and expanded gill-like epipodite.

One genus, *Marrella*.

*Observations*.—This family is instituted to include *Marrella splendens*, a species that, despite its remarkable carapace and cephalic appendages, recalls *Apus* and *Lepidurus*. It differs from the two latter so markedly in its carapace and abdomen that it becomes the type of a family that is less primitive than the Apodidæ and may be considered as near the Trilobita (p. 162).

### MARRELLA, new genus

The generic description is included with that of the species.

*Genotype*.—*Marrella splendens*, new species.

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

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

The generic name is given in recognition of the geologic and paleontologic work of my friend, Dr. John E. Marr, Johns College, Cambridge, England.

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[1] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pl. 2, fig. 1; pl. 6, fig. 3; pl. 17, fig. 1.

[2] The Trilobite, New and Old Evidence relating to its Organization. Bull. Mus. Comp. Zoöl., Vol. 8, 1881, pp. 208-211.

**MARRELLA SPLENDENS, new species**

Plate 25, figs. 1-6, and plate 26, figs. 1-6

The general form is shown by figures 1, 4, and 5, plate 26. The exoskeleton is composed of a strong cephalic carapace (c) (fig. 1, pl. 26) which extends as two long, strong, curved spines (x) that continue posteriorly over the back of the thorax beyond the end of the body. At each antero-lateral angle a strong, backward-curving spine (a′) complements the great dorsal thoracic spines. A pair of large crescentiform sessile eyes occur on the anterior margin just within the base of the anterior spines (pl. 25, figs. 4 and 5). The great dorsal spines are beautifully crenulated on the outer margin by short, strong backward-curving spines.

*Appendages.*—The antennæ (a″, fig. 5, pl. 26) are long, slender, and many-jointed; they unite with the head near the posterior end of the labrum; the third pair of appendages, mandibles (m), are large, long, 7 ?-jointed and with fine setæ on the edge of the joints which give the appearance of a slender feather to the appendage (fig. 3, pl. 25, and fig. 3, pl. 26). The fourth and fifth cephalic appendages are slender, and with long joints.

There are 24 pairs of thoracic appendages. Each one is composed of a jointed leg of seven joints with a flattened, short, broad spine on all but the proximal and distal joints (thl, fig. 6, pl. 26) ; ten legs, (endopodites) with the expanded joints are shown in figure 6, plate 26; anterior to these there are preserved 4 setiferous appendages that appear to be the exopodites of the leg. These are more fully shown by figure 6, plate 25, also figure 3. Another view of the long, jointed endopodite is found in figures 3 and 5, plate 26. The presence of a gill (epipodite) was unsuspected until the specimen represented by figure 4, plate 26, was found; this fine example is so delicate and so beautifully preserved that it is almost unique even among the wonderful Burgess shale fossils.

*Abdomen.*—The abdomen (ab, figs. 1, 3, 4, and 6, pl. 26) forms a small, plate-like termination of the long body.

*Interior structure.*—The alimentary canal is very distinct in a number of specimens (i, figs. 3 and 6, pl. 26). It extends from the posterior margin of the labrum back to the plate-like abdomen. The head is too much smashed down to show any details of interior structure, but the alimentary canal appears to widen out and occupy much of the space beneath the subquadrangular carapace. The large dorsal spines have a central canal that appears to open into the space (stomach ?) beneath the carapace; this canal may represent the hepatic cæca of *Burgessia* (pl. 27, figs. 1-3). The slender canal of the antennules joins the visceral space beneath the carapace at its antero-lateral angle.

*Dimensions.*—The average length is 15 mm. The size, proportions and relations of parts are shown by the figures on plates 25 and 26. The animal was so delicate that it was readily smashed and distorted.

*Observations.*—This beautiful fossil (it was called the "Lace crab" at camp) is the most abundant of the many species in the phyllopod bed. It must have swarmed in large numbers in the quiet waters.

Reference to its relations to other crustaceans will be found in the introduction.

*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.

### Family (undetermined)

### NATHORSTIA, new genus

The generic description is included with that of the type species.

*Genotype.—Nathorstia transitans,* new species.

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

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

The generic name is proposed in honor of Dr. Alfred G. Nathorst, the distinguished Swedish paleontologist and paleobotanist.

### NATHORSTIA TRANSITANS, new species

Plate 28, fig. 2

Dorsal shield elongate-oval in outline, very thin and delicate in structure. It may be divided into a cephalic region (cephalon), thorax, and abdomen. The cephalon is transversely semicircular with a short spine at each posterolateral angle; obscurely trilobed. One of the crescent-shaped, medium-sized eyes (e) is indicated on the right of the central axis.

Thorax faintly trilobed, composed of eight rather long (longitudinal) segments. The specimen illustrated is so flattened and crushed that it is difficult to determine the form of the segments, but other specimens with several segments united show them to be much like those of *Molaria spinifera* (pl. 29, fig. 2).

The abdomen (pygidium) is apparently semicircular with a rudely defined median lobe and two or three segments outlined on it.

*Appendages.*—Head. A portion of what may be an antenna projects from beneath the right anterior margin; from near the left posterolateral angle a large four-jointed appendage extends backward. I assume that this may be the outer portion of the large posterior appendage (maxilla) of the head.

Thorax. Traces of several slender-jointed thoracic legs project from beneath the anterior segments and back of these on the right side more or less of six legs have been pushed out from beneath the dorsal shield; these are composed of three to four long, slender joints; fragments of the three proximal joints indicate that they are shorter and larger and that they have a fringe of fine setæ. Indications of a branchial lobe (gill) are seen in two specimens where the legs are not preserved. This is often the case both among the Merostomata (pl. 29, fig. 3) and Trilobita (pl. 24, fig. 2).

Two caudal rami project a little distance from beneath the posterior margin of the dorsal shield.

*Dimensions.*—The only entire specimen has a length of 45 mm. Its other proportions are shown by figure 2, plate 28.

*Observations.*—I have given the specific name *transitans* to this species on account of its suggesting a transition between a Merostome-like form, such as *Molaria spinifera,* and the trilobites (pl. 24, figs. 1 and 2). This is mentioned under remarks on the appendages of the trilobites (p. 191).

The specimen illustrated was found by my son Sidney where we were using dynamite to "sledge" our way into the solid ledge of hard shale as it was back from the action of frost that the most beautifully preserved specimens were found. A few fragments turned up later, and we hope to find more perfect specimens in the future.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

### Order HYPOPARIA Beecher

#### Family (undetermined)

It is highly probable that the new genera *Mollisonia* and *Tontoia* will come within the family Microdiscidæ Coquin, 1896.

### MOLLISONIA, new genus

General outline elongate, sides subparallel; cephalon and pygidium subequal in size and outline, and indistinctly lobate as now known. Eyes unknown. Thorax with seven simple transverse segments that may or may not be divided into axial and lateral longitudinal lobes by slight depressions on the line of each third of the segment. Surface finely granular.

*Genotype.*—*Mollisonia symmetrica,* new species.

*Stratigraphic range.*—Middle Cambrian: Burgess shale member of the Stephen formation, British Columbia.

The generic name is derived from Mollison, the name of a mountain southwest of Field on the Canadian Pacific Railway, British Columbia, Canada.

*Observations.*—In its subequal cephalon and pygidium this genus resembles *Agnostus* and *Microdiscus,* but it differs in the absence of distinct lobes and the greater number of thoracic segments. The almost unsegmented cephalon and pygidium and few simple thoracic segments are characters of the most highly developed families of the Trilobites, such as Asaphidæ and Illænidæ, but in the absence of satisfactory evidence of the presence of eyes on the cephalon further study of better material is needed. The form of the thorax recalls that of *Bohemilla stupenda* Barrande.[1]

### MOLLISONIA SYMMETRICA, new species

Plate 24, fig. 3

General outline elongate, length about three times the width; sides subparallel; cephalon and pygidium nearly equal in size and contour; thorax with seven segments. Test thin with a minutely granular surface.

Cephalon a little shorter than its width at the posterior margin; sides nearly straight and sloping slightly inward toward the broadly rounded antero-lateral angles and front margin. The presence of eyes is very doubtfully suggested by small, faint, crescentiform depressions about 2 mm. from the antero-lateral margin. A raised line that possibly may be the facial suture extends back to the margin midway of the length of the cephalon; in front of the possible eye lobe it appears to pass across the front parallel to the margin and about 1.5 mm. from it. There are faint traces of transverse furrows indicating the presence of about five transverse lobes on the central portion of the cephalon.

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[1] Système Silurien du Centre de la Bohême, Vol. I, Suppl., 1872, pl. 14, figs. 30 and 32.

The thorax has seven transverse segments outlined, the anterior of which is somewhat narrower than the others; the segments terminate in blunt, falcate, slightly furrowed ends that overlap on the next posterior segment within the posterior curve of the free portion of the end of the segment. A lobation of the thorax is indicated by the presence of a shallow, elongate depression on seven of the segments one-third of the distance across from the left side; if similar depressions existed on the right side they have been obscured by the flattening of the test in the shale.

The pygidium curves outward from its anterior margin, and the rounded outline extends along the sides and posterior margin; it shows traces of an anterior transverse furrow indicating a segment.

| Dimensions. | mm. |
|---|---|
| Length of dorsal shield | 48.0 |
| Width of cephalon | 17.0 |
| Length of cephalon | 13.5 |
| Greatest width of thorax | 18.0 |
| Length of thorax | 24.0 |
| Width of pygidium | 15.0 |
| Length of pygidium | 12.5 |

*Observations.*—The only known specimen of this unique fossil was found on a large slab of calcareous shale in association with *Bathyuriscus rotundatus* (Rominger), *Ogygopsis klotzi* (Rominger), and *Anomalocaris canadensis* Whiteaves. The impression of the thin test is very clear and along the left side some of the test remains as a very thin dark scale. The specimen is in the same condition of preservation as the thin tests of the shields and body of *Anomalocaris canadensis* and was evidently much thinner and more delicate than the tests of the associated trilobites.

*Formation and locality.*—Middle Cambrian: (14s) Lower portion of the Stephen formation, northwest slope of Mount Stephen, above Field, British Columbia, Canada.

## MOLLISONIA GRACILIS, new species

Plate 24, fig. 5

Of this species only one specimen is known. The general outline and proportions of the dorsal shield are shown in figure 5. The specimen has been laterally compressed so that the lateral edges of the cephalon, segments, and pygidium are wrinkled and suggest fine spines.

One of the striking peculiarities is the transverse anterior merging of the cephalon into the short blunt spines projecting from it.

There are no indications of eyes on the cephalon. A narrow median longitudinal ridge occurs on the posterior half of each of the seven segments of the thorax and on an eighth segment that appears to be still attached to the pygidium.

This little species, 16 mm. in length, appears to be generically identical with *Mollisonia symmetrica,* which occurs at about the same geological horizon a few miles distant. It is much smaller and more slender than that species.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

### MOLLISONIA ? RARA, new species

Plate 24, figs. 6 and 7

Of this species there are several fragmentary specimens. The species differs from *M. gracilis,* with which it is associated, in the character of the thoracic segments and pygidium; also, so far as we can determine from this superficial study, there are seven segments and the pygidium shows distinct segmentation with a denticulated border.

The specimen illustrated by fig. 6 indicates that the species was the largest of the genus and may have had a length of from 5 to 6 cm.

*Formation and locality.*—Middle Cambrian: (35k) Burgess shale member of the Stephen formation (phyllopod bed), 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.

### TONTOIA, new genus

The generic description is included with that of the type species.

*Genotype.*—*Tontoia kwaguntensis,* new species.

*Stratigraphic range.*—The stratigraphic range is limited to the upper portion of the Tonto sandstone on the surface of a few thin layers of sandstone.

*Geographic distribution.*—The species has been found only in Kwagunt Valley off the eastern end of Kiabab Plateau in the Grand Canyon of the Colorado, Northern Arizona.

The generic name is derived from Tonto, an Indian name applied to the basal sandstone of the Cambrian series in the Grand Canyon region.

**TONTOIA KWAGUNTENSIS**, new species

Plate 24, fig. 4

This unusual form has a convex dorsal shield divided into a cephalon, thorax, and pygidium. The cephalon has a narrow, raised margin with the lateral third on each side of the cephalon rising rapidly to the elevated central section. The central section is slightly flattened and has a sharp median ridge extending from the anterior end back to the posterior margin. A similar ridge crosses each thoracic segment and extends back on the pygidium about one-fourth its length.

The segmentation of the cephalon is suggested by two narrow ridges crossing the right lateral space beneath the elevated central portion.

There is a suggestion of the presence of eyes on the posterior outer edge of the elevated central portion of the cephalon.

The thorax is divided into four segments by rounded, elevated, narrow ridges as shown by figure 4.

The pygidium is shorter and smaller than the cephalon, but I think this may be owing to the breaking away of the margin.

There is only one specimen and that is a matrix in a fine, hard sandstone. Trails that appear to have been made by this or a similar form occur on the surface of several of the layers of sandstone adjoining the one on which the specimen illustrated occurred.

I am not at all sure that this species should be placed with the trilobites, but with such forms as those illustrated by figures 3 and 5 at the same geological horizon it seems best to classify it with them for the present.

The total length of the specimen illustrated is 25 mm. Other proportions are shown by figure 4.

*Formation and locality.*—Middle Cambrian: (73) Tonto sandstone, upper portion, Kwagunt Valley, Grand Canyon of the Colorado, Northern Arizona.

## Sub-Class MEROSTOMATA

### Order AGLASPINA, new order

Body elongate, transversely trilobed. Cephalo-thorax with or without sessile eyes; on the ventral side it has an epistoma and five pairs of movable appendages.

Thorax with 8 to 11 segments, each of which has a pair of jointed appendages. Abdomen with 1 to 3 segments.

One family, Aglaspidæ Clarke.

### Family AGLASPIDÆ Clarke

### MOLARIA, new genus

The description of *Molaria* is outlined in that of the type species.

*Genotype.—Molaria spinifera,* new species.

*Stratigraphic range.*—The stratigraphic range is limited to a thin layer of dark siliceous shale about 2 inches in thickness forming the base of the phyllopod bed of the Burgess shale member of the Stephen formation.

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

The generic name is derived from Molar, the name of one of the mountain peaks east of the "Valley of the Ten Peaks," south of Laggan, Alberta, Canada.

The family reference is tentative.

### MOLARIA SPINIFERA, new species

Plate 29, figs. 1-5

The dorsal test, when flattened on the shale and viewed from above, is elongate-oval in outline with a long, slender telson; it is obscurely trilobed longitudinally. Surface slightly roughened by minute shallow punctæ. Cephalic shield semicircular in outline, moderately convex. It is divided into a central area with a conical outline corresponding to the glabella of the trilobite and three transverse lobes are indicated by short furrows on each side. Posterolateral angles without genal spines.

The examination of over 20 specimens has failed to reveal any traces of an eye on the cephalic shield. This might escape observation, but from the close relation of this species to the species in the genus *Habelia* it is probable that the eyes were pedunculated and beneath the rim of the cephalic shield.

Thorax with eight transverse segments divided into a median and two lateral lobes. The form and arrangement of the segments is clearly shown by figure 2. Abdomen with one long segment and a slender, spine-like telson.

*Appendages.*—The appendages of the head are not satisfactorily preserved. In one (fig. 5) a pair of short, jointed antennules (a′) may be traced by their impression on the test to where they extend beyond the rim of the cephalic shield. On the left a larger and longer appendage may possibly represent an antenna. Several specimens show slender jointed appendages projecting from beneath the edge of the cephalic shield; these terminate in a minute joint having several fine setæ or spines on its margin.

On the thoracic leg two or three of the inner joints are widened out and setiferous; the outer three joints are long and slender; on the outer side of the inner joints (exopodite probably) there is a broad flabellum-like setiferous lobe, also a small oval gill (fig. 3). From beneath the posterior margin of the long abdominal segment shown in figure 4, a minute jointed leg projects on each side of the base of the telson.

*Interior structure.*—The alimentary canal is outlined in several specimens. On one of them (fig. 2) it extends to the posterior end of the long abdominal segment, thus indicating the position of the anal opening. Traces of the hepatic cæca beneath the head are shown by figure 3.

*Dimensions.*—This is a small species. The largest specimen has a length, exclusive of the telson, of 40 mm. The average length is about 18 to 20 mm. The proportions of the dorsal shield and telson are indicated by figure 2.

*Observations.*—I have employed above the terminology used in describing the dorsal shield of trilobites as it applies so well to this interesting species. In outward aspect the dorsal shield is essentially that of a trilobite except that there are no sessile eyes on the head shield and the posterior segments are more nearly related in form to such branchiopod crustaceans as *Emeraldella brocki* (pl. 30, fig. 2).

So far as can be determined, a pair of jointed legs, with an exopodite bearing a gill and flabellum, occurs on the outer side of each of the eight thoracic segments. A moderate number of specimens of the species were found in 1910 and it may be that more will be collected during the season of 1912 and that among them the cephalic appendages will be preserved. The test is thin and easily wrinkled, which obscures parts that would otherwise show through 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.

### HABELIA, new genus

The description of the genus is included with that of the type species.

*Genotype.*—*Habelia optata,* new species.

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

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

*Observations*.—The generic name is derived from the name Habel as applied to a mountain peak near Wapta glacier at the head of Yoho Valley, British Columbia, Canada.

### HABELIA OPTATA, new species

Plate 29, fig. 6

In form the body of this species resembles *Yohoia tenuis*, but its long slender telson and thoracic appendages quickly separate it.

The test of the head is finely punctate, and crenulated with minute short spines on the margin. There are eleven body segments bearing appendages that are of nearly uniform size, one smaller abdominal segment without appendages, and the slender telson.

The eye has not been observed in any of the four specimens preserving the head.

*Appendages*.—On one specimen six slender jointed appendages project forward from beneath the carapace; the posterior of these is a little larger than the others. They represent, in front at least, the first five pairs of appendages of the head. Another specimen shows two slender jointed antennules and posterior to (below) them two larger jointed antennæ with delicate spines extending forward; another antenna is indicated by a small jointed leg-like appendage. The thoracic appendages are somewhat difficult to interpret. One specimen shows the broad terminal joint on eight legs, with traces of it on the three anterior legs; another specimen has five long, slender, jointed legs with a sixth posterior to them that is not over one-half as long; back of the latter there are five of the short legs with the broad terminal joint. The five anterior legs have a rather large gill attached to a short exopodite (?).

The terminal joints of the posterior legs have almost the outline of the pleuron of the segments of the thorax; they gently curve from a broad base to a fine point and have five or more short sharp spines on the anterior margin and somewhat finer spines on the posterior margin; their function was probably natatory.

*Surface*.—The surface of the head test and tergite of the segments is finely punctate. The telson appears to have been longitudinally striate or smooth.

*Dimensions*.—The largest specimen has a length of 22 mm. exclusive of the long telson, which is about as long as the body.

*Observations*.—The presence of this species in the collection was not noted until too late to illustrate it thoroughly. This will now be left until a further study can be made of 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.

**EMERALDELLA, new genus**

The description of this genus is outlined in the description of the type species.

*Genotype.*—*Emeraldella brocki,* new species.

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

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

*Observations.*—This genus appears to come within the limits of the family Aglaspidæ.

The generic name is derived from the name Emerald as applied to a mountain, lake, and glacier north of Burgess Pass, British Columbia, Canada.

**EMERALDELLA BROCKI, new species**

Text figure 8, p. 204, and plate 30, fig. 2

Body elongate, strong. As flattened in the shale it is about twice as long as its greatest diameter. Cephalon transversely semicircular. Eyes unknown. Thorax with ten segments bearing appendages. Abdomen with two long anterior segments and a short segment to which is joined a long, slender spine-like telson. Epistoma elongate and a little more than one-half the length of the cephalon.

*Appendages.*—The base of an antenna is fairly well shown by a specimen in which the head has been largely broken away (a′, fig. 2, pl. 30). It has a thick, jointed basal portion. The two slender, jointed appendages projecting below the head on figure 2 may be the outward extensions of the maxillula (mx′) and maxilla (mx″).

A specimen found in 1911 shows a short antennule (text figure 8), very long slender antennæ, and three cephalic appendages.

The thoracic limbs are not well preserved, but what is shown indicates a broad, large terminal joint somewhat similar to that of *Opabinia regalis* (pl. 27, fig. 6) and another inner joint that is expanded and provided about its margin with strong setæ. The gill appears to be present but it cannot be satisfactorily determined.

*Alimentary canal.*—This canal is large and may be traced from the last abdominal segment through and into the head as shown in figure 9.

| Dimensions. | mm. |
|---|---|
| Length of body | 40 |
| Caudal spine | 30 |
| Head | 9 |
| Thorax | 26 |
| Abdomen | 4 |

FIG. 8.—*Emeraldella brocki,* n. sp. Dorsal view of a flattened specimen. $\times$ 1.5, showing antennules, antennae, 3 posterior cephalic appendages, epistoma, and position of mouth.

*Observations.*—The specific name is given in honor of R. W. Brock, Director of the Geological Survey of Canada, who has been most courteous to me in connection with my work in the Canadian Rocky Mountains.

*Formation and locality.*—Middle Cambrian: (35) 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.

**EMERALDELLA MICRURA, new species**

Text figure 9

This species is founded on a single weathered specimen that we found in the shale about 80 feet above *Emeraldella brocki.* It differs from the latter mainly in its greater proportional width.

*Formation and locality*—Middle Cambrian: $\left(\frac{35k}{10}\right)$ Burgess shale member of the Stephen formation (about 75 feet above the phyllopod bed near the base of the shale) 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.

FIG. 9.—*Emeraldella micrura,* n. sp. Type specimen Natural size.

Order LIMULAVA Walcott

*Limulava* WALCOTT, 1911, Smithsonian Misc. Coll., Vol. 57, No. 2, p. 21. (Described as a new sub-order.)

**Family SIDNEYIDÆ Walcott**

**Genus SIDNEYIA Walcott**

**SIDNEYIA INEXPECTANS Walcott**

Text figure 10, p. 206

*Sidneyia inexpectans* WALCOTT, 1911, Smithsonian Misc. Coll., Vol. 57, No. 2, p. 24, pl. 2, figs. 1-3, pl. 3, figs. 1-4, pl. 4, figs. 1-4, pl. 5, figs. 1-3, pl. 6, fig. 3, and pl. 7, fig. 1. (Original description and illustrations.)

A specimen found during the summer of 1911, text figure 10, shows the form of the head and four pairs of the cephalic appendages projecting forward in fine shape, but unfortunately the chelate terminal joints of the third pair are not attached. The antennæ are not preserved. The biramous appendages of the first 9 segments of the body are formed of an endopodite of four or five broad, short joints and two slender distal joints. Each joint has one or more short, sharp spines curving forward from the outer end, and the terminal joint has two large and one small forward-curving spines not unlike the spines on the terminal joints of the cephalic appendages of *Eurypterus*. In other specimens the exopodite appears to be in the form of a lobe or lamellæ not unlike the branchial lobes of *Pterogotus bilobus* as illustrated by Dr. Henry Woodward.[1] The branchial appendages of *Sidneyia* are illustrated in my paper on Middle Cambrian Merostomata.[2]

FIG. 10.—*Sidneyia inexpectans* Walcott. × 3. Flattened dorsal shield with 4 pairs of cephalic appendages, and jointed setiferous thoracic legs.

The discovery of the jointed body legs of *Sidneyia* strengthens the conclusion reached in 1911, that *Sidneyia* was a transition form between the Trilobita and Eurypterida.

The accompanying text figure illustrates one of the specimens of *Sidneyia* showing the jointed body appendages.

For description of mode of occurrence and locality, see original description.

[1] Monogr. British Fossil Crustacea, Order Merostomata, 1866-1878; Pal. Soc. London; Pl. 12, figs. 1a and 1d.

[2] Smithsonian Misc. Coll., Vol. 57, No. 2, 1911, pl. 6, fig. 3, and pl. 7, fig. 1.

## DESCRIPTION OF PLATE 24



Fig. 1. (Natural size.) A partly exfoliated specimen, showing (a') an antenna, 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.

1a. (Natural size.) Pygidium with the caudal rami extending out from beneath it in their probable natural position. U. S. National Museum, Catalogue No. 57657.



Fig. 2. (×6.) Dorsal view of a specimen from which the dorsal shield has been removed, leaving the branchiæ (br) exposed; also a few of the thoracic legs (thl). U. S. National Museum, Catalogue No. 57658.



Fig. 3. (Natural size.) Dorsal view of the type specimen found in the Stephen formation on Mount Stephen above Field, locality (14s). U. S. National Museum, Catalogue No 57659.



Fig. 4. (×2.) Dorsal view of a cast made in the natural mold, which is the type specimen. From the Tonto sandstone, Kwagunt Valley, Grand Canyon, Arizona, locality (73). U. S. National Museum, Catalogue No. 57660.



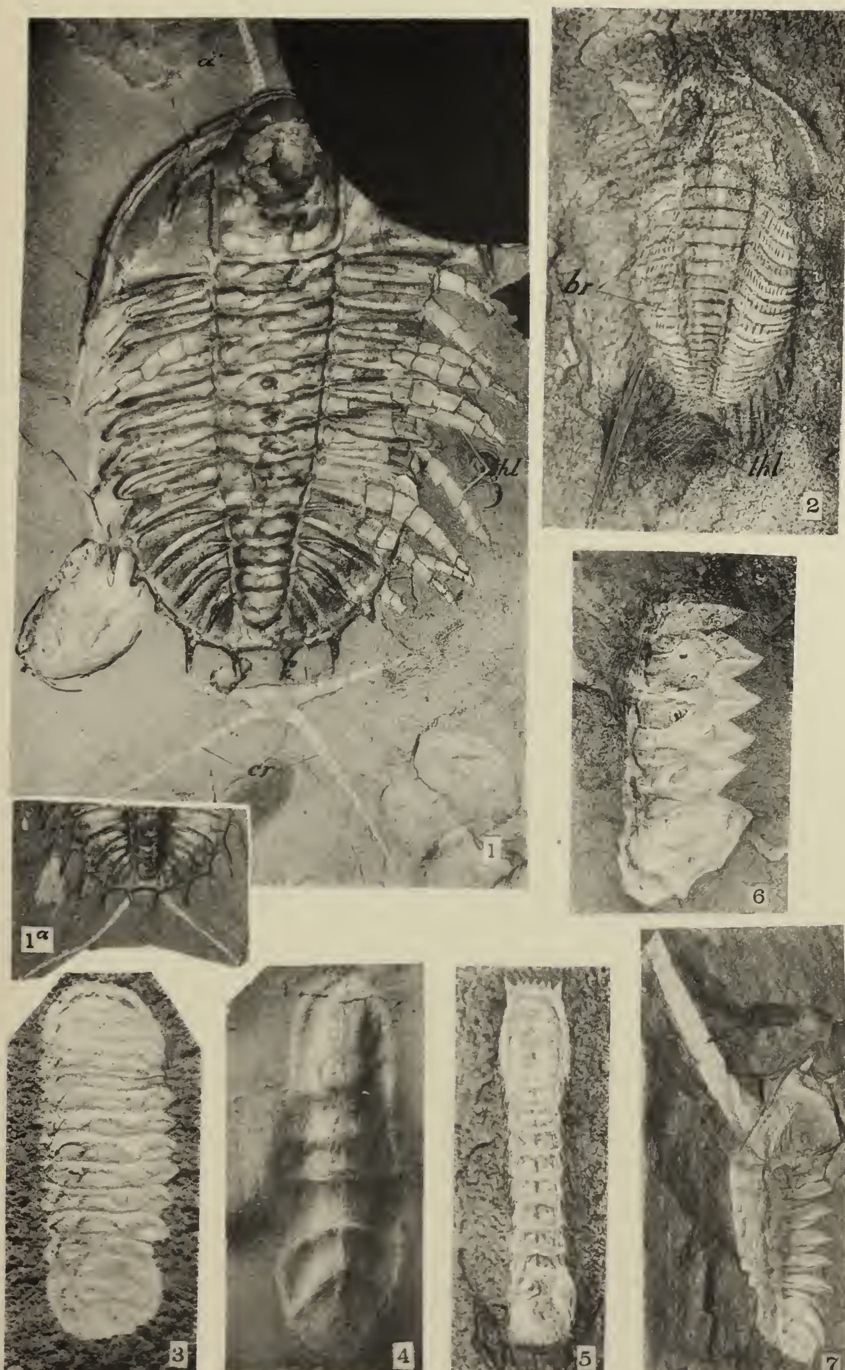
Fig. 5. (×2.5.) Dorsal view of the type specimen of the species and genus. The specimen is laterally compressed. U. S. National Museum, Catalogue No. 57661.



Fig. 6. (Natural size.) A fragment of this species, showing the form of the ends of the thoracic segments. U. S. National Museum, Catalogue No. 57662.

7. (×2.) A small crushed specimen, showing a portion of the cephalic shield, thoracic segments, and pygidium. U. S. National Museum, Catalogue No. 57663.

The specimens represented by figures 1, 1a, 2, 5, 6, and 7 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 25

Legend:

c=carapace.
x=posterior spines or lobes of carapace.
e=eye.
lb=labrum.
th=thorax.
ab=abdomen.
a′=antennule ?.
a″=antennæ.
m=third appendage=mandible.
m′=fourth appendage=maxillula.
m″=fifth appendage=maxilla.
i=intestine or alimentary canal.
thl=thoracic legs [endopodites].
l=setiferous jointed exopodite.
br=branchial lobes or gills [epipodites].

PAGE

*Marrella splendens* Walcott (see pl. 26) .............................. 193

FIG. 1. (×4.) Dorsal view of a crushed specimen in which the juncture of the antennules ? (a′) and the carapace is clearly shown. U. S. National Museum, Catalogue No. 57664.

2. (×4.) Dorsal view illustrating the segments of the body, carapace and its great posterior spines. U. S. National Museum, Catalogue No. 57665.

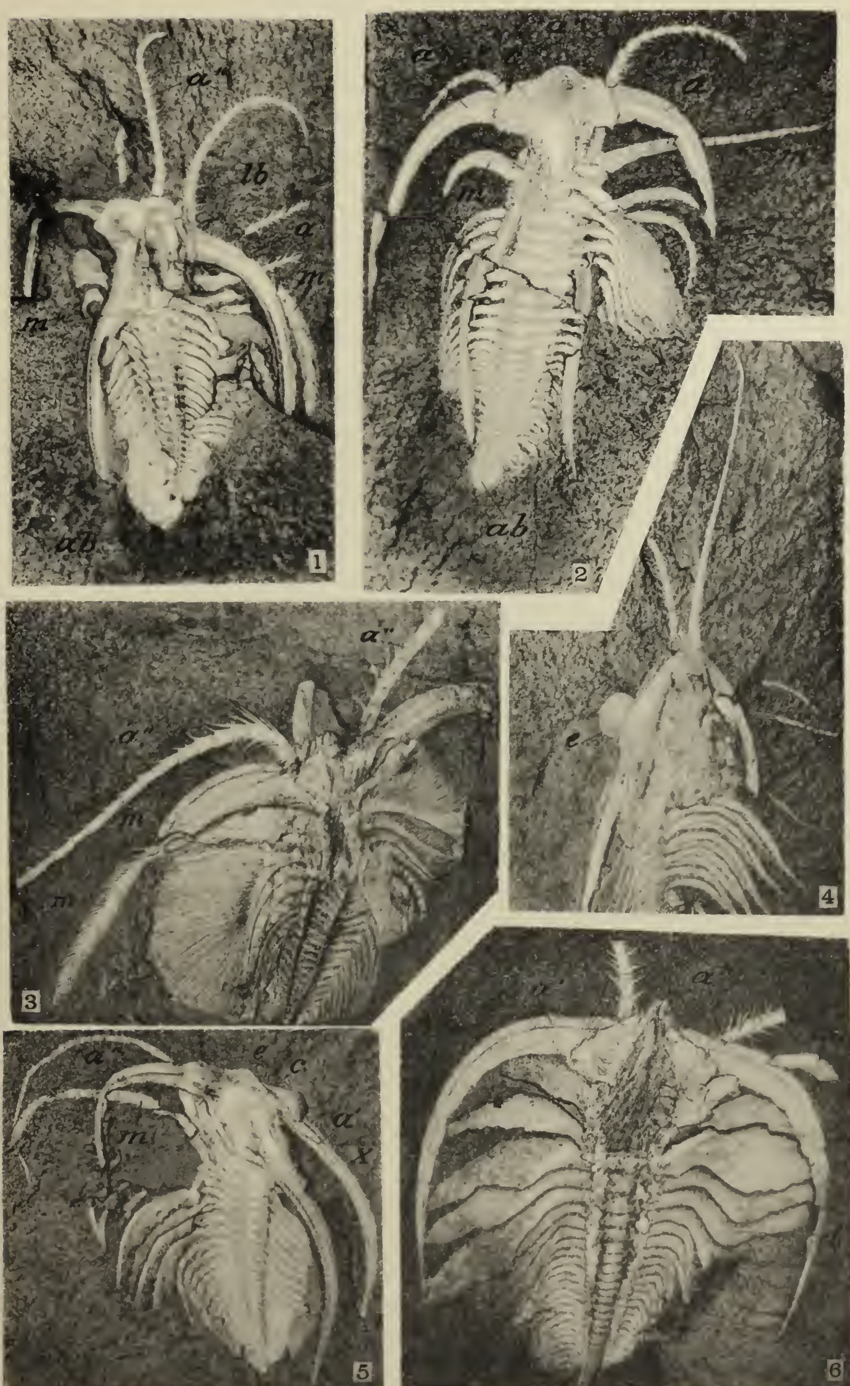
3. (×4.) Dorsal view of a partly exfoliated specimen showing the antennæ (a″), a feather-like maxillula, and one of the remarkable setiferous exopodites. U. S. National Museum, Catalogue No. 57666.

4. (×3.) A specimen crushed sideways so as to force the eye (e) out prominently on the left side. U. S. National Museum, Catalogue No. 57667.

5. (×3.) A slightly distorted specimen illustrated to show the eyes (e). U. S. National Museum, Catalogue No. 57668.

6. (×4.) Dorsal view of a specimen showing the setiferous exopodites as they lie one on the other with the setæ pointing forward and outward. U. S. National Museum, Catalogue No. 57669.

All of the specimens illustrated on Plate 25 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 26

Legend:

c=carapace.
x=posterior spines or lobes of carapace.
e=eye.
lb=labrum.
th=thorax.
ab=abdomen.
a′=antennule ?.
a″=antennæ.
m=third appendage=mandible.
m′=fourth appendage=maxillula.
m″=fifth appendage=maxilla.
i=intestine or alimentary canal.
thl=thoracic legs [endopodites].
l=setiferous jointed exopodite.
br=branchial lobes or gills [epipodites].

PAGE

*Marrella splendens* Walcott (see pl. 25) .............................. 193

FIG. 1. (×3.) Dorsal view of a specimen showing the carapace with its great posterior spines or lobes and the large antennules?. U. S. National Museum, Catalogue No. 57670.

2. (×3.) Ventral view of a crushed specimen showing the labrum (hypostoma) nearly in its normal position. U. S. National Museum, Catalogue No. 57671.

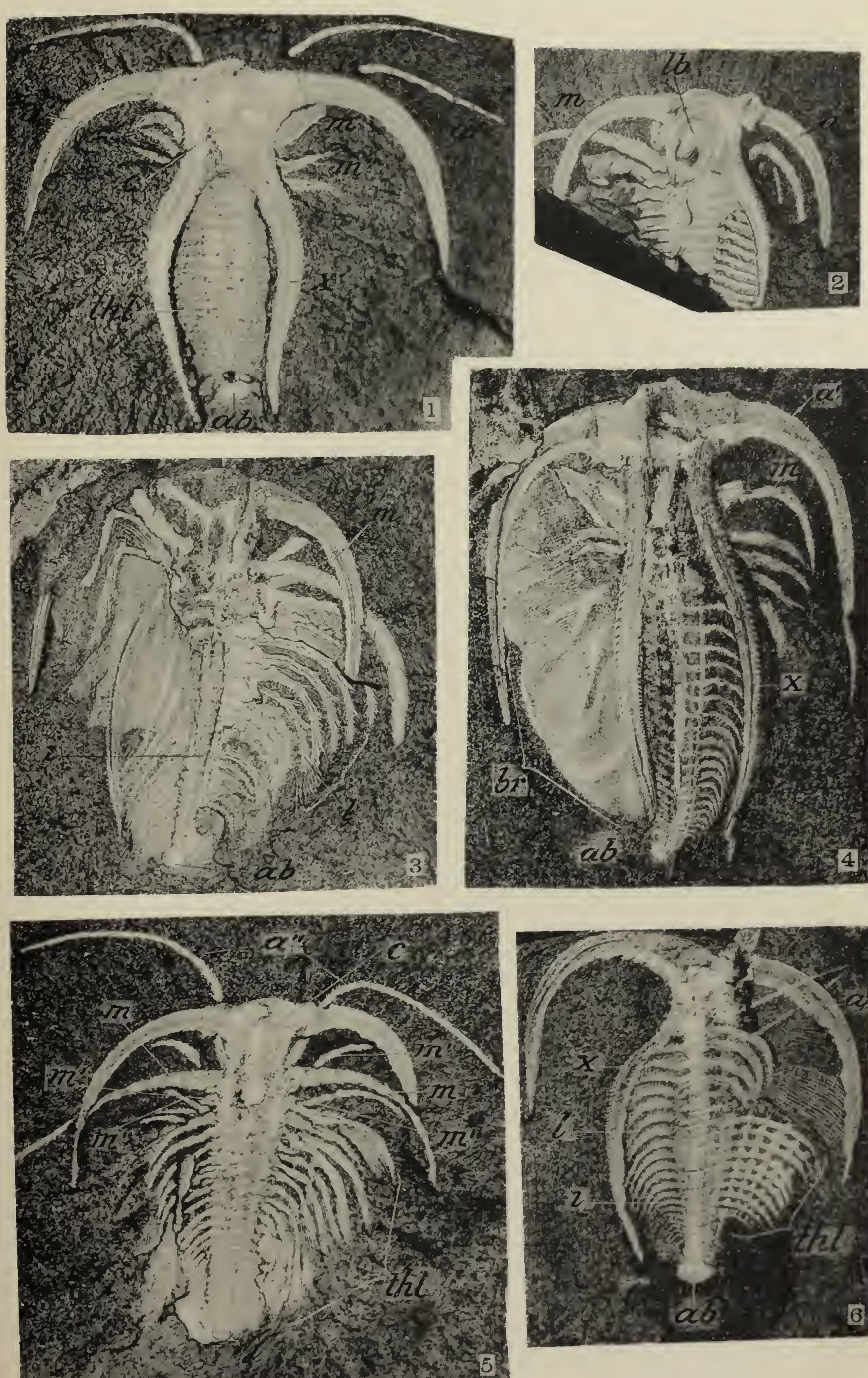
3. (×3.) Dorsal view of a specimen showing intestinal canal, feather-like maxillula (m), and the long joints of the setiferous exopodites. U. S. National Museum, Catalogue No. 57672.

4. (×4.) Ventral view of a specimen showing the large gill lobes (br) (epipodites). U. S. National Museum, Catalogue No. 57673.

5. (×3.) Dorsal view of a specimen that illustrates the relative position of the antennæ, the mandible, maxillula, and maxilla. U. S. National Museum, Catalogue No. 57674.

6. (×4.) Ventral view of a specimen showing the thoracic legs (thl, endopodites) and the setiferous legs (l, exopodite). U. S. National Museum, Catalogue No. 57675.

All of the specimens illustrated on Plate 26 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 27

PAGE

*Burgessia bella* Walcott (see pl. 30) .................................. 177

FIG. 1. (×3.) Dorsal view of a specimen showing the internal structure through the thin carapace. st = stomach, i = intestinal canal, kd = hepatic cæca, cl = connection between hepatic cæca and alimentary canal, thl = thoracic legs, ab = abdominal region, but the segmentation is not preserved in this specimen. U. S. National Museum, Catalogue No. 57676.

2. (×3.) Ventral view of the region beneath the carapace. Lettering the same as for figure 1 with the addition of a′ = antennæ, lb = labrum. U. S. National Museum, Catalogue No. 57677.

3. (×3.) Dorsal view of area within the cephalic shield, showing interior and appendages of the head. e = eye, a″ = antennæ, 3, 4, 5 = cephalic appendages, th = base of thoracic appendage. Other lettering as in figures 1 and 2. U. S. National Museum, Catalogue No. 57678.

*Waptia fieldensis* Walcott .......................................... 181

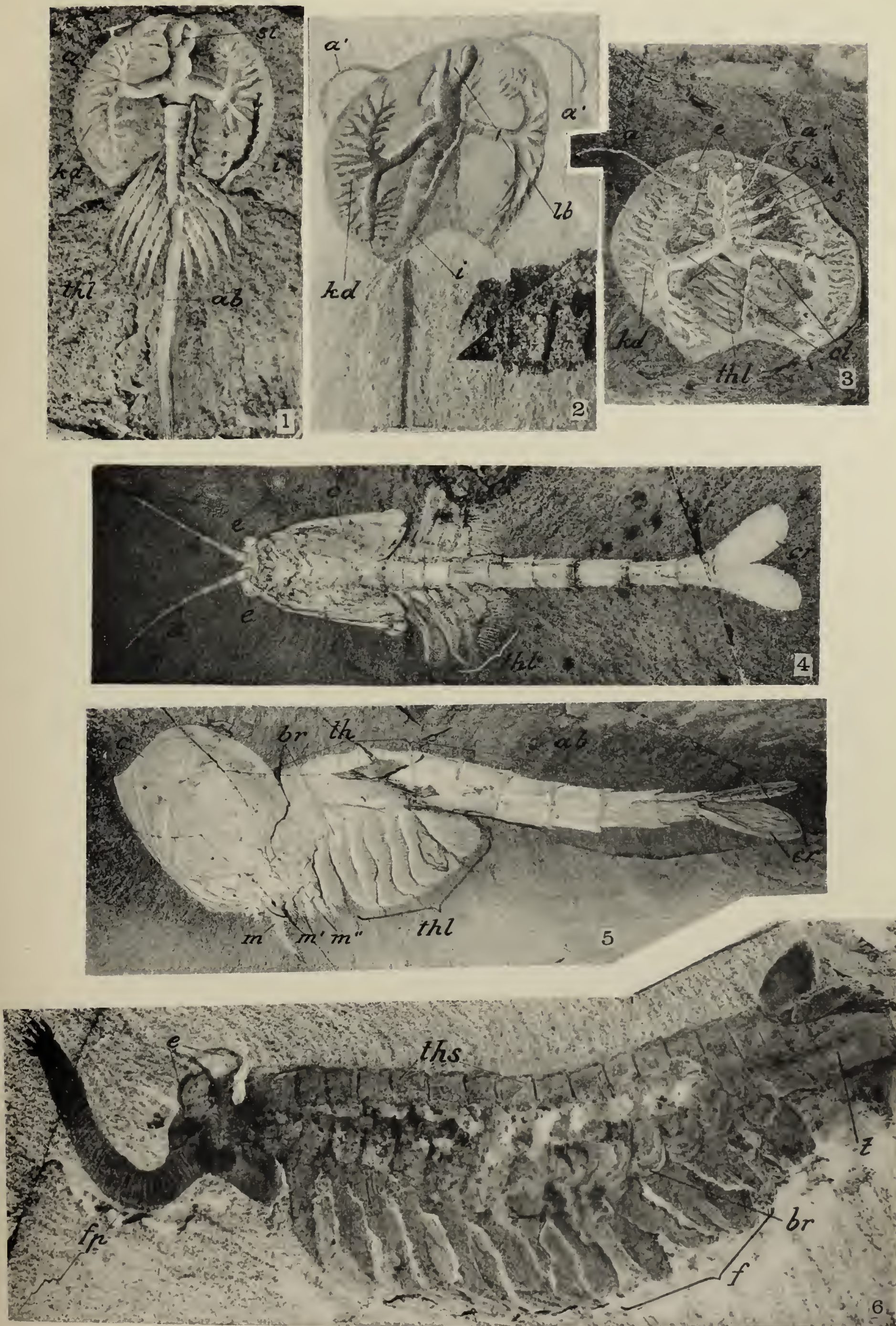
FIG. 4. (×1.5.) Dorsal view of a specimen flattened on the shale. c = carapace, e = eye, a′ = antennæ, thl = thoracic legs, cr = caudal rami. U. S. National Museum, Catalogue No. 57681.

5. (×2.) Side view with carapace (c) pushed over forward so as nearly to reverse the position of the dorsal line. th = thoracic segments, thl = thoracic legs, ab = abdominal segments, cr = caudal rami, m = mandible, m′ = maxillula, m″ = maxilla, br = gill lobe. U. S. National Museum, Catalogue No. 57682.

*Opabinia regalis* Walcott (see pl. 28, fig. 1) ............................ 167

FIG. 6. (×2.) Lateral view of the type specimen of the male of the species. The eyes (e) are crushed one beside the other. fp = frontal appendage, ths = trunk somites, br = gills, f = terminal lobe-like joints of thoracic legs, t = telson or terminal somite. U. S. National Museum, Catalogue No. 57683.

All of the specimens illustrated on Plate 27 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 28

PAGE

*Opabinia regalis* Walcott (see pl. 27, fig. 6) .................................... 167

FIG. 1. (×2.) Dorsal view of a male specimen, flattened in the shale, showing fp = frontal appendage, e = eye, ths = thoracic somites, i = intestine, ab = abdominal segment. U. S. National Museum, Catalogue No. 57684.

*Nathorstia transitans* Walcott .................................... 194

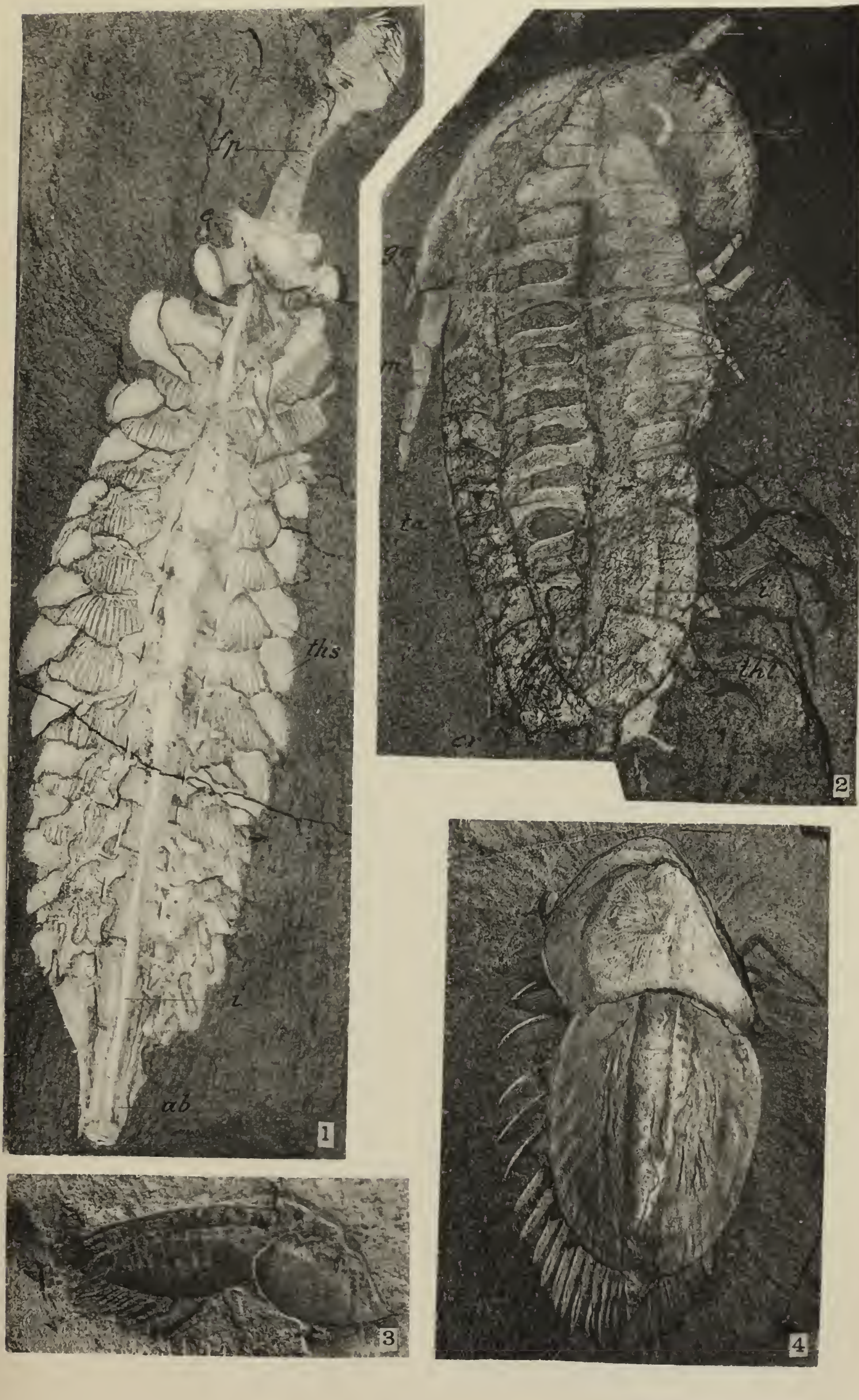
FIG. 2. (×2.) Dorsal view of the type specimen of the species. It is flattened and slightly distorted with the left side more or less crushed in towards the center. a′ = antenna, e = eye, gs = genal spine, pl = pleura of thoracic segments, m = 4 joints of leg (mandible?), ta = central or thoracic axis, i = intestine, thl = thoracic legs, cr = caudal rami. U. S. National Museum, Catalogue No. 57685.

*Naraoia compacta* Walcott .................................... 175

FIG. 3. (×2.) Side view of cephalo-thoracic carapace with traces of appendages showing through it. U. S. National Museum, Catalogue No. 57686.

4. (×2.) Dorsal view of specimen described. U. S. National Museum, Catalogue No. 57687.

All of the specimens illustrated on Plate 28 are from locality (35k) Middle Cambrian: 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, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 29

PAGE

*Molaria spinifera* Walcott .......................................... 200

FIG. 1. (×3.) Side view in which the thoracic pleuræ of the segments have been broken away so as to show appendages. U. S. National Museum, Catalogue No. 57688.

2. (×3.) Dorsal view. U. S. National Museum, Catalogue No. 57689.

3. (×3.) Ventral view, showing some of the gills (br), liver (k) beneath the cephalic shield, and alimentary (al) canal. The ends of the thoracic segments (ths) are marked by fine lines. U. S. National Museum, Catalogue No. 57690.

4. (×3.) Dorsal view. Minute appendages show from beneath abdominal segment, also setiferous joints of the thoracic legs. U. S. National Museum, Catalogue No. 57691.

5. (×3.) Dorsal view. a′ = antennules. U. S. National Museum, Catalogue No. 57692.

*Habelia optata* Walcott .......................................... 202

FIG. 6. (×2.) Side view of a specimen flattened in the shale. Three of the setiferous legs near the head have been pushed out above the body. U. S. National Museum, Catalogue No. 57693.

*Yohoia tenuis* Walcott .......................................... 172

FIG. 7. (×2.) Side view showing the pleuræ of the thorax and traces of the appendages of the head. U. S. National Museum, Catalogue No. 57694.

8. (×3.) Specimen with abdomen and expanded rami forming a swimming tail. U. S. Museum, Catalogue No. 57695.

9. (×2.) Fragment of thorax and head, showing segmentation of thorax, eyes, antennule in center and part of a large antenna. The latter has its spiniferous terminal joint turned down towards the eye on the right side (upper in drawing). U. S. National Museum, Catalogue No. 57696.

10 and 11. (×2.) Small specimens seen from above. U. S. National Museum, Catalogue Nos. 57697 and 57698.

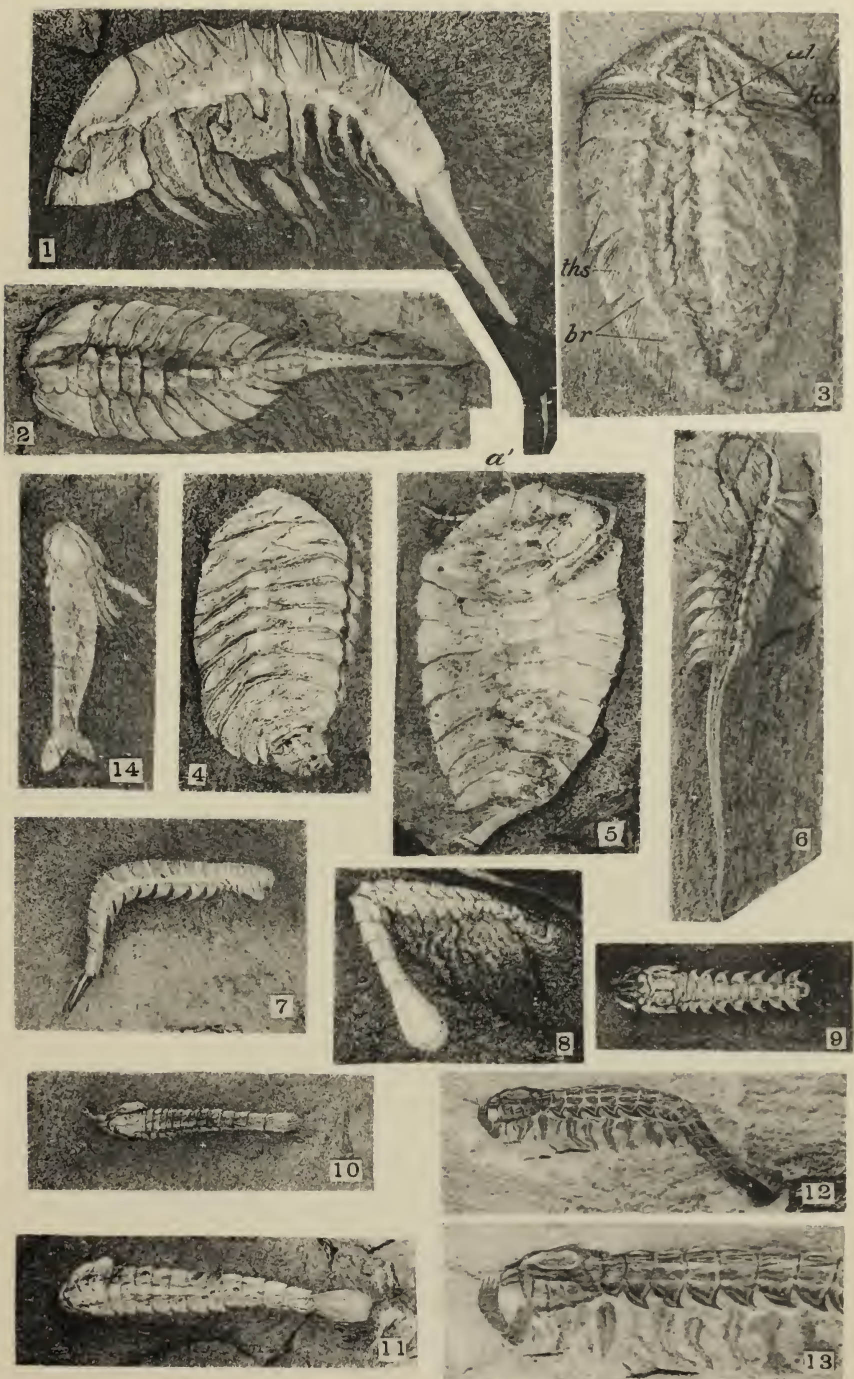
12. (×2.) Side view of a specimen showing segmentation of head and thorax; antenna and portions of thoracic appendages. U. S. National Museum, Catalogue No. 57699.

13. (×3.) The anterior half of figure 12, still further enlarged.

*Yohoia plena* Walcott .......................................... 173

FIG 14. (×3.) A small specimen showing the general form of the species. Better specimens have been found since the plate was prepared and will be illustrated in a future paper. U. S. National Museum, Catalogue No. 57700.

All of the specimens illustrated on Plate 29 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 30

PAGE

*Bidentia difficilis* Walcott ........................................ 174

Fig. 1. (×2.) Side view of a flattened specimen that has been injured by water percolating through the shale. The antennæ (a′) are fairly well shown. U. S. National Museum, Catalogue No. 57701.

*Emeraldella brocki* Walcott ........................................ 203

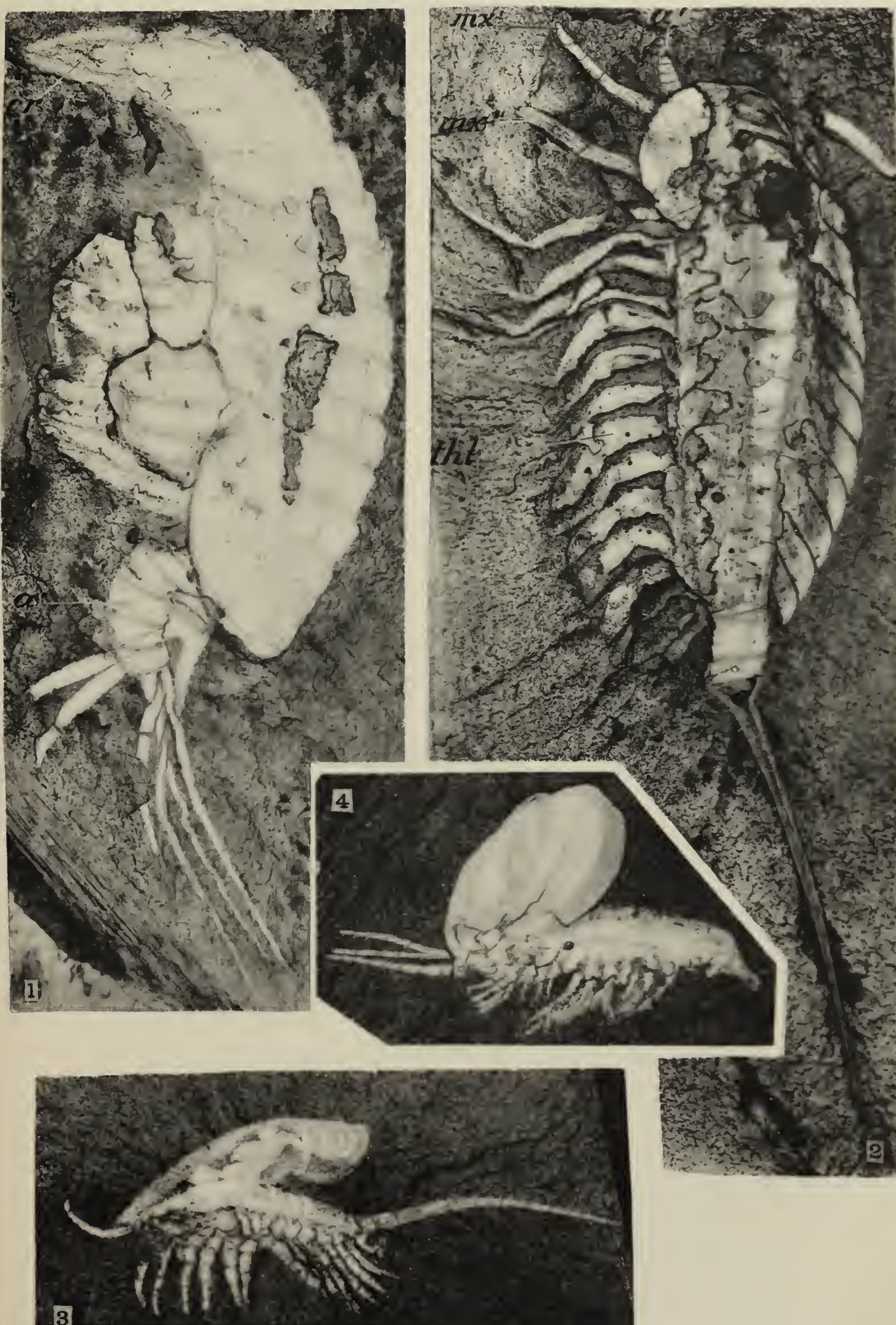
Fig. 2. (×2.) A specimen flattened out so as to give a partial view of the head and body and a fine profile view of the abdomen and telson. e = eye, a′ = antenna, mx′ = maxillula, mx″ = maxilla, thl = thoracic legs, i = alimentary canal. U. S. National Museum, Catalogue No. 57702.

*Burgessia bella* Walcott (see pl. 27) ........................................ 177

Fig. 3. (×3.) Profile view of a specimen with carapace crushed and distorted. U. S. National Museum, Catalogue No. 57679.

4. (×3.) Side view of another specimen in which the carapace has been crowded off the body and out of shape. U. S. National Museum, Catalogue No. 57680.

The specimens illustrated on Plate 30 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 31

PAGE

*Hymenocaris perfecta* Walcott .................................... 183

FIG. 1. (×2.) Side view of the right valve, showing the form of the valve, abdomen, and numerous appendages. Adductor muscle scar (ad), intestine (i), thoracic legs (thl), gills (br). U. S. National Museum, Catalogue No. 57703.

2. (×1.5.) Dorsal view of a specimen from which the test has been exfoliated. This shows the antenna (a), adductor muscle scars (ad), intestine (i), and traces of the basal joints of the legs. U. S. National Museum, Catalogue No. 57704.

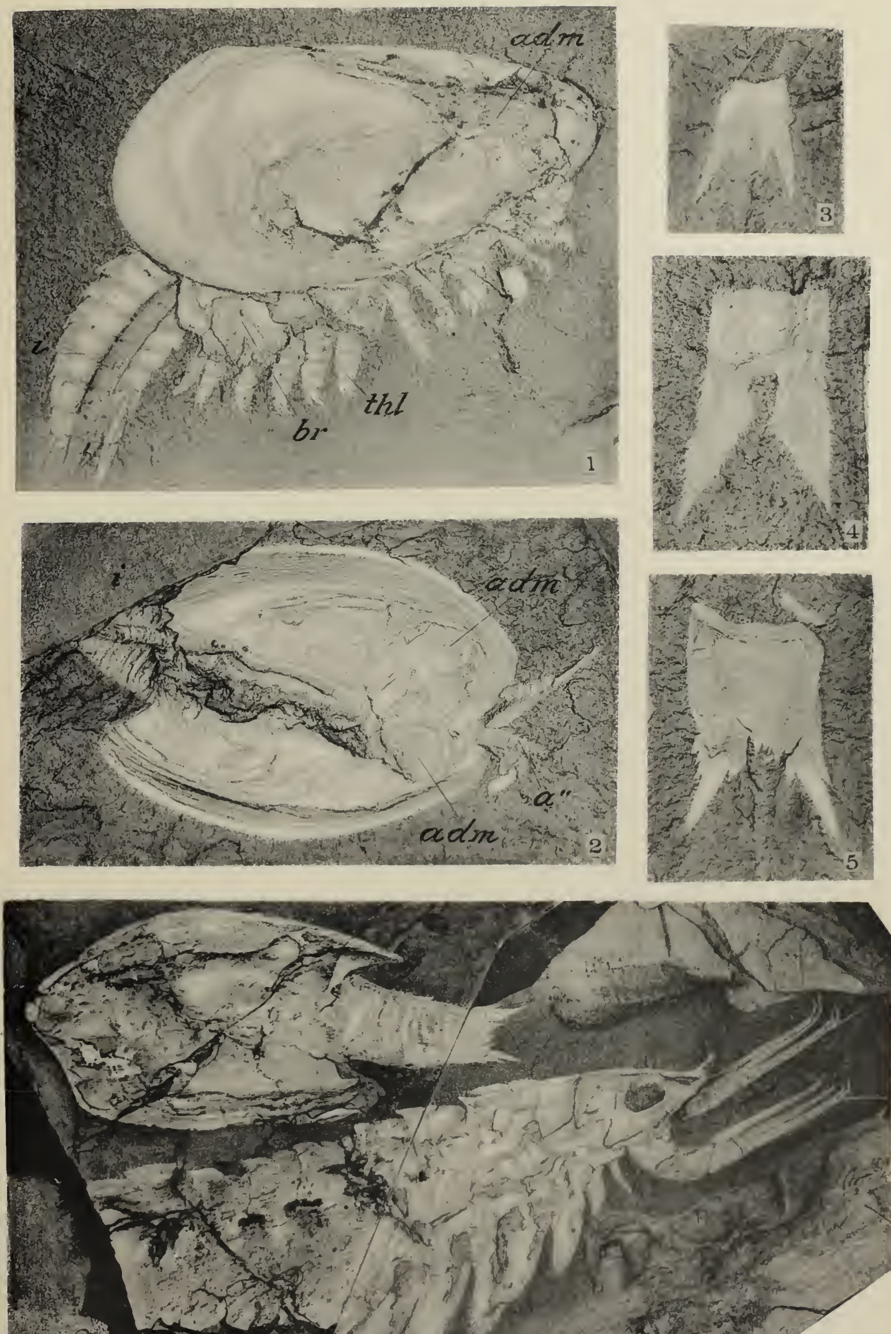
3, 4, and 5. (×2.) Illustrations of the posterior end of the abdomen with cercopods. U. S. National Museum, Catalogue Nos. 57705, 57706, and 57707.

6. Specimen in upper left hand corner of figure. (Natural size.) Dorsal view of a crushed speicmen showing the carapace, abdomen, and cercopods. U. S. National Museum, Catlogue No. 57708.

*Leanchoilia superlata* Walcott .................................... 170

FIG. 6. Lower specimen. (Natural size.) Side view of the type and only specimen known of the species and genus. U. S. National Museum, Catalogue No. 57709.

All of the specimens illustrated on Plate 31 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 32

PAGE

*Hymenocaris obliqua* Walcott .................................. 185

Fig. 1. (Natural size.) Side view of the type specimen of the species, showing carapace, abdomen, and cercopods. U. S. National Museum, Catalogue No. 57710.

2. (Natural size.) Side view of the left valve of the carapace compressed so as to shorten it. U. S. National Museum, Catalogue No. 57711.

3. (Natural size.) Side view of a right valve that has been compressed so as to shorten it a little. U. S. National Museum, Catalogue No. 57712.

*Hymenocaris ? circularis* Walcott.................................. 184

Fig. 4. (×3.) A somewhat distorted valve with a number of legs projecting below its margin. U. S. National Museum, Catalogue No. 57713.

*Hymenocaris ovalis* Walcott .................................. 185

Fig. 5. (×3.) Side view of the right valve showing the general form. U. S. National Museum, Catalogue No. 57714.

6. (×3.) Dorsal view of a carapace, abdomen, and two cercopods. U. S. National Museum, Catalogue No. 57715.

*Hymenocaris ? parva* Walcott .................................. 185

Fig. 7. (×4.) Type specimen of the species and genus, showing several appendages and the abdomen turned forward on the carapace. U. S. National Museum, Catalogue No. 57716.

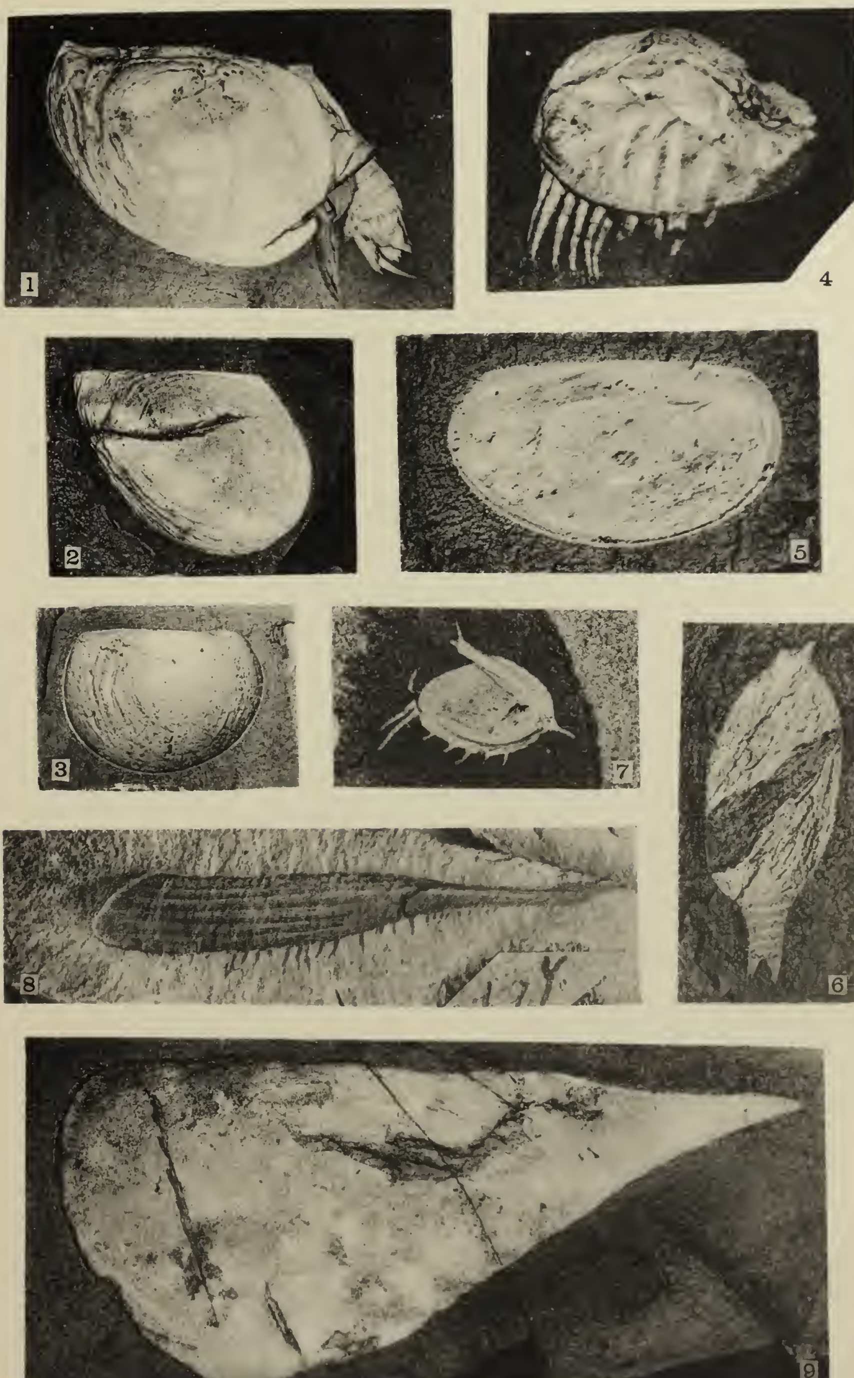
*Fieldia lanceolata* Walcott .................................. 188

Fig. 8. (×2.) Side view, left valve, of the type specimen, illustrating characters described. U. S. National Museum, Catalogue No. 57717.

*Hurdia victoria* Walcott .................................. 186

Fig. 9. (Natural size.) Side view of the left valve. U. S. National Museum, Catalogue No. 57718.

All of the specimens illustrated on Plate 32 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.



MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 33

PAGE

*Carnarvonia venosa* Walcott .......................................... 189

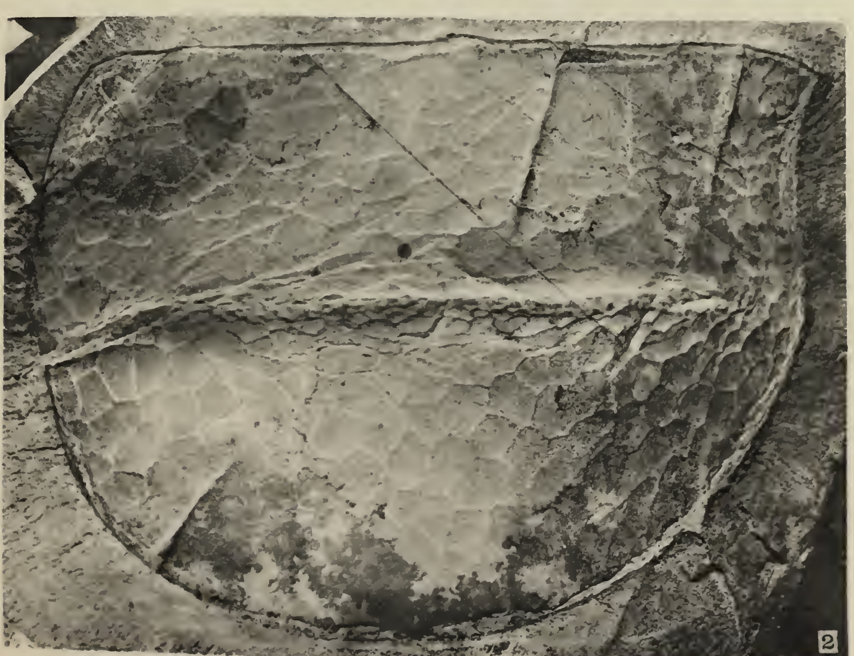
FIG. 1. (Natural size.) Dorsal view of the two valves of the carapace flattened on the surface of the shale. The adductor muscle scar (adm) shows through the test, and the fine venation extending from the head portion backward is beautifully shown. U. S. National Museum, Catalogue No. 57719.

The specimen illustrated by fig. 1 is from locality $\left(\frac{35k}{10}\right)$ Middle Cambrian: Burgess shale member of the Stephen formation (about 75 feet above the phyllopod bed near the base of the shale), 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.

*Tuzoia retifera* Walcott .......................................... 187

FIG. 2. (Natural size.) View of flattened right valve showing reticulate surface markings. U. S. National Museum, Catalogue No. 57720.

The specimen illustrated by fig. 2 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.


MIDDLE CAMBRIAN CRUSTACEANS

## DESCRIPTION OF PLATE 34

PAGE

*Hurdia triangulata* Walcott .............................................. 186

Fig. 1. (Natural size.) Typical form of valve (right). U. S. National Museum, Catalogue No. 57721.

*Odaraia alata* Walcott .............................................. 188

Fig. 2. (Natural size.) A right valve with the end of the abdomen and two cercopods projecting from posterior end. The latter are evidently displaced. U. S. National Museum, Catalogue No. 57722.

*Anomalocaris gigantea* Walcott .............................................. 180

Fig. 3. (Natural size.) Portion of the abdomen showing segments and appendages. U. S. National Museum, Catalogue No. 57723.

All of the specimens illustrated on Plate 34 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




MIDDLE CAMBRIAN CRUSTACEANS

# INDEX

NOTE.—The first reference to each of the species described gives the page upon which the description begins and the figure references. References to the description of certain parts or features of a species are as a rule only given in the index if the description occurs outside of the detailed description of the species. For instance: the description of the pygidium of a certain species will be found in the description of that species and there will be no specific reference in the index to the pygidium unless it is described or discussed at some other point in the paper.

The references in heavy-faced type refer to the pages upon which the species are described.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 7



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 7.—CAMBRO-ORDOVICIAN BOUNDARY IN BRITISH COLUMBIA WITH DESCRIPTION OF FOSSILS

WITH PLATE 35

BY

CHARLES D. WALCOTT

(PUBLICATION 2075)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
MARCH 8, 1912

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 7

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(With Plate 35)

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PLATE 35



In a preliminary description of the Mount Bosworth Section of British Columbia[2] I placed the summit of the Upper Cambrian at the top of the Sherbrooke formation, it being stated that the highest beds on the summit of Sherbrooke Ridge contained obscure fossils that suggest *Ophileta,* also that the strata near the summit are much broken up owing to a fault line that crosses the ridge. During the summer of 1911 Mr. J. A. Allan, of the Geological Survey of Canada, and Mr. L. D. Burling, of the United States National Museum, visited the locality on the summit of Sherbrooke Ridge and found specimens of *Lingulella isse* (Walcott) and a species of *Ptychoparia* in the upper beds, that correlates the upper limestones with the Cambrian.

[1] Published with the permission of the Director of the Geological Survey of Canada and the approval of Mr. John A. Allan.

[2] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 204.

During the past three years Mr. Allan has been making a detailed areal survey of the Ice River Valley region east of Leanchoil on the Canadian Pacific Railway, British Columbia. He found a series of thin-bedded gray argillaceous and calcareous slates, weathering reddish, yellowish, and fawn; underlain by grayish calcareous slates, shales, and argillites, highly cleaved and phyllitic; and weathering greenish, grayish, reddish, yellowish, and buff, about 2500 feet in thickness, which he has named the *Chancellor* formation and which he places above the *Sherbrooke* formation limestones as developed on Mount Dennis, south of Field.

Above the *Chancellor* formation Mr. Allan has named a series of massive blue limestones, with included shaly bands, the *Ottertail* formation, assigning to it a thickness of 1550+ feet. In this limestone he collected a *Lingulella* very much like *Lingulella isse* Walcott, an undetermined species of *Agnostus*, and a rather large but undetermined species of *Ptychoparia*.

Above the *Ottertail* formation there is a great series of interbedded cherts, cherty limestones, dolomitic limestones, and siliceous and calcareous slates and shales, forming the main portion of Mount Goodsir. This great series over six thousand feet in thickness he designates as the *Goodsir* formation. In the lower portion of it he collected several species of fossils which were sent to me for study. In addition to an obscure species of *Agnostus* and one small *Obolus* four species have been identified and named as follows:

*Obolus mollisonensis*, new species
*Lingulella ? allani*, new species
*Lingulella moosensis*, new species
*Ceratopyge canadensis*, new species

The discovery of fairly well characterized specimens of the trilobitic genus *Ceratopyge* associated with brachiopods of the same general type as those found in the *Ceratopyge* shale of Sweden is most important, as it gives the first definite suggestion of a base for the Ordovician in the section along the Canadian Pacific Railway west of the Continental Divide. In Sweden the *Ceratopyge* shale and limestone are now by general assent placed at the base of the Ordovician, and with our knowledge of the stratigraphy of the upper portion of this section as determined by Mr. Allan I am inclined to agree with him in placing, at least tentatively, the boundary between the Cambrian and Ordovician at the summit of the Ottertail limestone and the base of the Goodsir formation.

During the season of 1911 Mr. L. D. Burling examined the eastern side of the Van Horne Range southwest of Otto Creek, west-northwest of Field, and found on the west side of the amphitheater about 4 miles southwest of the mouth of Otto Creek, in the shales of the Goodsir formation and within two hundred feet of the Ottertail limestone, three species of fossils, two of which, *Lingulella moosensis* and *Ceratopyge canadensis,* are identical with species found at about the same horizon in the Ice River region by Mr. Allan. The third species is probably identical with *Lingulella ? allani* of the same formation.

The broad question of the Cambro-Ordovician boundary in other sections of North America is one that is still in process of adjustment owing to the absence of detailed information as to the boundaries between formations and the character of the faunas in the formations.

In the monograph of the Cambrian Brachiopoda,[1] now in press, several formations have been included in the Cambrian or in "passage beds" between the Cambrian and Ordovician that will ultimately be classified with the Ordovician, or, as in the case of the Missouri section[2] of the Mississippi region, placed in a terrane between the Cambrian and Ordovician.

### OBOLUS MOLLISONENSIS, new species

Plate 35, figs. 10-12

In external form this shell is similar to *Obolus* (*Bröggeria*) *salteri*[3] of the Upper Cambrian and Lower Ordovician of northwestern Europe. It differs in having the area and vascular markings of *Obolus* instead of the very characteristic interiors of *O.* (*B.*) *salteri.*

The surface is marked by fine, irregular, concentric lines and striæ of growth, and may be slightly roughened by the irregular lines forming a minute, very irregular pseudo-reticulated surface.

The largest ventral valve has a length of 7 mm. and a width of about 8 mm. The average size is about 5 mm. in length.

*Formation and locality.*—Lower Ordovician: Goodsir formation (lower part), west side of Moose Creek Valley on east slope of the north ridge of Mount Mollison, elevation 6550 feet, about 10 miles in an air line southeast of Leanchoil on the Canadian Pacific Railway, British Columbia.

Collection, J. A. Allan.

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[1] Monogr. U. S. Geol. Survey, Vol. 51, 1912. [In press.]

[2] Ulrich, Bull. Geol. Soc. America, 1911, Vol. 22, pl. 27.

[3] Cambrian Brachiopoda, Monogr. U. S. Geol. Survey, Vol. 51, 1912, pl. 13, figs. 1, 1a-n; pl. 15, figs. 4, 4a-d; and p. 424. (In press.)

### LINGULELLA MOOSENSIS, new species

Plate 35, figs. 1-6

This fine species is quite abundant in several localities. In size and outline of the valves it is not unlike *Lingulella davisi* (McCoy)[1] of the Ordovician and Upper Cambrian of England and Wales. It differs in being proportionately more elongate and acuminate in the outline of the ventral valve. It may also be compared with *Lingulella ampla* (Owen).[2]

Two of the largest shells are represented by figures 1 and 6. The form of the valves is best shown by figures 3 and 5.

The surface is marked by fine concentric lines with stronger lines of growth at irregular intervals.

*Formation and locality.*—Lower Ordovician: Goodsir formation (in lower part), Ice River Valley at head of East Fork, elevation 8000 feet, on the north side of the amphitheater near the top of the ridge overlooking Ottertail Valley; also on northwest side of Mollison Creek, elevation 4800 feet, west slope of Mount Mollison, about 6 to 8 miles east and southeast of Leanchoil on the Canadian Pacific Railway, British Columbia, Canada.

The species also occurs on the west side of Moose Creek Valley on east slope of the north ridge of Mount Mollison, elevation 6550 feet, and on west slope of Mount Mollison, elevation 4800 feet, at northwest side of Mollison Creek, about 4 miles southeast of the Ice River Valley as mentioned above. On the east side of Moose Creek near the head of the east fork of the creek it occurs at an elevation of 8100 feet.

Collection, J. A. Allan.

Mr. L. D. Burling found this species at about the same horizon above a cliff of the Ottertail limestone four miles southwest of the mouth of Otto Creek which flows into the Amiskwi River west-northwest of Field, British Columbia, Canada.

### LINGULELLA ? ALLANI Walcott

Plate 35, figs. 7-9

In external form this species approaches very closely to *Dicellomus prolificus* Walcott[3] from the Middle Cambrian limestones of Utah. It also has a longitudinal median depression on the ventral valve similar to that of *Lingulella buttsi* Walcott.[4]

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[1] Cambrian Brachiopoda, Monogr. U. S. Geol. Survey, Vol. 51, 1912, pl. 31, figs. 6, 6a-h.

[2] Idem, pl. 28.

[3] Smithsonian Misc. Coll., Vol. 53, No. 3, 1908, pl. 8, figs. 3 and 3a.

[4] Idem, pl. 8, fig. 6.

*Dimensions.*—The average length is about 6 mm. An uncompressed specimen of the ventral valve 6 mm. in length has a width of 5 mm., with a depth of about 1 mm. The dorsal valve is slightly shorter in proportion to the width.

*Surface.*—The surface is marked by fine concentric lines of growth and a few stronger concentric ridges of growth.

*Observations.*—There are two or three very imperfect interiors of the ventral valve that appear to have the characters of the interior of *Lingulella,* but it may be that more perfect specimens will prove that the species is more nearly related to *Obolus* (*Fordinia*)[1] than to *Lingulella.*

*Formation and locality.*—Lower Ordovician: Goodsir formation (lower part), west slope of Moose Creek valley, on the east slope of the north ridge of Mount Mollison, elevation 6550 feet, about 10 miles in an air line southeast of Leanchoil on the Canadian Pacific Railway; this species is also found at about the same horizon in Ice River Valley at head of East Fork, elevation 8000 feet, about 4 miles northwest of the Moose Creek locality, British Columbia, Canada.

Collection, J. A. Allan.

Mr. L. D. Burling found this species, which is somewhat doubtfully identified, at about the same horizon above a cliff of the Ottertail limestone four miles southwest of the mouth of Otto Creek which flows into the Amiskwi River west-northwest of Field, British Columbia, Canada.

### Genus CERATOPYGE Corda

### CERATOPYGE CANADENSIS, new species

Plate 35, figs. 13-22

This species differs from *Ceratopyge forficula* Sars[2] in the greater length of the frontal limb of the cranidium, longer palebral lobes, and narrower fixed cheeks. The pygidium differs most in having a shorter median lobe, broader border, and the side spine springing from the first instead of the second segment.

The thorax of *C. canadensis* has ten transverse segments with a strong transverse furrow on each segment that terminates on each pleural lobe in a blunt point about two-thirds the distance from the median lobe to the slightly falcate ends of each segment.

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[1] Smithsonian Misc. Coll., Vol. 53, No. 3, 1908, p. 64.

[2] Moberg and Segerberg, 1906, Medd. från Lunds Geol. Fältklubb, Ser. B, No. 2 (Aftryck ur K. Fysiografiska Sällskapets Handl., N. F., Bd. 17), pl. 5, figs. 2-5.

The strong lateral spine on each side of the pygidium is a continuation of the first segment instead of the second as in *C. forficula* Sars. In view of the close similarity of the cranidium in the two species, I do not consider the difference in position of the pygidial spine as more than of specific value.

*Formation and locality.*—Lower Ordovician: Goodsir formation (lower part), at northwest side of Mollison Creek, elevation 4800 feet, on west slope of Mount Mollison; Ice River Valley, about 10 miles southeast of Leanchoil; west slope of Moose Creek Valley on the east slope of the north ridge of Mount Mollison, elevation 6550 feet; Ice River Valley at head of East Fork, elevation 8000 and 8100 feet, on the north side of the amphitheater near the top of the ridge overlooking the Ottertail Valley, about 8 miles southwest of Leanchoil on the Canadian Pacific Railway, British Columbia, Canada.

Collection, J. A. Allan.

Mr. L. D. Burling found this species at about the same horizon above a cliff of the Ottertail limestone four miles southwest of the mouth of Otto Creek which flows into the Amiskwi River west-northwest of Field, British Columbia, Canada.

## DESCRIPTION OF PLATE 35

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FIG. 1. (Natural size.) Interior of a ventral valve, showing a trace of the pedicle furrow. U. S. National Museum, Catalogue No. 58342.

2. (Natural size.) Matrix of the specimen illustrated by fig. 1. U. S. National Museum, Catalogue No. 58342.

3. (× 2.) Interior of a ventral valve that appears not to have been distorted. U. S. National Museum, Catalogue No. 58343.

4. (× 2.) Partly exfoliated ventral valve, that is somewhat broader posteriorly than the specimen represented by fig. 3. U. S. National Museum, Catalogue No. 58344.

5. (× 2.) Imperfect interior of a dorsal valve. U. S. National Museum, Catalogue No. 58345.

6. (Natural size.) Interior of a dorsal valve shortened by compression. U. S. National Museum, Catalogue No. 58346.

All of the specimens of this species are very much compressed and flattened in the shale.

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FIG. 7. (× 3.) View of exterior of ventral valve and side outline. U. S. National Museum, Catalogue No. 58347.

8. (× 4.) Exterior view and side outline of a broader form of the ventral valve than that represented by fig. 7. U. S. National Museum, Catalogue No. 58348.

9. (× 4.) View of exterior and side outline of a dorsal valve associated with the specimen represented by fig. 8. U. S. National Museum, Catalogue No. 58349.

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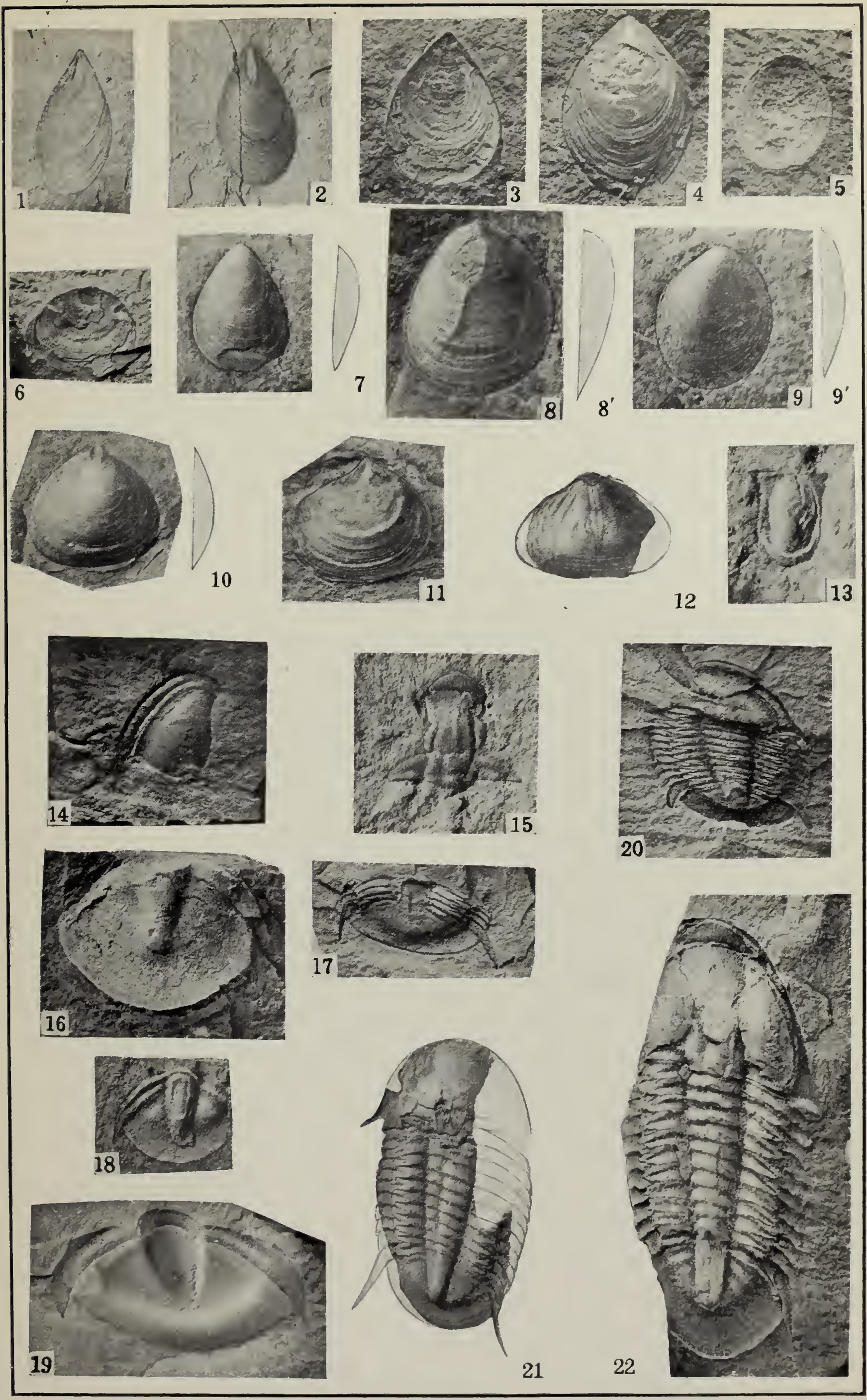
FIG. 10. (× 3.) Exterior view and side outline of ventral valve. U. S. National Museum, Catalogue No. 58350.

11. (× 3.) Partly exfoliated ventral valve, showing the thickness of the shell. U. S. National Museum, Catalogue No. 58351.

12. (× 3.) A somewhat distorted and exfoliated dorsal valve, showing the area and central muscle scars. U. S. National Museum, Catalogue No. 58352.




BRACHIOPODS AND TRILOBITES

## DESCRIPTION OF PLATE 35 (Continued)



FIG. 13. (× 3.) A somewhat imperfect hypostoma associated with this species. U. S. National Museum, Catalogue No. 58353.

14. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58354.

15. (× 2.) Cranidium flattened in the shale, but preserving many of its characters. U. S. National Museum, Catalogue No. 58355.

16. (Natural size.) An imperfect pygidium flattened in the shale. U. S. National Museum, Catalogue No. 58356.

17. (Natural size.) Imperfect pygidium, showing a lateral spine on each side. U. S. National Museum, Catalogue No. 58357.

18. (× 2.) A small pygidium, showing the anterior segment extended into a spine. U. S. National Museum, Catalogue No. 58358.

19. (Natural size.) Matrix of a pygidium with its anterior segment. U. S. National Museum, Catalogue No. 58359.

20. (Natural size.) An entire exfoliated dorsal shield very much shortened by compression. U. S. National Museum, Catalogue No. 58360.

21. (Natural size.) An imperfect dorsal shield, somewhat distorted, but still preserving what was probably its natural form and outline. U. S. National Museum, Catalogue No. 58361.

22. (Natural size.) An imperfect dorsal shield elongated by lateral compression. U. S. National Museum, Catalogue No. 58362.

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## INTRODUCTION

The genus *Olenopsis* has received considerable attention from authors who have written on the stratigraphy and paleontology of the Cambrian strata of the Island of Sardinia, but up to the present it has not been recognized in any Cambrian section where its stratigraphic position in relation to the *Olenellus* and *Paradoxides* faunas could be definitely determined.

The presence of the genus in America has not been announced, although a number of the cranidia of species referred to *Ptychoparia* were very much like the cranidia of *Olenopsis*.

The three species described in this paper give the genus a recognized stratigraphic position over a wide area in North America, and from this it is thought probable that the type species, *Olenopsis zoppii,* occurs in the Cambrian series of Sardinia beneath the Middle Cambrian *Paradoxides* beds, either in passage beds from the Lower to the Middle Cambrian, or in the upper beds of the Lower Cambrian.

Dr. J. F. Pompeckj considered it probable that *Olenopsis* was derived from *Paradoxides,*[1] but with our present information I am inclined to consider that *Olenopsis* is more likely to be a form intermediate between *Holmia* (restricted) and *Paradoxides,* or that the two genera are descendent from the *Holmia* type of the Mesonacidæ.[2] We do not appear to have evidence that *Olenopsis* is stratigraphically above *Paradoxides*. On the contrary it is below the horizon of the Middle Cambrian in Pennsylvania and it is in the passage beds at

[1] *Paradoxides*-Stufe von La Cabitza in Sardinien. Zeitschr. Deutschen geol. Gesellsch., Bd. 53, Heft 1, 1901, p. 19.

[2] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pp. 253 and 254.

the base of the Middle Cambrian in Montana, Alberta, and British Columbia.

*Protolenus* Matthew[1] occurs in the passage fauna between the Lower and Middle Cambrian,[2] and the genus has been compared to *Olenopsis*,[3] but I agree with Doctor Pompeckj[4] that there is not much in common between them, so far as can be demonstrated by the means of comparison available.

### Genus OLENOPSIS Bornemann

*Olenopsis* Bornemann, 1891, Nova Acta Kais. Leop.-Carol. Deutsch. Akad. Naturforscher, Bd. 56, No. 3, p. 450. (Defines and discusses genus.)

*Olenopsis* Matthew, 1895, Trans. New York Acad. Sci. Vol. 14, pp. 144-145. (Compares *Olenopsis* and *Protolenus*.)

*Olenopsis* Matthew, 1899, Bull. Nat. Hist. Soc. New Brunswick, No. 17, p. 141. (Repeats observations in paper of 1895.)

*Olenopsis* Pompeckj, 1901, Zeitschr. Deutschen geol. Gesellsch., Bd. 53, Heft 1, p. 19. (Compares *Olenopsis* and *Paradoxides*, etc.)

*Genotype.*—*Olenus zoppii* Meneghini [1888, Memoire R. Comitato Geol. d'Italia, Vol. 3, Pt. 2; Pal. dell' Iglesiente Sardegna, p. 7].

*Stratigraphic range.*—The type species of the genus occurs in an argillaceous shale and associated sandstones. Their thickness is undetermined owing to the folding and disturbance of the strata.

*Olenopsis americanus* (p. 243) ranges through about 10 feet (3 m.) of shale and thin-bedded sandstones of the upper portion of the Lower Cambrian or passage beds to the Middle Cambrian.

*Olenopsis agnesensis* (p. 242) is limited to a band of siliceous shale about 10 feet (3 m.) thick that occurs just above the *Olenellus canadensis* zone[5] and beneath the Middle Cambrian.

*Olenopsis roddyi* (p. 244) has been found only at one locality as a single specimen in a silico-argillaceous shale of the upper horizon of the Lower Cambrian in association with *Olenellus thompsoni*.

It thus appears that the known stratigraphic range of the genus is from the upper zone of the Lower Cambrian into passage beds leading up to the Middle Cambrian.

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[1] Trans. New York Acad. Sci., Vol. 14, 1895, pp. 144-145. Bull. Nat. Hist. Soc. New Brunswick, No. 17, 1899, p. 142.

[2] Proc. Washington Acad. Sci., Vol. 1, 1900, pp. 320, 321, 325-327.

[3] Matthew, 1899, Bull. Nat. Hist. Soc. New Brunswick, No. 17, p. 17.

[4] Zeitschr. Deutschen geol. Gesellsch., Bd. 53, Heft 1, 1901, p. 46.

[5] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, p. 318.

*Geographic distribution.*—The type species, *Olenopsis zoppii,* occurs on the Island of Sardinia at Canal Grande and vicinity. In North America *Olenopsis roddyi* is found on the eastern side of the Continent near Lancaster in the central part of Pennsylvania. On the western side of the Continent *Olenopsis americanus* is found in the northern central part of Montana, and *Olenopsis ? agnesensis* on the line of the Continental Divide near the Canadian Pacific Railway in both Alberta and British Columbia. It is quite probable that if entire specimens of a number of species now represented by cranidia and referred to the genus *Ptychoparia* were available for study other species of *Olenopsis* would be found at approximately the same stratigraphic horizon.

*Observations.*—Doctor Bornemann distinguishes *Olenopsis* from *Olenus* on account of its having a small, rounded tail-shield with unsegmented axis; by the particularly semicircular outline of the cephalon, the conic, nearly smooth glabella, and 14 or 15 body segments; from *Liostracus,* by the difference in shape of the pygidium, although the similarity of the form of the cephalon is very great.

Among American genera of the family Olenidæ a number of species of the genus *Ptychoparia* have a cephalon more or less closely resembling that of *Olenopsis,* but the marked variation in the thoracic segments and pygidium serves to clearly separate them.

Doctor Bornemann has given a very detailed description of *Olenopsis* and the Sardinian species referred to it, also numerous illustrations. In consideration, however, of the fact that his work is not readily accessible to many students, I am reproducing photographs of a number of specimens of *Olenopsis zoppii,* collected at the type locality, that are now in the collections of the United States National Museum. These will enable the student to make direct comparisons between Sardinian and American species.

I am in doubt about referring *Olenopsis ? agnesensis* to *Olenopsis* on account of the character of the pygidium. In *Olenopsis zoppii* and *Olenopsis roddyi* the pygidium is elongate and slightly marked by transverse furrows on the axis, whereas in *Olenopsis ? agnesensis* the axis of the pygidium is transverse and very distinctly divided into segments by transverse furrows. The entire assemblage of characters in the cephalon and thorax in *Olenopsis ? agnesensis* is such, however, that it is included in the genus pending a study of a considerable group of species that have in each characters of *Olenus, Ptychoparia, Liostracus* and *Olenopsis.*

**OLENOPSIS ZOPPII Meneghini**

Plate 36, figs. 3-7

*Olenus zoppii* MENEGHINI, 1882, Proc. Verb. Soc. Tosc. Sci. Nat., July 2, 1882; Fauna Cambriana dell' Iglesiente, p. 163: Note alla Fauna Cambriana, etc. (Idem, Nov., 1883.)

*Conocephalites* sp. MENEGHINI, 1882, Fauna Cambriana dell' Iglesiente.

*Olenus zoppii* MENEGHINI, 1888, Mem. Real. Comitato Geol. Italia, Vol. 3, Pt. 2, Pal. dell' Iglesiente Sardegna, p. 7.

*Olenopsis zoppii* BORNEMANN, 1891, Nova Acta Kais. Leop.-Carol. Deutsch. Akad. Naturforscher, Bd. 56, No. 3, p. 459.

References to the very full description and illustration of this species by Doctor Bornemann are given under the genus *Olenopsis.*

**OLENOPSIS ? AGNESENSIS, new species**

Plate 36, fig. 2

*Olenopsis agnes* WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 214. (Name printed by error as *agnes* in lists of fossils from No. 3 of the Mount Whyte formation.)

The cephalon of this species is much like that of *Olenopsis zoppii,* except that the fixed cheeks are broader and the palpebral lobes smaller. The thoracic segments are of the same character, except that the outward extensions of the pleural lobes are shorter and broader. The pygidium is more transverse and it has the axial lobe divided into segments by four transverse furrows, that are continued out as faint furrows on the pleural lobes.

*Olenopsis ? agnesensis* differs from *Olenopsis roddyi* in its thoracic segments and pygidium, and presumably in its cephalon. It agrees with *Olenopsis americanus* in having less prolonged extensions of the pleuræ of the thoracic segments, but differs in the details of the cephalon. The most marked difference is in the character of the pygidium which is more like that of *Ptychoparia* or *Liostracus* than that of *Olenopsis.* The greatest point of similarity in the four species is the finely reticulate surface formed of irregular, very minute ridges.

*Formation and locality.*—Lower Cambrian: (35e) Dark gray siliceous shale forming the lower two feet of 5 (64 feet) of the Lakes Louise and Agnes Section, amphitheater between Popes Peak and Mount Whyte, south of Lake Agnes, south of Laggan, on the Canadian Pacific Railway in western Alberta; (35m) Mount Whyte formation (*Albertella* zone) 3 miles southwest of the head of Lake Louise, on east slope of Mount Whyte, Alberta; and (57t and 58q) about 250 feet below the top of the Lower Cambrian in gray siliceous shale (102 feet) forming 5 of Mount Whyte formation, Mount Stephen Section, just above the tunnel, north shoulder of Mount Stephen, 3 miles east of Field, British Columbia; all in Canada.

### OLENOPSIS AMERICANUS, new species

Plate 36, figs. 8-11

*Olenopsis* ? sp., WALCOTT, 1908, Smithsonian Misc. Coll., Vol. 53, No. 5, p. 202. (Mention of genus in list of fossils from Gordon Mountain.)

This species is a rare form and is known only by a few fragments of the dorsal shield and several specimens of the cranidium. Its locality has been thoroughly worked on two occasions without securing entire specimens.

The cephalon as restored by uniting the cranidium and free cheeks, has a transverse, semicircular outline with rather strong spines at the genal angles. Marginal border rather broad, slightly flattened, and uniting at the genal angles with the well-defined, rounded posterior border. In front of the glabella the inner margin of the border curves gently backward, narrowing the frontal limb.

Glabella subconical and marked by three pairs of glabellar furrows, the anterior of which are shallow and often obscure. A shallow furrow connects the inner ends of the slightly oblique posterior pair. Occipital ring strong and separated from the glabella by a narrow, shallow occipital furrow. Dorsal furrow about glabella very distinct. Fixed cheeks broad, large, and merging posteriorly into large posterolateral limbs, and anteriorly into the narrow frontal limb. Palpebral lobes of medium size; a strong, narrow ridge extends from the front end of each lobe across the fixed cheeks to the dorsal furrow opposite the second lobe of the glabella. Free cheek large and rising rapidly from the margin to the base of the medium-sized eye.

A portion of the thorax showing 16 segments indicates that the pleural lobes were about twice as wide as the axial lobe and the pleural furrow of each segment long, strongly impressed, and extending from the inner anterior margin out to the falcate extremity of the pleura.

Pygidium unknown.

Surface formed of a fine irregular network of elevated, very narrow ridges, suggestive of the reticulated surface of the Mesonacidæ.

*Observations.*—This was the first species of this genus discovered and identified in America. I put the specimen aside in 1905 with the hope that better material might be found at about the same horizon in British Columbia. Several of the species found in association with *Olenopsis americanus* occur there in the Mount Whyte formation, notably *Acrothele colleni* Walcott, *Wimanella simplex* Walcott, and *Albertella helena* Walcott,[1] but no traces of *Olenopsis americanus* were found. The genus *Olenopsis* is there represented by *Olenopsis ? agnesensis* described in this paper. *Olenopsis americanus* differs from that species in having its palpebral lobes near the transverse median line of the cephalon; its more distinctly defined frontal border that curves slightly backward in front of the glabella; and its narrower frontal limb and, probably, several more segments in the thorax. The differences between *Olenopsis americanus* and *Olenopsis roddyi* are so marked that it will suffice to call attention to the figures illustrating them. It has many characters in common with *Olenopsis zoppii* (Meneghini) but differs in having a larger number of thoracic segments and in surface sculpture as well as minor details.

*Formation and locality.*—Lower Cambrian: (4v) shale about 200 feet (61 m.) above the uncomformable 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,[2] Gordon Creek, 6 miles (9.6 km.) from the South Fork of Flathead River, Ovando quadrangle (U. S. Geol. Survey), Powell County, Montana.

### OLENOPSIS RODDYI, new species

Plate 36, fig. 1

The general form and relative proportions of the cephalon, thorax, and pygidium are shown by the accompanying illustration, which is a reproduction of a photograph of the type specimen of the species. The cephalon and thorax have been shortened by longitudinal compression. This has materially affected the glabella by crowding back its frontal lobe so as to give it a quadrangular outline, and the palpebral lobes, too, have been pushed back toward the posterior margin.

The marginal border of the cephalon is of medium width, slightly rounded, and uniting at the genal angles with the rounded posterior border of the fixed cheeks before merging into a strong, sharp, narrow, rounded, backward-projecting genal spine.

---

[1] Smithsonian Misc. Coll., Vol. 53, No. 2, 1908, pp. 19-22.

[2] Idem, p. 202.

The glabella is marked by three pairs of furrows that divide it into two smaller anterior lobes and two posterior lobes. The two middle pairs of furrows are short, transverse, and with a smooth space of about one-third the width of the glabella between them; the anterior furrows have a length of about one-fourth the distance across the glabella, and are not as deep as the other three pairs. The posterior furrows are connected by a narrow, shallow transverse furrow. Occipital furrow, narrow, distinct, and slightly curved forward. Occipital ring strong, rounded, widest at the center, tapering slightly toward the slight furrow separating it from the fixed cheeks.

Fixed cheeks broad, slightly convex in compressed specimens, and with a relatively large palpebral lobe situated well back toward the posterior margin, as shown on the right side of fig. 1. A rather strong palpebral ridge extends from the palpebral lobe across each fixed cheek to the dorsal furrow opposite the second glabellar lobe. Free cheeks narrow within the marginal border. Visual surface of eye elongate, width unknown. Facial sutures not clearly shown; they appear to cut the posterior margin well within the genal spine and to curve forward to the posterior end of the palpebral lobes, around which they curve and then continue obliquely forward to the frontal margin which they cut on a line with a point midway between the glabella and the posterior end of the palpebral lobe.

Thorax with 19 segments. Axial lobe about one-fifth the entire width, rounded, and marked on each side by a shallow, rounded furrow that serves to separate the outer end of the segment as a low, rounded tubercle. Pleural lobes about twice as wide as the axial lobe. The lobes of each segment are formed of an inner straight portion marked by a narrow furrow that starts off the inner anterior margin and extends obliquely across the segment nearly to the posterior margin at the outer body margin of the thorax, beyond which slightly flattened, long, backward-curving spines add about one-fifth to the width of the dorsal shield. The spinose extensions of the posterior segments curve backward more and more until the posterior segment almost encloses the pygidium.

Pygidium very small, lanceolate in outline, and crossed near the anterior margin by a shallow furrow.

Surface of cephalon and body portion of thorax with a somewhat irregular network of very fine, narrow ridges that give the appearance of being a modified form of the reticulated surface so characteristic of the Mesonacidæ.[1]

---

[1] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 28, fig. 7; pl. 37, figs. 4 and 5.

*Dimensions.*—The only specimen known to me of this species has a length of 18 mm. The relative proportions of the various parts have probably been fairly well retained in fig. 1, although the cephalon and thorax have been shortened and widened by longitudinal compression and flattening in the shale.

*Observations.*—This fine species was found by Professor H. Justin Roddy at the Fruitvale stone quarry in a dark gray silico-argillaceous shale containing numerous specimens of *Pædeumias transitans* Walcott of the upper portion of the Lower Cambrian fauna. The reasons for placing it in the genus *Olenopsis* are given under notes on the genus.

The specific name is given in recognition of the excellent work of Professor Roddy, of the Normal School, Millersville, who for several years has been studying the areal geology of and collecting fossils in Lancaster County.

*Formation and locality.*—Lower Cambrian: (12 w) Silico-argillaceous shale, in quarry just west of Fruitvale, 2 miles (3.2 km.) north of Lancaster, Lancaster County, Pennsylvania.

## DESCRIPTION OF PLATE 36

PAGE

*Olenopsis roddyi* Walcott .......................................... 244

FIG. 1. (× 3.) The type specimen of the species. The cephalon has been compressed so as to shorten it and distort the glabella. Original type presented by Professor H. Justin Roddy, Millersville, Pa., to the National Museum. U. S. National Museum, Catalogue No. 58363.

*Olenopsis ? agnesensis* Walcott .......................................... 242

FIG. 2. (× 2.) A somewhat broken specimen showing the character of the species. The free cheek terminates in a short spine. U. S. National Museum, Catalogue No. 58364.

The locality of the type is (35m) Mount Whyte formation (*Albertella* zone), 3 miles southwest of the head of Lake Louise, on east slope of Mount Whyte, Alberta, Canada.

*Olenopsis zoppii* Meneghini .......................................... 242

FIG. 3. (Natural size.) View of a natural cast, showing the form of the cranidium and thoracic segments. U. S. National Museum, Catalogue No. 18304.

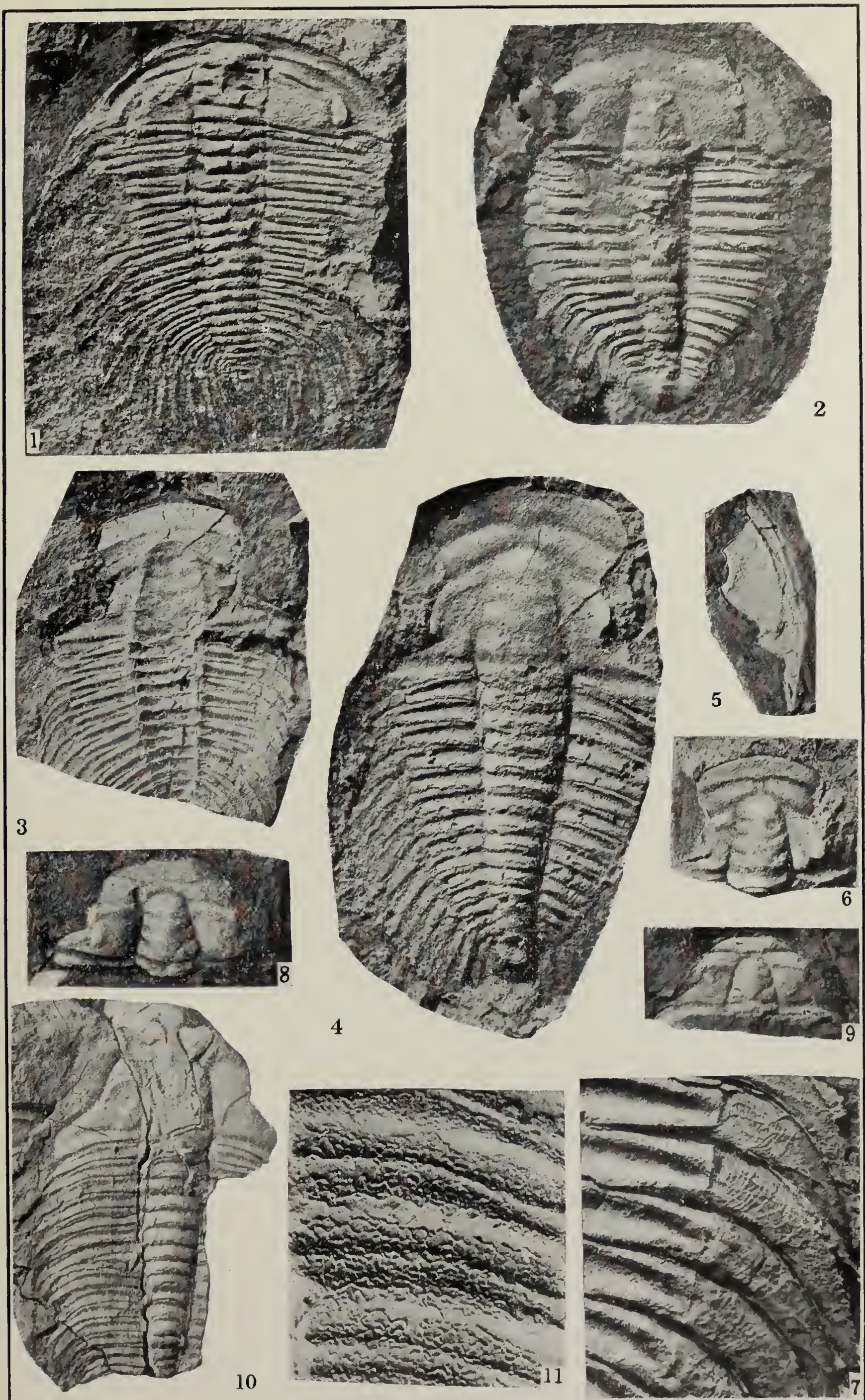
4. (× 2.5.) A nearly entire specimen, illustrating the general characters of the species. U. S. National Museum, Catalogue No. 58365.

5. (Natural size.) Under side of a free cheek. U. S. National Museum, Catalogue No. 58366.

6. (× 2.) A cranidium preserving the form of the glabella, frontal limb, and margin. The ridge crossing the frontal limb at the center was caused by a break in the test. U. S. National Museum, Catalogue No. 58367.

7. (× 3.) Enlargement of several of the falcate extensions of the pleural lobe to show the surface markings of the under side of the doublure of the pleuræ. U. S. National Museum, Catalogue No. 18304.

All of the specimens illustrating this species are from the locality of Canal Grande, Sardinia.




TRILOBITES

DESCRIPTION OF PLATE 36 (Continued)

PAGE

*Olenopsis americanus* Walcott ........................................ 243

FIGS. 8. and 9. (Natural size.) Two cranidia that preserve a little of their original convexity. The glabella in both is slightly distorted by compression. U. S. National Museum, Catalogue Nos. 58368 and 58369, respectively.

10. (Natural size.) A fragmentary specimen, showing the greater part of the thorax. U. S. National Museum, Catalogue No. 58370.

11. (× 4.) Enlargement of the outer surface as shown in the matrix of the specimen represented by figure 10. U. S. National Museum, Catalogue No. 58371.

All of the specimens illustrating this species are from locality (4v) Lower Cambrian; about 200 feet above the unconformable base of the Cambrian and 75 feet above the top of the quartzitic sandstones in a shale which corresponds in stratigraphic position to shale No. 6 of the Dearborn River section [Walcott, Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 202], Gordon Creek, 6 miles (9.6 km.) from the South Fork of Flathead River, Ovando quadrangle (U. S. Geol. Survey), Powell County, Montana.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 9

# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 9.—NEW YORK POTSDAM-HOYT FAUNA

WITH PLATES 37-49

BY
CHARLES D. WALCOTT

(PUBLICATION 2136)

CITY OF WASHINGTON
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(WITH PLATES 37 TO 49)

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PLATES



## INTRODUCTION

When engaged in reconnaissance work in Saratoga County, New York, during the summer of 1878 I found a small group of fossils in a thick-bedded, hard gray siliceous limestone at Hoyts quarry, 4 miles west of Saratoga Springs. The limestone and included fossils were referred to the " Califerous formation "[1] and attention called to the relation of the Hoyt quarry fauna to that of the " Potsdam sandstone of Iowa and Wisconsin." The species described were *Platyceras minutissima, Metoptoma cornutaforme, Conocephalites calciferus, C. hartti,* and *Ptychaspis speciosus.* Subsequently drawings were prepared illustrating the species and a large plate was made up, photographed, and distributed to a few investigators in July, 1885. In 1890 several additional species were described from the Hoyt quarry and illustrated and referred to the Upper Cambrian.[2] These included *Platyceras hoyti, Trochus ? saratogensis,* and *Agraulos saratogensis.* At various times in 1886 and 1888 I made brief visits to different localities about the Adirondack Mountains, New York, where the Potsdam sandstone member of the series was exposed. The results cf these observations were included in a summary published in 1891[3] of the Cambrian formations of the Adirondack subprovince, reference being made to the fossils found. In 1903 the name " Saratogian " was proposed[4] for the formations and contained faunas then referred to the Upper Cambrian.

[1] Thirty-second Ann. Rept. New York State Museum, 1879, pp. 129-131.
[2] Proc. U. S. National Museum, Vol. 13, 1890. pp. 268 and 276.
[3] Bull. U. S. Geol. Survey, No. 81, 1891, pp. 341-347.
[4] Journ. Geol., Chicago, Vol. 11, No. 3, 1903, pp. 318, 319.

The "Saratogan" fauna of New York was correlated with the *Dicellocephalus* fauna of the Upper Mississippi Valley in 1879,[1] and in 1891 the list of fossils was corrected by the recognition of the genus *Dicellocephalus*.[2]

In proposing the name "Saratogian" a list of the fauna at the Hoyt quarry was given as follows:[3]

| | |
|---|---|
| "*Cryptozoa proliferum.* | *Billingsia saratogensis.* |
| *Obolus* (*Lingulepis*) *acuminatus.* | *Matthevia variabilis.* |
| *Platyceras minutissimum.* | *Dikelocephalus hartti.* |
| *Platyceras hoyti.* | *Dikelocephalus speciosus.* |
| *Metoptoma cornutiforme.* | *Ptychoparia calcifera.* |
| *Metoptoma simplex.* | (*A.*) *saratogensis.*" |

In a small drift block of sandstone I found on the road from Trenton to Trenton Falls, Oneida County, New York, in 1867, there is an unusual, apparent association of Upper Cambrian (Hoyt limestone) and Ordovician (Aylmer sandstone, Chazy) fossils. The Hoyt limestone species are *Ptychaspis speciosus* and *Agraulos* cf. *saratogensis.* The Aylmer sandstone species are *Leperditia armata, L.* sp. ?, and *Bathyurus* cf. *angelina* Billings.

When, as a boy, I found the rounded block of sandstone referred to I broke out all the fossils possible, as at the time I was well acquainted with the Trenton limestone fauna, and the fossils in the block were strangers to me, with the exception of *Leperditia armata.* The following winter I endeavored to locate the stratigraphic position of the trilobites, but could not, further than that they were evidently of pre-Trenton age. This study aroused an interest in the American early Paleozoic fossils that gradually led me to take up the Cambrian rocks and faunas as my special field of research.

The block of sandstone was about 3 inches in thickness by 12 in diameter. The impact of the wheel of the wagon in which I was riding split the block open and exposed several cranidia of the trilobite now known as *Ptychaspis speciosus.* Neither this nor *Agraulos* cf. *saratogensis* occurred in direct association with the Chazy *Leperditia* and *Bathyurus.* This now leads me to adopt a suggestion of Dr. E. O. Ulrich that the block of sandstone was part of a bed formed by the overlap of the Aylmer sandstone of the Chazy on a layer of Potsdam sandstone. This would make the line of demarcation between

[1] Walcott. Thirty-second Ann. Rept. New York State Museum, 1879, p. 131.
[2] Bull. U. S. Geol. Survey, No. 81, 1891, p. 346.
[3] Journ. Geol., Chicago, Vol. 11, No. 3, 1903, p. 318.

the Cambrian and Ordovician deposits within the block of sandstone that I found. With this view in mind the Hoyt limestone species are referred to the Upper Cambrian and the Aylmer sandstone species to the Ordovician.

## STRATIGRAPHIC POSITION OF FAUNA.

The Potsdam-Hoyt fauna as it occurs about the Adirondack Mountains in New York State is found in the Potsdam sandstone and the superjacent Hoyt limestone. We have represented in the collection of the United States National Museum the following species:

| | Upper Cambrian. | |
|---|---|---|
| | Potsdam sandstone. | Hoyt limestone. |
| *Protozoa.* | | |
| Cryptozoön proliferum Hall | + | .. |
| *Annelida.* | | |
| Climactichnites | + | .. |
| Scolithus linearis Haldeman ? | + | .. |
| Planolites | + | .. |
| *Brachiopoda.* | | |
| Lingulella prima (Conrad) | + | .. |
| Lingulella (Lingulepis) acuminata (Conrad) | + | + |
| *Gastropoda.* | | |
| Triblidium cornutaforme (Walcott) | .. | + |
| Matherella saratogensis (Walcott) | .. | + |
| Palæacmæa typica Hall and Whitfield | + | .. |
| Eccyliopterus sp | + | .. |
| Ophileta ? sp | + | .. |
| Sinuopea ? sp | + | .. |
| Matthevia variabilis Walcott | .. | + |
| *Pteropoda.* | | |
| Hyolithes gibbosus Hall and Whitfield | + | .. |
| Hyolithellus papillatus Walcott | + | .. |
| Pelagiella hoyti (Walcott) | .. | + |
| Pelagiella minutissima (Walcott) | .. | + |
| *Trilobita.* | | |
| Ptychoparia minuta (Bradley) | + | .. |
| Ptychoparia matheri Walcott | + | .. |
| Conocephalina whitehallensis Walcott | + | .. |
| Pagodia seelyi Walcott | + | .. |
| Agraulos saratogensis Walcott | .. | + |
| Lonchocephalus calciferus (Walcott) | .. | + |
| Ptychaspis speciosus Walcott | + | .. |
| Dicellocephalus hartti (Walcott) | .. | + |
| Dicellocephalus tribulis Walcott | .. | + |
| Protichnites logananus Marsh | + | .. |
| Protichnites wilsoni Logan | + | .. |

The facies of the fauna is essentially Cambrian, with the possible exception of the gastropods *Matherella saratogensis, Eccyliopterus* sp., *Ophileta* ? sp., and *Sinuopea* ? sp. These, however, are all small forms and might well be the Cambrian progenitors of the Ozark gastropod fauna of Missouri. Dr. E. O. Ulrich has recently placed the " Saratogan " fauna far above the top of the Cambrian[1] but with the evidence now known to me from New York and the Appalachian region to the southwest I am inclined tentatively to refer the fauna as found in New York State to the upper limit of the Cambrian. This is subject to investigations now being made in the Upper Mississippi Valley region of Wisconsin and Minnesota that will probably determine more definitely the horizon of some of the upper faunas that have been referred to the " St. Croix sandstone." As now known, the " Saratogan " fauna would be correlated with the fauna of one of the upper horizons of the " St. Croix sandstone " and thus included in the Upper Cambrian.

The most recent expression of opinion on the stratigraphic horizon of the Potsdam sandstone in New York is by Mr. William J. Miller in 1911.[2] He includes it with the Theresa formation and the Little Falls dolomite in the Upper Cambrian and states that the dolomite was everywhere eroded prior to the deposition of the Tribes Hill limestone, a formation which is frequently absent, and that the Black River-Trenton limestone (generally the Lowville) rests upon an eroded surface of the dolomite.

In Dutchess County, New York,[3] the " Saratogan " fauna is represented by *Lingulella prima, Lingulella* (*Lingulepis*) *acuminata, Agraulos saratogensis,* and *Lonchocephalus calciferus.*

Near Blairstown, New Jersey,[4] the fauna in the horizon of the " Kittatinny " limestone there exposed has *Agraulos* cf. *saratogensis* and *Lonchocephalus* cf. *calciferus* of the Hoyt limestone " Saratogan " fauna. The frontal limb of the Saratoga specimen of *Agraulos* is more convex than the one from Blairstown, and the *Lonchocephalus* is identified by a fragment of the occipital segment and median spine. Both identifications are too uncertain to be of value in correlation. The species of *Dicellocephalus, D. newtonensis* Weller, is unlike the Hoyt limestone species *D. hartti* Walcott. It is similar to the *Dicello-*

[1] Bull. Geol. Soc. America, Vol. 22, 1911, No. 3, pl. 27: Table of formations.

[2] Bull. New York State Museum, No. 153, Geology of the Broadalbein Quadrangle, 1911, pp. 25-31.

[3] New York State Museum, Geology of the Poughkeepsie Quadrangle, C. E. Gordon, 1911, p. 49.

[4] Geol. Surv. New Jersey, Rept. on Pal., Vol. 3, 1903, p. 13.

*cephalus* from the Eminence formation of the Ozark section of Missouri. It is evident from the lists of fossils given by Weller[1] that they belong to more than one faunal horizon. This makes the evidence for correlating the "Saratogan" fauna of New York with that of New Jersey of little value.

Dr. E. O. Ulrich[2] has correlated the Eminence formation of Missouri with that of the Potsdam sandstone and Hoyt limestone of New York; but with the present faunal evidence I think that we should hesitate to accept the correlation as established. The *Dicellocephalus* of the Eminence formation is a later type and the *Agraulos* has little weight because the cranidia of that genus have a close resemblance in specific characters from the Lower Cambrian to basal post-Cambrian strata.

I greatly appreciate the work Dr. Ulrich has done in endeavoring to establish an upper limit to the Cambrian system, and regret that I cannot yet fully agree with him that the "Saratogan" of New York should be classed as post-Cambrian.

## USE OF THE TERMS SARATOGAN AND ST. CROIXAN

When I proposed the name "Saratogian" in 1903[3] for the Upper Cambrian group of formations, an examination of several lists of geological formation names failed to show that the name Saratoga had been used by Dr. J. C. Branner[4] for a Cretaceous chalk marl in Arkansas, in his description of "The Cement Materials of Southwest Arkansas."[5] A description of the formation is given, with sections illustrating its stratigraphic position. In 1902 Mr. J. A. Taff used the name Saratoga formation in the same sense as Branner and gave illustrations of sections and contained fossils.[6]

In view of the prior use of the name Saratoga by Branner and Taff, I doubt the advisability of continuing the use of Saratogan as a group name for the Cambrian formations. There is also the fact that the two formations of Saratoga County, New York, that are used as the basis for the name, are not typically of Upper Cambrian age. A present tendency is to include them as passage beds between

[1] Geol. Surv. New Jersey, Rept. on Pal., Vol. 3, 1903, pp. 12 and 13.

[2] Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27.

[3] Journ. Geol., Chicago, Vol. 11, 1903, pp. 318-319.

[4] Dr. John M. Clarke recently (May 27, 1912), called my attention to the use of the name Saratoga by Branner, and wrote that he was then discussing the history of the name in a paper in press.

[5] Trans. American Inst. Mining Engineers, Vol. 27, 1898, pp. 52-55.

[6] Twenty-second Ann. Rept. U. S. Geol. Survey, 1902, pp. 714-720.

the Cambrian and the superjacent system of strata, or as belonging to the higher systems.[1] With the evidence now known to me from New York and the Appalachian region to the southwest I am inclined tentatively to refer the fauna as found in New York State to the upper limit of the Cambrian. (See pages 255 and 256 for further discussion of this question.)

My present view is that the use of the name Saratoga should be restricted to the Cretaceous formation, another name adopted for the group of formations included in the Upper Cambrian, and another name for the Potsdam-Hoyt fauna if that fauna is considered as distinct from the Upper Cambrian fauna.

When looking up a name for the Upper Cambrian formations in 1903, I thought of St. Croixan, but as the name St. Croix had become fixed in geological literature for the Cambrian sandstone of the Upper Mississippi Valley[2] I did not use it. In 1911[3] Dr. E. O. Ulrich proposed to use the name St. Croixan for the sea in which the St. Croix sandstones were deposited, and in his table of correlations of formations (pl. 27) and on page 614 of the same work he uses the term as a collective name for his Upper Cambrian formations. If we drop the term "St. Croix" as a formation name for the sandstones of Wisconsin and Minnesota containing the Upper Cambrian fauna, then the term St. Croixan may be used for the assemblage of formations characterized by the Upper Cambrian fauna.

## DESCRIPTIONS OF GENERA AND SPECIES

### Genus CRYPTOZOÖN Hall

*Cryptozoön* HALL, 1884, Thirty-sixth Ann. Rept. New York State Mus. Nat. Hist., desc. of pl. 6. (Genus described and discussed as below.)

The original description is as follows:

In the town of Greenfield, Saratoga County, there occurs a bed of limestone which presents a very remarkable appearance, the surface being nearly covered by closely arranged circular or subcircular discs which are made up of concentric laminæ, closely resembling in general aspect the structure of *Stromatopora*. It very often happens that within these larger discs there occur two or more smaller ones, each with its own concentric structure and exterior limitation, and appearing as if budding from the parent mass. A farther examination shows that the entire form of these masses is hemispheric or turbinate, with the broadest face exposed upon the upper surface of the

[1] See Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27, and p. 612.

[2] See N. H. Winchell, 1873, Ann. Rept. Board of Regents, University of Minnesota. First Ann. Rept. Geol. and Nat. Hist. Surv. for 1872, pp. 68-80.

[3] Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, p. 613.

limestone layer; that their growth has begun from a point below, and rapidly expanding upwards, has often extended one or two feet in diameter, as now shown upon the exposed surface of the limestone bed. At a single exposure on the farm of Mr. Hoyt, the surface of the limestone is covered by these bodies for many rods in extent. The entire area of the cellar beneath the house of Mr. Hoyt is upon this bed of limestone closely covered by these hemispheric masses with concentric structure. For a distance of one or two miles to the southward the outcrop of this limestone can be traced, and everywhere presenting the same characters in the presence of these masses. Large numbers of specimens of various sizes have been weathered out and lie scattered over the surface. This fossil has also been found at Little Falls, Herkimer County, New York.

These bodies have long been known under the name of *Stromatopora,* from their general resemblance in form and structure to that fossil; but their position in reference to the bedding of the rock is uniformly the reverse of that of Stromatoporæ, which occur in the higher limestones, growing from a broad base which is covered by an epitheca, while these bodies under consideration grow upward and expand from a point below, while the convex surface is on the lower side. A careful examination of the nature of these bodies proves that while having the concentric structure common to *Stromatopora* they have not the regular succession of layers of tubuli characteristic of the species of that genus and cannot properly be included under that term. I, therefore, propose the term *Cryptozoön* as a designation for this peculiar form and mode of growth which will be more fully elucidated in the future.

### CRYPTOZOÖN PROLIFERUM Hall

Plate 37, figs. 1-3

*Cryptozoön proliferum* Hall, 1884, Thirty-sixth Ann. Rept. New York State Mus. Nat. Hist., desc. of pl. 6. (Species defined in description of plate as below, and illustrated by plate 6.)

The original description is as follows:

These bodies are made up of irregular, concentric laminæ of greater or less density and of very unequal thickness. The substance between the concentric lines, in well-preserved specimens, is traversed by numerous, minute, irregular canaliculi which branch and anastomose without regularity. The central portions of the masses are usually filled with crystalline, granular, and oölitic material and many specimens show the intrusion of these extraneous and inorganic substances between the concentric laminæ. That these are intrusions, and not inclusions, is shown from the fact that they can be traced to a vertical fissure or break leading to the exterior of the fossil and which allowed the crystalline matter to enter.

*Formation and locality.*—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus CLIMACTICHNITES Logan

Plates 38-40

*Climactichnites* LOGAN, 1860, Canadian Nat. and Geol., Vol. 5, pp. 279-285, text figs. 1-5. (Describes and illustrates trails. Thinks they may have been made by mollusks.)

*Climactichnites* Logan, JONES, 1862, The Geologist, London, Vol. 5, pp. 138-139. (Suggests that the trails are infallen gallery-tracks of burrowing crustaceans.)

*Climactichnites* Logan, DAWSON, 1862, Canadian Nat. and Geol., Vol. 7, pp. 274-277. (Suggests that *Climactichnites* may have been made by a crustacean allied to *Limulus*.)

*Climactichnites* Logan, CHAPMAN, 1864, Exposition of Minerals and Geology of Canada, p. 160. (Brief remarks on genus.)

*Climactichnites* Logan, BILLINGS, 1870, Quart. Journ. Geol. Soc. London, Vol. 26, p. 485. (Considers that both *Protichnites* and *Climactichnites* trails may have been made by same animal.)

*Climactichnites* Logan, CHAPMAN, 1877, Canadian Journ. Sci., Lit., and Hist., Vol. 15, pp. 486-490. (Suggests fucoidal origin of *Climactichnites* trails.)

*Climactichnites* Logan, TODD, 1882, Trans. Wisconsin Acad. Sci., Vol. 5, pp. 276-281. (Describes and illustrates *C. youngi* Chamberlin MS., and concludes that the trails were not made by crustaceans.)

*Climactichnites* Logan, DAWSON, 1890, Quart. Journ. Geol. Soc. London, Vol. 46, pp. 596 and 600. (Same conclusion as in 1862, with a good illustration.)

*Climactichnites* Logan, WOODWORTH, 1903, Bull. New York State Mus., No. 69, pp. 956-966. (Describes trails and elongate oval bodies at end of trails, as remains of animal that made trail. Suggests molluscan origin.)

*Climactichnites* Logan, CLARKE, 1905, Bull. New York State Mus., No. 80, pp. 18-20, pl. 3. (General description of the trails described by Woodworth.)

Until after the appearance of Woodworth's description and illustration of the trails found at Mooers, Clinton County, New York,[1] there was very little more than conjecture as to the nature of the animal that made the trails. The discovery of elongate oval bodies at the terminations of each one of a group of trails (pl. 40, fig. 2) immediately suggested a mollusk of some kind that had left a trace of the under side of the foot. Woodworth's conclusions are:[2]

1. The transverse ridges and their lateral extensions running forward to the next transverse ridge were made by the same movement of some organic structure lying transverse to the longitudinal axis of the organism.

2. The unity, identity, and spacing of successive transverse ridges indicate that they were made singly and in succession, that their spacing indicates the forward stride of the organism, and that it went forward by a crawling, hitching movement.

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[1] Bull. New York State Museum, No. 69, 1903, pp. 959-966.

[2] Idem, pp. 962, 963-964, and 966.

3. The varying position of the median ridge with reference to the lateral ridges points to the conclusion that the transverse body was at the time characterized by a mesial sinus or upfold, and that the axis of this fold played to the right and left as a fold might in the flexible muscular foot of a crawling mollusk . . . .

4. The pressed sand on the slopes and over the crest of the transverse ridges eliminates from the processes by which the ridges may have been made the backward push of the posterior margin of such an animal as the trilobite or of any transverse gill plate so placed as not to permit, under the condition in which the creature moved, the smoothing down of the successive ridges by some soft, pliable body still further *au derrière.*

. . . . The trail itself, therefore, it seems safe to state, was made by some flexible body like the mesially up-curved posterior margin of the expanded, retractile foot of a large crawling organism.

It remains to note the nature of the terminal impressions associated with many of the trails in the Mooers occurrence. In the first place, the postulate above made that the trails were made progressively toward these oval terminal impressions may now be explained by stating that, where the relation of the oval impressions to the trail can be made out, it is clear that the oval impression has obliterated a portion of the trail which once extended into the area of the oval impression; this is taken to mean that the animal which made the trail reached the end of the track and there, resting on the sandy bottom, left an impression of the outline of some marginally relatively rigid structure of the ventral surface. Had the organism started out from this oval area, it is obvious that the oval would have been partly effaced and merged into the trail. The complete adjustment of the oval terminal impressions to the trails thus becomes of extreme interest; for it must be that in these impressions there is a clue to the outline of the organism which produced *Climactichnites.*

The larger of the terminal impressions measured at Bidwell's crossing gave a length of 16 inches and a breadth of 6 inches.

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The manner in which several of the trails approach in a common direction and end close to each other in sedentary impressions is exactly what takes place in the case of the trails of many gregarious aqueous forms, which crawl up a beach or a partly exposed sand bar and rest on the dry sand.

Among some fine specimens of *Climactichnites youngi* Chamberlin, received from Rev. A. A. Young of New Lisbon, Wisconsin, in 1886, there was one good example (pl. 38) of the outline of a terminal elongate oval body of essentially similar outline to those subsequently found by Woodworth at the ends of the trails at Mooers, New York. I put the specimen aside in the hope that more and better ones would be found so that we would have evidence upon which to base conclusions as to the animal that made the trail.

Woodworth suggests that the animal crawled up from the water at low tide across the ripple-marked and smooth beach sand; that it was of a gregarious habit, sufficiently heavy to smooth out the ripple marks; and that it disappeared with the incoming tide. His conclusion that it was a mollusk explains some but not all of the facts observed. The impression on the sandstone illustrated by plate 38 shows that the front of the body making the impression was curved forward and that the arching lines extended back to the base of the large oval impression made by the under surface of the animal. So far as known to me, there is no recognized mollusk that would make such forward curving lines, and we do not know of any chiton or mollusk capable of making such an impression. In view of this it occurred to me to inquire into the possibility of the trails having been made by an annelid. Since many annelids have been found in the Middle Cambrian Burgess shale fauna [1] there appears to be no reason why remains and trails of large annelids should not be found in later formations. Among the Burgess shale forms there is a large Chætopod worm (*Pollingeria grandis* [2]), a crushed specimen of which has a length of 13 cm., width 7 cm. The larger scales found in the same layer of shale indicate that some individuals attained near twice that size. Such an annelid would have had sufficient size, weight, and strength to make the *Climactichnites* trails. Among recent annelids species of the Aphroditidæ attain a large size and some have a shallow water habitat and crawl about on the wet sand between tides. We can readily imagine that such an animal made the tracks under consideration. I have not seen any traces of the bristles or stiff setæ that occur on the parapodia of most of the Aphroditidæ, but this is not unexpected in a sandstone formation.

A reproduction of the figure of the specimen described by Woodworth [3] from Clinton County, New York, is made on pl. 40, fig. 2, and on pls. 38 and 39 specimens are illustrated of *C. youngi* from New Lisbon, Wisconsin. Much could be written about the details of these trails, but with the reproductions based on photographs and the descriptions of the figures the student may draw his own conclusions.

*Genotype.*—*Climactichnites wilsoni* Logan. 1860.

*Formation and locality.*—Upper Cambrian: (**220b**) Potsdam sandstone, Rogier's farm just west of town of Beauharnois, Province of Quebec, Canada.

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[1] Smithsonian Misc. Coll., Vol. 57, No. 5, 1911, pp. 110-144, pls. 18-23.

[2] Single scales only are illustrated; Smithsonian Misc. Coll., Vol. 57, No. 5, 1911, pl. 21, figs. 7-9.

[3] Bull. New York State Museum, No. 69, 1903, pp. 956-966.

Upper Cambrian: (99c) "St. Croix sandstone," near banks of Lemon-weir River, 4 miles (6.4 km.) north of New Lisbon, Wisconsin.

### LINGULELLA PRIMA (Conrad MS.) (Hall)

Plate 41, figs. 8-11

*Lingula prima* (CONRAD MS.) HALL, 1847, Nat. Hist. New York, Paleontology, Vol. 1, p. 3, pl. 1, fig. 2. (Described and discussed.)

For the synonymy of this species up to 1912, see Monograph 51, U. S. Geol. Survey, p. 526. (In press.)

An extended description and illustration of *Lingulella prima* are given in Monograph 51, pp. 526-527, pl. 27, figs. 1, 1a-c. (In press.)

*Formation and locality.*—Upper Cambrian: (77)[1] Potsdam sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70 to 75 feet (21 to 23 m.) above the water, in Ausable Chasm; (367f) sandstone at French Creek, 1 mile (1.6 km.) east of Keeseville; (367g) sandstone in the bed of the brook, in the suburbs of Port Henry; (367h) Rosse Bridge, 4 miles (6.4 km.) west of Essex; (136) Potsdam sandstone in bank of stream opposite the first Y on the Port Henry and Maine Railroad out of Port Henry; and (338t) Potsdam sandstone in Ausable Chasm, below Keeseville; all in Essex County, New York.

### LINGULELLA (LINGULEPIS) ACUMINATA (Conrad)

Plate 42, figs. 1-7

*Lingula acuminata* CONRAD, 1839, Third Ann. Rept. New York State Surv., p. 64. (Described as a new species.)

For the synonymy of this species up to 1912, see Monograph 51, U. S. Geol. Survey, p. 545. (In press.)

An extended description and discussion of this species are given in Monograph 51, that include its geographic and stratigraphic distribution and a large number of illustrations.

It occurs in the Upper Cambrian, both in the Hoyt limestone (76) and the Potsdam sandstone (76a) in Saratoga County, New York.

*Formation and locality.*—For these see Monograph 51, pp. 548-550. (In press.)

[1] 77 is the type locality, though the specimens to which that number is assigned in the United States National Museum were collected later than the type specimens.

### Genus TRIBLIDIUM Lindström

### TRIBLIDIUM CORNUTAFORME Walcott

Plate 41, figs. 12-14

*Metoptoma cornutaforme* WALCOTT, 1879, Thirty-second Ann. Rept. New York State Museum, p. 129. (Original description, as below.)

Oval, subconical; apex incurved, depressed, extending beyond the anterior margin; distance from the posterior margin to the apex twice the width. The most elevated point is about two-thirds the distance from the posterior margin to the apex; from this point the outline curves regularly to the posterior margin and anteriorly to the apex. Outline from the apex to the anterior margin convex. Length, 18 mm.; width, 9 mm.

Surface, with narrow concentric ribs, 1 mm. apart; finely striate vertically.

*Formation and locality.*—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus MATHERELLA, new genus

Univalve shells, sinistrally coiled; spire composed of round volutions that are more or less elevated; umbilicus open; peristome, so far as known, entire, united with the preceding volution on the inner side and probably not expanded to any considerable extent.

*Genotype.*—*Matherella saratogensis,* new species.

*Stratigraphic range.*—Upper Cambrian Hoyt limestone at Hoyts quarry.

*Geographic distribution.*—Saratoga County, New York, in the United States. Doubtfully in Shantung, China.

*Observations.*—This genus was recognized in 1886 and the name *Billingsia* used for it in a list of fossils.[1] As pointed out in the monograph on the Cambrian Brachiopoda [2] this name was previously used by both De Koninch (1876) and Ford (1886).

Comparison may be made between *Matherella* and *Scævogyra* Whitfield.[3] Both shells are sinistrally coiled, with rounded volutions, but *Scævogyra* has a more or less trumpet-shaped peristome, and it has rounded rather than flattened volutions.

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[1] Bull. U. S. Geol. Survey, No. 30, 1886, pp. 5, 21, 60, and 62. Also Bull. U. S. Geol. Survey, No. 81, 1891, p. 346.

[2] Monogr. U. S. Geol. Survey, Vol. 51, 1912, p. 561. (In press.)

[3] Geol. Surv. Wisconsin, Vol. 55, 1878, p. 198, pl. 3, figs. 7-9.

### MATHERELLA SARATOGENSIS (Walcott)

Plate 41, figs. 18-21

*Billingsia saratogensis* WALCOTT, 1886, Bull. U. S. Geol. Surv., No. 30, p. 21. (Name given in list of species, but no description or figure.)

*Trochus ? saratogensis* WALCOTT, 1890, Proc. U. S. Nat. Mus., Vol. 13, pp. 268-269, pl. 20, fig. 3. (Original description as below.)

*Billingsia saratogensis* WALCOTT, 1891, Bull. U. S. Geol. Surv., No. 81, p. 346. (Copy of the first reference.)

Shell trochiforme, sinistral, broadly conical with about four slightly convex whorls; base concave; umbilical surface sloping inward from the angle produced by its union with the outer curvature of the body whorl; umbilicus rounded and of medium size; aperture obliquely subelliptical; periphery unknown. Surface marked by a few fine striæ of growth.

This shell is not a true *Trochus*, and in the photographic plate illustrating the Potsdam fauna of Saratoga County, New York, that I prepared in 1885 (page 252), it bears the name *Billingsia saratogensis*. This generic name was used in lists of species in 1886,[1] but no publication of the description of the genus has yet appeared. The name *Billingsia* having been preoccupied (page 263) the species was in 1890 provisionally referred to *Trochus* until further comparisons could be made.

*Formation and locality.*—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus PALÆACMÆA Hall and Whitfield

*Palæacmæa* HALL AND WHITFIELD, 1873, Twenty-third Ann. Rept. New York State Mus. Nat. Hist., p. 242. (Description of genus.)

### PALÆACMÆA TYPICA Hall and Whitfield

Plate 43, figs. 1 and 2

*Palæacmæa typica* HALL AND WHITFIELD, 1873, Twenty-third Ann. Rept. New York State Mus. Nat. Hist., p. 242, pl. 2, figs. 4 and 5. (Description of species as below, figures 4 and 5 being reproduced in this paper as figures 1 and 2 of plate 43.)

The original description is as follows:

Shell patelliform, broadly oval in outline, with a depressed conical exterior, and a pointed subcentral apex, situated three-sevenths of the greatest length from one extremity. Surface of the shell marked by several strong folds or undulations parallel to the lines of growth.

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[1] Bull. U. S. Geol. Survey, No. 30, 1886, pp. 5, 21, 60, and 62.

*Formation and locality*.—Upper Cambrian: (77) Potsdam sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70-75 feet (21.3-22.9 m.) above the water, in Ausable Chasm, Essex County; and in Potsdam sandstone at the north end of the town of Whitehall, Washington County; both in New York.

### Genus MATTHEVIA Walcott

*Matthevia* Walcott, 1885, American Journ. Sci., 3d ser., Vol. 30, p. 17. (Genus described and discussed.)

*Matthevia* Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, pp. 223-224. (A copy of the previous description.)

### MATTHEVIA VARIABILIS Walcott

Plate 42, figs. 1-15

*Matthevia variabilis* Walcott, 1885, Amer. Journ. Sci., 3d ser., Vol. 30, p. 18, and figs. 1-6, p. 20. (Species described and illustrated.)

*Matthevia variabilis* Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, pp. 224-225, pl. 32, figs. 1-12, pl. 33, figs. 1, 1a-f. (Described as in 1885, with added illustrations.)

This species is described very fully in Bulletin 30, of the U. S. Geological Survey.

*Formation and locality*.—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus HYOLITHES Eichwald

### HYOLITHES GIBBOSUS Hall and Whitfield

Plate 43, figs. 5 and 6

*Hyolithes gibbosus* Hall and Whitfield, 1873, Twenty-third Ann. Rept. New York State Cab. Nat. Hist., p. 242, pl. 11, figs. 1-3. (Description of species as below, figures 1 and 2 of plate 11 being reproduced in this paper as figures 5 and 6 of plate 43.)

The original description is as follows:

Shell elongate conical, gradually tapering to an obtuse point, and slightly curving; very depressed, convex on the ventral side, and highly convex and gibbous on the dorsal, the sides being nearly vertical for a short distance from their junction with the ventral margin. Aperture rather more than semicircular; the lip on the ventral portion moderately projecting.

This species resembles *Hyolithes* (*Theca*) *primordialis* Hall, from the Potsdam sandstones of Wisconsin, but differs in being much more convex on the dorsal side, and in the less projecting lip of the ventral side of the aperture. The outlines given in figure 3 show the relative convexity of the two species, the outer dorsal line being that of *H. gibbosus*, and the inner of *T. primordialis*.

*Formation and locality.*—Upper Cambrian: (77) Potsdam sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70-75 feet (21.3-22.9 m.) above the water, in Ausable Chasm, Essex County, New York.

### Genus PELAGIELLA Matthew

*Pelagiella* Matthew, 1895, Trans. New York Acad. Sci., Vol. 14, p. 131.

### PELAGIELLA MINUTISSIMA (Walcott)

Plate 41, figs. 15 and 16

*Platyceras minutissimum* Walcott, 1879, Thirty-second Ann. Rept. New York State Museum, p. 129. (Original description as below.)

Shell small, subspiral, regularly arcuate from near the aperture to the apex, making nearly three-fourths of one volution; section subelliptical, somewhat carinate upon the dorsum. Two transverse depressions upon the sides give a slight undulation to the body of the shell.

Surface marked by faint longitudinal striæ.

*Formation and locality.*—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### PELAGIELLA HOYTI (Walcott)

Plate 41, fig. 17

*Platyceras hoyti* Walcott, 1890, Proc. U. S. Nat. Mus., Vol. 13, p. 268, pl. 20, fig. 8. (Original description as below.)

Shell small, depressed, making about three volutions, the interior below the plane of the outer volution. Volutions contiguous throughout their extent, expanding gradually to the somewhat compressed, more rapidly expanding outer whorl. Aperture unknown.

Outer surface of shell marked by fine concentric striæ and the inner surface by longitudinal striæ.

This species differs from the associated *P. minutissima* in the form of the whorls and surface characters. The longest specimen has a transverse diameter of 4 mm.

*Formation and locality.*—Upper Cambrian: (76) Arenaceous Hoyt limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus HYOLITHELLUS Billings

*Hyolithellus* Billings, 1871, Canadian Nat. and Geol., new ser., Vol. 6, p. 240.

### HYOLITHELLUS PAPILLATUS, new species

Plate 43, figs. 3 and 4

Long, slender, cylindrical tube with a circular section. The largest specimen in the collection has a length of 12 mm., with a diameter of 2 mm. A difference in diameter in the 12 mm. of length is not perceptible. The surface is thickly studded with minute, rounded, flattened papillæ.

This species differs from described forms in its papillose surface.

*Formation and locality.*—Upper Cambrian: (111) At the top of the Potsdam sandstone on Marble River, one mile (1.6 km.) south of Chateaugay, Franklin County, New York.

### Genus PTYCHOPARIA Corda

### PTYCHOPARIA MINUTA (Bradley)

Plate 43, figs. 20-24

*Conocephalites minutus* Bradley, 1860, American Journ. Sci., 2d ser., Vol. 30, pp. 241-242, text figs. 1-3. (Detailed description of species, with note by E. Billings.)

*Conocephalites minutus* Bradley, Billings, 1860, Idem, pp. 242-243 (discussion of species), and pp. 337-338, text figs. 4a-c. (Additional data on species and further discussion of it.)

*Conocephalites minutus* Bradley, 1860, Can. Nat. and Geol., Vol. 5, pp. 420-421, and text figs. 1-3. (Reprint of paper in American Journal of Science noted above.)

*Conocephalites minutus* Bradley, Billings, 1860, Idem, pp. 422-425, and text figs. 4a-c. (Reprint of two notes in American Journal of Science noted above.)

*Conocephalites minutus* Bradley, 1861, Proc. American Assoc. Adv. Sci., Vol. 14, pp. 161-163, and text figs. 1-3. (Reprint of paper mentioned in first reference.)

*Conocephalites minutus* Bradley, Billings, 1861, Idem, pp. 163-166, and text figs. 4a-c. (Reprint of his two notes mentioned in the second reference.)

*Conocephalites minutus* Bradley, Hall, 1863, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., pp. 150-151, pl. 8, figs. 5-7. (Describes species and compares it with *C. minor.*)

*Conocephalites minutus* Bradley, Hall, 1867, Trans. Albany Inst., Vol. 5, pp. 134-135, pl. 3, figs. 5-7. (Reprint of the preceding reference, with same figures.)

*Ptychoparia minutus* Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 91. (Refers to species and places it under *Ptychoparia.*)

The very full description of the characters of the cephalon of this species given by Messrs. Bradley, Billings, and Hall are well represented by figures 20-22 on plate 43. The associated pygidium is shown by figures 23 and 24. The closely related *Ptychoparia minor* (Shumard)[1] of the "St. Croix sandstone" of Wisconsin occurs at a lower stratigraphic horizon. In Nevada a somewhat similar species, *Ptychoparia ? annectans* Walcott[2] occurs in the lower part of the Ordovician Pogonip limestone. So far as known to me the type of trilobite cephalon represented by *P. minuta* occurs in the Upper Cambrian and in higher beds that may now be grouped in the Lower "Ozarkian" of Ulrich.[3]

*Formation and locality.*—Upper Cambrian, Potsdam sandstone formation: (77) Near the water level below the falls at the high bridge and also at several horizons in the section above, the highest point being 70-75 feet (21.3 to 22.9 m.) above the water, Ausable Chasm, near Keeseville, Essex County; (136a) in sandstone on a large brook at a point on the Mineville Railroad at the turning of the first Y near Port Henry, Essex County; (109) in sandstone 25 feet (7.6 m.) above the Archean 1.5 miles (2.4 km.) south of Deweys Bridge on the Champlain Canal, Washington County; (110a) in sandstone a little above and east of the canal road north end of town of Whitehall, Washington County; and (111) at the top of the Potsdam sandstone on Marble River, one mile (1.6 km.) south of Chateaugay, Franklin County; all in New York.

### PTYCHOPARIA MATHERI, new species

Plate 44, figs. 15-17

This species is represented by the cranidium, free cheeks, and fragments of an associated pygidium referred to it. It is one of the larger species of the genus and may be compared to *Ptychoparia striata* (Barrande), the type of the genus, and *P. richmondensis* (Walcott).[4] That such a large species of *Ptychoparia* should occur in the Potsdam sandstone is most interesting as the genus reaches its greatest development in the Middle Cambrian.

The largest cranidium has a length of 28 mm. Surface minutely granular.

*Formation and locality.*—Upper Cambrian: (110) Potsdam sandstone formation, shaly calcareous sandstone resting on massive layers of sandstone in bluff on east side of town of Whitehall, Washington County, New York.

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[1] Well illustrated by Hall, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., 1863, pl. 8, figs. 1-4.

[2] Monogr. U. S. Geol. Survey, Vol. 8, 1884, p. 91, pl. 12, fig. 18.

[3] Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27.

[4] Monogr. U. S. Geol. Survey, Vol. 8, 1884, p. 41, pl. 10, fig. 7.

### Genus CONOCEPHALINA Brögger

### CONOCEPHALINA WHITEHALLENSIS, new species

Plate 44, figs. 9-11a.

Although fragments of this species are abundant they are so broken and abraded that only imperfect specimens of the cranidium, free cheeks, and associated pygidia have been seen.

The elongate-subquadrangular glabella, narrow free cheeks, and long palpebral lobes of the cranidium relate this species to *Conocephalina ornata* Brögger, the type of the genus. The free cheek probably had a short, sharp genal spine. The cranidium illustrated has a length of 7.5 mm.

*Formation and locality.*—Upper Cambrian: (110a) Potsdam sandstone formation, in sandstone a little above and east of the canal road north end of town of Whitehall, Washington County, New York.

### Genus PAGODIA Walcott

*Pagodia* Walcott, 1905, Proc. U. S. Nat. Mus., Vol. 29, p. 63.

### PAGODIA SEELYI, new species

Plate 44, figs. 12-14a.

This very neat species is fairly abundant at one locality of the Potsdam sandstone near Port Henry. It is represented by casts of the cranidium and pygidium and is much like *Pagodia dolon* Walcott[1] from the Upper Cambrian of China. Somewhat similar forms occur in the lower portion of the Pogonip limestone of Nevada.[2]

One of the largest cranidia in the collection has a length of 7 mm.

*Formation and locality.*—Upper Cambrian: (136a) Potsdam sandstone, on a large brook at a point on the Mineville Railroad at the turning of the first Y near Port Henry, Essex County, New York.

### AGRAULOS SARATOGENSIS Walcott

Plate 43, figs. 11-15a.

*Bathyurus armatus* (Billings), Walcott, 1879, Thirty-second Ann. Rept. New York State Museum, p. 131. (Provisionally identified as *B. armatus.*)

*Ptychoparia* (*A.*) *saratogensis* Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, p. 21. (Name used in list.)

*Ptychoparia saratogensis* (Walcott), Dwight, 1887, Trans. Vassar Bros. Inst., Vol. 4, pp. 207-208. (Species mentioned in text.)

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[1] Proc. U. S. National Museum, Vol. 29, 1905, p. 66.

[2] Monogr. U. S. Geol. Survey, Vol. 8, 1884, pl. 12, fig. 5.

*Ptychoparia* (*A.*) *saratogensis* Walcott, LESLEY, 1889, Geol. Surv. Pennsylvania Rept. P 4, Dictionary of Fossils, Vol. 2, p. 834, 4 text figures only. (Reproduces 4 drawings sent him by Walcott.)

*Agraulos saratogensis* WALCOTT, 1890, Proc. U. S. Nat. Mus., Vol. 13, p. 276, pl. 21, fig. 14. (Description of species.)

*Agraulos saratogensis* (Walcott), WELLER, 1903, Geol. Surv. New Jersey, Report on Paleontology, Vol. 3, The Paleozoic Faunas, pp. 118-119, pl. 1, figs. 7-9. (Describes and illustrates specimens from New Jersey.)

Nothing has been added to our information about this species since its description in 1890, except that the outer surface of the test is finely granulated and the species occurs in other localities.

The cranidia of the Hoyt quarry specimens have an average length of about 10 mm., and a few large ones reach 15 mm., and one from near Poughkeepsie has a length of 20 mm.

The specimens from Newton, New Jersey, are smaller, but appear to be similar so far as can be determined by comparing the cranidia.

*Formation and locality.*—Upper Cambrian, Hoyt limestone: (76) Arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs; also (76a) in a railroad quarry 1 mile (1.6 km.) north of Saratoga Springs; both in Saratoga County; and arenaceous limestone 2 miles (3.2 km.) south of Poughkeepsie, Dutchess County; all in New York.

Doubtfully in lower portion of Kittatinny limestone: (11c) Hardyston quartzite [Weller, 1900, pp. 10 and 12], O'Connell and McManniman's quarry, Newton, Sussex County, New Jersey.

Specimens of similar cranidia occur in a block of drift sandstone, found near Trenton Falls, Oneida County, New York, supposed to have been derived from the Potsdam sandstone somewhere west of the Adirondack Mountains, New York.

## Genus LONCHOCEPHALUS Owen

### LONCHOCEPHALUS CALCIFERUS (Walcott)

Plate 43, figs. 7-10a

*Conocephalites calciferous* WALCOTT, 1879. Thirty-second Ann. Rept. New York State Museum, pp. 129-130. (Description of species, as below.)

*Ptychoparia calcifera* WALCOTT, 1886, Bull. U. S. Geol. Surv., No. 30, p. 21. (Name in list of species.)

*Ptychoparia calcifera* Walcott, DWIGHT, 1887, Trans. Vassar Bros. Inst., Vol. 4, pp. 207-208. (Species mentioned in text.)

*Ptychoparia calcifera* Walcott, LESLEY, 1889, Geol. Surv. Pennsylvania, Rept. P 4, Dictionary of Fossils, Vol. 2, p. 831. (Text fig. 1 reproduced from drawing sent him by Walcott.)

*Ptychoparia calcifera* Walcott, WELLER, 1903, Geol. Surv. New Jersey, Report on Paleontology, Vol. 3, The Paleozoic Faunas, pl. 1, fig. 14. (Illustrates a fragment doubtfully referred to this species.)

Head semicircular, convex. Glabella truncato-conical, moderately convex; width at the base nearly equal to the length; anterior margin straight, abruptly rounded at the angles; sides straight and regularly converging; the posterior and middle glabellar furrows oblique and well marked, the anterior furrow indicated by a smooth line upon the granulose outer shell, and a slight depression when the outer shell is removed. Occipital furrow broad and well impressed. Occipital ring narrow at the sides, widening at the center to form the base of a strong, slightly curved spine, which extends obliquely backward; the length of the spine in large individuals equals the length of the head. The glabella in very young individuals is more convex, the glabellar furrows more strongly impressed, and the spine projecting from the occipital ring shorter and less obliquely inclined backward. Dorsal furrows equally impressed at the sides and front of the glabella. Facial suture, curving slightly outward from the frontal margin, passes directly to the anterior angles of the palpebral lobe opposite the anterior glabellar furrow, thence curving to the posterior angle of the palpebral lobe, it extends obliquely outward to the lateral margin of the posterior limb.

Fixed cheeks narrow; frontal limb extending a distance equal to one-half the length of the glabella, sloping somewhat abruptly to a comparatively broad, thickened margin; posterior limb narrow, elongate, with a strongly defined furrow along the center. Palpebral lobe separated from the fixed cheeks by a sigmoid groove, which unites anteriorly with the dorsal furrow. Surface of glabella and fixed cheeks granulose; on the frontal limb the granules are so arranged as to give the appearance of lines running from the dorsal furrow to the broad margin, which has lamellose striæ subparallel to the margin. The largest head of this species obtained is nearly 25 mm. in length, with a spine of equal length projecting from the occipital ring.

*Observations.*—This species is closely related to *Lonchocephalus wisconsinensis* (Owen). It differs in having a relatively shorter frontal limb and longer palpebral lobes and it occurs at a somewhat higher horizon.

The fragment provisionally referred to *L. calciferus* by Dr. Stuart Weller may possibly belong to it, but it is too doubtful to base any conclusion on.

Some of the specimens of *L. calciferus* from south of Poughkeepsie are larger than those from Hoyts quarry. One cranidium is over 21 mm. in length, exclusive of the occipital spine.

*Formation and locality.*—Upper Cambrian, Hoyt limestone: (76) Arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of

Saratoga Springs, Saratoga County; (76a) in a railroad quarry, 1 mile (1.6 km.) north of Saratoga Springs, Saratoga County; and in arenaceous limestone, 2 miles (3.2 km.) south of Poughkeepsie, Dutchess County; all in New York.

## Genus PTYCHASPIS Hall

### PTYCHASPIS SPECIOSUS Walcott

Plate 43, figs. 16-19

*Ptychaspis speciosus* WALCOTT, 1879, Thirty-second Ann. Rept. New York State Museum, p. 131. (Species described as below.)

*Ptychaspis speciosus* Walcott, LESLEY, 1889, Geol. Surv. Pennsylvania, Rept. P 4, Dictionary of Fossils, Vol. 2, p. 830. (Text figure reproduced from a drawing sent him by Walcott.)

Glabella large, very convex, almost subcylindrical, width a little less than the length, nearly straight in front, the lateral angles rounded, sides straight and nearly parallel; posterior glabellar furrow extending deeply and obliquely about one-third across the glabella and connected by a straight transverse furrow; the middle glabellar furrow is less deeply impressed and extends across the glabella subparallel to the posterior furrow; the anterior furrow is indicated by a very obscure line opposite the anterior angle of the palpebral lobe. The occipital furrow is deeply impressed throughout its length. The occipital ring is strong and prominent, but not elevated above the general surface of the glabella. Dorsal furrow deeply excavated at the sides and well defined in front.

The facial suture, cutting the frontal margin on a line with the outer edge of the palpebral lobe, curves slightly outward, and passes directly to the anterior angle of the palpebral lobe; curving around this it passes obliquely outward to the margin of the posterior limb.

Fixed cheeks of medium width; the frontal limb is impressed with a groove midway between the dorsal furrow and its anterior margin; the posterior limb is subtriangular, with a furrow extending from the dorsal furrow to its lateral margin; the palpebral lobe is large and separated from the fixed cheeks by a deep sigmoid furrow. Surface granulose with waving striæ on the central portion of the fixed cheeks opposite the palpebral lobes.

This species is referred to the genus *Ptychaspis* from its strongly furrowed subcylindrical glabella and the direction of the facial suture. The largest specimen obtained of the head has a length of 12.5 mm., with a breadth of 13.7 mm. at the palpebral lobes.

*Observations.*—This very striking form is represented by numerous specimens of the cranidium with a few free cheeks and pygidia referred to it. The most nearly related species is *Ptychaspis granulosa* (Owen), which differs in having a proportionately shorter, more convex cranidium and smaller palpebral lobes. The pygidium (fig. 18) is very doubtfully referred to the species. The generic reference is somewhat doubtful as the large palpebral lobes and broadly rounded anterior margin of the glabella suggest *Dicellocephalus lodensis* (Whitfield).

*Formation and locality.*—Upper Cambrian, Hoyt limestone: (76) Arenaceous limestone at Hoyts quarry 4 miles (6.4 km.) west of Saratoga Springs; and (76a) in a railroad quarry, 1 mile (1.6 km.) north of Saratoga Springs; both in Saratoga County, New York.

A form apparently identical with *P. speciosus* was found in a drift block of sandstone, near Trenton Falls, Oneida County, New York, supposed to have been derived from the Potsdam sandstone west of the Adirondack Mountains.

### Genus DICELLOCEPHALUS Owen

### DICELLOCEPHALUS HARTTI (Walcott)

Plate 44, figs. 1-7a.

*Conocephalites hartti* Walcott, 1879, Thirty-second Ann. Rept. New York State Museum, p. 130. (Original description of species.)

*Dicellocephalus hartti* Walcott, 1886, Bull. U. S. Geol. Surv., No. 30, p. 21. (Name used in list of species.)

*Dicellocephalus hartti* (Walcott), Lesley, 1889, Geol. Surv. Pennsylvania, Rept. P 4, Dictionary of Fossils, Vol. 1, p. 199. (Text figure reproduced from drawing sent him by Walcott.)

Glabella truncato-conical, moderately convex; width at base, excluding occipital segment, equal to the length; slightly rounded in front, with anterior lateral angles abruptly rounded; posterior glabellar furrow extends obliquely in about one-third the distance across the glabella from each side, where it is united by a transverse furrow; middle furrow extends obliquely in from each side, but is not united at the center; anterior furrow obscurely defined opposite the anterior angle of the palpebral lobe. Occipital furrow broad and not deeply impressed. Occipital ring broad and slightly convex. Dorsal furrow well defined at the sides and front.

The facial suture curves slightly outward from the frontal margin, thence curving in to the anterior angle of the palpebral lobe, passes to the posterior angle of the palpebral lobe, and thence obliquely outward to the margin of the posterior limb.

Fixed cheeks comparatively broad; frontal limb about one-fifth the length of the head, curving gently from the dorsal furrow to the anterior margin; posterior limb elongate, with a strong furrow from the dorsal furrow to its extremity. Palpebral lobe elongate, separated from the fixed cheeks by a groove within the margin; surface covered with fine lamellose striæ.

This species is much larger than *Lonchocephalus calciferus.* The largest cranidium in the collection has a length of 30 mm., and a large pygidium has a length of 37 mm. with a width of 60 mm. The surface is finely punctate and marked by very fine, irregular imbricating lines.

*Observations.*—This species differs from *Dicellocephalus minnesotensis* in details, but it appears to come within the limits of the genus.

In the larger specimens the frontal rim is broad and slightly convex and in some specimens merged directly into the frontal limb. In the small specimens the frontal rim is more rounded and a distinct broad groove separates it from the narrow frontal limb. Comparing specimens of the cranidium 8 to 10 mm. in length with specimens 30 mm. in length two species would appear to be indicated, but there is a gradual transition by the widening out and flattening of the frontal limb so that the two extremes are united by forms that grade from the narrow rounded frontal limb to the broad flattened rim.

A somewhat similar gradation exists between small pygidia and large pygidia. In the small pygidia the median lobe extends back nearly to the posterior margin. The space between the margin and the end of the lobe increases in size until in the large forms, 37 millimeters in length, the flattened border is nearly one-third the length of the pygidium.

*Formation and locality.*—Upper Cambrian, Hoyt limestone: (76) Arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs; and (76a) in a railroad quarry, 1 mile (1.6 km.) north of Saratoga Springs; both in Saratoga County, New York.

### DICELLOCEPHALUS TRIBULIS, new species

Plate 44, figs. 8 and 8a.

A second well-marked species of *Dicellocephalus* occurs in association with *D. hartti.* It is closely allied to *D. misa* Hall of the "St. Croix sandstone" of Wisconsin. It differs in having slightly wider fixed cheeks, a more rounded frontal rim, and granulated surface.

The pygidium provisionally referred to this species also varies considerably from the pygidium referred to *D. misa.*

The largest specimen of a cranidium in the collection has a length of 16 mm.

*Formation and locality.*—Upper Cambrian, Hoyt limestone: (76) Arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

### Genus PROTICHNITES Owen

*Protichnites* OWEN, 1852, Quart. Journ. Geol. Soc. London, Vol. 8, p. 214. (Describes *Protichnites septem-notatus* and thus uses generic name.)

*Protichnites* Owen, BILLINGS, 1857, Canadian Nat. and Geol., Vol. 1, pp. 35-39. (General remarks and quotations from Owen's paper of 1852.)

*Protichnites* Owen, DAWSON, 1862, Idem, Vol. 7, pp. 271-277. (Discusses relations of *Protichnites* to the tracks of *Limulus*.)

*Protichnites* Owen, CHAPMAN, 1864, Exposition of the Minerals and Geology of Canada, pp. 159-160. (General remarks.)

*Protichnites* Owen, BILLINGS, 1870, Quart. Journ. Geol. Soc. London, Vol. 26, pp. 484-485. (Discusses Dawson's views and concludes that the tracks were made by trilobites.)

*Protichnites* Owen, CHAPMAN, 1877, Canadian Journ. Sci., Lit., and Hist., new ser., Vol. 15, pp. 486-490. (Discusses tracks and concludes that the so-called tracks of *Protichnites* and *Climactichnites* are of fucoidal origin.)

*Protichnites* Owen, DAWSON, 1890, Quart. Journ. Geol. Soc. London, Vol. 46, pp. 599-601, figs. 4 and 5a. (States that *Protichnites* are indubitable tracks of crustaceans.)

*Protichnites* Owen, PACKARD, 1900, Proc. American Acad. Arts and Sci., Boston, Vol. 36, pp. 63-71. (Restricts use of *Protichnites* to tracks with individual footprints.)

The first notice of the tracks subsequently named *Protichnites* appeared in the Montreal Gazette in 1847. They were referred to as the tracks of a tortoise. The editor, Mr. Abraham, called Mr. William E. Logan's attention to them and the latter subsequently made a geological study of the region where they occurred in Beauharnois County, Ontario, Canada. He [1] identified the sandstone as the Potsdam formation of the New York state geologists and took great pains to have casts made of the first tracks for Prof. Richard Owen, who at first thought that the tracks might be those of a tortoise.[2] Later, with more material, he described the tracks under the generic name *Protichnites*.[3] He described and illustrated six species, *Protichnites septem-notatus, P. octo-natatus, P. latus, P. multinotatus,*

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[1] Quart. Journ. Geol. Soc. London, Vol. 7, 1851, pp. 247-250.

[2] Idem, pp. 250-252.

[3] Idem, Vol. 8, 1852, p. 214.

*P. lineatus,* and *P. alternans.*[1] Professor Owen concludes[2] that a crustacean like *Limulus* was nearest to his idea of the kind of animal which left the impressions on the Potsdam sandstone.

In 1857[3] Mr. E. Billings wrote a general paper on the fossils of the Potsdam sandstone, but did not add any observations of importance.

Dr. J. W. Dawson, in order to test Professor Owen's view that an animal like *Limulus* may have made the *Protichnites* tracks experimented with a living *Limulus* at the seashore, causing it to creep about on the sand under various conditions. Summarized, his conclusions are:[4]

1. The conjecture of Owen that they may have been made by a creature somewhat resembling *Limulus,* is verified by the impressions made by that animal.

2. The further view of Owen that the grouping of the impressions depended on multifid limbs, and that the number of impressions in a group might indicate specific diversity, is also vindicated by the facts, with this limitation, anticipated by Professor Owen, that tracks like *P. lineatus,* might have been made by any of the animals which made the other impressions, and that if like *Limulus* they possessed one large pair of feet making the principal marks, and smaller ones occasionally used, the numbers of marks may have somewhat differed in different circumstances . . . .

3. The animal or animals producing the *Protichnites* probably resembled *Limulus* in general form, and in the possession of a strong caudal spine. They probably differed from *Limulus* in the less breadth or depth of the cephalothorax, and in the greater complexity and comparative size of the feet.

4. Some at least of the *Protichnites* were probably produced by animals creeping on wet sand; but *P. lineatus* and the *Climactichnites,* if the work of a similar animal, were formed under water . . . .

5. The suppositions above stated would account for the absence or rarity of remains of the animals which produced the *Protichnites* . . . .

6. If we enquire what animals, known to palæontologists, have produced the *Protichnites,* it would seem that no others fulfil the necessary conditions in any particular, except the larger trilobites, for instance those of the genus *Paradoxides* . . . . On the whole we may safely conclude that if any of the larger primordial trilobites were provided with walking and swimming feet of the type of those of *Limulus,* but differing in details of structure, they may have produced both the *Protichnites* and the *Climactichnites.* On the other hand, it is quite possible that these impressions have been formed by crustaceans yet undiscovered, and approaching in some respects more nearly to *Limulus* than any of the known trilobites. In this last case I should suppose that the animal in question had a flatter or more shallow cephalo-thorax than

[1] Quart. Journ. Geol. Soc. London, Vol. 8, 1852, pp. 214-225.

[2] Idem, p. 224.

[3] Canadian Nat. and Geol., Vol. 1, 1857, pp. 35-39.

[4] Idem, Vol. 7, 1862, pp. 276 and 277.

that of *Limulus,* proportionately stronger and perhaps more divided feet, and a stouter caudal spine.

Mr. E. Billings in 1870[1] concluded that:

1. The tracks could have been made either by a *Limulus* or by a trilobite.
2. No fossils of the order (Ziphosura) to which *Limulus* belongs have been found so low down as the Potsdam sandstone.
3. Large trilobites occur there in abundance.

The weight of evidence, therefore, favors the opinion that the tracks in question are those of trilobites.

Prof. E. J. Chapman in 1877[2] broached the view that the tracks named *Protichnites* and *Climactichnites* were of fucoidal origin. I will refer to this view again under *Climactichnites* (see p. 278).

In a very fine paper on burrows and tracks Sir J. William Dawson in 1890[3] stated that the *Protichnites* of the Potsdam sandstone are indubitable tracks of crustaceans, and that both *Protichnites* and *Climactichnites* may have been made by the same animal.

My own interest in the tracks began in 1886 when I first met with them north of the Adirondack Mountains in Beauharnois, Canada, and on the eastern side of the mountains in Essex County, New York. At the Beauharnois locality, west of the town, on Rogier's farm I obtained fine specimens of the *Protichnites* tracks, showing that many of the impressions were trifid (pls. 46 and 47) and made by a crustacean having legs terminating in a joint that had three strong, narrow, terminal spines. It was this trifid aspect of the tracks that probably led the first observers to consider that the tracks might have been made by a three-toed vertebrate similar to the tortoise. For twenty-six years I have had the specimens, or photographs of them, in my laboratory, waiting for something to turn up that would explain more satisfactorily not only the complicated and varied series of tracks described by Owen, but also the trifid impressions illustrated on plates 46 and 47 of this paper. The explanation came with the discovery in 1911 of the series of appendages of the trilobite *Neolenus serratus* (Rominger). On plate 45, figure 1, is shown a series of the legs on the left side of the trilobite extending far beyond the margin of the dorsal shield. In figure 2, the terminal joints of several of the legs have three terminable, movable, slightly curved spines. The cephalic legs of figure 3 project forward from the side of the cephalon, and figure 4 shows the trifid arrangement of the short, strong spines of the terminal joint of the cephalic legs.

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[1] Quart. Journ. Geol. Soc. London, Vol. 26, 1870, pp. 484-485.

[2] Canadian Journ. Sci., Lit., and Hist., new ser., Vol. 15, 1877, p. 490.

[3] Quart. Journ. Geol. Soc. London, Vol. 46, 1890, p. 599.

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 particular trilobites that left the tracks on the beaches of Potsdam sandstone time were undoubtedly species of the genus *Dicellocephalus*. Individuals of this genus attained a large size, and *Dicellocephalus hartti* occurs in the Potsdam sandstone both north and south of the Adirondack Mountain area of New York.

With our present information of the structure of the trilobites I do not think that we can consider *Climactichnites* as the trail of a trilobite. This has been referred to under discussion of that genus (pp. 259-261).

*Summary.*—The *Protichnites* tracks found on the surface of layers of Potsdam sandstone were made by trilobites of the genus *Dicellocephalus*.

The trifid imprint resulted from the impress of the end of the terminal joint of the trilobite's leg with its three movable spines.

The trails named *Climactichnites* were not formed by trilobites and have a quite different origin from the *Protichnites* tracks.

### PROTICHNITES SEPTEMNOTATUS Owen

Plates 46 and 47

*Protichnites septem-notatus* Owen, 1852, Quart. Journ. Geol. Soc. London, Vol. 8, pp. 214-217, pl. 9. (Description of species.)

I shall not attempt to insert the synonymy of this species. The principal papers treating of the genus have been mentioned. In a future paper on the trilobite I may consider in detail the various series of tracks to which Owen gave specific names. At present I am inclined to consider that all the Beauharnois tracks were made by one species of *Dicellocephalus* and the Keeseville, Essex County, New York, tracks by another species. The latter tracks are on a finergrained, smoother surface than those at Beauharnois, and the individual impressions of the feet are more numerous and crowded along the main lines of tracks.

*Formation and locality.*—Cambrian (Upper ?), Potsdam sandstone: (**220b**) Rogier's farm just west of Beauharnois, Province of Quebec, Canada.

### PROTICHNITES LOGANANUS Marsh

Plates 48 and 49

*Protichnites logananus* Marsh, 1869, American Journ. Sci., 2d ser., Vol. 48, pp. 46-49. (General description, discussion, and illustration.)

*Protichnites logananus* Marsh, 1869, Proc. American Assoc. Adv. Sci., Vol. 17, pp. 322-324. (Same as preceding reference, except that the plate is omitted; also the footnote regarding Doctor Dawson's view.)

The tracks are described as having been made by a smaller animal than the one that made the Beauharnois *Protichnites* tracks; also that there was no medial trail or tail mark as in the latter tracks.

I collected from near the type locality several slabs of the sandstone with many tracks on them. Some of these have a median trail or furrow that indicates two terminal spines on the pygidium, or, which I think is the more correct view, the furrow with deep sides was formed by the dragging of the anterior portion of the caudal furca of the trilobite on the sand. That some series of tracks are without the median trail indicates that the animal that made the tracks kept well up from the sand, while others that may have been heavier or weaker touched and dragged some portion of the median dorsal surface or the caudal furca along on the sand.

*Formation and locality.*—Upper Cambrian, Potsdam sandstone: (77) Sandstone near the water below the falls at the high bridge, and also at several horizons in the canyon, the highest point being 70-75 feet (21-22 m.) above the water, in Ausable Chasm, Essex County, New York.

## DESCRIPTION OF PLATE 37

PAGE

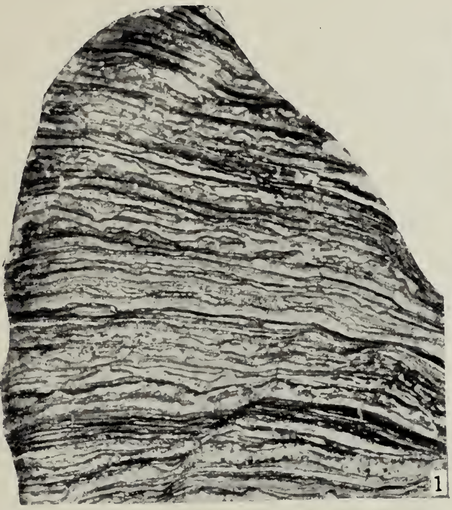
*Cryptozoön proliferum* (Hall) .................................... 258

Fig. 1. (Natural size.) View, by transmitted light, of a thin transverse section, showing the lamellæ. U. S. National Museum, Catalogue No. 58541.

2. (Natural size.) View, by transmitted light, of a thin section, showing the lamellæ where there was a slight dislocation, caused by irregularity of growth. U. S. National Museum, Catalogue No. 58542.

3. (Natural size.) View of the weathered surface of limestone, showing several specimens. U. S. National Museum, Catalogue No. 58543.

The specimens represented by figs. 1-3 are from locality (110) Upper Cambrian, shaly calcareous sandstone resting on massive layers of Potsdam sandstone, east side of the town of Whitehall, Washington County, New York.



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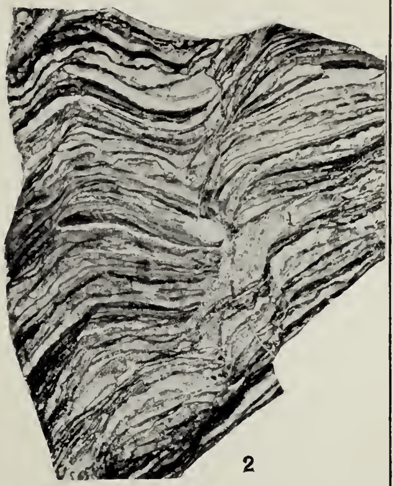

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CRYPTOZOÖN PROLIFERUM HALL

## DESCRIPTION OF PLATE 38

PAGE

*Climactichnites youngi* (Chamberlin). (See pl. 39) .................... 259

FIG. 1. (Reduced one-sixth.) Impression on beach sand by the lower surface of the animal making the *Climactichnites* trails. A portion of the trail is shown, also the forward arching lines on the transverse ridges made by the backward push of the animal in creeping forward. These are well shown by fig. 2, pl. 39. U. S. National Museum, Catalogue No. 58544.

The specimen represented is from locality (99c) Upper Cambrian, near New Lisbon, Wisconsin.


TRAIL OF ANNELID

## DESCRIPTION OF PLATE 39

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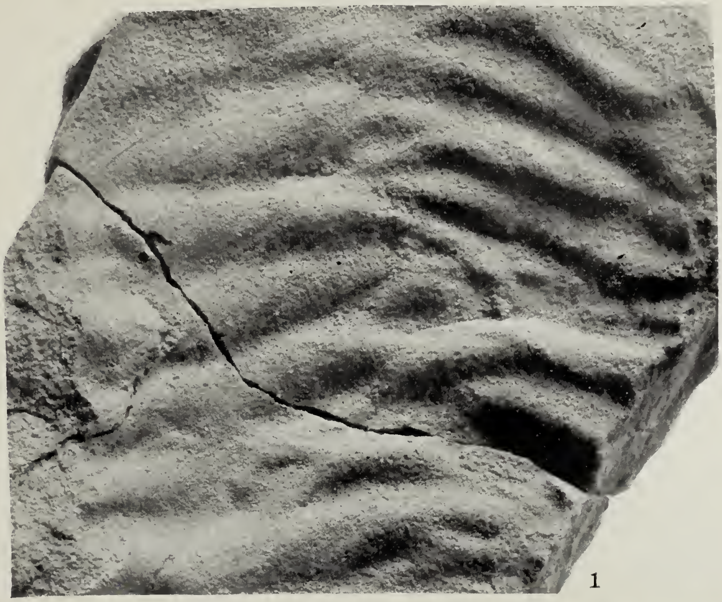
*Climactichnites youngi* (Chamberlin). (See pl. 38) ..................... 259

Fig. 1. (Natural size.) Portion of a trail where the animal made a very irregular track and thus recorded the fact of its having a very flexible under surface. U. S. National Museum, Catalogue No. 58546.

2. (Reduced about one-seventh.) Portion of a very regular trail, showing forward-curving transverse furrows made by pressing the beach sand backward in creeping, also curved lines made by the impression of the very fine, forward-arching transverse ridges on the ventral surface of the animal. U. S. National Museum, Catalogue No. 58545.

Both specimens represented are from locality (**99c**) Upper Cambrian, near New Lisbon, Wisconsin.





TRAIL OF ANNELID

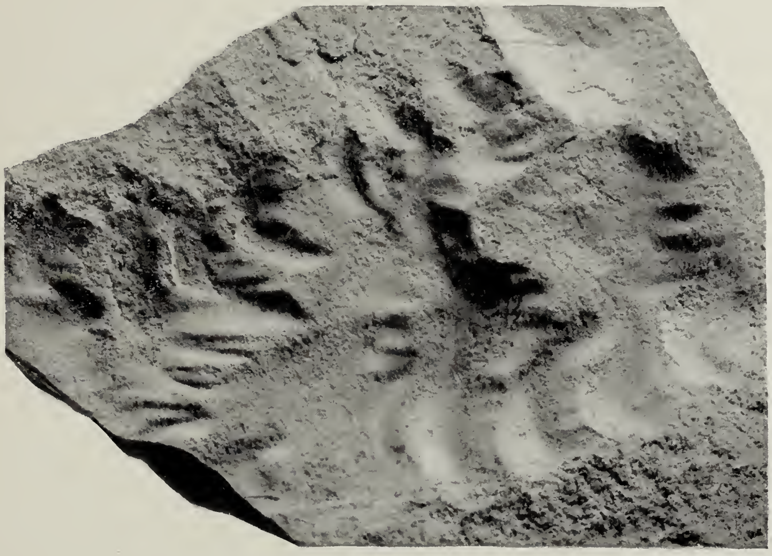
## DESCRIPTION OF PLATE 40



FIG. 1. (Reduced to about one-half natural size.) Trail showing longitudinal furrows very much like those on fig. 1, pl. 39. This specimen strongly suggests the action of water in forming the longitudinal furrows. U. S. National Museum, Catalogue No. 58547.

The specimen represented is from locality (99c) Upper Cambrian, near New Lisbon, Wisconsin.

2. (One-twenty-fifth of natural size.) Copy of portion of plate illustrating a series of trails discovered at Mooers, Clinton County, New York. [Bull. New York State Museum, No. 80, 1905, pl. 3.] The specimen represented is now in the New York State Museum, Albany, New York.



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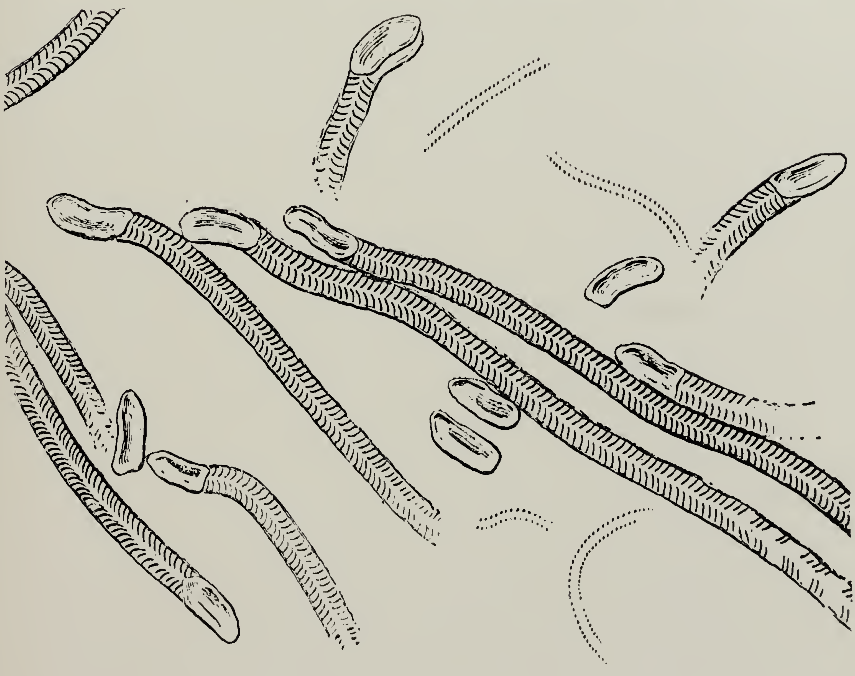


2

TRAILS OF ANNELID

## DESCRIPTION OF PLATE 41

PAGE

*Lingulella* (*Lingulepis*) *acuminata* (Conrad) .......................... 262

FIGS. 1-4. Varying forms of the ventral valve. Fig. 4 is much like that of the type specimen of "*Lingulella pinnaformis* Owen."

5-7. Varying forms of the dorsal valve.

Figs. 1-7 are copied from the figures illustrating this species on Plate XL, figs. 1h-n, respectively, of Monogr. 51 U. S. Geol. Survey, 1912 (in press). The specimen represented by figure 1h is in the U. S. National Museum, Catalogue No. 52469a; the specimens represented by figures 1i-n are in the U. S. National Museum, Catalogue Nos. 51878a-f, respectively.

*Lingulella prima* (Conrad MS.) Hall .................................. 262

FIG. 8. Fragment of a ventral valve, showing the cast of the area, the divided umbonal muscle scar (g), and the pedicle scar (m). U. S. National Museum, Catalogue No. 27435c.

9. Exterior of a ventral valve, showing rather strong undulations of growth. U. S. National Museum, Catalogue No. 27435b.

10. Cast of the interior of a ventral valve, showing the pestle-shaped ridge that filled the median groove of the interior of the shell. U. S. National Museum, Catalogue No. 27435a.

11. Partly exfoliated dorsal valve. U. S. National Museum, Catalogue No. 27435d.

The specimens represented are all from locality (77), Upper Cambrian sandstone, Ausable Chasm, Essex County, New York.

Figs. 8-11 are copied from the figures illustrating this species on Plate XXVII, figs. 1b, 1a, 1, and 1c, respectively, of Monogr. 51, U. S. Geol. Survey, 1912 (in press).

*Triblidium cornutaforme* (Walcott) .................................. 263

FIG. 12. (× 3.) Side view of a small, rather depressed specimen, showing the profile. U. S. National Museum, Catalogue No. 58548.

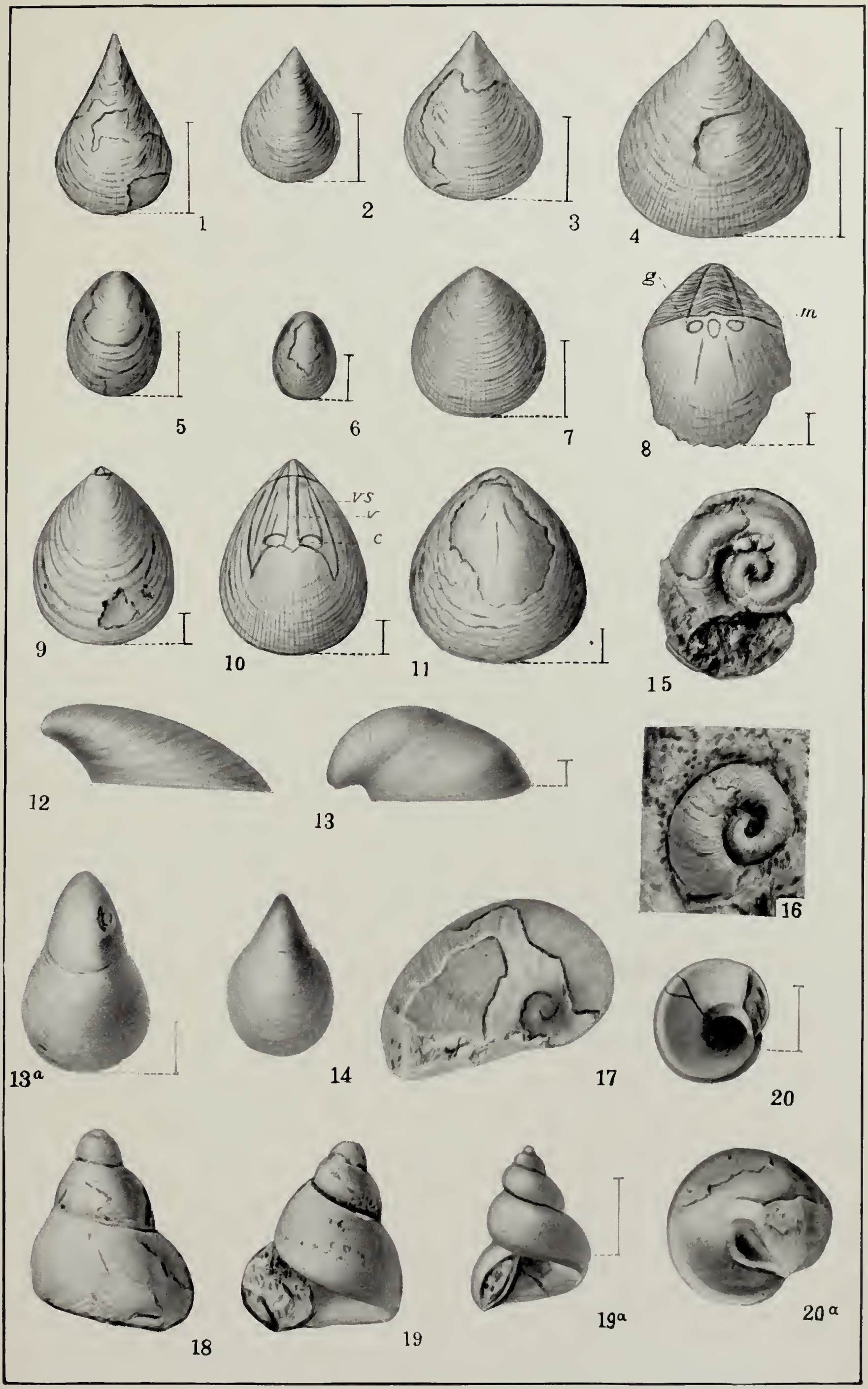
13 and 13a. (× 5.) Side and top view of a small specimen having an irregular growth. U. S. National Museum, Catalogue No. 58549.

14. (× 1.5.) Top view. U. S. National Museum, Catalogue No. 58550.

*Pelagiella minutissima* (Walcott) .................................. 266

FIG. 15. (× 6.) Side view of a partly exfoliated specimen. U. S. National Museum, Catalogue No. 58551.

16. (× 6.) Side view of a specimen preserving the striated outer surface. U. S. National Museum, Catalogue No. 58552.




POTSDAM-HOYT FAUNA

DESCRIPTION OF PLATE 41 (Continued)

PAGE

*Pelagiella hoyti* (Walcott) ........................................ 266

FIG. 17. (× 6.) Side view of the type specimen. U. S. National Museum Catalogue No. 23846.

*Matherella saratogensis* (Walcott) ........................................

FIGS. 18 and 19. (× 2.) Anterior and posterior sides of the same shell. U. S. National Museum, Catalogue No. 23847.

20. (× 2.) Umbilical view of the shell illustrated by figs. 18 and 19.

21. (× 2.) Anterior view of two whorls of a shell attached to the matrix. U. S. National Museum, Catalogue No. 23847.

All the specimens illustrated on this plate, with the exception of figs. 1 and 8-11, are from locality (76), Upper Cambrian, Hoyt limestone, Potsdam horizon, Hoyt's quarry, 4 miles (6.4 km.) west of Saratoga Springs, New York.

The specimen represented by figure 1 is from locality (76a), Upper Cambrian, 1 mile (1.6 km.) north of Saratoga Springs, New York.

## DESCRIPTION OF PLATE 42

PAGE

*Matthevia variabilis* Walcott ........................................ 265

FIGS. 1, 1a-b. (× 2.5.) End, summit, and side views of one of the most characteristic forms of the species.

2. (× 2.) A more conical form than the specimen represented by fig. 1b.

3. (× 3.) Associated operculum with portions of the shell broken away.

4. (× 3.) Natural cast of the interior of an operculum.

5, 5a-b. (× 3.) Side, end, and summit views of a conical specimen, having a deeply sinuous margin.

6. (Natural size.) Cast of the interior of the chamber of habitation and inner chambers. The septa are seen at s, s′. The outline of the shell about the chambers is traced.

7. (Natural size.) Cast of the chambers of a more conical specimen than that represented by fig. 6.

8. (Natural size.) Cast of the chambers of a shorter specimen than those represented by figs. 6 and 7.

9. (× 6.) Natural transverse section of a specimen on a line of the septa separating the chamber of habitation and the inner chambers.

10. (× 6.) Transverse septum separating one of the inner chambers and the chamber of habitation.

11. (× 5.) Enlarged transverse section of a portion of a shell, illustrating the peculiar vesiculose structure of the shell.

12. Enlargement of the interior surface of a part of a chamber of habitation, as seen on the specimen represented by fig. 7.

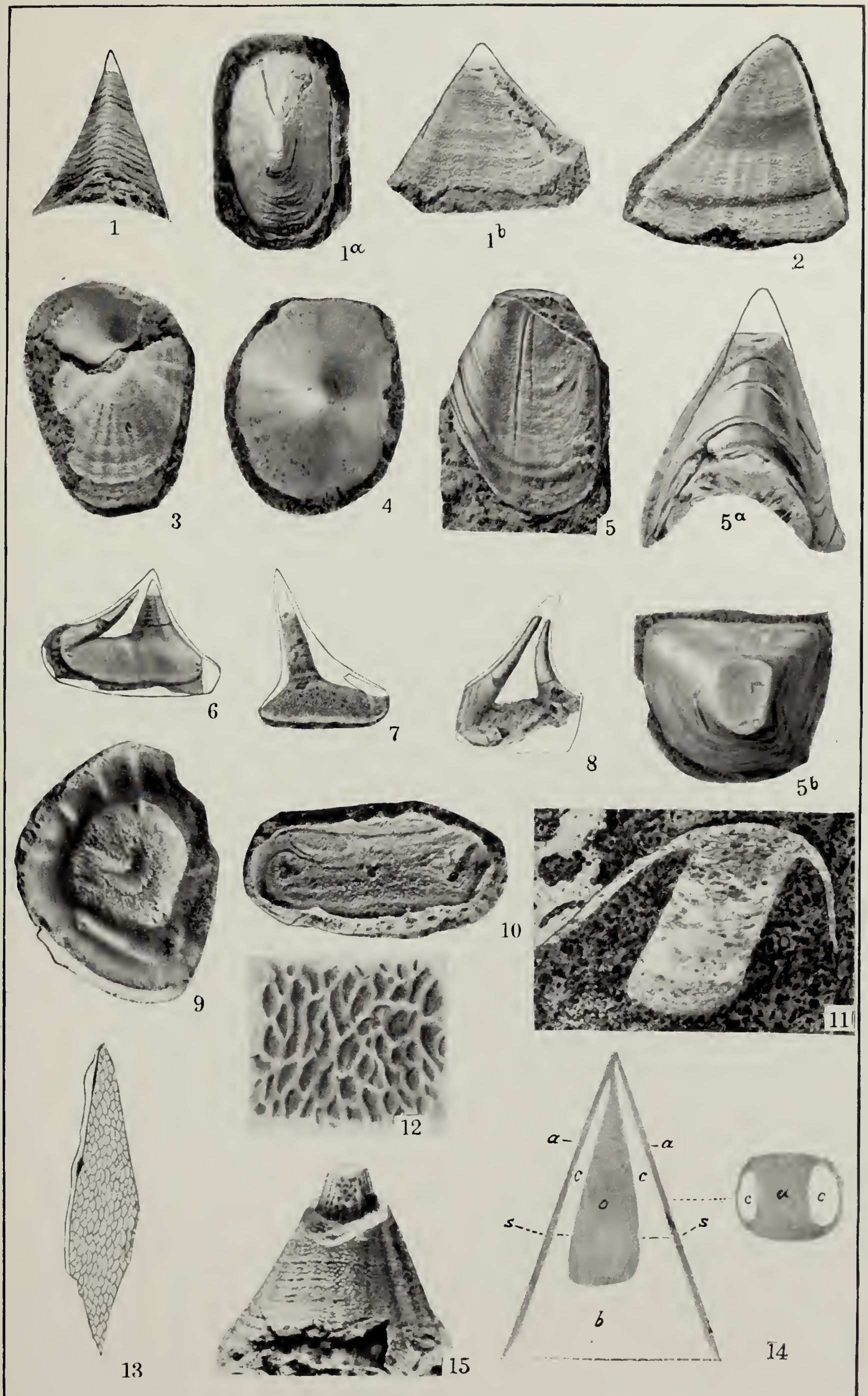
13. (× 4.) Thin section of a portion of a shell, showing the vesiculose structure of the shell.

14. Diagrammatic vertical section to illustrate a shell (a, a); inner chambers (c, c); chamber of habitation (d), and septa (s, s) between the chamber of habitation and the inner chambers.

    On the left side the transverse section of a shell (a), and the inner chambers (c, c).

15. (× 3.) End view of a conical specimen, showing the cast of one of the inner chambers, the thickness of the outer shell, and the papillose character of the outer surface.

All the specimens illustrated on this plate are included under one number, U. S. National Museum, Catalogue No. 24598. From locality (76), Upper Cambrian, Hoyt limestone, Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.




POTSDAM-HOYT FAUNA

## DESCRIPTION OF PLATE 43

PAGE

*Palæacmæa typica* Hall and Whitfield .................................. 264

FIG. 1. (Natural size.) View of the upper side of a large specimen.

2. Profile view, showing the convex side and curvature of the shell represented by fig. 1.

These figures are reproduced from illustrations by Hall and Whitfield (Twenty-third Ann. Rept. New York State Cab. Nat. Hist., 1873, pl. 11, figs. 4 and 5). The specimens represented by figs. 1 and 2 are from the Potsdam sandstone, Keeseville, New York.

*Hyolithellus papillatus* Walcott .................................. 267

FIG. 3. (Natural size.) Portion of a rather large tube. U. S. National Museum, Catalogue No. 58553.

4. (× 4.) Enlargement of a portion of the specimen illustrated by fig. 3, to illustrate the surface characters.

The specimens represented by figs. 3 and 4 are from locality (111), Upper Cambrian, at the top of the Potsdam sandstone on Marble River, one mile (1.6 km.) south of Chateaugay, Franklin County, New York.

*Hyolithes gibbosus* Hall and Whitfield .................................. 265

FIG. 5. (Natural size.) View of the ventral, rounded side, showing the form of the shell.

6. (Natural size.) Profile view, showing the convex side and curvature of the shell.

These figures are reproduced from illustrations by Hall and Whitfield (Twenty-third Ann. Rept. New York State Cab. Nat. Hist., 1873, pl. 11, figs. 1 and 2). The specimens represented by figs. 5 and 6 are from the Potsdam sandstone, Keeseville, New York.

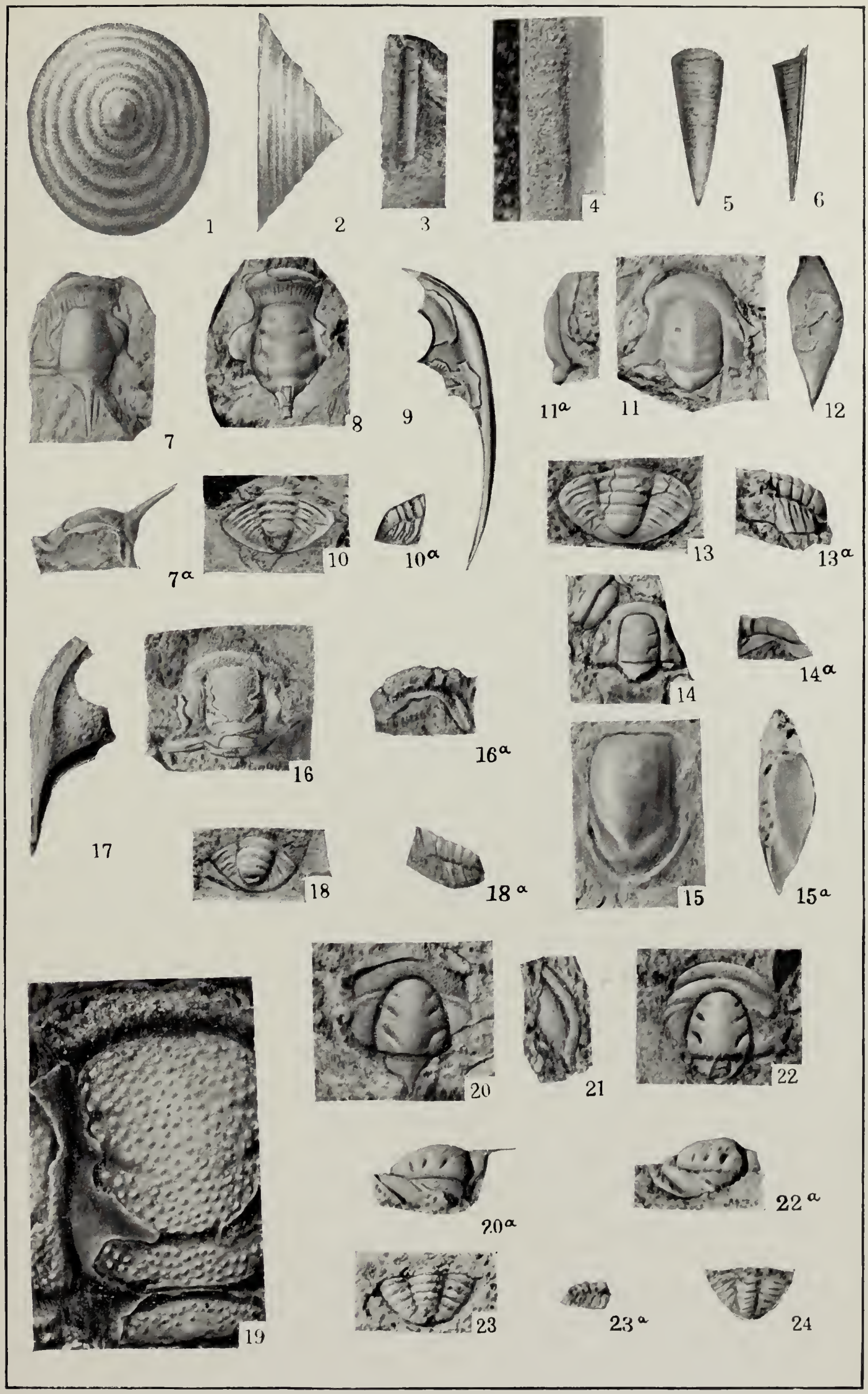
*Lonchocephalus calciferus* (Walcott) .................................. 270

FIGS. 7 and 7a. (Natural size.) Dorsal and side views of an imperfect cranidium. U. S. National Museum, Catalogue No. 58554.

8. (Natural size.) Dorsal view of a cranidium, showing the characters of the glabella. U. S. National Museum, Catalogue No. 58555.

9. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58556.

10 and 10a. (× 2.) Dorsal view and side outline of pygidium associated with this species. U. S. National Museum, Catalogue No. 58557.




POTSDAM-HOYT FAUNA

DESCRIPTION OF PLATE 43 (Continued) PAGE

*Agraulos saratogensis* Walcott .......................................... 269

FIGS. 11 and 11a. (Natural size.) Dorsal and side views of an imperfect cranidium. U. S. National Museum, Catalogue No. 58558.

12. (Natural size.) A large free cheek associated with this species. U. S. National Museum, Catalogue No. 58559.

13 and 13a. (× 2.) Dorsal and side views of associated pygidium. U. S. National Museum, Catalogue No. 58560.

14 and 14a. (× 2.) Dorsal and side views of a nearly entire cranidium. U. S. National Museum, Catalogue No. 58561.

15 and 15a. (× 3.) Ventral and side views of an hypostoma associated with this species. U. S. National Museum, Catalogue No. 58562.

*Ptychaspis speciosus* Walcott.......................................... 272

FIGS. 16 and 16a. (Natural size.) Dorsal and side views of an imperfect cranidium. U. S. National Museum, Catalogue No. 58563.

17. (× 2.) Associated free cheek referred to this species. U. S. National Museum, Catalogue No. 58564.

18 and 18a. (× 2.) Dorsal and side views of associated pygidium referred to this species. U. S. National Museum, Catalogue No. 58565.

19. (× 4.) Enlargement of the central portions of the cranidium of the specimen represented by fig. 16, showing the coarse tubercles on the glabella and fine tubercles on the anterior margin. U. S. National Museum, Catalogue No. 58563.

The specimens represented by figs. 7-19 are from locality (76), Upper Cambrian, Hoyt limestone, Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

*Ptychoparia minuta* (Bradley) .......................................... 267

FIGS. 20 and 20a. (× 3.) Dorsal and side views of a convex cranidium. U. S. National Museum, Catalogue No. 58566.

21. (× 3.) Associated free cheek. U. S. National Museum, Catalogue No. 58567.

22 and 22a. (× 3.) Dorsal and side views of a cranidium preserving the anterior rim and border. U. S. National Museum, Catalogue No. 58568.

23 and 23a. (× 3.) Dorsal and side views of a pygidium from which the test has been exfoliated. U. S. National Museum, Catalogue No. 58569.

24. (× 3.) Dorsal view of a pygidium preserving the test. U. S. National Museum, Catalogue No. 58570.

The specimens represented by figs. 20-24 are from locality (77), Upper Cambrian, Potsdam horizon, sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70-75 feet (21.3-22.9 m.) above the water in Ausable Chasm, Essex County, New York.

## DESCRIPTION OF PLATE 44



FIGS. 1 and 1a. (Natural size.) Dorsal and side views of a large, imperfect cranidium. U. S. National Museum, Catalogue No. 58571.

2. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58572.

3 and 3a. (Natural size.) Dorsal and side views of a smaller cranidium than that illustrated by fig. 2. U. S. National Museum, Catalogue No. 58573.

4. (Natural size.) Hypostoma with outline restored. U. S. National Museum, Catalogue No. 58574.

5. (Natural size.) Portion of thoracic segment. U. S. National Museum, Catalogue No. 58575.

6 and 6a. (Natural size.) Dorsal and side views of a large pygidium, illustrating the increase in width of the border as compared with the specimen represented by fig. 7. U. S. National Museum, Catalogue No. 58576.

7 and 7a. (Natural size.) Dorsal and side views of a smaller pygidium. U. S. National Museum, Catalogue No. 58577.



FIGS. 8 and 8a. (× 2.) Dorsal and side views of the type specimen of cranidium. U. S. National Museum, Catalogue No. 58578.

The specimens represented by figs. 1-8a are from locality (**76**), Upper Cambrian, Hoyt limestone, Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.

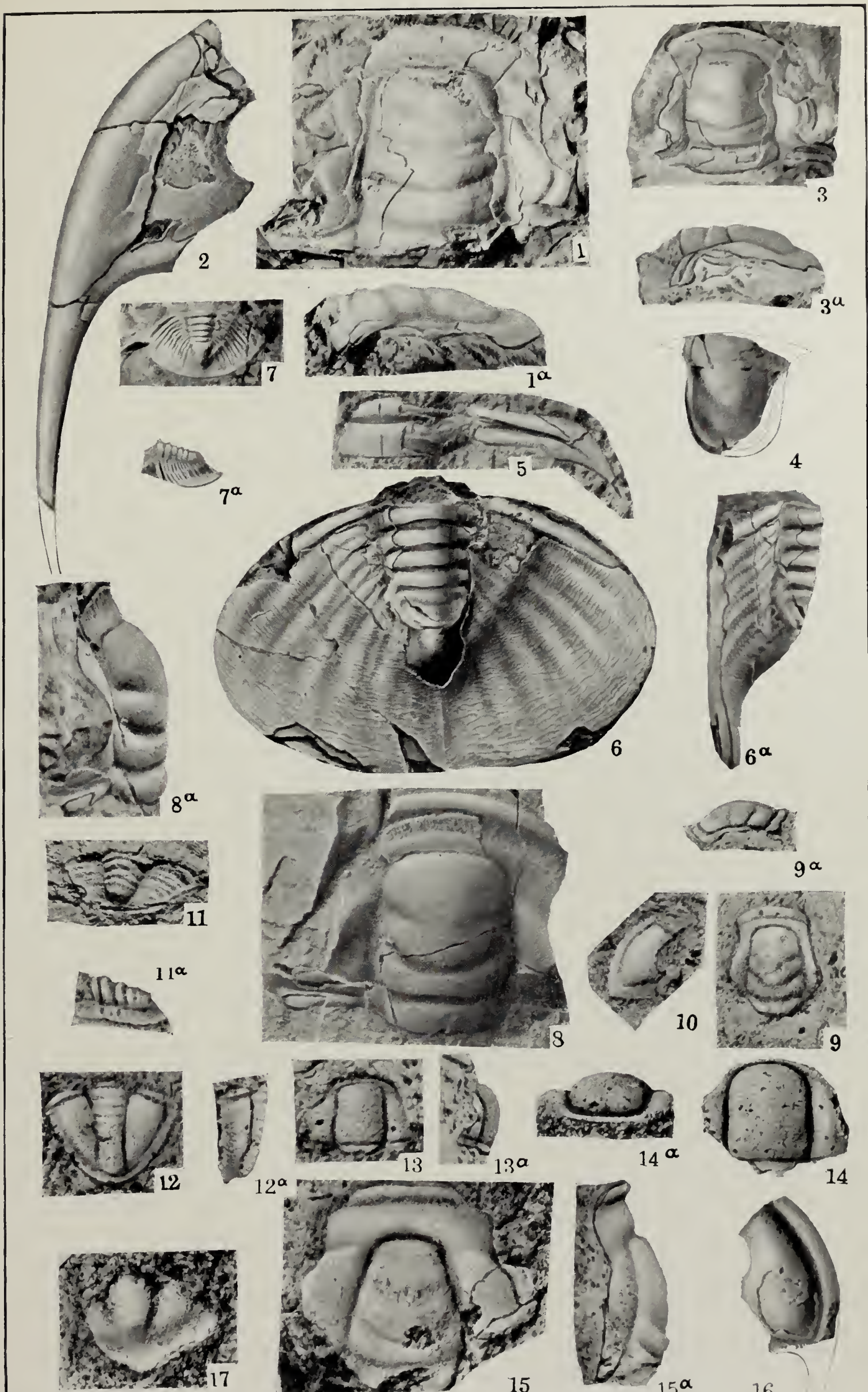


FIGS. 9 and 9a. (× 2.) Dorsal and side views of the type specimen of the cranidium. U. S. National Museum, Catalogue No. 58579.

10. (× 3.) Free cheek associated with the specimen represented by fig. 8. U. S. National Museum, Catalogue No. 58580.

11 and 11a. (× 2.) Dorsal and side views of an associated pygidium referred to this species. U. S. National Museum, Catalogue No. 58581.

The specimens represented by figs. 9-11a are from locality (**110a**) (just above **110**), Upper Cambrian, sandstone on the east side of the town of Whitehall, Washington County, New York.




POTSDAM-HOYT FAUNA

## DESCRIPTION OF PLATE 44 (Continued)

PAGE

*Pagodia seelyi* Walcott .......................................... 269

FIGS. 12 and 12a. (× 2.) Dorsal and side views of pygidium. U. S. National Museum, Catalogue No. 58582.

13 and 13a. (× 3.) Dorsal and side views of a small cranidium. U. S. National Museum, Catalogue No. 58583.

14 and 14a. (× 2.) Dorsal and front views of a larger cranidium. U. S. National Museum, Catalogue No. 58584.

The specimens represented by figs. 12-14a are from locality (77), Upper Cambrian, Potsdam sandstone near the water below the falls at the high bridge, and also at several horizons in the section, the highest point being 70-75 feet (21.3-22.9 m.) above the water in Ausable Chasm, Essex County, New York.

*Ptychoparia matheri* Walcott .......................................... 268

FIGS. 15 and 15a. (Natural size.) Dorsal and side views of an imperfect cranidium. U. S. National Museum, Catalogue No. 58585.

16. (Natural size.) Associated free cheek. U. S. National Museum, Catalogue No. 58586.

17. (× 2.) Fragment of the interior cast of the posterior portion of a pygidium associated with this species. U. S. National Museum, Catalogue No. 58587.

The specimens represented by figs. 15-17 are from locality (110), Upper Cambrian, shaly calcareous sandstone resting on massive layers of Potsdam sandstone, east side of the town of Whitehall, Washington County, New York.

## DESCRIPTION OF PLATE 45



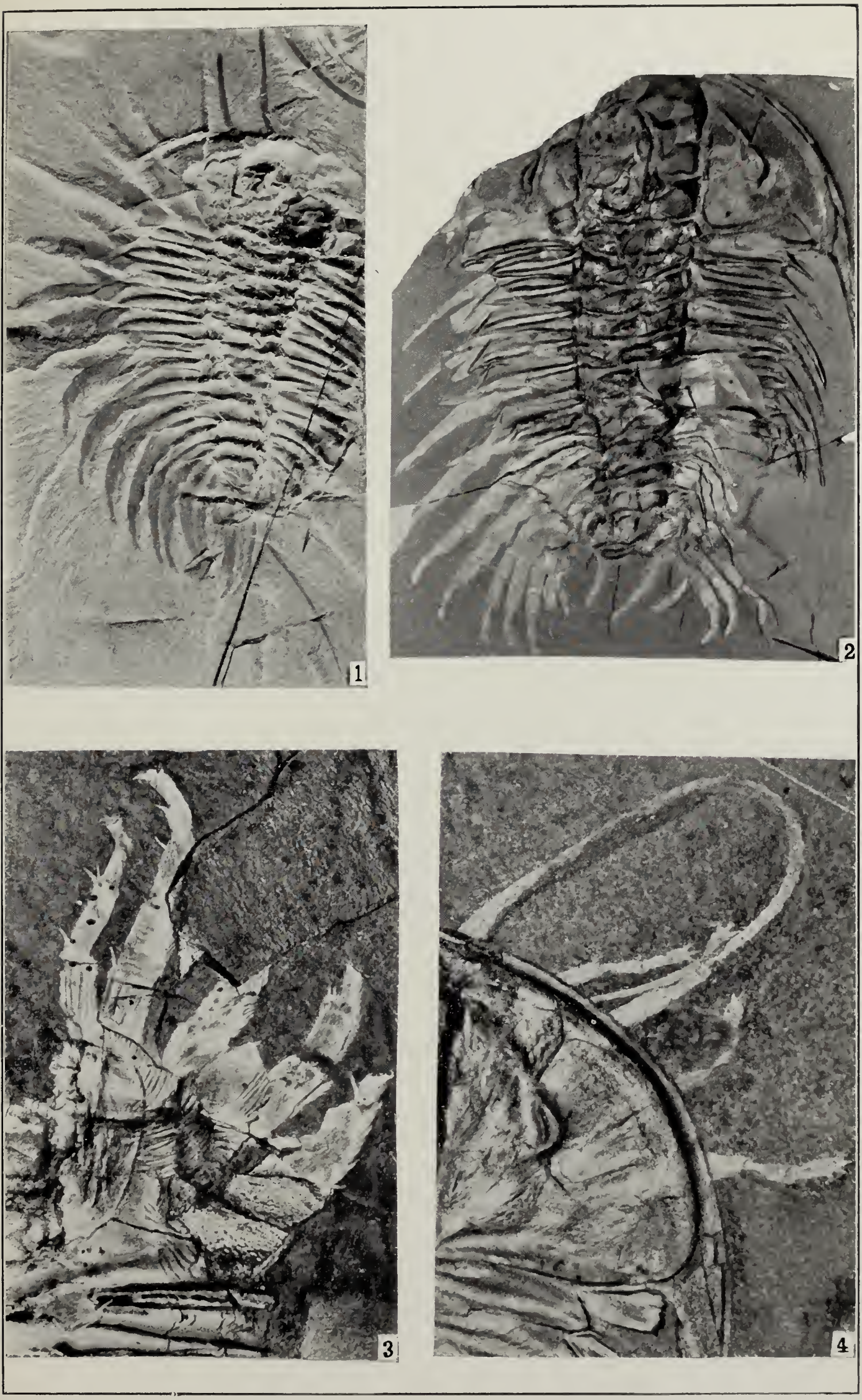
FIG. 1. (Natural size.) A specimen showing on the left side 12 thoracic abdominal legs and portions of three imperfect cephalic legs, also antennæ and one of the caudal furca. U. S. National Museum, Catalogue No. 58588.

2. (Natural size.) A specimen showing thoracic-abdominal legs and how they vary in length beneath the pygidium. This variation would necessarily make the imprints of the terminal joint occur at varying distances from the median line as represented by the base of the caudal furca. The posterior legs on the left side have three short spines attached to the distal end of the terminal joint. U. S. National Museum, Catalogue No. 58589.

3. (× 2.) Cephalic legs projecting forward. U. S. National Museum, Catalogue No. 58590.

4. (× 2.) Legs showing terminal joint with trifid termination. Such legs would make an imprint similar to the trifid tracks on plates 48 and 49. U. S. National Museum, Catalogue No. 58591.

The specimens represented by figs. 1-4 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, one mile (1.6 km.) northeast of Burgess Pass, above Field, British Columbia.




LEGS OF TRILOBITES

## DESCRIPTION OF PLATE 46



FIG. 1. (Natural size.) Broad track showing trifid imprint and furrow made by dragging of ventrum or more probably base of caudal furca in the sand. U. S. National Museum, Catalogue No. 58592.

The specimen represented is from locality (**220b**), Upper Cambrian, Potsdam sandstone, near Beauharnois, Province of Quebec, Canada.

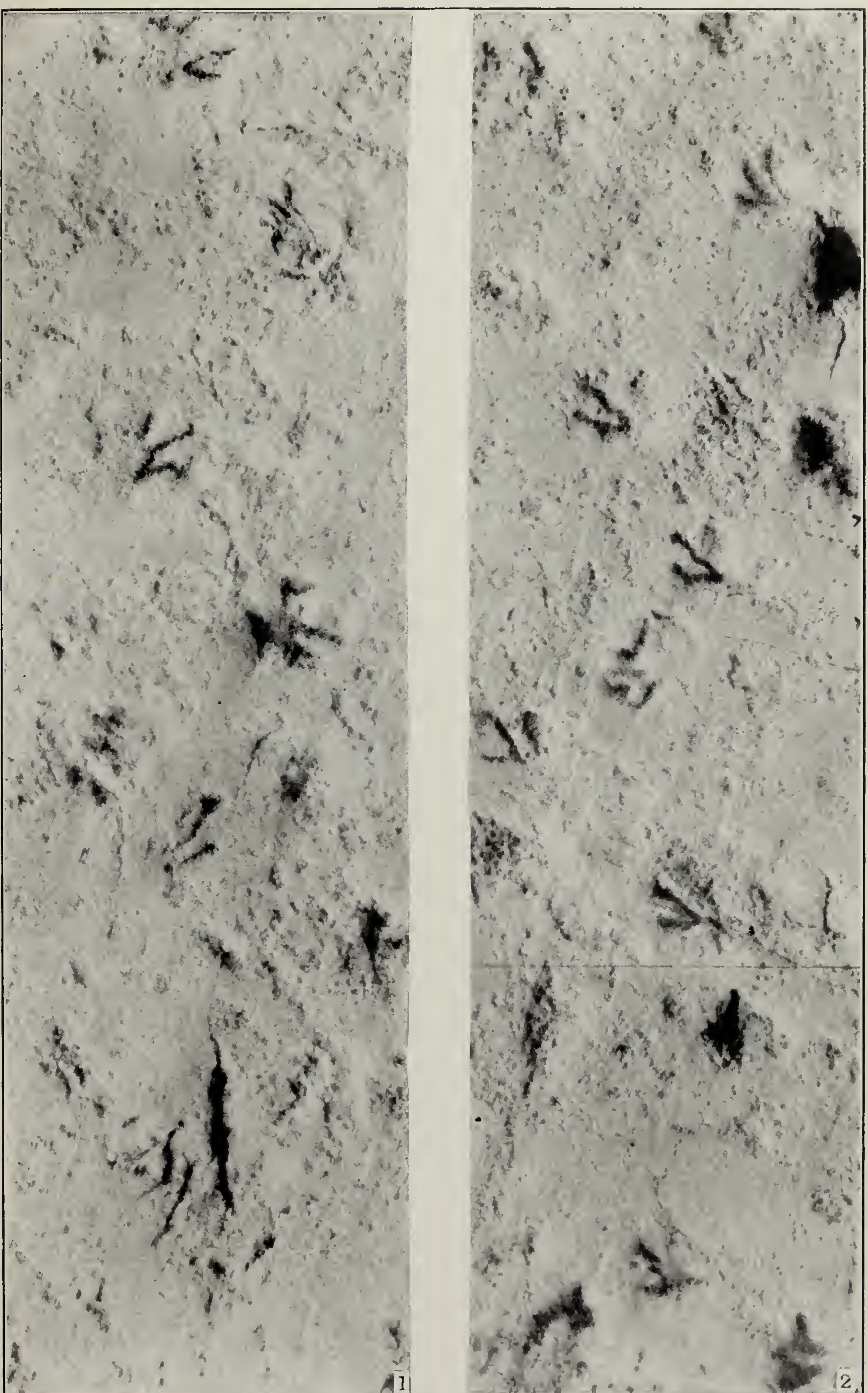
TRACKS OF TRILOBITES

## DESCRIPTION OF PLATE 47



FIGS. 1 and 2. (Natural size.) Right and left side of broad track 13-15 cm., showing the trifid tracks. 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.




TRACKS OF TRILOBITES

## DESCRIPTION OF PLATE 48

PAGE

*Protichnites logananus* Marsh. (See pl. 49) .......................... 279

Fig. 1. Photograph of slab 4 ft. 10 in. x 2 ft. 11 in., reduced to about one-eighth natural size. This slab has numerous series of tracks on its smooth surface. These trails are quite unlike the trails of *Climatichnites* and evidently were not made by the same kind of animal. U. S. National Museum, Catalogue No. 58402.

The specimen represented is from locality (77), Upper Cambrian, Potsdam sandstone in Ausable Chasm, Essex County, New York.


TRACKS OF TRILOBITES

## DESCRIPTION OF PLATE 49

PAGE

*Protichnites logananus* Marsh. (See pl. 48) .............................. 279

FIG. 1. (Reduced to about one-fifth natural size.) Part of the trail shown in the upper part of plate 48. In the central trail, crossing diagonally from the left lower to upper right corner, the imprint made by the caudal furca shows that the animal partly lifted its body from the sand as it moved along. U. S. National Museum, Catalogue No. 58402.

The specimen represented is from locality (77), Upper Cambrian, Potsdam sandstone in Ausable Chasm, Essex County, New York.


TRACKS OF TRILOBITES

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57. NUMBER 10

# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 10.—GROUP TERMS FOR THE LOWER AND UPPER CAMBRIAN SERIES OF FORMATIONS

BY

CHARLES D. WALCOTT

(Publication 2137)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 16, 1912

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By CHARLES D. WALCOTT

With the development of the mapping of the geological formations of the United States, it has increasingly become evident that the use of more than one term derived from the same geographic name is faulty in principle and confusing in usage. I have long been guilty of doing it in the use of Georgian for the Lower Cambrian series of formations, and I now find that the name I derived Saratogan from, for the Upper Cambrian series, was previously used for the Cretaceous Saratoga formation. (See page 306.) Much as we may regret the change to new terms, I think that in the long run of time it will facilitate the understanding of the nomenclature of the Cambrian system by the student.

### WAUCOBAN OR LOWER CAMBRIAN

Under the principle stated in the preceding paragraph, the term Georgian as used by me in 1891 [1] is in bad form and should be replaced by a geographic name that has not been used for any geologic formation or group of formations. The history and use of the name Georgia is given in Bulletin 81, cited above, on pp. 98-113, 249-250, and 360.

Since the publication of Bulletin 81 in 1891, it has been found that the greatest development of the Lower Cambrian terrane is in Esmeralda County, Nevada, and the adjoining county of Inyo, California.

The Barrel Spring section of Nevada [2] has several thousand feet of Lower Cambrian strata with a fine Lower Cambrian fauna. The Waucoba [3] section, 30 miles to the southwest in California, is also finely exposed, and it has a well-marked Lower Cambrian fauna that extends through 4,000 feet of strata.

[1] Bull. U. S. Geol. Survey, No. 81, 1891, p. 360.

[2] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 188-189.

[3] Idem, pp. 185-188.

In view of the fine section east of Waucoba Springs on the northeastern side of Saline Valley, and the great development of Lower Cambrian strata to the north and east in Nevada, the term Waucoban is selected to replace Georgian as a group name for the formations included in the Lower Cambrian.

## ST. CROIXAN OR UPPER CAMBRIAN[1]

When I proposed the name "Saratogian" in 1903[2] for the Upper Cambrian group of formations, an examination of several lists of geological formation names failed to show that the name Saratoga had been used by Dr. J. C. Branner[3] for a Cretaceous chalk marl in Arkansas, in his description of "The Cement Materials of Southwest Arkansas."[4] A description of the formation is given, with sections illustrating its stratigraphic position. In 1902[5] Mr. J. A. Taff used the term Saratoga formation in the same sense as Branner and gave illustrations of sections and contained fossils.

In view of the prior use of the name Saratoga by Branner and Taff, I doubt the advisability of continuing the use of Saratogan as a group name for the Upper Cambrian formations. There is also the fact that the two formations of Saratoga County, New York, that are used as the basis for the name, are not typically of Upper Cambrian age. A present tendency is to include them as passage beds between the Cambrian and the superjacent system of strata, or as belonging to the higher systems.[6] With the evidence now known to me from New York and the Appalachian region to the southwest I am inclined tentatively to refer the fauna as found in New York State to the upper limit of the Cambrian. The "Saratogan" would thus be correlated with one of the upper horizons of the "St. Croix sandstone" and included in the Upper Cambrian.[7]

My present view is that the use of the name Saratoga should be restricted to the Cretaceous formation, another name adopted for the

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[1] Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27, and pp. 613 and 614.

[2] Journ. Geol., Chicago, Vol. 11, 1903, pp. 318-319.

[3] Dr. John M. Clarke recently (May 27, 1912) called my attention to this use of the name Saratoga by Branner, and wrote that he was then discussing the history of the name in a paper in press.

[4] Trans. American Inst. Mining Engineers, Vol. 27, 1898, pp. 52-55.

[5] Twenty-second Ann. Rept. U. S. Geol. Survey, 1902, pp. 714-720.

[6] See Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, pl. 27, and p. 612.

[7] See Smithsonian Misc. Coll., Vol. 57, No. 9, 1912, pp. 255, 256, for a fuller discussion of this question.

group of formations included in the Upper Cambrian, and another name for the Potsdam-Hoyt fauna if that fauna is considered as distinct from the Upper Cambrian fauna.

When looking up a name for the Upper Cambrian formations in 1903, I thought of St. Croixan, but as the name St. Croix had become fixed in geological literature for the Cambrian sandstone of the Upper Mississippi Valley[1] I did not use it. In 1911[2] Dr. E. O. Ulrich proposed to use the name St. Croixan for the sea in which the St. Croix sandstones were deposited, and in his table of correlations of formations (pl. 27) and on page 614 of the same work he uses the term as a collective name for his Upper Cambrian formations. If we drop the term "St. Croix" as a formation name for the sandstones of Wisconsin and Minnesota containing the Upper Cambrian fauna, then the term St. Croixan may be used for the assemblage of formations characterized by the Upper Cambrian fauna.

[1] See N. H. Winchell, 1873, Ann. Rept. Board of Regents, University of Minnesota. First Ann. Rept. Geol. and Nat. Hist. Surv. for 1872, pp. 68-80.

[2] Ulrich, Bull. Geol. Soc. America, Vol. 22, No. 3, 1911, p. 613.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 57, NUMBER 11

# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 11.—NEW LOWER CAMBRIAN SUBFAUNA

(With Plates 50 to 54)

BY

CHARLES D. WALCOTT

(Publication 2185)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY 21, 1913

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# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 11.—NEW LOWER CAMBRIAN SUBFAUNA

By CHARLES D. WALCOTT

(With Plates 50 to 54)

CONTENTS



ILLUSTRATIONS



## INTRODUCTION

During the season of 1912, while making a reconnoissance of a portion of the Robson Peak District north of the Peak I found a block of dark siliceous shale on the surface of Mural Glacier that contained a fine species of *Olenellus* and numerous specimens of a species of *Mickwitzia* and *Lingulella.* The source from which the block came was found in a cliff two miles up the glacier at the foot of Mumm

Peak, which is a high point (9,740 feet = 2,968 m.) directly north of Robson Peak. The blocks of shale falling from the cliff had been carried out and down on the ice of Mural Glacier. The glacier also passes over the cliff of shale for half a mile to the west. We reached the glacier by climbing up over the cliffs of Mural Brook, which enters Smoky River about a mile (1.6 km.) below the mouth of Calumet Creek. From the foot of the glacier it is about two miles (3.2 km.) up to the base of Mumm Peak. A better way to go is to climb up the mountain side 2,000 feet and cross Hitka Pass, a divide between Mumm Peak and Hitka Mountain. The locality is high up where rain, fog, and snow squalls may be expected nearly every day of the year.

The fauna includes the species described in this paper, also a species of *Planolites* (annelid trail), Cystid ? sp. undt., *Hyolithes* sp. undt., and *Hymenocaris* sp. undt. These, with the new species, make up a subfauna in the upper portion of the Lower Cambrian that has not been found elsewhere. It is marked by the absence of *Olenellus canadensis* Walcott and *Protypus fieldensis* Walcott, the typical forms of the upper part of the Lower Cambrian section along Kicking Horse Pass.

There is undoubtedly a larger fauna to be obtained from the *Olenellus truemani* zone, but to find it will require a camp near the locality on Hitka Pass and thorough collecting under adverse conditions.

## DESCRIPTION OF SPECIES

### MICKWITZIA MURALENSIS, new species

Plate 50, figs. 10, 11; plate 51, figs. 1-6; plate 52, fig. 1

This species differs from *Mickwitzia monilifera* Linnarsson[1] in having a less elevated apex on the ventral valve, a varying position of the apex, and in being in general more transverse.

The shell is built up of several layers or lamellæ that give it thickness and strength. The outer surface is fairly well shown by figure 6, plate 51. It is formed of fine, concentric, minutely undulating and inosculating ridges that are crossed by low, irregular radiating ridges. There is also a pitted appearance resulting from the hollows between the ridges. On many shells there appear to be true punctæ that penetrate through the outer layer of the shell. The inner layers are marked by fine concentric and radiating lines.

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

The largest shell in the collection has a diameter of 46 mm. (pl. 51, fig. 4).

Specimens of the shell are abundant as casts and impressions in the siliceous shale. The original shell has disappeared, but from what we know of the shell of *Mickwitzia monilifera,* it was probably formed of calcium phosphate.

One other American species of *Mickwitzia* is known, *M. occidens* Walcott.[1] The punctate surface is much like that of *M. muralensis,* but the form as far as known is not similar.

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of the summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### LINGULELLA CHAPA, new species

Plate 50, figs. 4-9

In form this species is not unlike *Lingulella schucherti* (Walcott)[2] from the Lower Cambrian of New York. It differs in having a more acuminate ventral valve, and possibly in other details not shown by the rather poor specimens of *L. schucherti.* Several species of *Lingulella* from the Upper Cambrian have nearly the same outline of the valves as those of *L. chapa,* notably *L. randomensis* (Walcott)[3] and *L. mosia osceola* (Walcott).[4] Comparison may also be made with the broader forms of *L. perattenuata* (Whitfield).[5] *Linguella chapa* is distinguished by the very strong vascular canals of the ventral valve (fig. 6) and the shallow median sinus of the dorsal valve (figs. 4, 8, and 9).

The average length of the ventral valve is from 6 to 7 mm. The dorsal valve is about one-sixth shorter than the ventral.

Specimens of this species occur in such large numbers on partings in the shale as nearly to cover the surface, or they may be scattered about among other brachiopods and fragments of trilobites.

The specific name is taken from Chapa (beaver), the name of the high point at the foot of Mural Glacier where the first specimens of this species were found in a block of shale lying on the glacier.

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[1] Monogr. U. S. Geol. Survey, Vol. 51, 1912, p. 331, pl. 6, fig. 4.

[2] Idem, pl. 21, fig. 6.

[3] Idem, pl. 21, figs. 5, 5*a*.

[4] Idem, pl. 18, figs. 2, 2*a-c*.

[5] Idem, pl. 21, figs. 1*c-d*.

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### LINGULELLA HITKA, new species

Plate 50, figs. 1-3

This species is represented by a number of compressed valves partly flattened in the shale. The outer surface has concentric striæ and lines of growth, and the shell is built up of several layers of what was probably calcareo-corneous material arranged as in typical Obolinæ.[1]

The average size and appearance of the valves are shown by figure 1, plate 50. A few ventral valves have a length of 13 mm., but the average is about 10 mm.

In outline of valves and general appearance, this species is similar to *Lingulella bella* (Walcott).[2] It is so highly improbable that a Lower Cambrian species of the Cordilleran sea could persist until the close of Cambrian time in the Atlantic Province that I do not think it advisable to identify the two widely separated forms as belonging to the same species.

There are no Lower Cambrian forms that seem to be similar to *L. hitka*.

The specific name is taken from the Indian name Hitka (brown), a name applied to the mountain that rises on the east side of the ravine in which the specimens of *L. hitka* were found.

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### OBOLELLA NUDA, new species

Plate 52, figs. 3-7

The first impression given by the shells of this species is that they are closely allied to *Obolella atlantica* Walcott.[3] They have about the same size and form. They differ in having a flattened median space,

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[1] Monogr. U. S. Geol. Survey, Vol. 51, 1912, p. 371.

[2] Idem, pl. 19, figs. 2, *2a-q;* pl. 36, fig. 4.

[3] Idem, pl. 55, figs. 1, 1*a-i*.

occupying a little more than one-third of the surface that extends from the apex of the valves to the front margin. The casts of the interior of the valves show the cardinal area, main vascular sinuses, and the form of the visceral area.

The average size of the valves is from 4 to 6 mm. in diameter.

As far as can be determined from the casts of the valves which are compressed in the shale the shells were thinner than those of *Obolella chromatica* Billings,[1] and had a somewhat different arrangement of the various features of the interior of the valves. The mode of occurrence is much like that of *O. chromatica* and *O. atlantica,* as the valves occur in large numbers on partings of the shale. If specimens can be found in a calcareous deposit, much closer comparison may be made with other species.

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### OBOLELLA cf. CHROMATICA Billings

Plate 52, fig. 2

*Obolella chromatica* Billings, 1861. For synonymy see Monogr. U. S. Geol. Survey, Vol. 51, 1912, p. 591.

This form is represented by casts of the exterior and partial interiors of several valves of a shell that is very much like what *O. chromatica* might be if preserved in the same siliceous, shaly matrix. The shell is larger than that of *Obolella nuda* (p. 312) as it averages 8 mm. in diameter, and the valves are evenly convex and not flattened as is the case with *O. nuda.*

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### HOLMIA ? MACER, new species

Plate 54, fig. 1

This species is characterized by its proportionally large cephalon and narrow thorax, in these respects resembling *Holmia kjerulfi.*[2]

[1] Monogr. U. S. Geol. Survey, Vol. 51, 1912, p. 591, pl. 54, figs. 1, 1*a-i.*
[2] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 27, fig. 7.

It differs, however, from the latter in many details of the cephalon and thorax. The cephalon more closely resembles that of *Holmia rowei*[1] in its glabella and strong, rounded marginal border, but it does not have the strong occipital spine of the latter. There are 13 segments of the thorax preserved in the type specimen. The ends of the plural lobe terminate rather abruptly in sharp, backward-pointing spines, in this respect resembling *Holmia kjerulfi*.

Nothing is known of the posterior segments of the thorax or the pygidium.

The type and only specimen of this species was discovered by Professor H. Justin Roddy of the State Normal School, Millersville, Pennsylvania, who presented it to the United States National Museum.

*Formation and locality.*—Lower Cambrian: (**12v**) Upper portion of York formation, 2 miles (3.2 km.) north of the city of Lancaster, near Fruitville, Lancaster County, Pennsylvania.

### WANNERIA OCCIDENS, new species

Plate 53, fig. 2

Of this species only a single cephalon occurs in the collection. This has the characteristic short palpebral lobe and elongate boss between the latter and the dorsal furrow adjoining the glabella. The sides of the glabella are subparallel opposite the two posterior pairs of glabellar furrows. The margin of the cephalon is broad and slightly rounded. A short occipital spine that is about one-fourth the length of the cephalon projects backward from the center of the occipital ring.

The cephalon differs from that of *Wanneria walcottanus*[2] in being proportionally more elongate, and in the presence of an occipital spine instead of an occipital node or tubercle.

It differs from *Olenellus gilberti*[3] in its small, short palpebral lobe and strong marginal rim, also in the presence of an occipital spine.

The small palpebral lobe and tubercle back of it suggest *Olenellus canadensis*,[4] but the other parts of the cephalon differ.

*Formation and locality.*—Lower Cambrian: (**61k**) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a

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[1] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 29.

[2] Idem, pl. 30.

[3] Idem, pl. 36.

[4] Idem, pl. 38, figs. 4-6.

direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### CALLAVIA EUCHARIS, new species

Plate 53, fig. 1

This fine species is represented by one entire specimen. It has 23 segments in the thorax, and a very small and narrow pygidium. The cephalon is very much like that of *Callavia perfecta,* but the thoracic segments are proportionally narrower and there are six more of them.

The dorsal shield has a length of 38 mm., with a width of 30 mm. at the back of the cephalon.

Traces of the surface show it to have been ornamented with a fine network formed of low, sharp ridges such as is found on most species of the Mesonacidæ.

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

### CALLAVIA PERFECTA, new species

Plate 53, figs. 3-5

This species recalls *Callavia crosbyi* Walcott.[1] It differs in having a more tapering glabella, smaller palpebral lobes, and in the absence of a strong occipital spine. The cephalon of *Callavia burri* Walcott[2] is very similar, but, as may be seen by comparing figures 9 and 10 of the latter with figure 5, plate 53, of *Callavia perfecta,* the palpebral lobes are larger and farther out from the glabella.

*Callavia perfecta* has 17 thoracic segments and a very small, narrow pygidium. The exterior surface has a very minute fretwork of lines that is difficult to be seen even with a strong lens, in this respect differing from the associated *Callavia eucharis.*

*Formation and locality.*—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

[1] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, p. 284, pl. 28.
[2] Idem, pl. 28 figs. 9 and 10.

### OLENELLUS TRUEMANI, new species

Plate 54, figs. 2-10

This species differs from *Olenellus thompsoni* (Hall)[1] and *O. gilberti* Meek[2] in having shorter palpebral lobes and eyes, smaller and shorter plural lobes of the third thoracic segment, and in having a more coarsely reticulated outer surface of the test, in the latter character resembling *O. reticulatus* Peach.[3] It differs from the latter and *O. lapworthi* Peach[4] in having a stronger rim about the cephalon, the anterior glabellar lobe closer to the frontal rim, and a broader thorax and smaller, shorter pleural lobe on the third segment. The third thoracic segment is distinctly larger than the others in all specimens; proportionally it decreases in size from the young to the largest adults, as may be seen by comparing figure 10 and figure 2, plate 54.

The hypostoma has a denticulated posterior margin similar to that of *Pœdeumias transitans*[5] and *Wanneria halli*.[6] It appears to have been attached to the doublure by its anterior margin and not by a process as in *Pœdeumias transitans*.

The specimens of this species are abundant and usually well preserved. The largest cephalon collected has a width of 50 mm. and a length of 22 mm., and the entire dorsal shield has a length of 56 mm. exclusive of the spine-like telson.

The specific name is given in memory of Dr. J. M. Trueman, of the Geological Survey of Canada, a most promising young geologist who was drowned in a canoe accident that occurred (June 24, 1912) while he was showing me the Huronian fossil-bearing limestones of Steeprock Lake, Ontario, Canada.

*Formation and locality*.—Lower Cambrian: (61k) Mahto formation; dark, hard siliceous shale; northeast base of Mumm Peak above Mural Glacier on west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

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[1] Smithsonian Misc. Coll., Vol. 53, No. 6, 1910, pl. 35.

[2] Idem, pl. 36.

[3] Idem, pl. 39.

[4] Idem, pl. 39.

[5] Idem, pl. 34, fig. 8.

[6] Idem, pl. 31, fig. 9.

## DESCRIPTION OF PLATE 50



FIG. 1. (Natural size.) Group of shells flattened on surface of shale. (Locality 61k.) U. S. National Museum, Catalogue No. 60067.

2. (× 2.) A ventral and a dorsal valve enlarged from fig. 1.

3. (× 2.) A dorsal valve that occurs on fig. 1.



FIG. 4. (× 3.) A group of shells on surface of shale. (Locality 61k.) U. S. National Museum, Catalogue No. 60068.

5. (× 4.) A small uncompressed ventral valve. (Locality 61k.) U. S. National Museum, Catalogue No. 60069.

6. (× 4.) Natural matrix of the interior of a ventral valve. (Locality 61k.) U. S. National Museum, Catalogue No. 60070.

7. (× 4.) A partly exfoliated ventral valve. (Locality 61k.) U. S. National Museum, Catalogue No. 60071.

8. (× 4.) A small, uncompressed dorsal valve. (Locality 61k.) U. S. National Museum, Catalogue No. 60072.

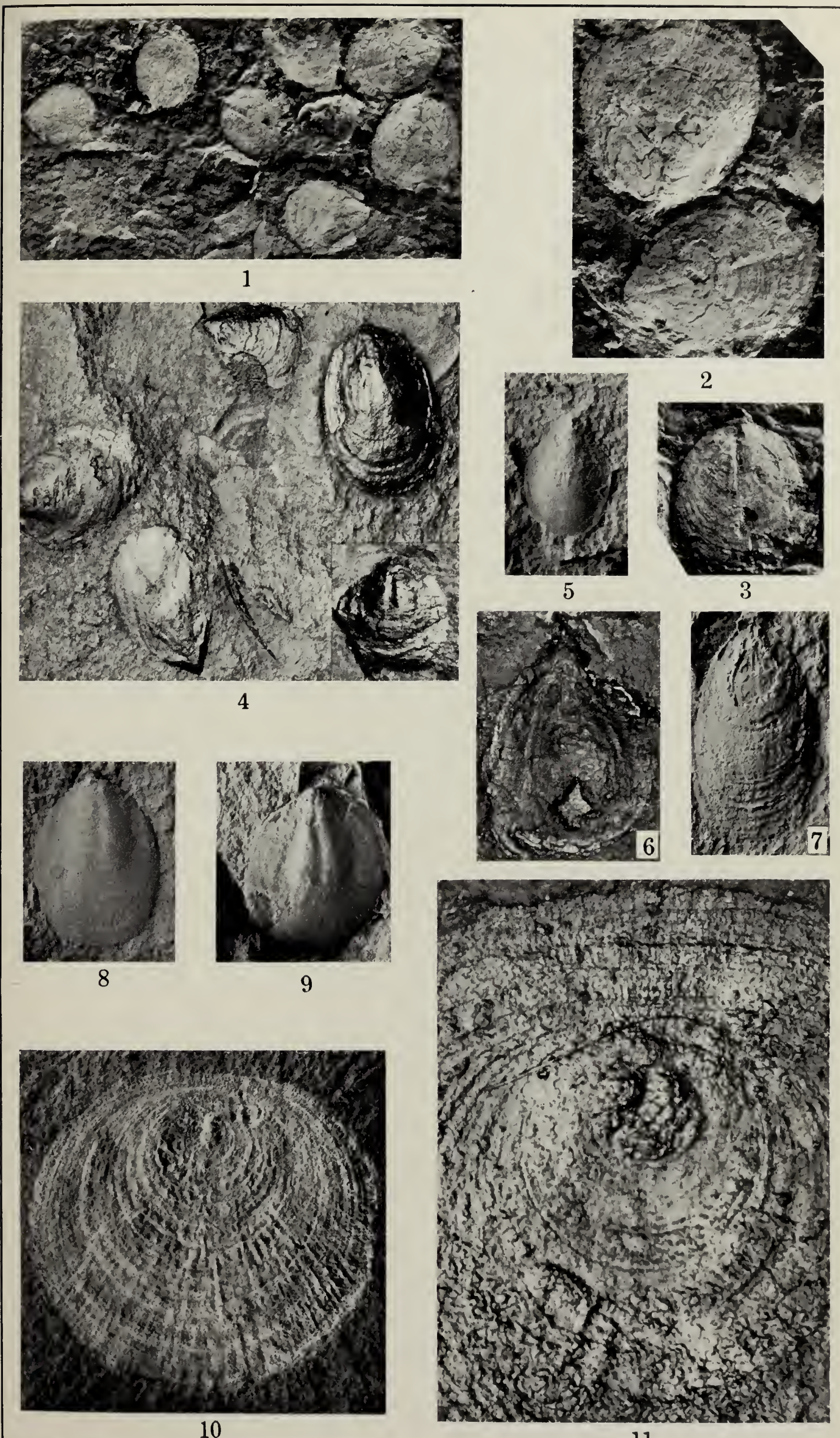
9. (× 4.) A broader form of the dorsal valve than that represented by fig. 8. (Locality 61k.) U. S. National Museum, Catalogue No. 60073.



FIG. 10. (× 3.) Flattened dorsal valve with excentric apex. (Locality 61k.) U. S. National Museum, Catalogue No. 60093.

11. (× 6.) Area about apex and posterior margin enlarged to illustrate surface character. (Locality 61k.) U. S. National Museum, Catalogue No. 60094.

The specimens represented by figs. 1-11 are from locality 61k. Lower Cambrian: Mahto formation; dark, hard siliceous shale, northeast base of Mumm Pass above Mural Glacier on the west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.




BRACHIOPODA

## DESCRIPTION OF PLATE 51

PAGE

*Mickwitzia muralensis* Walcott. (See Plates 50 and 52) .................. 310

FIG. 1. (× 2.) Small ventral valve with submarginal apex. (Locality **61k.**) U. S. National Museum, Catalogue No. 60095.

2. (Natural size.) Small ventral valve with apex nearly at its center. (Locality **61k.**) U. S. National Museum, Catalogue No. 60096.

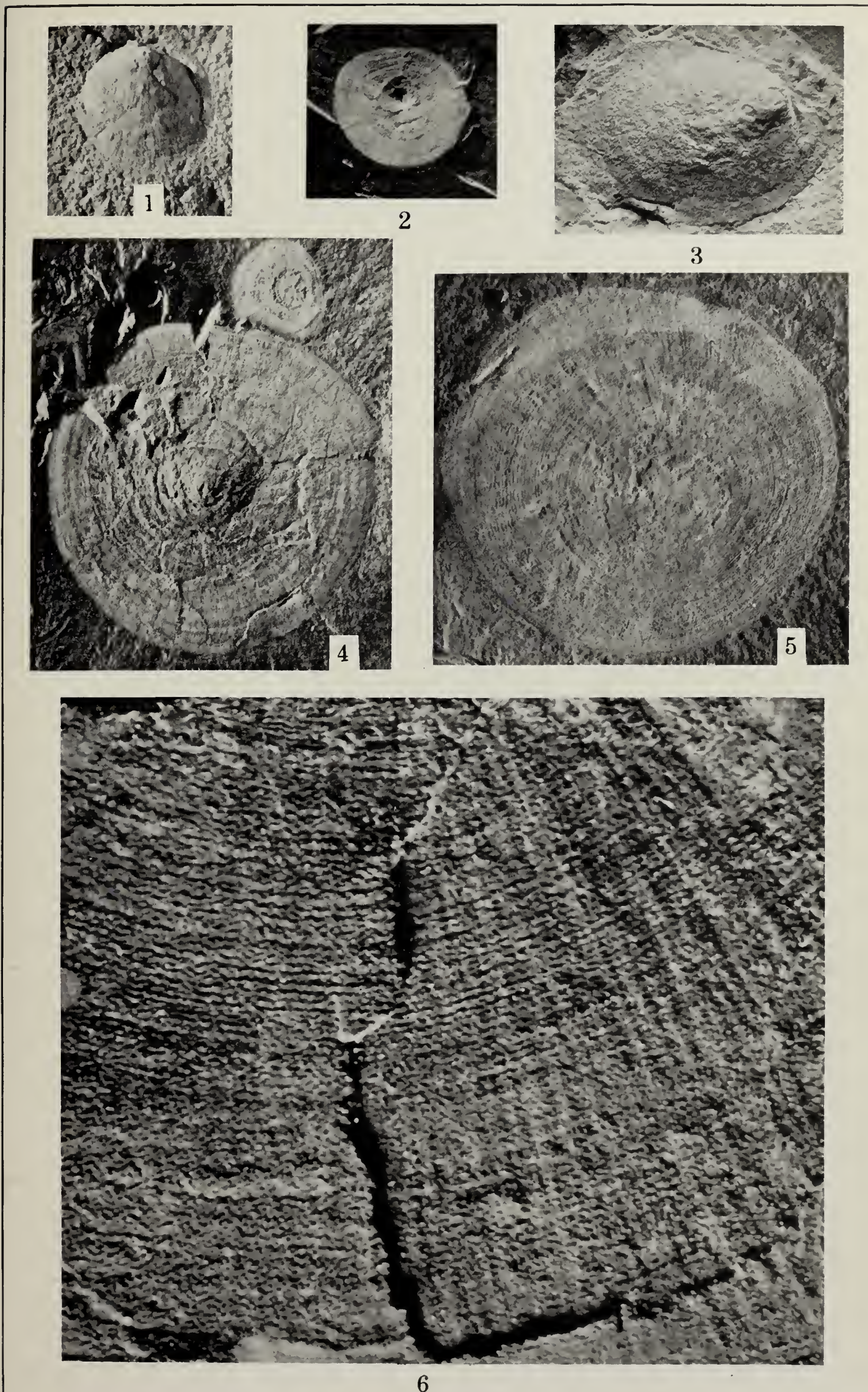
3. (× 3.) Ventral valve preserving much of its original convexity. (Locality **61k.**) U. S. National Museum, Catalogue No. 60097.

4. (Natural size.) Large ventral valve with apex near its center and small dorsal valve on same piece of shale. (Locality **61k.**) U. S. National Museum, Catalogue No. 60098.

5. (× 2.) Dorsal valve flattened in the shale. (Locality **61k.**) U. S. National Museum, Catalogue No. 60099.

6. (× 8.) Enlargement of exterior surface of a ventral valve. (Locality **61k.**) U. S. National Museum, Catalogue No. 60100.

The specimens represented by figs. 1-6 are from locality **61k.** Lower Cambrian: Mahto formation; dark, hard siliceous shale, northeast base of Mumm Peak above Mural Glacier on the west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.




BRACHIOPODA

## DESCRIPTION OF PLATE 52

PAGE

*Mickwitzia muralensis* Walcott. (See Plates 50 and 51) ................ 310

FIG. 1. (Natural size.) Ventral and dorsal valves flattened in the shale. (Locality **61k.**) U. S. National Museum, Catalogue No. 60101.

*Obolella* cf. *chromatica* Billings .................................... 313

2. (Natural size.) Natural cast of both ventral and dorsal valves. (Locality **61k.**) U. S. National Museum, Catalogue No. 60073.

*Obolella nuda* Walcott .................................... 312

3. (× 4.) Ventral valve. (Locality **61k.**). U. S. National Museum, Catalogue No. 60074.
4. (× 4.) A ventral and a dorsal valve. (Locality **61k.**) U. S. National Museum, Catalogue No. 60075.
5. (× 4.) Natural cast of the interior of a ventral valve. (Locality **61k.**) U. S. National Museum, Catalogue No. 60076.
6. (× 4.) Natural cast of the interior of a dorsal valve. (Locality **61k.**) U. S. National Museum, Catalogue No. 60077.
7. (× 4.) Natural casts of the interior of ventral and dorsal valves. (Locality **61k.**) U. S. National Museum, Catalogue No. 60078.

The specimens represented by figs. 1-7 are from locality **61k.** Lower Cambrian: Mahto formation; dark, hard siliceous shale, northeast base of Mumm Peak above Mural Glacier on the west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

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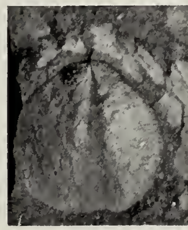

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BRACHIOPODA

## DESCRIPTION OF PLATE 53

PAGE

*Callavia eucharis* Walcott .......................................... 315

FIG. 1. (× 2.) Type specimen of the species. (Locality **61k.**) U. S. National Museum, Catalogue No. 60079.

*Wanneria occidens* Walcott .......................................... 314

2. (Natural size.) Type specimen of the cephalon of the species. (Locality **61k.**) U. S. National Museum, Catalogue No. 60080.

*Callavia perfecta* Walcott .......................................... 315

3. (× 2.) Type specimen of the species. (Locality **61k.**) U. S. National Museum, Catalogue No. 60081.
4. (Natural size.) Specimens of the cephalon found in a parting of the shale. (Locality **61k.**) U. S. National Museum, Catalogue No. 60082.
5. (Natural size.) A large cephalon flattened in the shale. (Locality **61k.**) U. S. National Museum, Catalogue No. 60083.

The specimens represented here by figs. 1-5 are from locality **61k.** Lower Cambrian: Mahto formation; dark, hard siliceous shale, northeast base of Mumm Peak above Mural Glacier on the west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.

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5

TRILOBITA

## DESCRIPTION OF PLATE 54

PAGE

*Holmia ? macer* Walcott ........................................ 313

Fig. 1. (× 3.) Type specimen of the species. (From locality **12v.**) Lower Cambrian shale, Fruitville, Lancaster County, Pennsylvania. U. S. National Museum, Catalogue No. 60092.

*Olenellus truemani* Walcott ........................................ 316

2. (× 2.) Surface of shale with two compressed, nearly entire dorsal shields and a small cephalon. (Locality **61k.**) U. S. National Museum, Catalogue No. 60084.

3. (× 2.) Compressed and slightly distorted hypostoma. (Locality **61k.**) U. S. National Museum, Catalogue No. 60085.

4 and 5. (× 5.) Two small hypostomas. (Locality **61k.**) U. S. National Museum, Catalogue No. 60086.

6. (Natural size.) Cephalon with outer test of cheeks exfoliated so as to show casts of radial canals. (Locality **61k.**) U. S. National Museum, Catalogue No. 60087.

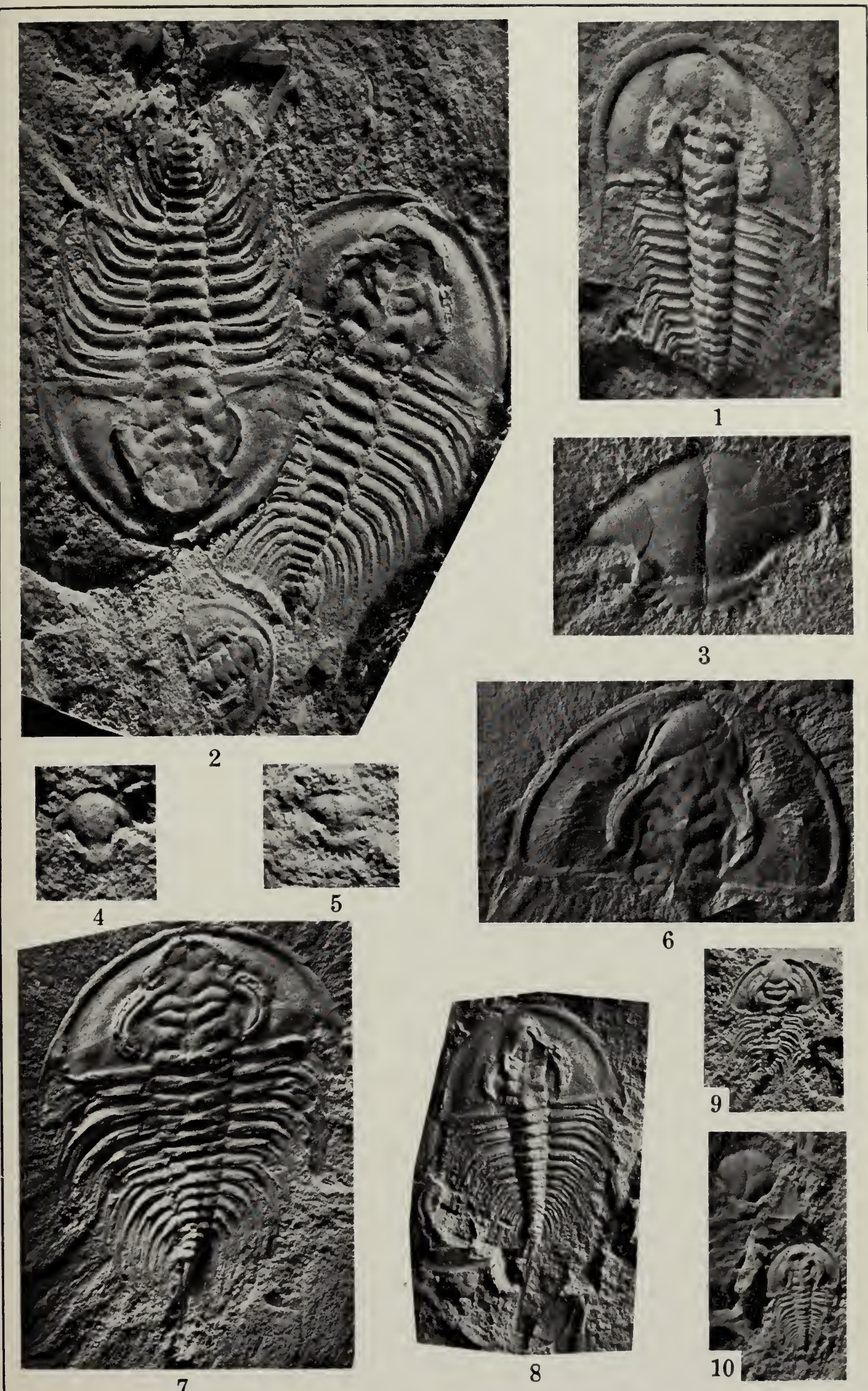
7. (Natural size.) Broad, flattened dorsal shield with enlarged third thoracic segment. (Locality **61k.**) U. S. National Museum, Catalogue No. 60088.

8. (× 2.) A small, almost entire dorsal shield. (Locality **61k.**) U. S. National Museum, Catalogue No. 60089.

9. (× 2.) A small cephalon preserving much of its original convexity. The attached thoracic segments are more or less displaced. (Locality **61k.**) U. S. National Museum, Catalogue No. 60090.

10. (× 2.) Small, nearly entire, undistorted dorsal shield with large third thoracic segment. (Locality **61k.**) U. S. National Museum, Catalogue No. 60091.

The specimens represented by figs. 2-10 are from locality **61k.** Lower Cambrian: Mahto formation; dark, hard siliceous shale, northeast base of Mumm Peak above Mural Glacier on the west side of Hitka Pass, 6 miles (9.6 km.) in a direct line north of summit of Robson Peak and northwest of Yellowhead Pass, in western Alberta, Canada.




TRILOBITA

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 12



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 12.—CAMBRIAN FORMATIONS OF THE ROBSON PEAK DISTRICT, BRITISH COLUMBIA AND ALBERTA, CANADA

WITH PLATES 55–59

BY

CHARLES D. WALCOTT

(PUBLICATION 2186)



CITY OF WASHINGTON
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## ILLUSTRATIONS

PLATES



TEXT FIGURES



## INTRODUCTION

Robson, the most majestic known peak of the Canadian Rockies, is situated six miles (9.6 km.) north in a direct line from the Fraser River and the Mount Robson station on the Grand Trunk Pacific Railway, and thirty-two miles (51.2 km.) west-northwest of Yellowhead Pass on the Continental Divide. The Divide trends very irregularly to the northwest and passes between Adolphus and Berg Lakes three and one-half miles (5.6 km.) north-northeast of the summit of Robson. At this point a part of the water derived from the great Hunga Glacier (pl. 58, figs. 1, 2) flows northeast into the Smoky River drainage area of Alberta and thence through the Peace and Slave Rivers to Great Slave Lake and north through the Mackenzie River to the Arctic Ocean. The larger stream flows southwest into Berg Lake and thence through the Grand Fork into Fraser River and on to the Pacific.

For my present purpose I have included in the Robson Peak District an area with a radius of about ten miles (16 km.) to the northeast and south from the summit of Robson. I was prevented by bad weather from visiting the region west of the Peak and across the valley of the Grand Fork. As seen from above it appears to be separated by a great fault line from the Robson massif.

After a short reconnaissance, I decided to examine the geological section between Robson Peak and Moose Pass, an air line distance of nine and one-half miles (15.2 km.).

Robson Peak is in a broad, shallow syncline that is more or less broken about its outer limits by faults and minor displacements of the strata. To the northeast and east of the Peak, ridge after ridge exposes the strata that slope in toward the Robson massif and thus present a fine opportunity to study the downward extension of the stratigraphic section from Robson to Moose Pass, where a great fault cuts out the base of the Cambrian series of the region and in the ridges of the Tokana Mountains (pl. 55, fig. 1) east and southeast of Moose Pass repeats the Upper and possibly Middle Cambrian beds of Lynx, Phillips (pl. 57, fig. 2), and Titkana Mountains east of Robson.

## GEOLOGICAL SECTION

The oldest Cambrian beds occur on the southwest side of Moose Pass (pl. 55, fig. 1). From there the strata are well exposed in Tah Peak, a sharp point (fig. 11) above the Pass, and then in several ridges to the south on the eastern side of the upper Smoky River valley. The line of the section passes through Tah Peak southwest to Mahto Mountain (pl. 55, fig. 2), and south across Coleman Brook, Hota Cliffs, Chetang Cliffs, and Tatay Cliffs (pl. 56, fig. 2), thence south-southeast over Titkana Peak to Phillips and Lynx Mountains (pl. 57, fig. 2) and the ridges to the southeast of Robson Peak. This irregular course of the section is necessary in order to obtain exposures of the strata free from snow fields and glaciers, but by following the strike of the strongly marked strata it was not difficult to maintain a practically continuous section.

The time available for actual field work was greatly limited during the season of 1912 by the unusual rainfall. This condition and also the necessity of making a general reconnaissance before determining where to establish the typical section prevented careful measurements and the working out of detailed sections. Several horizons were found containing fossils and rather careful estimates made of the thickness of the various formations between Tah Pass and the summit of Robson.

The oldest rocks noted were quartzite sandstones on the southwest side of Moose Pass and the valley of Moose River below the Pass. The contact of the Lower Cambrian sandstone with the pre-Cambrian rocks was not seen in the Robson District, but to the north, west, south, and southeast of Yellowhead Pass it is finely shown in Mount McEvoy and Yellowhead Mountain, Mount Fitzwilliam, and other high points from eight to twenty miles (12.8 km. to 32 km.) east of the mouth of the Moose River.

*Location of the section.*—The location of the section is graphically shown by the photographs reproduced on plates 55-59. These will enable the future student of the geology of the region to recognize the localities and the general position of the formation.

*Lower Cambrian.*—In figure 1, plate 55, the lowest Cambrian beds of the Robson section are shown at the foot of Tah Peak. These are more clearly seen in the text figure No. 11. In figure 2, plate 55, the sandstones of the Tah formation and of the lower beds of the superjacent Mahto formation slope to the southwest and pass beneath Mahto Mountain, while the higher beds of the Mahto formation form the south face of the mountain. In figure 1, plate 56, the masses of strata forming Tah Peak and Mahto Mountain are clearly outlined.

The Hota formation on the west and southwest slope of Mahto Mountain is shown on the left side of figure 2, plate 56. It forms the slope in the foreground, also in the ridge back, and passes beneath limestones of the Chetang formation at Coleman Brook.

*Middle Cambrian.*—The Chetang limestones rest on the Hota formations on the west side of Coleman Brook and form the Chetang Cliff above the brook (pl. 56, fig. 2; pl. 57, fig. 1) for 900 feet. Above, the siliceous limestones of the Tatay formation form the Tatay Cliffs, and west of the latter the thin-bedded arenaceous limestones and shales of the Hitka formation carry the section up to the massive-bedded arenaceous limestones of the Mumm formation. The latter occur on the westward slope of the ridge east-northeast of the lower end of Lake Adolphus. All these Middle Cambrian strata occur between Coleman Brook and the west slope of the point (marked "x" on pl. 56, fig. 2; pl. 57, fig. 1) northeast of the summit of Titkana Peak.

The Titkana formation forms the north and west slopes of Titkana Peak, and extends over the summit toward Snowbird Pass (pl. 57, fig. 2) and the summit of Titkana Peak as seen in figure 1, plate 58.

The Middle Cambrian formations also form the mountains west of the Smoky River, as beautifully shown by figure 1, plate 57.

*Upper Cambrian.*—The Lynx formation of the Upper Cambrian begins on the south slope of Titkana Peak near Snowbird Pass, and extends over Phillips Mountain (pl. 57, fig. 2), and into the base of Billings Butte.

Fig. 11.—Near view of Tah Peak rising above Moose Pass. On the left Tokana Mountain. Photograph by R. C. W. Lett, Grand Trunk Pacific Railway, 1912.

FIG. 12.—Robson Peak from northwest slope of Mahto Mountain. In the foreground Chetang Cliff; in the center Iyatunga [black rock] Mountain with the foot of Hunga Glacier at its base, and beyond a portion of Blue Glacier above Berg Lake. In the distance [illegible] Grand Trunk Pacific Railway, 1912.

*Ordovician.*—The Robson formation (pl. 58, fig. 1,) is considered to extend from the summit of Robson some 3,000 feet down. This estimate is based on the view obtained from Billings Butte (pl. 58, fig. 2) of the Upper Cambrian beds as they extend along the base of Mount Resplendent into Robson. There is abundant opportunity for error as to the actual thickness of the strata, but I think it is on the side of too low an estimate and that in the future a greater thickness will be assigned to the Ordovician of the Robson massif. One element that could not be estimated for is the faults that have dropped and tipped the mass of strata forming the Helmet between Robson and Iyatunga.

## NOMENCLATURE

Although not an original explorer of the Robson Peak District, it fell to my lot to be the first to study the geologic section, and in this connection it was necessary to apply additional names in order to properly locate, describe, and name the geologic formations.

*Changes in names.*—Of the names previously used and printed on the Wheeler map of 1912,[1] I thought it might be well to change the following:

1. Ptarmigan Peak to Titkana (bird) Peak.
2. Rearguard to Iyatunga (black rock) Mountain.
3. Extinguisher to Billings Butte.
4. Robson Glacier to Hunga (chief) Glacier.
5. Mount Robson to Robson Peak.
6. East Branch Moose River to Moose River.
7. West Branch Moose River to Hihuna (owl) River.
8. Mount Toot-toot to McEvoy Mountain.

My reasons for the above changes are:

1. The name "Ptarmigan" has been applied to a mountain and a lake north of Laggan in Alberta.

2. "Rearguard" does not appear to be an appropriate name for one of the great portals of the main glacier.

3. "Extinguisher" was given by Coleman to a butte that is of the greatest geologic importance as it is made up of rocks containing the finest Cambro-Ordovician fauna yet known in Western Canada. The name "Billings" is proposed for this butte in honor of E. Billings, the distinguished Canadian paleontologist, who described the famous Cambro-Ordovician fauna of Point Lévis, Province of Quebec, and Western Newfoundland.

[1] Canadian Alpine Journal, Vol. 4, 1912.

4. The name "Robson" has been used for six distinct features:

Robson Peak, Milton and Cheadle, 1865.

Robson Cirque, Wheeler, 1912.

Robson Pass, Coleman, 1908.

Robson Glacier, Wheeler, 1912, = Main Glacier, Coleman, 1908, = Great Glacier, Collie, 1912.

Lake Robson, Collie, 1912, p. 226.

Robson Park, Government of British Columbia, 1913.

Thinking that the name "Robson" is somewhat over-applied I have suggested the Indian name "Hunga" (= chief) for the great glacier.

5. "Robson Peak" is the name given by Milton and Cheadle, 1865, and used by McEvoy on his map of 1900. There does not appear to be any good reason for changing it to "Mount Robson," as it is the highest "Peak" in the Canadian Rockies.

6. The name "Moose River" should be extended up the main river to its head below Moose Pass, as the so-called "West Branch" is quite a distinct stream and should bear a distinct name.

7. Hihúna[1] (owl) River drains the southeast side of the Robson Peak area. It is a large stream and its valley is one of the most beautiful features of the Robson District. At its upper end Resplendent Valley is very attractive. In the future the broad flat slopes of the Hihuna will be a favorite camping place when made accessible by a well-graded road. Hihuna River is the west branch of Moose River as given on the Wheeler map.

8. "Mount Toot-toot," north of Yellowhead Pass, I am calling McEvoy Mountain after J. McEvoy, who first made a map of this area. The mountain furnishes a fine illustration of the Cambrian rocks overlying the pre-Cambrian of the Yellowhead Pass.

*New names.*—A number of names are here given to certain mountains and points that are indicated on the photographs. They are mostly derived from the language of the Assiniboine Indians. Of these names, the following have received the approval of the Geographic Board of Canada:

*Iyatúnga*[1] (black rock) for the mountain southwest of Hunga Glacier (pl. 58, fig. 1).

*Titkána* (bird) for the peak on the northeast side of Hunga Glacier (pl. 58, fig. 1).

*Chetáng* (hawk) for the line of cliffs above and southwest of Coleman Glacier (pl. 56, fig. 2).

[1] The accent mark is used here merely to indicate the syllable to be accented.

The following additional names are used in this paper and may in due time come before the Geographic Board for its consideration:

*Billings Butte* (pl. 57, fig. 2), a rocky butte rising above Hunga Glacier on a north ridge of Mount Resplendent and west of Lynx Mountain. (The Extinguisher of Coleman.) Named in honor of the late Mr. E. Billings of the Geological Survey of Canada.

*Chápa* (beaver) *Point*, northwest point above Mural Brook and Smoky River at the southern end of Shota Mountain (pl. 57, fig. 1).

*Chúshina* (small) *Glacier*, west slope of Phillips Mountain (pl. 57, fig. 2).

*Chupó* (fog, mist) *Glacier*, southwest glacier of northwest snow field of Robson Peak (pl. 58, fig. 1).

*Hihúna* (owl) *River*, west branch of Moose River extending into Resplendent Valley.

*Hitká* (brown) *Mountain*, south point above Mural Brook and above Smoky River and Mural Glacier (pl. 57, fig. 1).

*Hóta* (gray) *Cliffs*, of southwest slope of Mahto Mountain above Coleman Brook (pl. 57, fig. 1).

*Húnga* (chief) *Glacier*, great north glacier of Robson Peak = Robson Glacier of Wheeler (pl. 58, fig. 1).

*Hútam* (east) *Mountain*, 2.75 miles (4.4 km.) west-northwest of Yellowhead Pass on the Continental Divide.

*McEvoy Mountain*, point on Continental Divide northwest of Yellowhead Pass. Named in honor of James McEvoy who surveyed the Yellowhead Pass region.

*McLaurin Mountain* (9,004 feet), northwest of Berg Lake. The Whitehorn east station of the Wheeler map.

*McNaughton Mountains*, mountain ridges between Moose River and Grant Creek, of which Mowatt Mountain is the southeastern point. Named in honor of Mrs. McNaughton, who crossed the Yellowhead Pass and was the author of a book on the subject in 1862.

*Mahtó* (grizzly-bear) *Mountain*, between Smoky River and Calumet Creek (pl. 55, fig. 2).

*Minióhan* (through the water) *Mountains*, west and northwest of Robson Peak, across the Valley of a Thousand Falls (pl. 58, fig. 1).

*Phillips Mountain* (9,542 feet). Named for Donald Phillips who climbed Robson Peak with Dr. Kinney in 1909 (pl. 57, fig. 2).

*Sápa* (black) *Mountain*, ridge northeast of Smoky River and northwest of Calumet Creek.

*Shió* (grouse) *Point*, high point northwest of Moose Pass.

*Shóta* (smoke) *Mountains,* southwest side of Smoky River, below mouth of Calumet Creek (pl. 57, fig. 1).

*Tah* (moose) *Mountain* (8,817 feet), peak southwest side of Moose Pass (pl. 55, figs. 1, 2; pl. 56, fig. 1).

## NEW FORMATION NAMES

FEET

**ROBSON LIMESTONES.**—[Ordovician] massive and thin-bedded limestones forming the upper portion of Robson Peak.

Estimated thickness ........................................ 3,000

*Fauna.*—Fossils occur near the base where there is a commingling of Upper Cambrian and Ordovician types; also from higher up, where numerous Linguiæ of Ordovician characteristics occur.[1]

**LYNX LIMESTONES.**—[Upper Cambrian] thin-bedded gray and bluish-gray limestone with bands of shale.

Estimated thickness ........................................ 2,100

*Fauna.*—None found.

*Name* derived from Lynx Mountain, which is almost entirely formed of the strata included in the formation.

**TITKANA LIMESTONES.**—[Middle Cambrian] massive beds of thin layers of bluish-gray limestone, interbedded with bands of dolomitic limestone.

Estimated thickness ........................................ 2,200

*Fauna.*—Characteristic Middle Cambrian fossils, which may be compared with the fauna of the Stephen formation that occurs 200 miles (321.8 km.) to the south.

*Name* derived from Titkana Peak, where the formation is extensively developed.

**MUMM LIMESTONES.**—[Middle Cambrian] massive-bedded gray arenaceous limestones.

Estimated thickness ........................................ 600

*Fauna.*—No fossils.

*Name* derived from Mumm Peak, where the limestones form the upper part of the mountain.

**HITKA FORMATION.**—[Middle Cambrian] alternating bands or thin layers of arenaceous limestones and shales.

Estimated thickness ........................................ 1,700

*Fauna.*—No fossils.

*Name* derived from Hitka Mountain that rises above Smoky River Valley east of Mumm Peak and north of Titkana Peak.

**TATAY LIMESTONES.**—[Middle Cambrian] massive-bedded gray arenaceous limestones.

Estimated thickness ........................................ 800

*Fauna.*—No fossils.

*Name* derived from Tatay Cliffs, east of Lake Adolphus and northwest of Titkana Peak.

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[1] For lists of fossils see detailed geologic section, pp. 336-340.


FIG. 1.—Panoramic view from Shio Point, looking down Moose River Valley. The strata
Upper Cambrian age. A fault line with a throw of about 9,000 feet has thrust the Lower C


FIG. 2.—Panoramic view of Tah Peak, Mahto Mountain, and Calumet Creek. On the le
are Titkana Peak and Robson Peak. On the right Calumet Creek with Mumm

Moose River Valley — Moose Pass — Mahpiya Snow Field — Tah Peak — Lynx Mt.

.he mountains on the right of the Pass are of Lower Cambrian age, and those on the left of
rian over the Upper Cambrian on the line of the Pass. Photograph by C. D. W., 1912.

Titkana Peak =T. — Robson Peak =R. — Mahto Mt. =Ma. — Mumm Peak =M. — Mural Glacier =M. G. — Gendarme Mt. =G.


Calumet Creek=C.

ıh Peak slopes to the northwest, merging into Mahto Mountain, and beyond in the distance
:, and to the right of the Peak Mural Glacier. Photograph by C. D. W., 1912.

**CHETANG LIMESTONES.**—[Middle Cambrian] bluish-gray thin-bedded limestones.

Estimated thickness .......................................... 900

*Fauna.*—Characteristic fossils of the lower portion of the Middle Cambrian, found at two horizons.

*Name* derived from Chetang Cliffs above Coleman Glacier, north of Titkana Peak.

**HOTA FORMATION.**—[Lower Cambrian] gray arenaceous limestones and siliceous shales alternating with massive quartzitic sandstone.

Estimated thickness .......................................... 800

*Fauna.*—*Olenellus* and other genera characteristic of the upper part of the Lower Cambrian.

*Name* derived from Hota Cliffs rising above Coleman Brook which runs along the southwest base of Mahto Mountain.

**MAHTO SANDSTONES.**—[Lower Cambrian] massive-bedded quartzitic sandstone with bands of siliceous shale.

Estimated thickness .......................................... 1,800

*Fauna.*—Fragments of *Olenellus* in the upper portion on Mahto Mountain.

*Name* derived from Mahto Mountain, which faces the valley on the south side of Calumet Creek east of Smoky River.

**TAH FORMATION.**—[Lower Cambrian] siliceous shale and interbedded siliceous limestones.

Estimated thickness .......................................... 800

*Fauna.*—No fossils found.

*Name* derived from Tah Mountain, east-northeast of Mahto Mountain and southwest of Moose Pass. The formation occurs just above the Pass at the base of the mountain.

**McNAUGHTON SANDSTONES.**—[Lower Cambrian] quartzitic sandstones.

Estimated thickness .......................................... 500

*Fauna.*—No fossils found.

*Name* derived from McNaughton Mountain, situated opposite the mouth of the Hihuna River where it enters Moose River.

**MIETTE SANDSTONES.**—[Pre-Cambrian] Belt series, massive gray sandstones with interbedded siliceous shales.

Estimated thickness .......................................... 2,000+

*Fauna.*—No fossils found.

*Name* derived from Miette River, which cuts through the Miette formation for many miles in the vicinity of Yellowhead Pass.

## STRATIGRAPHIC SECTION FROM ROBSON PEAK NORTH-NORTHWEST TO MOOSE PASS

### ORDOVICIAN SYSTEM

FEET

**ROBSON LIMESTONES.**—Light-gray or dove-colored and bluish-gray thin-bedded limestones, forming massive strata on cliff exposures .................................................. 3,000

The upper 1,500 feet of Robson Peak are practically inaccessible. The limestones appear to be more massive-bedded and arenaceous than the strata below. They weather like the great arenaceous limestones of the Kicking Horse Pass section 150 miles to the south. Large blocks of the arenaceous and dolomitic buff-weathering limestone, also siliceous and calcareous gray shale with buff-weathering magnesian limestone in thin layers, were brought down from high up on Mount Robson by the central moraine of Hunga Glacier.

There is no known well-defined lithological break between the Ordovician and the Cambrian. A line is now tentatively drawn in a series of thin-bedded and shaly limestones, at Billings Butte, where there is a commingling of the lower Ordovician and Upper Cambrian faunas.

*Fauna.*—(**61u**) In the gray thin-bedded limestones brought down by Chupo Glacier on the northeast slope of Robson Peak four species of fossils were found that indicate an horizon very close to if not within the base of the Ordovician:

*Lingulella* cf. *L. manticula* White
*Acrotreta* sp. undt.
*Hyolithes* sp. undt.
*Ptychoparia* sp. undt.

In Billings Butte (Locality **61n**) in the upper part of the shaly limestone the fossils are distorted. The collection includes a *Lingulepis* that appears to be identical with *Lingulella* (*Lingulepis*) *acuminata* Conrad, and a species of *Asaphus* the fragments of which indicate a rather large species.

Below the *Lingulepis* zone, limestones occur interbedded in the shaly layers that indicate by the contained fossils the base of the Ordovician. Locality **61q** is in Billings Butte which rises above Hunga Glacier 2.5 miles (4 km.) north of the summit of Mount Resplendent (fig. 2, pl. 58). The following fauna was collected:

*Lingulella* cf. *L. isse* Walcott
*Acrothele* sp. undt.
*Acrotreta* cf. *A. sagittalis* Salter
*Eoorthis desmopleura* Meek
*Eoorthis ?*
*Syntrophia nundina* Walcott
*Bellerophon* sp. undt.
*Orthoceras* sp. undt.
*Agnostus* sp. undt.
*Hungia billingsi* n. sp.
*Triarthrus* sp. undt.
*Solenopleura* sp. undt.
*Peltura* (Pygidia)
*Apatocephalus*
*Chuangia robsonensis* n. sp.
*Illænurus* n. sp. (*a*)
*Illænurus* n. sp. (*b*)

Shio Point = S. Tokana Mts. = T. Moose Pass = M.


Calumet Creek

Fig. 1.—Looking south across Calumet Creek and Flats. In the center Tah Peak; to th
the Tokana Mountains and Calumet

Mt. Mahto = Ma. Mahpiya Snow Field = Mp. Coleman Glacier = C.


Fig. 2.—Looking southwest from south slope of Mahto Mountain. On the left Coleman G
with Robson Peak in the distance

Peak Mahpiya Snow Field. Mahto Mt.

ht Mahpiya snow field and the dark mass of Mahto Mountain; to the left of Tah Peak
:. Photograph by C. D. W., 1912.

Titkana Peak = T. Iyatunga Mt. = I. Robson Peak = R. Miniohan Range = Mi.


Berg Lake

nan Brook = C. B.

r and Creek and rising above the creek Chetang Cliffs, Tatay Cliff, and Titkana Mountain.
otograph by C. D. W., 1912.

## CAMBRIAN SYSTEM

### UPPER CAMBRIAN

**LYNX LIMESTONES.**—Thin-bedded bluish-gray limestone with interbedded bands of light gray shale, and at the base a band of about 200 feet in thickness of gray, greenish and reddish-brown shale .......................................... 2,100

*Fauna.*—No fossils were found below the arbitrary line drawn at the base of the shaly limestones containing the fauna from Locality 61q.

### MIDDLE CAMBRIAN

**TITKANA LIMESTONES.**—Massive-bedded bluish-gray limestone in thin layers interbedded with gray siliceous, buff-weathering limestone that occurs in bands 50 to 100 feet thick............ 2,200

This formation is best seen in the west slopes of Titkana Peak and Iyatunga Mountain. Fossils were found at two horizons that clearly correlate the lower part of the Titkana formation with the Stephen formation of Mount Stephen.

*Fauna.*—At the upper horizon the following species occur (Locality 61v) 1 mile (1.6 km.) each of summit of Titkana Peak in cliff above Hunga Glacier:

*Micromitra zenobia* Walcott
*Obolus mcconnelli* Walcott
*Obolus septalis* Walcott
*Acrotreta* cf. *depressa* Walcott
*Wimanella ? borealis* n. sp.
*Hyolithes carinatus* Matthew
*Selkerkia major* Walcott
*Agnostus montis* Matthew
*Zacanthoides spinosus* Walcott
*Kootania dawsoni* Walcott
*Ptychoparia* n. sp.

Of the above all but *Wimanella ? borealis* occur in the Stephen formation.

At an horizon estimated to be 1,000 feet lower, the following genera are represented in the collection from localities 61l and 61m, about 1.5 miles (2.4 km.) west-northwest of the summit of Titkana Peak on slopes above Lake Adolphus:

| | |
|---|---|
| *Acrothele* | *Olenoides* |
| *Acrotreta* cf. *sagittalis* Salter | *Zacanthoides* |
| *Agnostus* | *Ptychoparia* |

**MUMM LIMESTONES.**—Massive-bedded, gray siliceous limestone weathering to gray and buff tints on cliffs.................... 600

Exposed at northwest base of Titkana Peak and north face of Mumm Peak.

*Fauna.*—No fossils found.

**HITKA FORMATION.**—Alternating bands of gray thin-bedded arenaceous limestone and siliceous, arenaceous, and argillaceous shales, that form very striking broken cliffs and steep slopes. . 1,700

This formation forms high slopes along the valley of Smoky River below Lake Adolphus and east of Mumm Peak.

*Fauna.*—No fossils found.

**TATAY LIMESTONES.**—Massive-bedded gray siliceous and arenaceous limestones . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 800

*Fauna.*—No fossils found.

**CHETANG LIMESTONES.**—Bluish-gray, thin-bedded limestones forming a cliff beneath the Tatay formation [limestones], a talus slope of about 100 feet, and then a second cliff above Coleman Glacier and Brook . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 900

This formation is well shown in Chetang Cliff, 3 miles (4.8 km.) north of the summit of Titkana Mountain.

*Fauna.*—At about 100 feet (30 m.) from the summit of the formation (**61 o**):

*Nisusia* sp. undt.
*Zacanthoides* sp. undt.
*Bathyuriscus* sp. undt.

At about 350 feet (105.6 m.) down in the formation at top of lower cliff (**61p**) the following fauna occurs:

*Albertella bosworthi* Walcott (Occurs at about same horizon in Mount Bosworth section [1]).

In a drift block (Locality **61w**) the following species were found:

*Albertella* cf. *bosworthi* Walcott
*Albertella* n. sp.
*Agraulos* sp. undt.
*Ptychoparia* sp.

## LOWER CAMBRIAN

**HOTA FORMATION.**—Massive-bedded arenaceous limestone in great bands of light and dark gray color with a band of gray, pinkish-weathering limestone at the top that forms the south slope of the ridge on the north side of Coleman Brook and the southwest spur of Mahto Mountain . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 800

*Fauna.*—Fragments of *Olenellus,* etc., were found in the upper layers of the formation on the line of the section.

At Locality **61s**, west slope of Mahto Mountain about 300 feet (90 m.) from the top,

*Olenellus canadensis* Walcott.

At Locality **61t**, gray siliceous limestone near top of the formation on west slope of Mahto Mountain,

*Olenellus* sp. undt.
*Ptychoparia ?*

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

Titkana Peak = T. Robson Peak = R. Iyatunga Mt. = I. Berg Lake = B. Miniohan Mts. = Mi.


Coleman Brook = C. B.

Fig. 1.—View from the south slope of Mahto Mountain, showing on the left Coleman Creek and to the right of Berg Lake, Mumm Peak, Hitka Mountain, Chapa Point, and

Chushina Glacier Phillips Mt. (9,542 ft.) Lynx M (10,47

Snowbird Pass


Fig. 2.—View from southwest slope of Titkana Peak, looking south. On the left Phillips Mo to the right Mount Resplendent, Billings Butte, and portions of Hunga Glacier. Photograp portions of Hunga Glacier.

Mumm Peak = M. Hitka Mt. = H. Gendarme Mt. = G. Chapa Point = C. Shota Mts. = S.


Smoky River = S. R. Hota Cliffs = H. C. Smoky River = S. R.

ıbove Chetang Cliff, Tatay Cliff, and Titkana Mountain. In the distance Robson Peak, ;hota Mountain rising above Smoky River. Photograph by C. D. W., 1912.

Mt. Resplendent = Rs. (11,173 ft.) Billings Butte = B. Hunga Glacier = H. G


with the slope toward Snowbird Pass. Back of Phillips Mountain, Lynx Mountain, and :. D. W., 1912. Fig. 2 joins fig. 2 of plate 58, forming a panoramic view of the upper

At Locality **61k**, 2.5 miles (4 km.) west of **61t** beneath the north face of Mumm Peak and just above Mural Glacier, the following 12 species were found in a band of dark siliceous shale:

*Planolites* (Annelid trail.)
Cystid ? sp. undt.
*Lingulella chupo* Walcott
*Lingulella hitka* Walcott
*Obolella hota* Walcott
*Obolella* cf. *chromatica* Billings
*Hyolithes* sp. undt.
*Callavia eucharis* Walcott
*Callavia perfecta* Walcott
*Wanneria occidens* Walcott
*Olenellus truemani* Walcott
*Hymenocaris* sp. undt.
*Agraulos* sp.

**MAHTO SANDSTONES.**—Massive-bedded quartzitic sandstones with thin-bedded hard sandstones and dirty grayish-brown shale in thin bands ........................................ 1,800

This series extends down the northeast face of Mahto Mountain and the slope of Tah Mountain nearly 800 feet (241 m).

*Fauna.*—No fossils found.

**TAH FORMATION.**—Hard, green and purple siliceous shales with irregular massive beds of gray and purple, compact limestone interbedded in central portion.............................. 800

*Fauna.*—No fossils found.

**McNAUGHTON SANDSTONES.**—Light gray, massive-bedded quartzitic sandstone ........................................ 500+

*Fauna.*—No fossils found.

At Moose Pass there are only a few layers of this formation exposed, but to the southwest toward Yellowhead Pass the sandstones have a thickness estimated at 500 feet (151 m.). This, however, is very uncertain as it is difficult to determine the line of demarcation between the sandstone of Cambrian and pre-Cambrian (Belt) age.

## UNCONFORMITY BY EROSION

### PRE-CAMBRIAN

**BELT SERIES, MIETTE FORMATION.**—Massive-bedded gray sandstones with thick bands of gray and greenish siliceous shales. . 2,000+

The best exposures seen of the Belt series were along both sides of Yellowhead Pass from the vicinity of Grant Brook on the west to Fitzhugh on the east.

In the Yellowhead Pass the cuts of the Grand Trunk Pacific and the Canadian Northern railroads afford fine sections of the Miette sandstones and shales. Some of the layers of sandstone are clean and fresh, but most of the rock suggests deposition of the sand in muddy water.

It may be that more than one formation occurs in the Belt series, but without detailed study and mapping it will be difficult to determine the limits to be assigned to the strata provisionally grouped in the Miette formation.

On both the north and south sides of Yellowhead Pass the Miette formation occurs in rounded, wooded ridges that rise over 2,500 feet (754 m.) above the Pass. To the north the Cambrian of McEvoy Mountain rises as great castelated masses on the northwest side of Miette River, and on the west side Hutam Mountain forms an outlying butte of Cambrian sandstone and limestone.

To the south of the Pass the banded cliffs of Cambrian rocks in Mount Fitzwilliam and Mount Pelee rise high above their base of Miette sandstones.

At the Pass the valley is essentially the same type as the valley of Bow River near Laggan. In both, the valley is eroded in the Belt series of impure sandstones and the Cambrian sandstones and limestones form high, bold mountains to the north and south of the valley.

Titkana Peak | Phillips Mt. = P. | Hunga Glacier = H. G. | Iyatunga Mt. (9,000 ft.)


FIG. 1.—Panoramic view of the Robson massif from a point on the ridge south of Mumm Pe
on left side of Hunga Glacier, water on right flowing to the

Mt. Resplendent = Rs. | Billings Butte = B. | Hunga Glacier


FIG. 2.—Panoramic view of the Robson massif and adjoining mountains, with the great Hun
above the glacier on the slope of Titkana Peak,

Blue Glacier = B. | Robson Peak (13,000 ft.) | Chupo Glacier = C. | Little Grizzly Peak = L. G.


Berg Lake | Miniohan Mountains

ıd 1,800 feet (546 m.) above Berg Lake. The Continental Divide passes over the rock knoll
c, on left to the Arctic Ocean. Photograph by C. D. W., 1912.

obson Peak | Iyatunga Mt.

acier in the foreground. The photograph was taken from a point nearly 2,000 feet (604 m.)
in figure 1. Photograph by C. D. W., 1912.

## SUMMARY OF ROBSON DISTRICT

### STRATIGRAPHIC SECTION

| | | Formation | Character | Estimated thickness in feet |
|---|---|---|---|---|
| *Ordovician* | | Robson | Massive and thin-bedded limestones partly siliceous, arenaceous and dolomitic | 3,000 |
| *Cambrian* | Upper | Lynx | Thin-bedded gray and bluish-gray limestone with bands of shale | 2,100 |
| | Middle | Titkana | Massive beds of thin layers of bluish-gray limestone interbedded with bands of dolomitic limestone | 2,200 |
| | | Mumm | Massive-bedded gray arenaceous limestones | 600 |
| | | Hitka | Alternating bands of thin layers of arenaceous limestones and shales | 1,700 |
| | | Tatay | Massive-bedded gray arenaceous limestone | 800 |
| | | Chetang | Bluish-gray thin-bedded limestones | 900 |
| | Lower | Hota | Gray arenaceous limestone, alternating with massive quartzitic sandstone | 800 |
| | | Mahto | Massive-bedded quartzitic sandstone with bands of siliceous shale | 1,800 |
| | | Tah | Siliceous shale and interbedded siliceous limestones | 800 |
| | | Mc Naughton | Quartzitic sandstones | 500 |
| | Total thickness, Cambrian sediments | | | 12,200 |
| *Unconformity* | | | | |
| *Algonkian* | Belt | Miette | Massive gray sandstones with interbedded siliceous shales. Base concealed. | 2,000+ |

For purposes of comparison a summary of the Bosworth section as it occurs along the Kicking Horse Pass route of the Canadian Pacific Railway is inserted here, as published in 1908.[1]

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 216, 217.

## SUMMARY OF MOUNT BOSWORTH SECTION

### STRATIGRAPHIC SECTION

| | Formations | Character | Feet | Feet |
|---|---|---|---|---|
| Upper Cambrian | Sherbrooke | Gray, partly cherty limestones | 175 | |
| | | Oölitic limestones and shaly band | 590 | |
| | | Arenaceous dolomitic limestone | 610 | 1,375 |
| | Paget | Massive-bedded bluish-gray limestone | 60 | |
| | | Oölitic limestone with bands of shale | 300+ | 360+ |
| | Bosworth | Gray, arenaceous, dolomitic limestone | 600+ | |
| | | Shaly and thin-bedded dolomitic limestone with two bands of shale | 987 | |
| | | Shales | 268 | 1,855+ |
| Middle Cambrian | Eldon | Siliceous and arenaceous limestone | 788 | |
| | | Bluish-gray limestone | 95 | |
| | | Arenaceous limestone | 1,845 | 2,738 |
| | Stephen | Thin-bedded, dark and bluish-gray limestone | 315 | |
| | | Alternating limestones and shale | 325 | 640 |
| | Cathedral | Arenaceous dolomitic limestone | 1,595 | 1,595 |
| Lower Cambrian | Mount Whyte | Thin-bedded limestones | 224 | |
| | | Sandstone | 31 | |
| | | Siliceous shale | 115 | |
| | | Gray limestone | 20 | 390 |
| | St. Piran | Sandy shales and quartzitic sandstones as exposed at Lake Agnes | .... | 2,705 |
| | Lake Louise | Compact siliceous shale as exposed at Lake Louise | .... | 105 |
| | Fairview | Quartzitic sandstones as exposed at Lake Louise | .... | 600+ |
| | Total thickness of sections examined | | | 12,353+ |

## COMPARISON OF ROBSON SECTION WITH BOSWORTH SECTION

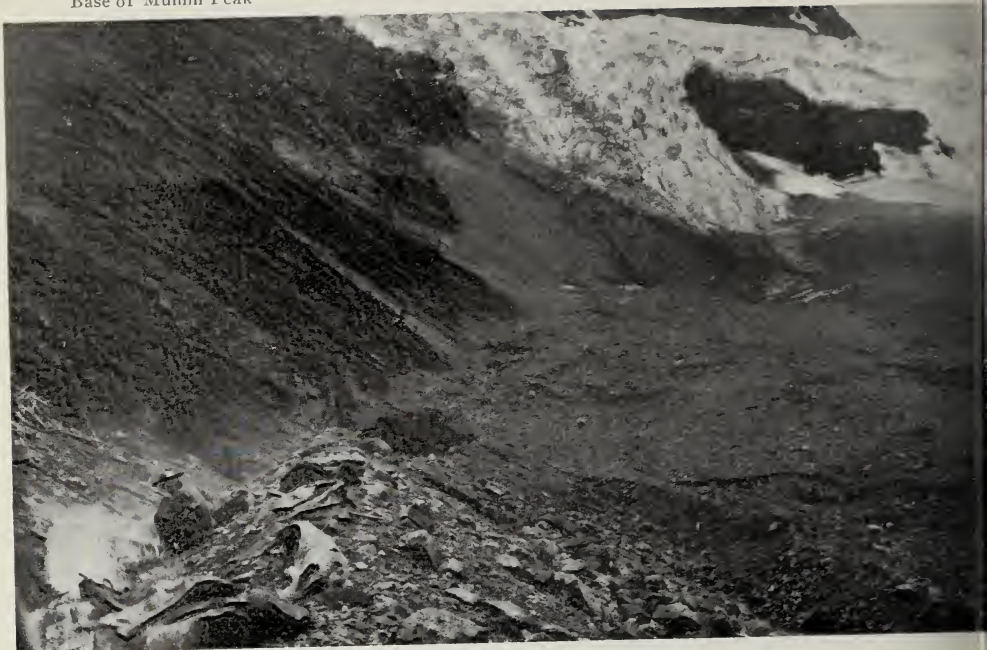
The Mount Bosworth section[1] has been much more carefully studied than the Robson section, but with the data available the two sections show a general similarity and yet there is such variation as to prevent the correlation of the various formations of the two sections; therefore, the same formational names cannot now be used.

In the following table the formations are arranged so as to present a rough correlation between the two sections. The data for further comparison are to be found in the summaries of the two sections

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 204-217.

Base of Mumm Peak

Mu



Gendarme Mt. = G.


FIGS. 1 and 2.—Panoramic view of Mural Glacier. In the lower cliff on the left at "x" n
foreground is covered with loose rock and débris, and the cliff over which th

acier Gendarme Mt. = G.


Shota Mts. Chapa Point Valley of Smoky River Sapa Mts. = S.


1) above the camp fire Lower Cambrian fossils are abundant. The entire glacier in the
tumbles is formed of Lower Cambrian rocks. Photograph by C. D. W., 1912.

(pp. 341, 342) and in the detailed sections (pp. 336-340) for the Robson section and for the Bosworth section in my paper on the Cambrian sections of the Cordilleran area.[1]

## COMPARATIVE STRATIGRAPHIC SECTIONS

| | ROBSON DISTRICT Formations | Feet | MOUNT BOSWORTH SECTION Feet | Formations |
|---|---|---|---|---|
| *Upper Cambrian* | | | 1,375 | Sherbrooke |
| | | | 360 | Paget |
| | | | 1,855+ | Bosworth |
| | Lynx | 2,100 | 3,590+ | |
| *Middle Cambrian* | Titkana | 2,200 | 2,728 | Eldon |
| | Mumm | 600 | | |
| | Hitka | 1,700 | 640 | Stephen |
| | Tatay | 800 | 1,595 | Cathedral |
| | Chetang | 900 | | |
| | | 6,200 | 4,963 | |
| *Lower Cambrian* | Hota | 800 | 390 | Mount Whyte |
| | Mahto | 1,800 | 2,705 | St. Piran |
| | Tah | 800 | 105 | Lake Louise |
| | McNaughton | 500+ | 600+ | Fairview |
| | | 3,900+ | 3,800+ | |
| Total thickness Cambrian sediments | | 12,200+ | 12,353+ | |

There are strong points of resemblance between the McNaughton and Fairview formations, both being formed of layers of quartzitic sandstone that weather to a dark, rusty-brown color and both being unconformably superjacent to the sandstone of the Belt series.

One of the most noticeable differences is in the thickness of the massive arenaceous limestones in the Robson section which is much less than in the Bosworth section. There is a thickness of only 1,400 feet (422.8 m.) in the Middle Cambrian, while in the Bosworth section the Eldon and Cathedral arenaceous limestones of the Middle Cambrian have a combined thickness of 4,333 feet (1,308.5 m.).

Future study of the Robson section and discovery of other fossil-bearing beds will undoubtedly lead to a shifting of the lines of demarcation, but the larger divisions of the section will probably be preserved.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 204-216.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 57, NUMBER 13



# CAMBRIAN GEOLOGY AND PALEONTOLOGY

## II

## No. 13.—DIKELOCEPHALUS AND OTHER GENERA OF THE DIKELOCEPHALINÆ

(With Plates 60 to 70)

BY

CHARLES D. WALCOTT

(Publication 2187)

CITY OF WASHINGTON
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CONTENTS

## ILLUSTRATIONS



## INTRODUCTION

Many years ago I planned an investigation of the genus *Dikelocephalus,* but under the pressure of other studies and administrative duties it was delayed. Dr. L. C. Wooster in 1883, Dr. Cooper Curtice in 1884, and Dr. Charles Schuchert in 1896 all made extensive collections from the Cambrian of Wisconsin and Minnesota, and it is from this material that many of the illustrations in this paper are taken and the association of species determined.

With but slight study in the past I have referred several species represented by fragments to *Dikelocephalus,* and also accepted similar references of species by authors. Fortunately Dr. W. C. Brögger studied the genus and in 1886 proposed three new genera that served in a measure to bring order out of the confusion before existing.

I have not been able to secure entire specimens of any species of *Dikelocephalus* (as restricted), but entire dorsal shields of the closely related *Saukia lodensis* (pl. 65) and *Saukia crassimarginata* (pl. 66) give some conception of the probable form of the dorsal shield of the genotype, *D. minnesotensis*.

I am indebted to Mr. Edgar E. Teller, of the Milwaukee Museum, for his permission to illustrate specimens of *Saukia lodensis* and to examine other material in his collection.

Mr. W. A. Finkelburg, of Winona, Minnesota, sent me numerous specimens from the St. Lawrence and Franconia formations about Winona and on the Wisconsin side of the Mississippi River.

## CLASSIFICATION

The subfamily Dikelocephalinæ Beecher[1] was proposed by its author in 1897 to include the genera *Dikelocephalus, Asaphelina* and *Crepicephalus*. Just before Dr. Beecher's paper appeared, Dr. Brögger called attention to the resemblance between *Asaphelina miqueli* Bergeron and the Asaphidæ,[2] and I agree with him that *Asaphelina* should be grouped under the Asaphidæ and not the Dikelocephalinæ.

The third genus mentioned by Beecher, *Crepicephalus* Owen, as shown by entire specimens of *C. texanus* Shumard,[3] appears to be more nearly related to the Oleninæ.

With the elimination of *Asaphelina* and *Crepicephalus* from the Dikelocephalinæ there remains of the genera referred to it by Beecher, only *Dikelocephalus*; with this there is now included in this paper the genus *Conokephalina* (Brögger)[4] with *Conocephalites ornatus* as the genotype. Brögger also included under *Conokephalina, Dikelocephalus osceola* Hall, *D. misa* Hall and *D. spiniger* Hall on account of their having narrow free cheeks, elongate palpebral lobes and an elongate, slightly narrowing glabella. Of these species *D. misa* is retained under *Conokephalina* and *D. osceola* and *D. spiniger* are referred in this paper to other genera. *Conokephalina* is represented by several species in the Cambrian fauna of China.[5] It is provisionally

[1] Natural Classification of the Trilobites, American Journ. Sci., 4th ser., Vol. 3, 1897, p. 192.

[2] Nyt Mag. for Naturvid., Vol. 36, 1897, p. 185.

[3] U. S. Geol. Survey, Monogr. 32, 1899, part 1, pl. 65, fig. 5.

[4] Geol. Fören. i Stockholm Förhandl., No. 101, Vol. 8, 1886, pt. 3, p. 206.

[5] Research in China, Vol. 3, Carnegie Institution of Washington, Pub. No. 54, 1913, Paleontology, The Cambrian Faunas of China, p. 138.

placed in the subfamily Dikelocephalinæ as it appears to be an intermediate form between *Dikelocephalus* and *Ptychoparia* as is suggested by Brögger. With the discovery of entire specimens of the genotype, *C. ornatus,* it is possible that it may be placed under some other family or subfamily. There is evidently a group of forms that like *Conocephalites* (= *Conokephalina*) *emmrichi* Barrande (Walcott)[1] will need careful consideration when a review is made of the Olenidæ.

Three new genera, *Saukia, Osceolia* and *Calvinella,* are proposed in this paper and are referred to the Dikelocephalinæ.

With our present information, the following genera are included in the subfamily Dikelocephalinæ:

*Dikelocephalus* Owen, 1852
*Conokephalina* Brögger, 1886
*Saukia* Walcott, 1914
*Osceolia* Walcott, 1914
*Calvinella* Walcott, 1914

*Observations on the genera.—Dikelocephalus* (restricted) appears to be distinct from all other genera by the broad, flattened border of its cephalon, large eyes placed well back, large, broad subquadrangular glabella with strong posterior furrow, and large, wide pygidum with broad, flattened border.

*Saukia* has a narrow frontal border about the cephalon and a glabella proportionally more elongate than in *Dikelocephalus.* The pygidium of *Saukia* is less expanded and proportionally more elongate than that of *Dikelocephalus.*

The cranidium of Brögger's genus *Conokephalina* (1886) has a somewhat similar form to that of *Saukia,* but the strong transverse posterior glabellar furrow of *Saukia,* and the absence of a clearly marked frontal limb in advance of the glabella serve to distinguish the cranidium of *Saukia.* The pygidium associated with *Conokephalina ornata* is transverse with a spinose margin, while that of *Saukia* is nearly as long as broad and the margin is unbroken by spines.

*Osceolia* is characterized by its concave frontal limb, elongate palpebral lobes; narrow fixed cheeks and transverse pygidium with its anterior segment extended beyond the margin as a long, strong spine.

*Calvinella* is most like *Saukia,* from which it differs in form of glabella, presence of a strong occipital spine and proportionally more

[1] Research in China, Vol. 3. Carnegie Institution of Washington, Pub. No. 54, 1913, Paleontology, The Cambrian Faunas of China, pl. 13, fig. 7.

elongate pygidium. It differs from *Osceolia* in frontal limb of cephalon; presence of occipital spine and character of pygidium.

Further observations on the genera will be found under the description of each genus.

## SYNONYMIC REFERENCES

The following is a list of the species that have been referred to *Dikelocephalus*[1] and which are now referred to other genera. It is only approximately complete, as many references that occur in textbooks and in general discussion of the fauna are omitted.

| FORMER GENERIC REFERENCE. | PRESENT GENERIC REFERENCE. |
|---|---|
| *Dikelocephalus affinis* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 197) | *Platycolpus* Raymond.[2] |
| *Dikelocephalus angusticauda* (Angelin) Linnarsson, Brögger (Die Sil. Etagen 2 und 3, Kristiania, 1882, p. 126) | *Apatokephalus* Brögger. |
| *Dikelocephalus* (?) *angustifrons* Walcott (Monogr. U. S. Geol. Survey, Vol. 8, 1884, p. 42, pl. 10, figs. 1, 1*a*, 1*b*) | *Lisania* Walcott. |
| *Dikelocephalus barabuensis* Whitfield (Ann. Rep. for 1877, Wis. Geol. Survey, 1878, p. 63) | *Platycolpus* Raymond. |
| *Dikelocephalus ? baubo* Walcott (Proc. U. S. Nat. Museum, Vol. 29, 1905, p. 91) | *Ptychaspis* Hall. |
| *Dikelocephalus ? bavaricus* (Barrande) Brögger (Nyt Mag. for Naturvid., Vol. 36, 1898, p. 212) | Genus undt. |
| *Dikelocephalus belli* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 403, text fig. 378) | *Anomocarella* Walcott. |
| *Dikelocephalus billingsi* Linnarsson (Geol. Fören. Stockholm Förhandl., Vol. 2, 1875, p. 492, pl. fig. 1) | *Acerocare* Angelin. |
| *Dikelocephalus bilobatus* Hall and Whitfield (U. S. Geol. Expl. 40th Parl., Vol. 4, 1877, p. 226, pl. 2, fig. 36) | *Platycolpus* Raymond. |
| *Dikelocephalus ? brizo* Walcott (Proc. U. S. Nat. Mus., Vol. 29, 1905, p. 92) | *Ptychaspis* Hall. |
| *Dicellocephalus bröggeri* Moberg (Aftryck ur Kongl. Fysiogr. Sällsk. Handl. Lund, Bd. 17, 1906, p. 87, pl. 5, figs. 7, 8) | Genus undt. cf. *Platycolpus* Raymond. |

[1] The original spelling of the genus is adhered to in this paper, but under synonymic references the spelling used by each author has been retained, the alphabetical sequence according to species names being followed.

[2] Memoirs Victoria Memorial Museum, Geol. Survey Canada, Bull. 1, 1913, p. 63.

| FORMER GENERIC REFERENCE. | PRESENT GENERIC REFERENCE. |
| --- | --- |
| *Dikelocephalus celticus* Salter (Mem. Geol. Surv. Great Britain, Vol. 3, 1866, p. 304) | Undt. genus. Species founded on distorted pygidia. |
| *Dikelocephalus cristatus* Billings (Canadian Nat. Geol., Vol. 5, 1860, p. 312, text fig. 10) | *Conokephalina* Brögger ? |
| *Dikelocephalus* (?) *corax* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 334, text fig. 322*a-b*) | Genus undt. |
| *Dikelocephalus crassimarginatus* Whitfield (Geol. Wisconsin, Vol. 4, 1882, p. 344, pl. 27, fig. 14) | *Saukia* Walcott. |
| *Dikelocephalus devinei* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 195, fig. 180) | *Ptychoparia ?* Corda. |
| *Dikelocephalus dicraeurus* (Angelin) (Linnarsson) Brögger (Die Sil. Etagen 2 und 3, Kristiania, 1882, p. 126) | *Dikelokephalina dicraeura.* |
| *Dikelocephalus discoidalis* Salter (Mem. Geol. Surv. Great Britain, Vol. 3, 1866, p. 304) | Genus undt. Species founded on fragments of distorted cranidia. |
| *Dikelocephalus dubius* (Linnarsson) Brögger (Nyt Mag. for Naturvid., Vol. 35, 1897, p. 175, figs, 5*a-b*) | *Apatokephalus dubius.* |
| *Dikelocephalus eatoni* Whitfield (Ann. Rep. Surv. Wisconsin for 1877, 1878, p. 65) | *Platycolpus* Raymond. |
| *Dikelocephalus* (?) *expansus* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 45, pl. 9, fig. 19) | *Dolichometopus* Angelin. |
| *Dikelocephalus finalis* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 89) | *Apatokephalus* Brögger (1896). |
| *Dikelocephalus flagricaudus* White (Geog. and Geol. Expl. and Surv. West 100th Merid., Vol. 4, pt. 1, 1875, p. 60) | *Zacanthoides* Walcott. |
| *Dikelocephalus flabellifer* Hall and Whitfield (U. S. Geol. Expl. 40th Parl., Vol. 4, 1877, p. 227, pl. 2, figs. 29, 30) | *Apatokephalus* Brögger (1896). |
| *Dikelocephalus florentinensis* Etheridge (Records Australian Museum, Sydney, Vol. 5, 1905, p. 99, pl. 10, fig. 4) | *Dikelokephalina* Brögger. |
| *Dikelocephalus* (*Centropleura ?*) *furca* Salter (Mem. Geol. Surv. Great Britain, Vol. 3, 1866, p. 303) | *Dikelokephalina* Brögger. |
| *Dikelocephalus ? gothicus* Hall and Whitfield (U. S. Geol. Expl. 40th Parl., Vol. 4, 1877, p. 242) | *Olenoides wasatchensis* Hall and Whitfield. |
| *Dikelocephalus granulosus* Owen (Rept. Geol. Surv. Wis., Iowa, and Minn., 1852, p. 575) | *Ptychaspis* Hall (1863). |

| FORMER GENERIC REFERENCE. | PRESENT GENERIC REFERENCE. |
|---|---|
| *Dikelocephalus hartti* (Walcott) Stose (U. S. Geol. Surv. Geol. Atlas, U. S. Folio No. 170, 1909, p. 6) | *Dikelocephalus* Owen. |
| *Dikelocephalus hisingeri* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 196) | *Lisania* Walcott ? |
| *Dicellocephalus inexpectans* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 90, pl. 1, fig. 10) | *Conokephalina* Brögger. |
| *Dicellocephalus ? interpres* Read (Mem. Geol. Surv. India, ser. 15, Vol. 7, Mem. No. 1, Cambrian Fossils of Spiti, 1910, p. 38, pl. 5, figs. 9-13) | *Ptychoparia* Corda ? |
| *Dicellocephalus iole* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 43, pl. 10, fig. 19) | *Conokephalina* Brögger ? |
| *Dikelocephalus iowensis* Owen (Geol. Surv. Wis., Iowa, and Minn., 1852, p. 575) | *Crepicephalus* Owen. |
| *Dikelocephalus latifrons* Shumard (Trans. Acad. Sci., St. Louis, Vol. 2, 1863, p. 101) | *Ptychoparia wisconsinensis* (Owen). |
| *Dicellocephalus ? leptænarum* Wiman (Arkiv för Zoologi, Bd. 3, 1906, No. 24, p. 5, pl. 12, figs. 1-3) | *Saukia* Walcott ? |
| *Dikelocephalus lodensis* Whitfield (Geol. Wisconsin, Vol. 4, 1882, p. 188, pl. 10, fig. 14, pl. 27, figs. 12, 13) | *Saukia* Walcott. |
| *Dikelocephalus* (*Centropleura*) *loveni* (Angelin) Koken (Die Leitfossilien, Leipzig, 1896, p. 17) | *Paradoxides loveni* Angelin. |
| *Dikelocephalus magnificus* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 400) | New genus *Hungaia* Walcott (MSS.). |
| *Dikellocephalus ? marcoui* Whitfield (Bull. American Mus. Nat. Hist., Vol. 1, 1884, p. 150) | *Olenoides* Meek. |
| *Dikelocephalus marica* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 44, pl. 10, fig. 13) | *Saukia* Walcott |
| *Dikelocephalus megalops* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 403) | *Conokephalina* Brögger. |
| *Dicellocephalus micropthalmus* Holm (Geol. Fören. i Stockholm Förhandl., Vol. 19, 1898, p. 466) | *Anomocare* Angelin ? |
| *Dicellocephalus minnesotensis ?.* Identified by R. P. Whitfield. (Monogr. U. S Geol. Survey, Vol. 12, 1886, p. 60) | *Saukia coloradoensis* Walcott. |
| *Dikelocephalus minnesotensis limbatus* Hall (Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1863, pl. 141, pl. 9, fig. 12) | *Dikelocephalus limbatus* Hall. |
| *Dikelocephalus miniscaensis* Owen (Geol. Surv. Wis., Iowa, and Minn.. 1852, p. 574) | *Ptychaspis* Hall. |

| FORMER GENERIC REFERENCE. | PRESENT GENERIC REFERENCE. |
|---|---|
| *Dicellocephalus misa* Berkey (Am. Geologist, Vol. 21, 1898, p. 290, pl. 20, figs. 12, 13) | *Anomocare ?* Angelin. |
| *Dikelocephalus misa* Hall (Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1863, p. 144, pl. 8, fig. 15; pl. 10, figs. 4, 5) | *Conokephalina* Brögger. |
| *Dikelocephalus missisquoi* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 199) | New genus. |
| *Dikelocephalus multicinctus* Hall and Whitfield (U. S. Geol. Expl. 40th Parl., Vol. 4, 1877, p. 226, pl. 2, fig. 36) | *Apatokephalus* Brögger (1896). |
| *Dikelocephalus nasutus* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 40, pl. 10, fig. 15) | *Proampyx* Frech. |
| *Dikelocephalus newtonensis* Weller (Geol. Surv. New Jersey, Rep. on Pal., Vol. 3, 1903, pp. 121-122, pl. 3, figs. 1-7) | *Calvinella* Walcott. |
| *Dikelocephalus osceola* Hall (Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1863, p. 146, pl. 10, fig. 18; pl. 7, fig. 49) | *Osceolia* Walcott. |
| *Dikelocephalus oweni* Billings (Canadian Nat. Geol., Vol. 5, 1860, p. 310, text fig. 8) | *Anomocarella* Walcott ? |
| *Dikelocephalus pauper* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 200) | *Ptychaspis* Hall ? |
| *Dikelocephalus pepinensis* Owen (Rept. Geol. Surv. Wis., Iowa, and Minn., 1852, p. 574, pl. 1, figs. 9, 9*a*) | *Saukia* Walcott. |
| *Dikelocephalus planifrons* Billings (Canadian Nat. Geol., Vol. 5, 1860, p. 309, text fig. 6) | *Anomocarella* Walcott ? |
| *Dikelocephalus quadriceps* Hall and Whitfield (U. S. Geol. Surv. 40th Parl., Vol. 4, 1877, p. 240) | *Olenoides* Meek. |
| *Dikelocephalus richmondensis* Walcott (Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 41, pl. 10, fig. 7) | *Ptychoparia* Corda. |
| *Dikelocephalus roemeri* Shumard (American Journ. Sci., 2d ser., Vol. 32, 1861, p. 220) | *Ptychoparia* Corda. |
| *Dikelocephalus selectus* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 199) | *Ptychaspis* Hall ? |
| *Dikelocephalus serratus* (Boeck) (Linnarsson) Brögger (Die Sil. Etagen 2 und 3, Kristiania, 1882, p. 126) | *Apatokephalus* Brögger. |
| *Dikelocephalus sesostris* Billings (Geol. Surv. Canada, Pal. Foss., Vol. 1, 1865, p. 198) | *Ptychaspis* Hall. |
| *Dicellocephalus ? sinensis* Bergeron (Bull Soc. géol. de France, Vol. 27, 1899, p. 508) | *Stephanocare* Monke. |
| *Dikelocephalus spiniger* Hall (Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., 1863, p. 143, pl. 10, figs. 1, 2, 3 ?) | *Calvinella* Walcott. |

| FORMER GENERIC REFERENCE. | PRESENT GENERIC REFERENCE. |
|---|---|
| *Dikelocephalus tasmanicus* Etheridge (Proc. Royal Soc. Tasmania for 1882, 1883, p. 155, pl. 1, fig. 4) | *Dikelokephalina* Brögger. |
| *Dicellocephalus ? villebruni* Bergeron (Bull. Soc. géol. de France, 3d ser., Vol. 23, 1895, p. 473, pl. 5, figs. 1, 2) | *Dikelokephalina* Brögger. |
| *Dikellocephalus wahsatchensis* Hall and Whitfield (U. S. Geol. Expl. 40th Parl., Vol. 4, 1877, p. 241) | *Olenoides* Meek. |

## STRATIGRAPHIC POSITION OF THE DIKELOCEPHALINÆ

It has been evident for several years that the various Cambrian formations of the Upper Mississippi Valley, which had been referred first to the Potsdam and then to the St. Croix sandstones, needed careful revision in relation to their stratigraphic position and succession.

The original classification of Owen (1852) was superseded by the classification of the Minnesota Survey for the Minnesota sections, and for Wisconsin by the classification of the Geological Survey of Wisconsin. The two latter classifications were as follows:

| Wisconsin | Minnesota |
|---|---|
| 1. Madison Sandstone. | 1. Jordan Sandstone. |
| 2. Mendota Limestone. | 2. St. Lawrence Limestone. |
| 3. Calcareous Sandstone. | 3. Sand and sandy Shales. |
| 3. Shale. | 3. Dresbach Sandstone. |
| 3. Fine quartzose Sandstones. | 3. Shales. |
| 3. Coarse quartzose Sandstone. | 3. Hinckley Sandstone. |

During the summer of 1913 Dr. E. O. Ulrich, who had long been studying the Lower Paleozoic formations of the Mississippi Valley south of Wisconsin and Minnesota, extended his investigations into those states and by combining stratigraphic and paleontologic methods succeeded in delimiting six formations, including the upper Jordan sandstone and the basal sandstone of the Minnesota Survey. He found that the Mendota limestone and the Madison sandstone, which had been previously correlated with the Jordan sandstone and the St. Lawrence limestone respectively of the Minnesota Survey, were both above the Jordan sandstone and separated from it by an unconformity; also that their included fossils correlated them with the Ozarkian formations of his Missouri section.[1]

[1] Bull. Geol. Soc. America, Vol. 22, 1911, p. 608, pl. 27.

The provisional classification of the pre-Ordovician formations in the Upper Mississippi Valley is as follows:

| | Formations. | Lithologic characters. |
|---|---|---|
| Canadian | Shakopee 60′ | Dolomite. |
| Ozarkian | Oneota 110′ | Dolomite. |
| | Madison 40′ | Magnesian and calcareous sandstone. |
| | Mendota | Dolomite. |
| Upper Cambrian (St. Croixan) | Jordan (Winchell 1874) 60-80′ | Heavy bedded soft, rather coarse-grained, yellowish sandstone. |
| | St. Lawrence (Winchell 1874) 120′ | Soft fine-grained brown, red, green or ash-colored sandstone often dolomitic near top. Yellow and ash-colored argillaceo-calcareous, thin-bedded rock near middle, and green sands interbedded with yellow sandstones in lower third. |
| | Franconia (Berkey 1898) 85′ | A series of thin and thick-bedded usually soft sandstones with much green material throughout or only in portions. The upper fifty feet often harder than the underlying beds and containing a considerable fauna, especially species of *Conaspis*. In many localities other fossiliferous beds occur in the central and lower portions. |
| | Dresbach (Winchell 1888) 100′ | Massive-bedded, rather coarse-grained sandstone, with a thin bed of shale at the base and shaly sandstone near the middle. Fossils at the top and base, consisting almost entirely of shells of *Dicellomus* and *Lingulella*. |
| | Eau Claire (Ulrich MSS. 1914) About 100′ | Mostly thin-bedded, in part shaly sandstone, with many fossiliferous layers, including Owen's Menomonie and Wooster's Eau Claire trilobite zones. Usually a coarse white friable sandstone with *Dicellomus* and *Lingulella* at the base. Numerous characteristic trilobites, *Crepicephalus iowensis* being one of the best of the guide fossils. |
| | Mt. Simon (Ulrich MSS. 1914) 235′+ | A series of coarse sandstones and grits resting on pre-Cambrian granite. About 225 feet are shown in the bluffs at Eau Claire and 50 feet of the base at Chippewa Falls, Wisconsin. Except *Scolithus* borings no fossils have been found. |

*Jordan formation.*—In Wisconsin this is a rather coarse-grained, thick-bedded, compact but soft, slightly calcareous, light-colored sandstone.[1] In Minnesota it is described as white and siliceous and locally forming rather firm layers that break up into angular blocks.[2]

As far as known the Jordan sandstone as limited by Ulrich has not furnished any fossils *in situ*. There is, however, a fauna collected from sandstones in the vicinity of Devil's Lake, Sauk County, Wisconsin, that may belong at this horizon. It includes from locality **81b** the following species:

*Arenicolites woodi* Whitfield
*Finkelnburgia finkelnburgi* (Walcott)
*Syntrophia barabuensis* (A. Winchell)
*Straparollus ?* (*Ophileta ?*) *primordialis* Winchell
*Dikelocephalus* cf. *limbatus* Hall
*Saukia* cf. *crassimarginata* (Whitfield)
*Saukia* cf. *pyrene* Walcott
*Osceolia* cf. *osceola* (Hall)
*Agraulos ?* sp. undt.
*Ptychaspis* sp. undt.
*Platycolpus barabuensis* (Whitfield)
*Platycolpus* cf. *eatoni* (Whitfield)
*Illœnurus* sp. undt.
*Conaspis* cf. *anatina* (Hall).

The specimens occur in a friable sandstone similar to that of the Jordan formation and unlike the supposedly older, more or less calcareous St. Lawrence formation. The fauna is of the same general facies as that of the upper portion of the St. Lawrence formation, but the trilobites differ in minor details, and there are also present two trilobites closely simulating *Platycolpus barabuensis* and *P. eatoni* (Whitfield). The two latter are types suggesting the succeeding Ozarkian period, the typical varieties of the species, being characteristic of the superjacent Mendota dolomite.

*St. Lawrence formation.*—The eastern Wisconsin phase of this formation is described as consisting of alternating strata of arenaceous magnesian limestone, sandy calcareous shales, and shaly and calcareous sandstones.[3]

In Minnesota the St. Lawrence limestone is formed of an upper regularly bedded magnesian limestone from 30 to 50 feet in thickness, and "below these massive layers, which constitute a part of the precipitous bluffs of the county, there is a varying thickness of more fragile indescribable rock, which can best be defined by Dr. Owen's term *siliceo-argillaceous dolomite,* with occasional layers of an inch or two of crumbling white sand. There is also a slow transition from the crumbling sandstone of the St. Croix to the dolomitic firm rock of the St. Lawrence. . . . . At ten or fifteen feet higher [from the base] the rock has assumed that character which is almost indescrib-

[1] Chamberlin, Geol. Wisconsin, Vol. 2, 1877, p. 260.
[2] Winchell, N. H., Geol. Minnesota, Vol. 1, 1884, p. 253.
[3] Geol. Wisconsin Vol. 2, 1877, p. 261.

able, being greenish and shaly and yet not a shale, calcareous but not a limestone, magnesian but not a dolomite, finely siliceous but not a sandstone. This character continues through a thickness of forty to fifty feet of strata."[1] . . . .

*St. Lawrence fauna.*—The fauna of the upper beds at Osceola, Wisconsin (Locality 78), includes a large group of species as follows:

*Lingulella mosia* (Hall)
*Lingulella mosia osceola* (Walcott)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Billingsella coloradoensis* (Shumard)
*Finkelnburgia finkelnburgi* (Walcott)
*Finkelnburgia osceola* (Walcott)
*Finkelnburgia osceola corrugata* (Walcott)
*Syntrophia barabuensis* (A. Winchell)
*Hyolithes ? corrugatus* Walcott
*Spirodentalium osceola* Walcott
*Holopea sweeti* Whitfield
*Metoptoma* sp.
*Platyceras ?*
*Owenella antiquata* (Whitfield)
*Murchisonia* sp. undt.
*Agnostus disparilis* Hall
*Ptychaspis* sp. (also at Devils Lake, 81)
*Ptychaspis ?* sp.
*Dikelocephalus ? limbatus* Hall
*Dikelocephalus minnesotensis* Owen ?
*Saukia leucosia* Walcott
*Saukia pyrene* Walcott
*Osceolia osceola* (Hall)
*Ptychoparia ? bindosa* (Hall)
*Ptychoparia* sp.
*Illænurus quadratus* Hall
*Triarthrella auroralis* Hall

At an horizon 50 feet (15 m.) above the St. Croix River *Saukia crassimarginatus* (Whitfield) (78b) occurs in association with several of the species in above list. *Calvinella spiniger* Hall is abundant at about this horizon in the calcareo-arenaceous beds of locality $83^1$ at Trempealeau, and it also occurs lower down in this section at $83^2$.

In the lower arenaceo-calcareous beds *Dikelocephalus minnesotensis* has its greatest development. This sub-fauna includes:

*Obolus* (*Westonia*) *aurora* (Hall)
*Obolus* (*Westonia*) *stoneanus* (Whitfield)
*Lingulella mosia* (Hall)
*Lingulella oweni* (Walcott)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Finkelnburgia osceola* (Walcott)
*Syntrophia primordialis* (Whitfield)
*Serpulites murchisoni* Hall
*Owenella antiquata* (Whitfield)
*Owenella vaticina* (Hall)
*Dikelocephalus minnesotensis* Owen
*Saukia crassimarginata* (Whitfield)
*Saukia lodensis* (Whitfield)
*Saukia pepinensis* (Owen)
*Calvinella spiniger* (Hall)
*Ptychoparia binodosa* (Hall)
*Triarthrella auroralis* Hall
*Ptychaspis* n. sp.
*Illænurus quadratus* Hall
*Illænurus* n. sp.
*Aglaspis eatoni* Whitfield
*Aglaspis barrandei* Hall

*Dendrograptus hallanus* Prout is not represented in our collection. Known from Osceola, Wisconsin, and Lake City, Minnesota.

[1] Geol. Minnesota, Vol. 1, 1884, p. 255.

*The Franconia formation.*—In Wisconsin and Minnesota beneath the strata referred to the St. Lawrence series are found more or less calcareous shales and sandstones. The only trace of the Dikelocephalinæ is in the upper arenaceous shales and thin layers of sandstone of the Franconia horizon. This is found in *Conokephalina misa* (Hall). The associated fauna is quite distinct from that of the St. Lawrence formation, and includes (79a, 79b, 80a, 97, 99a, 100):

*Obolus matinalis* (Hall)
*Obolus mickwitzi* Walcott
*Obolus* (*Westonia*) *aurora* (Hall)
*Lingulella mosia* (Hall)
*Lingulella mosia osceola* (Walcott)
*Lingulella oweni* (Walcott)
*Lingulella phaon* (Walcott)
*Lingulella similis* (Walcott)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Lingulella* (*Lingulepis*) *acuminata* (Conrad)
*Dicellomus politus* (Hall)
*Eoorthis ? diablo* Walcott
*Eoorthis remnicha* (N. H. Winchell)
*Eoorthis remnicha sulcata* (Walcott)
*Eoorthis remnicha winfieldensis* (Walcott)
*Eoorthis* sp.
*Otusia sandbergi* N. H. Winchell
*Billingsella coloradoensis* (Shumard)
*Finkelnburgia finkelnburgi* (Walcott)
*Finkelnburgia osceola* (Walcott)
*Syntrophia primordialis* (Whitfield)
*Syntrophia primordialis argia* Walcott
*Palæacmæa irvingi* Whitfield
*Eccyliomphalus* n. sp.
*Agnostus josepha* Hall
*Agnostus parilis* Hall
*Lonchocephalus hamulus* Owen
*Lonchocephalus wisconsinensis* Owen
*Ptychaspis granulosa* (Owen)
*Ptychaspis miniscaensis* (Owen)
*Ptychaspis striata* Whitfield
*Chariocephalus whitfieldi* Hall
*Chariocephalus* sp.
*Conaspis*[1] *anatina* (Hall)
*Conaspis bipunctata* (Shumard)
*Conaspis eryon* (Hall)
*Conaspis nasuta* (Hall)
*Conaspis oweni* (Hall) ?
*Conaspis patersoni* (Hall)
*Conaspis perseus* (Hall)
*Conaspis ? shumardi* (Hall ?)
*Ptychoparia diademata* (Hall)
*Elliptocephalus ? curtus* (Whitfield)
*Conokephalina misa* (Hall)

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[1] CONASPIS Hall.[1]

Dr. Th. Lorenz[2] places two species under the genus *Macrotoxus: Anomocare angelini* Grönwall [1902] and *Conocephalites perseus* Hall [1863]. I think *A. angelini* Grönwell is a true *Anomocare* and should be retained in that genus, which makes *Macrotoxus* a synonym of *Conaspis* Hall.

The genotype of *Conaspis* will now be *C. perseus* (Hall). It is representative of a group of species in the Upper Cambrian formations allied to *Ptychoparia* that are characterized by a subconical glabella, medium sized eye-lobes, rather strong postero-lateral limbs, narrow fixed checks, and with facial sutures extending almost directly forward from the eye lobes so as to form a narrow frontal limb; the frontal rim is usually well defined and cut obliquely by the facial sutures.

The species I now refer to *Conaspis* from the St. Croixan of the upper Mississippi Valley are:

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[1] Sixteenth Ann. Rept. New York State Cat. Nat. Hist., 1863, p. 152.
[2] Zeitschr. deutsch. geol. Gesellsch., Bd. 58, 1906, p. 61.

*Fauna of Eau Claire formation.*—The fauna of the Eau Claire sandstones is marked especially by *Anomocarella woosteri, Crepicephalus texanus,* and *Crepicephalus iowensis.*

The fauna includes near Eau Claire, Wisconsin, the following species at the highest horizon on Mount Washington, locality **78a**:

*Obolus* sp. undt.
*Dicellomus pectenoides* (Whitfield)
*Dicellomus politus* (Hall)
*Pagodia thea* (Walcott)
*Crepicephalus iowensis* Owen

At a slightly lower horizon the following species occur, locality **98x**:

Worm borings
*Obolus matinalis* (Hall)
*Lingulella mosia* (Hall)
*Lingulella phaon* (Walcott)
*Dicellomus politus* (Hall)
*Hyolithes primordialis* Hall
*Stenotheca* sp. undt.
*Agnostus josepha* Hall
*Ptychoparia ? calymenoides* Whitfield
*Ptychoparia chippewaensis* Owen
*Ptychoparia optata* Hall
*Crepicephalus iowensis* Owen
*Crepicephalus texanus* Shumard
*Agraulos* sp. undt.
*Pagodia thea* (Walcott)
*Anomocare* sp. undt.
*Anomocarella onusta* (Whitfield)
*Anomocarella woosteri* (Whitfield)

Additional species occur at other localities as follows:

*Obolus mickwitzi* Walcott
*Obolus namouna* Walcott
*Obolus rhea* Walcott
*Obolus (Westonia) aurora* (Hall)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Lingulella (Lingulepis) acuminata* (Conrad)
*Billingsella coloradoensis* (Shumard)
*Pemphigaspis bullata* Hall
*Lonchocephalus ? minor* (Shumard)
*Ptychoparia ? quadrata* (Whitfield)
*Anomocarella ? winona* (Hall)

*Pemphigaspis bullata* seems to be confined to the uppermost beds referred to the formation.

*Stratigraphic range of the genera.*—From the preceding lists it will be seen that with our present information the genera of the Dikelocephalinæ in the central region of the continent range from the sand-

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*Conocephalites anatinus* Hall
*Conocephalites eryon* Hall
*Conocephalites nasutus* Hall
*Conocephalites oweni* Hall
*Conocephalites perseus* Hall
*Ptychoparia patersoni* (Hall)
*Arionellus bipunctatus* Shumard ?

[All described in Sixteenth Ann. Rept. N. Y. State Cab. Nat. Hist., 1863.]

That from the Upper Cambrian of Texas is:

*Ptychoparia llanoensis* Walcott

[Described in Proc. U. S. Nat. Mus., Vol. 13, 1890, pp. 272-274.]

stones of the Franconia formation upward through the St. Lawrence formation into the base of the Jordan sandstone of Wisconsin and Minnesota.

In Missouri *Calvinella ozarkensis* (pl. 70, figs. 1-6) is associated with a large and varied fauna in which the Gastropoda and Cephalopoda are strongly developed. It thus appears to belong in a later fauna than the Jordan. *Calvinella tenuisculpta* from the lower Pogonip limestone of Nevada is also from about the same horizon as *C. ozarkensis*. With it are associated the following:

(Locality 201a) "Lower Ordovician" (Ozarkian or Canadian): Pogonip limestone, east slope of the ridge east of Hamburg Ridge, Eureka district, Eureka County, Nevada (C. D. Walcott, 1882):

*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 prolongus* Hall and Whitfield
*Apatokephalus finalis* (Walcott)
*Conokephalina inexpectans* (Walcott)
*Agraulos ? annectans* (Walcott)
*Anomocarella oweni* Meek and Hayden
*Amphion ??* sp. undt.
*Chuangia mccoyi* Walcott
*Illænurus ? eurekensis* Walcott
*Asaphus ? caribouensis* Walcott

Traces of *Dikelocephalus* are found in the southern Mississippi area in Oklahoma and Texas in the Upper Cambrian. The associated fauna in Texas includes *Saukia fallax* and in addition the following:

(Locality 70a) (below the fauna of locality 70) Upper Cambrian: Wilberns formation; Baldy Mountain, near Morgan's Creek, 8 miles (12.8 km.) northwest of Burnet, Burnet County, Texas (C. D. Walcott, 1884).

*Billingsella coloradoensis* (Shumard)
*Nileus ? dia* (Walcott)
*Lonchocephalus wisconsinensis* Owen
*Dikelocephalus texanus* Walcott
*Saukia fallax* Walcott
*Osceolia osceola* (Hall)

*Dikelocephalus*.—Of the seven species referred to the genus *Dikelocephalus* as restricted in this paper the stratigraphic position of all is known with the exception of *D. ? dalyi* n. sp. The type species of the genus, *D. minnesotensis* Owen, is recorded in literature as occurring at many localities, but I have inserted in this paper only those localities represented in the United States National Museum collections. It will be necessary to have more systematic and careful stratigraphic work and collecting done before any more accurate statement can be made.

*Dikelocephalus minnesotensis* Owen as now restricted does not occur in the supposed Jordan formation fauna exposed about Devils Lake, Wisconsin. The genus is there represented by a variety of *D. ? limbatus*. The typical form of this species occurs in the upper St. Lawrence beds at Osceola (78, 78b). There are fragments of a large trilobite that suggest *D. minnesotensis* at Osceola, but the identification is too uncertain to be of value. As far as known to me, *D. minnesotensis* does not occur in the Madison sandstone of the post-Cambrian. The species is found at the following, among other localities, in association with other genera and species as given in the following lists:

(Locality 85) Upper Cambrian: St. Lawrence formation at Prairie du Sac, Sauk County, Wisconsin (Cooper Curtice, 1884).

*Obolus* (*Westonia*) *aurora* (Hall)
*Obolus* (*Westonia*) *stoneanus* (Whitfield)
*Lingulella mosia* (Hall)
*Lingulella oweni* (Walcott)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Owenella antiquata* (Whitfield)
*Dikelocephalus minnesotensis* Owen
*Saukia crassimarginata* (Whitfield)
*Saukia lodensis* (Whitfield)
*Saukia pepinensis* (Owen)
*Illænurus quadratus* Hall
*Aglaspis barrandei* Hall
*Aglaspis eatoni* Whitfield

(Locality 86) Upper Cambrian: St. Lawrence formation at Van Ness quarry, Gibraltar Bluff, Lodi, Columbia County, Wisconsin (L. C. Wooster, 1883; Cooper Curtice, 1884).

*Obolus* (*Westonia*) *aurora* (Hall)
*Lingulella mosia* (Hall)
*Lingulella oweni* (Walcott)
*Dikelocephalus minnesotensis* Owen
*Saukia lodensis* (Whitfield)
*Illænurus quadratus* Hall
*Aglaspis barrandei* Hall

(Locality 113) Upper Cambrian: St. Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota (Cooper Curtice, 1884).

*Lingulella mosia* (Hall)
*Lingulella winona* (Hall)
*Serpulites murchisoni* Hall
*Owenella vaticina* (Hall)
*Triarthrella auroralis* Hall
*Ptychaspis* sp. ?
*Dikelocephalus minnesotensis* Owen
*Saukia pepinensis* (Owen)

*Saukia*.—The genotype of the genus, *Saukia lodensis,* occurs only in the Upper Cambrian St. Lawrence formation. It is associated at localities 85 and 86 with the species listed above.

*Saukia crassimarginata* has a somewhat greater vertical range as it occurs with *S. lodensis,* and also in the overlying Jordan sandstone. At locality 78b it is associated with the following species:

Upper Cambrian: (78b) St. Lawrence formation, 50 feet (15.2 m.) above St. Croix River, near the landing at Osceola, Polk County, Wisconsin (Cooper Curtice, 1884).

*Lingulella mosia* (Hall)
*Lingulella similis* (Walcott)
*Finkelnburgia osceola* (Walcott)
*Owenella* cf. *antiquata* (Whitfield)
*Dikelocephalus ? limbatus* Hall
*Dikelocephalus minnesotensis* Owen ?
*Saukia crassimarginata* (Whitfield)
*Osceolia osceola* (Hall)
*Illænurus quadratus* Hall

*Saukia pepinensis* (Owen) is found abundantly in the St. Lawrence formation (113, p. 360).

*Saukia fallax* (Locality 70a, p. 359) from Texas appears to be an Upper Cambrian species restricted to one locality and horizon as far as now known.

*Saukia leucosia* and *S. pyrene* both occur in the upper portion of the St. Lawrence formation at locality 78 in the following association:

Locality 78: Upper Cambrian: St. Lawrence formation; quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin (L. C. Wooster, 1883).

*Obolus* (*Westonia*) *aurora* (Hall)
*Lingulella mosia* (Hall)
*Lingulella mosia osceola* (Walcott)
*Lingulella winona* (Hall)
*Lingulella winona convexa* (Walcott)
*Billingsella coloradoensis* (Shumard)
*Finkelnburgia finkelnburgi* (Walcott)
*Finkelnburgia osceola* (Walcott)
*Finkelnburgia osceola corrugata* (Walcott)
*Syntrophia barabuensis* (A. Winchell)
*Spirodentalium osceola* Walcott
*Owenella antiquata* (Whitfield)
*Holopea ? sweeti* Whitfield
*Ophileta* (*Raphistoma*) *primordialis* A. Winchell
*Dikelocephalus ? limbatus* Hall
*Saukia leucosia* Walcott
*Saukia pyrene* Walcott
*Osceolia osceola* (Hall)
*Illænurus quadratus* Hall

*Saukia marica* is at the upper line of the Cambrian in Nevada. At locality 62 it is associated with the following:

Upper Cambrian: (62) Limestone in the Dunderberg shale in canyon immediately north of Adams Hill, Eureka district, Eureka County, Nevada (C. D. Walcott, 1880).

*Micromitra sculptilis* Meek
*Obolus discoideus* (Hall and Whitfield)
*Lingulella manticula* (White)
*Lingulella punctata* (Walcott)
*Acrotreta spinosa* Walcott
*Agnostus communis* Hall and Whitfield
*Agnostus prolongus* Hall and Whitfield
*Pagodia breviceps ?* (Walcott)
*Saukia marica* (Walcott)
*Arethusina ? americana* Walcott

Both *Saukia stosei* and *S. wardi* occur in the great Cambro-Ordovician limestones of the Appalachian region at about the horizon of the upper limit of the Upper Cambrian or possibly Lower Ozarkian.

*Osceolia.*—*Osceolia osceola* is associated with the St. Lawrence fauna in Wisconsin (Localities 78 and 83[1], see lists of fauna, pp. 356, 361). In Texas (Locality 70a, p. 359) and Nevada it is identified from the Upper Cambrian. In Nevada it occurs (Locality 66) with the following species:

Upper Cambrian: (66) Dunderberg shale, on the first ridge north of the Dunderberg mine, Eureka district, Eureka County, Nevada (C. D. Walcott, 1880).

*Obolus discoideus* (Hall and Whitfield)
*Agnostus communis* Hall and Whitfield
*Agnostus prolongus* Hall and Whitfield
*Agnostus tumidosus* Hall and Whitfield
*Lisania angustifrons* Walcott
*Osceolia osceola* (Hall)
*Euloma affinis* Walcott
*Arethusina ? americana* Walcott

*Calvinella.*—This genus is essentially one of the transition forms between Cambrian and Ozarkian. *Calvinella spiniger* is known only with the St. Lawrence fauna (p. 356). *Calvinella ozarkensis* in the Eminence fauna, *C. newtonensis* in the Kittatinny limestone, and *C. tenuisculpta* in the lower Pogonip limestone (p. 359).

*Calvinella newtonensis* occurs with the following species at locality 11c:

Lower Ozarkian: (11c) Lower part of Kittatinny limestone, O'Donnell and McManniman's quarry, Newton, Sussex County, New Jersey (H. E. Dickhaut, 1901).

*Obolus* (*Westonia*) *stoneanus* (Whitfield) variety or n. sp.
*Eoorthis newtonensis* (Weller)
*Ptychoparia newtonensis* Weller
*Anomocare ? parvula* Weller
*Calvinella newtonensis* (Weller)

*Conokephalina.*—This genus occurs only in the upper beds of the Franconia formation. The one species, *C. misa* (Hall), has been found in association with species of trilobites of the genera *Chariocephalus, Lonchocephalus, Ptychaspis,* and *Ptychoparia,* and the brachiopod *Billingsella coloradoensis.*

## DESCRIPTION OF GENERA AND SPECIES

### Genus DIKELOCEPHALUS[1] Owen

*Dikelocephalus* Owen, 1852, Rep. Geol. Surv. Wis., Iowa, and Minn., p. 573. (Description of genus and observations.)

*Dikelocephalus* Owen, Barrande, 1853, Neues Jahrb. für Min., Geol. und Geog., p. 336. (Comments on relation of *Dikelocephalus* to *Ogygia.*)

*Dikelocephalus* Owen, Emmons, 1855, American Geol., Vol. 1, pt. 2, p. 220. (Summarizes Owen's description of genus.)

*Dikelocephalus* Owen, Billings, 1860, Canadian Nat. Geol., Vol. 5, p. 306. (Comments on genus and refers several species to it.)

*Dikelocephalus* Owen, Hall, 1863, Sixteenth Ann. Rep. N. Y. State Cab. Nat. Hist., p. 137. (Reprints Owen's description, comments on the genus and describes three new species.)

*Dicellocephalus* Owen, Dana ?, 1864, American Journ. Sci. and Arts, 2d ser., Vol. 37, p. 139. (Changes spelling of name. The article is unsigned but was in all probability written by Prof. James D. Dana.)

*Dikelocephalus* Owen, Billings, 1865, Geol. Surv. Canada, Pal. Fossils, Vol. 1, p. 399. (Reprints remarks of 1860, noted above.)

*Dikelocephalus* Owen, Salter, 1866, Mem. Geol. Surv. Great Britain, Vol. 3, p. 303. (Comments on genus and refers four species to it.)

*Dikelocephalus* Owen, Hall, 1867, Trans. Albany Inst., Vol. 5, p. 116. (Reprint of article of 1863.)

*Dikellocephalus* Owen, Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Parallel, Vol. 4, p. 225. (Mentions genus and refers three new species to it.)

*Dicellocephalus* Owen, Whitfield, 1878, Ann. Rep. Wisconsin Geol. Surv. for 1877, p. 63. (Notes finding of uncompressed specimens of genus and refers two new species to it.)

*Dikelocephalus* Owen, Salter, 1881, Mem. Geol. Surv. Great Britain, Vol. 3, 2d ed., p. 497. (Reprint of paper of 1866.)

*Dikellocephalus* Owen, Whitfield, 1882, Geol. Wisconsin, Vol. 4, p. 200. (Reprint of paper of 1878, with illustrations of the two species described under the genus.)

*Dikellocephalus* Owen, Dames, 1883, China, Richthofen, Vol. 4, pp. 5, 6. (Comments on species referred to genus.)

*Dicellocephalus* Owen, Matthew, 1893, Trans. Royal Soc. Canada, Vol. 10, Sec. 4, p. 10. (Discusses the geographic and stratigraphic distribution of the genus and the validity of the generic reference.)

*Dikelokephalus* Owen, Brögger, 1897, Nyt Mag. for Naturvid., Vol. 36, pp. 179, 182, 183. (Discusses questions of species that have been referred to the genus.)

*Dikelocephalus* Owen, Beecher, 1897, American Journ. Sci., 4th ser., Vol. 3, p. 192. (Classifies *Dikelocephalus* as the type of a subfamily of the Olenidæ to be known as Dikelocephalinæ.

[1] Under the rule that, "The original orthography of the name is to be rigidly preserved unless a typographical error is evident," Owen's spelling of *Dikelocephalus* is followed. From *Gr.* δίκελλα, a mattock or two-pronged hoe, and κεφαλή, head. *Dikelocephalus* has been called "shovel-head" (Chamberlin, 1883, Geol. Wisconsin, 1873-79, Vol. 1, p. 131).

*Dicellocephalus* Owen, Berkey, 1898, American Geol., Vol. 21, p. 290. (Discusses forms related to *D. misa* Hall.)

*Generic description.*—General form, a broad ellipse, moderately convex with pleural lobes more or less flattened, cephalon transverse; genal angles extended into spine: cranidium roughly subquadrangular in outline, with narrow fixed cheeks and strong palpebral lobes posterior to the rounded outer rim of the palpebral lobes extending across the fixed cheeks as narrow ocular ridges. Glabella subquadrangular in outline, and narrowing slightly towards its broadly rounded front; posterior furrow strong and extending across the glabella; second furrow indicated by a pair of short side furrows; a third furrow is indicated; strong flattened occipital ring.

Facial sutures as shown by figures 1, 2, and 5, plate 61.

Thorax with probably twelve segments as in the closely related genus *Saukia* (pl. 65). Axial lobe convex; pleural lobes depressed and with each segment having a narrow, oblique furrow that begins near the inner anterior margin and terminates well out and near the posterior margin of the backward curving more or less bluntly pointed extremity.

Pygidium transverse, large and with a strong central axis that terminates within a broad flattened border: it is marked by clearly defined transverse rings that extend out as the pleural lobes and broad border. The margin may or may not have two short postero-lateral spines.

Surface with fine irregular more or less inosculating lines and, on some species, small granules over the glabella and median axis of the thorax and pygidium. It is punctate in *D. hartti* and *D. texanus*, the only two species in which the structure of the test is preserved.

Some of the species of *Dikelocephalus* attain a large size. Specimens of the cephalon of *D. minnesotensis* in the collection of the United States National Museum have a length of 9 cm. and a width of 24 cm. Pygidia occur 9.5 cm. in length, 18 cm. in width, and a thoracic segment has a length of 16 cm. *Dikelocephalus vanhornei* (pl. 62) is also a large species.

*Genotype.*—*Dikelocephalus minnesotensis* Owen, 1852.

*Stratigraphic range.*—Upper beds of Upper Cambrian.

*Geographic distribution.*—Upper Mississippi Valley in western Wisconsin and eastern Minnesota, also in central Texas, Nevada and Montana. About the Adirondack Mountains of New York, in Saratoga and Franklin Counties and in central British Columbia. There are many references in literature to the occurrence of *Dikelocephalus* in various parts of America and in foreign countries, but with the limitations now given the genus, it is restricted to the areas mentioned above. It is quite probable that with more thorough collecting, it will be found along the front range of the Rocky Mountains.

It does not occur in the St. Lawrence Valley of Canada, but fragments of what may be a species of the genus occur in the Champlain Valley in Franklin County, northwestern Vermont, both in the Upper Cambrian limestone (Locality **87**) and the superjacent limestone conglomerate (Locality **162**).

*Dimensions.*—This genus includes the largest species of the Dikelocephalinæ. One cranidium has a length of 9 cm. and width of 9 cm. at the palpebral lobes. If to this were added the proportional wide free cheeks, the width of the cephalon at its posterior margin would be 24 cm. A pygidium has a width of 18 cm. with length of 9.5 cm.

A fragment of a large thoracic segment, preserving the pleural lobe has a length of 18 cm. with a longitudinal width of 1.5 cm.

On the basis of the above parts an entire trilobite of this genus evidently existed 32 cm. in length with a width of 24 cm.

*Observations.*—The earliest illustrations of the genotype of *Dikelocephalus, D. minnesotensis,* are on a plate accompanying a report by Dr. David Dale Owen, published in 1848.[1] The plate faces page 58 of the report and the specimens are referred to the genus *Asaphus.* These include the cranidium and pygidium of a large trilobite that was in 1852 placed under the genus *Dikelocephalus.*

Dr. Owen (1852) did not have any entire specimens, but from the resemblance of fragments of *Dikelocephalus* to *Ogygia* he compared the genus with the latter and thought it probable that the number of thoracic segments was eight as in *Ogygia.* He described, illustrated, and named five species, *D. minnesotensis, D. pepinensis* (=*Saukia*), *D. miniscaensis* (=*Ptychaspis*), *D. granulosus* (=*Ptychaspis*), and *D. iowensis* (=*Crepicephalus*).

Dr. E. Billings (1869) noted that he thought the doublure beneath the head of *Dikelocephalus* was continuous and was not cut by the facial suture. He referred several new species to the genus, *D. magnificus* (=*Apatokephalus ??*), *D. planifrons* (=*Anomocare*), *D. belli* (=*Anomocarella*), *D. oweni* (=*Anomocare*), *D. megalops* (=*Anomocarella ?*), *D. cristatus* (=*Ptychaspis*).

Dr. James Hall reviewed the genus in 1863 and referred three new species to it, *D. spiniger* (= *Saukia*), *D. misa* (= *Conokephalina*), *D. osceola* (=*Osceolia*), and illustrated them from fragmentary

[1] Report of a Geological Reconnaissance of the Chippewa Land District of Wisconsin, etc. Senate Doc. Exec. No. 57, 30th Congress, 1st Session, 1848, p. 15, pl. 7, figs. 2, 3.

specimens. Dr. Owen's species, *D. granulosus* and *D. miniscaensis.* were placed in the genus *Ptychaspis,* and *D. iowensis* under *Conocephalites.*

In a review of Hall's work of 1863 in the American Journal of Science and Arts, the writer (probably James D. Dana) calls attention to the spelling of the name *Dikelocephalus* and states that the true orthography is *Dicellocephalus.*

In 1866 Mr. J. W. Salter gave a very brief interpretation of *Dikelocephalus* and referred four species to it: *Dikelocephalus (Centropleura ?) furca* (= *Dikelokephalina* Brögger ??), *Dikelocephalus celticus* (= Distorted pygidia, genus ?), *D. ? (Centropleura ?) discordalus* (= Perhaps *Anomocare ?*), *D. ? ( Centropleura ?)* sp. (= *Anomocare ?*).

Messrs. Hall and Whitfield (1877) mention the genus in connection with the reference of two forms of pygidium of three species to it. The first, *D. bilobatus,* has the generic name *Pterocephalus* bracketed with it in the description of the plate, but it is probably a species of *Anomocare.* The other two species, *D. multicinctus* and *D. flabellifer* may be referred to *Apatokephalus ?* (= Brögger, 1897).

In 1878 Prof. R. P. Whitfield noted the occurrence of specimens of trilobites preserving their natural convexity that he referred to "*Dikellocephalus,*" as *D. barabuensis* (=*Platycolpus*) and *D. eatoni* ( = *Platycolpus*). This matter was reprinted in 1882 with illustrations of the species.

Dr. W. Dames (1883, pp. 5, 6) calls attention to the confusion existing among the species referred to "*Dikellocephalus*" and suggests the establishing of a new genus for Owen's *D. pepinensis.* He comments favorably on Hall's references, but calls attention to the less careful work of Billings.

Dr. G. F. Matthew (1893) attempted in a general manner to discuss the value of the generic reference of the many species that had been placed under *Dikelocephalus* by authors and to draw conclusions on the supposed stratigraphic position of the genus. He concluded that in America it was strictly a Cambrian genus, and in Europe Ordovician.

In 1896 Dr. Brögger followed up a previous suggestion that he had made and placed several species that had been referred to *Dikelocephalus* under the new genera *Dikelokephalina, Conokephalina,* and *Apatokephalus.*

Dr. Beecher (1897) constituted the subfamily Dikelocephalinæ to include *Dikelocephalus* and allied genera.

In 1913, Dr. P. E. Raymond proposed the genus *Platycolpus* and referred Whitfield's species *Dikelocephalus barabuensis* and *D. eatoni* to it.[1]

The species now referred to the genus as restricted are:

*Dikelocephalus minnesotensis* Owen (pls. 60, 61, 62, 65)
*Dikelocephalus minnesotensis* var. undt. (pl. 61, fig. 4)
*Dikelocephalus ? dalyi* Walcott (pl. 64, figs. 1-5)
*Dikelocephalus hartti* (Walcott) (pl. 63, figs. 1-7, 7*a*)
*Dikelocephalus ? limbatus* Hall (pl. 65, figs. 5-8)
*Dikelocephalus texanus* Walcott (pl. 65, fig. 4)
*Dikelocephalus ? tribulis* Walcott (pl. 63, figs. 8-10, 10*a*)
*Dikelocephalus vanhornei* Walcott (pl. 62, figs. 1-3)
*Dikelocephalus* sp. undt.[2] (loc. 151)

### DIKELOCEPHALUS ? DALYI, new species

Plate 64, figs. 1-5

This fine species is founded on fragments of a large trilobite that include the cranidium, portions of thoracic segments and nearly entire pygidia which occur in limestone nodules embedded in a calcareous shale.

The smaller cranidia have the general outline of some of the species of *Anomocare* and *Anomocarella* from the Chinese Cambrian,[3] but the larger specimens have the broad, flattened frontal limb of *Dikelocephalus*. (Compare fig. 2, pl. 64, and fig. 5, pl. 61.) The palpebral lobe of *D. dalyi* is shorter than in typical *Dikelocephalus,* in this respect resembling some species of *Anomocare,* but not the typical species, *Anomocare læve* Angelin. The glabella is also much like that of *Anomocare,* but it might be included under *Dikelocephalus* by its outline and strong occipital furrow and long posterior glabella furrows. The associated free cheek might be referred to either genus as it has the general characters of each.

The fragments of the thoracic segments are similar to corresponding parts of the thoracic segments of *Dikelocephalus* and, to a less degree, of *Anomocare.*

The associated pygidia are essentially the same as the pygidium of *Dikelocephalus hartti* (pl. 63) and *D. minnesotensis,* with the exception of not having the two marginal spines of the latter species.

*Dikelocephalus ? dalyi* attains a much larger size than any known species of *Anomocare,* in this being comparable with *Dikelocephalus.*

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[1] Geol. Survey Canada, Victoria Mem. Mus., 1913, Bull. 1, pp. 63, 64.

[2] See footnote [2], p. 391, this paper.

[3] Research in China, Vol. 3, Carnegie Institution of Washington, Pub. No. 54, 1913, The Cambrian Faunas of China, pls. 18 and 19.

Fragments of the pygidium indicate a width of 20 cm. at the anterior margin, which is about twice the size of the pygidium of *D. vanhornei* represented by figure 3, plate 62.

The surface is marked by fine, raised, more or less irregular lines or sharp ridges that are subparallel to the outer margin of the border of the cephalon and pygidium and to the margins of the thoracic segments. These lines also probably occur on the glabella. Punctæ similar to those of the test of *Dikelocephalus* are indicated.

This species appears to indicate a genus intermediate in character between *Dikelocephalus* and *Anomocare*. In the absence of good specimens it is referred tentatively to *Dikelocephalus*. The only associated species is *Illænurus elongatus* n. sp.

The specific name is given in recognition of the discovery of the species by Dr. Reginald A. Daly.

*Formation and locality*.—Upper Cambrian: (346e) limestone nodules in calcareous shales in rock cut on Canadian Pacific Railway, 54.5 miles (87.2 km.) west of Field, and 2 miles (3.2 km.) west of Donald Station, British Columbia, Canada (R. A. Daly, 1912).

### DIKELOCEPHALUS HARTTI (Walcott)

Plate 63, figs. 1-7, 7*a*

*Conocephalites hartti* WALCOTT, 1879, Thirty-second Ann. Rept. New York State Mus., p. 130. (Original description of species.)

*Dicellocephalus hartti* (WALCOTT), 1886, Bull. U. S. Geol. Survey, No. 30, p. 21. (Name used in lists of species.)

*Dicellocephalus hartti* (Walcott), LESLEY, 1889, Geol. Surv. Pennsylvania, Rept. P4, Dictionary of Fossils, Vol. 1, p. 199. (Text figures reproduced from drawings sent him by Walcott.)

*Dicellocephalus hartti* (WALCOTT), 1912, Smithsonian Misc. Coll., Vol. 57, No. 9, p. 273, pl. 44, figs. 1-7, 7*a*. (Describes, illustrates, and comments on species.)

A description with comments on this species has been recently published (Walcott, 1912). The only additional information is to note the occurrence of several pygidia that appear to be identical with those illustrated on plate 63, figures 6, 7 of this species, in the upper layer of the Potsdam formation on Marble River, north of the Adirondack Mountains in New York.

*Formation and locality*.—Upper Cambrian: Hoyt formation; (76) arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, and (76a) in a railroad quarry, 1 mile (1.6 km.) north of Saratoga Springs, both in Saratoga County (C. D. Walcott and Cooper Curtice, 1883); also (111), at the top of the Potsdam sandstone on Marble River, 1 mile (1.6 km.) south of Chateaugay, Franklin County (C. D. Walcott, 1886), all in New York.

### DIKELOCEPHALUS ? LIMBATUS Hall

Plate 65, figs. 5-8

*Dikelocephalus minnesotensis* var. *limbatus* HALL, 1863, Sixteenth Ann. Rept. New York State Cab. Nat. Hist., p. 141, pl. 9, fig. 12. (Describes and illustrates anterior portion of a cranidium.)

*Dicellocephalus minnesotensis* Owen, WINCHELL, 1864, American Journ. Sci., 2d ser., Vol. 37, p. 229. (Remarks on occurrence of a species of *Dicellocephalus* doubtfully referred to this species.)

*Dikelocephalus minnesotensis* var. *limbatus* HALL, 1867, Trans. Albany Inst., Vol. 5, p. 121, pl. 4, fig. 12. (Reprint of paper of 1863.)

This very interesting species is represented by several fragments from locality 78 where the cranidium represented by figure 6 is associated with the pygidium represented by figure 7. The broad, slightly concave, frontal limb and subquadrilateral glabella bring the species close to *Dikelocephalus* as does the associated pygidium. The latter has the relatively short axial lobe and broad flattened border of the pygidia of *D. minnesotensis,* but it differs in the details of the furrows on the pleural lobes and in the absence of spines on the margin.

Dr. James Hall considered the fragment that he described as a variety of *D. minnesotensis,* but with the specimens now available for study the varietal name *limbatus* is used as the specific name.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (78) quarry near St. Croix River, in suburbs of Osceola, Polk County (L. C. Wooster, 1883); (78b) 50 feet (15.2 m.) above St. Croix River, near the landing at Osceola, Polk County (Cooper Curtice, 1884), and (134a) in a quarry 1 mile (1.6 km.) southeast of the county court house, in Menomonie, Dunn County (Chas. Schuchert, 1893), all in Wisconsin.

A number of specimens of the pygidium and free cheeks of a species closely related to *D. ? limbatus* occur in the Jordan sandstone (81b), near Devils Lake, Sauk County (Cooper Curtice, 1884). These are the forms described by Dr. Alexander Winchell. One of the pygidia is illustrated by figure 8, plate 65.

### DIKELOCEPHALUS MINNESOTENSIS Owen

Plate 60, figs. 1-8; plate 61, figs. 1-3, 5-7; plate 62, figs. 4-6; plate 66, fig. 1.

*Asaphus* OWEN, 1848, Rept. Geol. Reconnaissance, Chippewa Land District, Senate Doc., Exec. No. 57, 30th Congress, p. 15, pl. 7, figs. 2, 3. (Illustrates cranidium and pygidium under name *Asaphus.*)

*Dikelocephalus minnesotensis* Owen, 1852, Rept. Geol. Survey Wis., Iowa, and Minn., p. 574, pl. 1, figs. 1, 2; pl. 1*a*, figs. 3, 6. (Description and illustrations of species. Fig. 10, pl. 1, is now referred to *D. crassimarginatus.*)

*Ogygia minnesotensis* (Owen), Chapman, 1856, Canadian Journ., new ser., Vol. 1, p. 275. (Refers species to *Ogygia.*)

*Dikelocephalus minnesotensis* Owen, Mackie, 1859, The Geologist (London), Vol. 2, p. 189, fig. 4. (Text figure of Owen's restoration of the species.)

*Dikelocephalus minnesotensis* Owen, Hall, 1862, Rept. Geol. Survey Wisconsin, Vol. 1, p. 22, figs. 1, 2. (Illustrates a cranidium and a pygidium.)

*Dikelocephalus minnesotensis* Owen, Hall, 1863, Rept. Geol. Survey Wisconsin, p. 138, pl. 9, figs. 5-10; pl. 10, figs. 10-12; pl. 11, figs. 1, 3, and 4. (Species described and illustrated from fragmentary specimens.)

*Dikelocephalus minnesotensis* Owen, Hall, 1867, Trans. Albany Inst., Vol. 5, p. 117, pl. 4, figs. 5-10; pl. 5, figs. 10-12; pl. 6, figs. 1, 3, 4. (Reprint of paper of 1863.)

*Dikellocephalus minnesotensis* Owen, Whitfield, 1882, Geol. Wisconsin, 1873-79, Vol. 4, p. 187, pl. 3, fig. 1. (Describes species and illustrates a pygidium.)

*Dicellocephalus minnesotensis* Owen, Walcott, 1886, Bull. U. S. Geol. Survey, No. 30, p. 35, par. 66. (Notes occurrence of species in Highland Range, Nevada.)

*Dicellocephalus minnesotensis* Owen, Lesley, 1889, Geol. Survey Pa., Rept. P. 4, Dictionary of Fossils, Vol. 1, p. 198, fig. 1. (Reproduces figures from Owen.)

*Dicellocephalus minnesotensis* Owen, Miller, 1889, North American Geol. and Pal., p. 544, text fig. 999. (Restored figure of entire dorsal shield.)

*Dikelocephalus minnesotensis* Owen (?), Walcott, 1891, Bull. Geol. Survey, No. 81, p. 235. (Notes probable occurrence of species in Texas in giving names of fossils.)

*Dikelocephalus minnesotensis* Owen, Sardeson, 1896, Bull. Minnesota Acad. Nat. Sci., Vol. 4, p. 95. (Mentions occurrence of species at localities in Minnesota.)

Dr. James Hall in 1863 published a detailed description of all that was known to him of the species, and practically nothing has been added since. No entire specimens of the dorsal shield are known to me. It is probable that there were 12 segments in the thorax as in *Saukia,* but this is uncertain.

The species is confined to the Mississippi valley as far as now known, with the possible exception of a locality in Lincoln County, Nevada, where fragments associated with *Saukia pepinensis* appear to indicate its presence.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (85) at Prairie du Sac, Sauk County (Cooper Curtice, 1884), and (86) at Van Ness quarry, Gibraltar Bluff, Lodi, Columbia County (L. C. Wooster, 1883; Cooper Curtice, 1884), both in Wisconsin; also, (86b) hilltop, north end of city of Lansing, Allamakee County, Iowa (P. Bartsch, 1912).

Also from locality ($83^2$), an upper horizon of the St. Lawrence formation near Trempealeau, Trempealeau County (Cooper Curtice and G. H. Squiers, 1884; Chas. Schuchert, 1893); (113) at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County (Cooper Curtice, 1884); (85b) bank of St. Croix River, Stillwater, Washington County, all in Minnesota.

*Doubtful identifications.*—From the upper beds of the old "St. Croix sandstone," or St. Lawrence formation.

(339f) Among fragments from the Upper Cambrian sandstones at Minneiska, Minnesota, on the Mississippi River, there is one of a large thoracic segment that may belong to this or an allied species.

At Localities 78 and 78b, Osceola, Wisconsin, a somewhat similar segment and a fragment of a large cranidium (pl. 62, figs. 4, 6) indicate that a large species is present. Better specimens may prove that the material belongs to a distinct and undescribed species or to *Dikelocephalus limbatus.*

(78) Upper Cambrian: St. Lawrence sandstone series; quarry near St. Croix River, in suburbs of Osceola, Polk County (L. C. Wooster, 1883), and (78b) 50 feet (15.2 m.) above St. Croix River, near the landing at Osceola, Polk County (Cooper Curtice, 1884), both in Wisconsin; also (339f) near Minneiska (Miniska), on Mississippi River, near the line between Wabasha and Winona counties, Minnesota (F. M. Brown).

### DIKELOCEPHALUS MINNESOTENSIS var.

Plate 61, fig. 4

A variety of *D. minnesotensis* occurs at La Grange mountain (Locality 113) that is represented by the pygidium illustrated by figure 4, plate 61. This has four rings on the median lobe and four segments outlined on the pleural lobes, while *D. minnesotensis* has seven or eight rings on the median lobe and eight or ten segments outlined on the pleural lobes (pl. 61, fig. 6). A second pygidium possibly of this variety comes from Osceola at a horizon higher as indicated by the associated fauna.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (113) sandstone at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota (Cooper Curtice, 1884), and (78b) 50 feet (15.2 m.) above the St. Croix River, near the landing at Osceola, Polk County, Wisconsin (Cooper Curtice, 1884).

### DIKELOCEPHALUS TEXANUS, new species

Plate 65, fig. 4

Of this species only the fragment of the posterior half of the cranidium illustrated has been seen. This indicates a large form comparable with *Dikelocephalus minnesotensis*. It differs from that in having the palpebral lobe farther forward, and from *D. vanhornei* in having the palpebral lobe nearer the glabella. With better specimens probably other differences might be found.

The outer test has been exfoliated, but from the impression of the inner surface it is evident that it was marked by rather strong, narrow, irregular lines.

*Formation and locality.*—Upper Cambrian: (70a) Wilberns formation, Baldy Mountain, near Morgans Creek, 8 miles (12.8 km.) northwest of Burnet, Burnet County, Texas (C. D. Walcott, 1884).

Fragments of a large trilobite that may be a species of *Dikelocephalus* occur in the lower portion of the Arbuckle limestone of Oklahoma (12g), 150 miles (240 km.) north of the locality (70a) where *D. texanus* occurs. Unfortunately there is not sufficient material by which to compare the cranidia. The fragments at both localities indicate a large species comparable with *D. minnesotensis*.

### DIKELOCEPHALUS ? TRIBULIS Walcott

Plate 63, figs. 8-10, 10*a*

*Dicellocephalus tribulis* Walcott, 1912, Smithsonian Miscellaneous Coll., Vol. 57, No. 9, p. 274, pl. 44, figs. 8, 8*a*. (Illustrates and comments on species.)

With only imperfect specimens of the cranidium and a fragment of a pygidium doubtfully referred to the species, it is difficult to make a satisfactory generic reference. The position of the palpebral lobes and the slightly concave frontal limb suggest *Conokephalina misa* (Hall) (pl. 68, figs. 1, 2), while the form of the glabella is much like that of *Dikelocephalus hartti*. It may be that with the discovery of entire specimens of this species and *Conokephalina misa* the two will be found to be congeneric and an intermediate form between *Dikelocephalus* and *Saukia*.

The largest specimen of the cranidium in the collection has a length of 16 mm.

*Formation and locality.*—Upper Cambrian: (76) Hoyt formation; arenaceous limestone at Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York (C. D. Walcott and Cooper Curtice, 1883).

### DIKELOCEPHALUS VANHORNEI, new species

Plate 62, figs. 1-3

This is a fine, large species of which we have for study the cranidium thoracic segments, and pygidium. The cranidium is much like that of *D. minnesotensis.* It differs in having a proportionally shorter glabella and wider fixed cheeks. The thoracic segments are of the same type, but the pygidium is quite unlike that of *D. minnesotensis.* It is more transverse and has a larger axial lobe and a smoother margin unbroken by spines.

The type specimen of the cranidium (fig. 1) has a length of 5.5 cm. and an associated pygidium (fig. 3) has a length of 4.6 cm. and width of 9.8 cm.

The specimens occur as casts in a fine-grained, yellowish gray, shaly sandstone and show only a few traces of a roughened surface on the cranidium, and of fine raised, irregular lines on the flattened borders of the pygidium.

The specific name is given in recognition of the early work of Sir William Van Horne, who, as a young man, formed a collection of fossils in Wisconsin, which he subsequently presented to the Museum of McGill University, Montreal, Canada.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (**346d**) railroad dam at Hoka, Houston County, Minnesota. Type specimens in Walker Museum, University of Chicago. Pal. Coll. No. 14393.

Plastotype No. 346d, U. S. Nat. Mus., Cat. No. 58608.

While the above was in galley proof I received from Mr. W. A. Finkelnburg, of Winona, Minnesota, specimens of the pygidium of this species which were found in the bluffs near Winona.

### Genus SAUKIA, new genus

General form elongate oval; moderately convex. Cephalon transversely semi-ovate with genal angles extended backward in strong spines. Axial and pleural lobes strongly outlined. Marginal border slightly rounded or nearly flat and merging into genal spines; posterior margin with a narrow, rounded, well-defined rim; occipital ring strong, nearly transverse.

Glabella subquadrangular; usually narrowing opposite the palpebral lobes by slight incurving of its sides; frontal margin broadly rounded; occipital furrow strongly defined; posterior glabellar furrow strong, second furrow less pronounced than the first, and not connected at the center; third furrow usually faintly defined and represented by a short furrow on each side of the glabella that extends directly inward instead of slightly backward as in the first and second glabellar furrows. Free cheeks rather large and convex.

Palpebral lobe prominent, about one-half the length of the glabella; marked by a strong intramarginal furrow; anterior margin a little in advance of the transverse center of the glabella. Eye lobe narrow.

The facial sutures cut the posterior margin well out toward the genal spine and curve quickly inward to the posterior margin of the eye, outlining the narrow postero-lateral limbs of the cranidium; arching outward around the palpebral lobes they curve slightly outward and then inward so as to cut the front margin on a longitudinal line passing through the outer margin of the palpebral lobe.

Thorax with 12 segments. Axial lobe convex with each segment gently rounded and with a very faint longitudinal furrow on each side that serves to define a slight swelling at the end of each segment. Pleural lobes of nearly uniform width throughout and with each segment terminating in a short falcate end; pleural furrows narrow, deep, and crossing the pleuræ obliquely from the anterior inner end to the posterior third of the falcate terminal section.

Pygidium transversely and approximately semicircular with the anterior margin arched forward; strongly trilobed. Axial lobe convex, with four to eight transverse segments. Pleural lobes with flattened margin that is usually free from pleural and segmental furrows; surface marked by segmental lines and narrow pleural furrows of the same general character as the pleural furrows of the thoracic segments.

Surface pustulose as in *Saukia lodensis* (pl. 65, figs. 1, 2) to minutely granulose as in *Saukia pepinensis* (pl. 67).

*Dimensions.*—The largest specimen of the typical species is illustrated by figure 1, plate 65. None of the species referred to *Saukia* approaches in size *Dikelocephalus minnesotensis* (pl. 60).

*Genotype.—Dikelocephalus lodensis* Whitfield (pl. 65, fig. 1).

The genus *Saukia*[1] is proposed for a group of trilobites that have heretofore been referred to *Dikelocephalus*. It differs from the latter in having a comparatively narrow frontal limb to the cephalon; a proportionately longer glabella that may be narrowed opposite the palpebral lobes and slightly expanded anteriorly and that is more elongate proportionally than in *Dikelocephalus*. As far as known the

[1] Indian name *Sauk* applied to Sauk County, Wisconsin, in which localities specimens of *Saukia lodensis* occur.

thoracic segments of the two genera are similar. The pygidium of *Saukia* is less expanded and more elongate than that of *Dikelocephalus.*

*Saukia* differs from *Osceolia* (pl. 68, figs. 4-10) in having a concave instead of a depressed convex anterior margin to the cephalon, and a rounded, smooth margined pygidium.

It differs from *Calvinella* (pl. 69, figs. 1-5) in form of glabella, absence of a strong occipital spine, and proportionately less transverse pygidium. These characters may possibly be accompanied by other differences in the thorax not at present known.

The species now referred to the genus are:

*Saukia coloradoensis* Walcott (text figs. 13-16, p. 376)
*Saukia crassimarginata* (Whitfield) (pls. 61, 65, 66)
*Saukia fallax* Walcott (pl. 67, figs. 21, 21*a*, 22, 22*a*)
*Saukia junia* Walcott (text fig. 17, p. 378)
*Saukia ?? leptænarum* (Wiman)
*Saukia leucosia* Walcott (pl. 67, figs. 14-17)
*Saukia lodensis* (Whitfield) (pl. 65, figs. 1-3)
*Saukia marica* (Walcott) (pl. 64, figs. 6, 6*a*)
*Saukia pepinensis* (Owen) (pl. 67, figs. 1-13)
*Saukia pyrene* Walcott (pl. 67, figs. 18-20)
*Saukia rustica* Walcott (text figs. 18, 19, p. 383)
*Saukia stosei* Walcott (pl. 69, figs. 3-5)
*Saukia wardi* Walcott (pl. 69, figs. 1-2)

*Stratigraphic range.*—Found in both the upper and lower zones of the St. Lawrence formation and Lower Ozarkian.

*Geographic distribution.*—Several of the species are found in the upper Mississippi valley in Wisconsin and eastern Minnesota. *Saukia pepinensis* occurs in central eastern Nevada and *S. fallax* is from central Texas. *Saukia coloradoensis* occurs at Quandary Peak, Summit County, Colorado. Two species, *S. stosei* and *S. wardi,* are from the Appalachian Province in southwestern Pennsylvania and western Virginia.

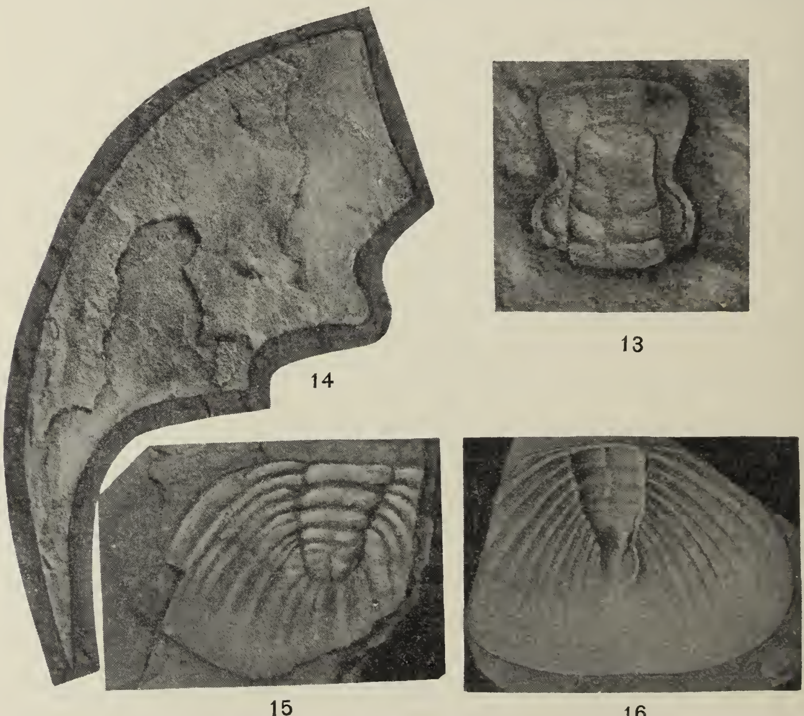
*Observations.*—The species referred to *Saukia* fall into two groups. The first, characterized by *S. lodensis, S. coloradoensis,* and *S. crassimarginata,* which most nearly approach *Dikelocephalus,* except in the character of the frontal limb and margin. The second, characterized by *S. pepinensis* and its allies, *S. leucosia, S. pyrene, S. stosei* and *S. wardi,* which appear to be intermediate between *Dikelocephalus* and forms referred to *Anomocare,* but with a leaning towards *Dikelocephalus.* With the discovery of entire specimens of the several species it may be that a rearrangement of the generic references of the several species now placed under *Saukia* will be necessary.

## SAUKIA COLORADOENSIS, new species

Text figures 13-16

*Dicellocephalus minnesotensis ?,* 1886, Monogr. U. S. Geol. Survey, Vol. 12, p. 60. (Name mentioned in text. Label with specimens states that the identification was by R. P. Whitfield.)

This species is represented by fragmentary specimens of the cranidium, free cheeks, thoracic segments, and pygidium. At first I referred it to *Saukia crassimarginata,* but on working the cranidium and pygidium free from the covering matrix it was found to differ. The frontal limb is less convex and is marked by a slight




SAUKIA COLORADOENSIS, new species

FIG. 13. (× 2.) Cranidium flattened in shale. Postero-lateral limbs restored. U. S. National Museum, Catalogue No. 60673.

FIG. 14. (Natural size.) Large free cheek with outline partly restored. U. S. National Museum, Catalogue No. 60674.

FIG. 15. (Natural size.) Pygidium with outline restored. U. S. National Museum, Catalogue No. 60675.

FIG. 16. (Natural size.) Matrix of pygidium with outline partly restored. U. S. National Museum Catalogue No. 60676.

transverse furrow that serves to outline a narrow flattened bordering rim. The associated pygidium has a longer axial lobe.

The specimens are all[1] from locality **20b**, Upper Cambrian; about 1 mile (1.6 km.) above Monte Cristo Mine, Quandary Peak, Summit County, Colorado (Whitman Cross, collector, 1880).

This is a large species and it may be the largest one of the genus. It is also of special interest owing to its geographic position. A careful search in the Upper Cambrian of the Leadville region may result in finding good specimens of this species and, of still greater importance, the fauna that accompanied the invasion of the Upper Cambrian sea in this region.

*Formation and locality.*—Upper Cambrian: (**20b**) about 1 mile (1.6 km.) above Monte Cristo Mine, Quandary Peak, Summit County, Colorado (Whitman Cross, collector, 1880).

### SAUKIA CRASSIMARGINATA (Whitfield)

Plate 61, fig. 8; plate 65, figs. 9, 10; plate 66, figs. 2-5, 5*a*

*Dikelocephalus* (*minnesotensis ?*) Owen, 1852 (in part), Rept. Geol. Survey Wis., Iowa, and Minn., p. 574, Tab. 1, fig. 10. (Figure of cranidium doubtfully referred to *D. minnesotensis.*)

*Dikelocephalus minnesotensis* var. Hall, 1863 (in part), Sixteenth Ann. Rept. New York State Cab. Nat. Hist., p. 141, pl. 9, fig. 11; pl. 10, fig. 9; pl. 11, fig. 2. (Two cranidia described and illustrated. Free cheek tentatively referred to *D. pepinensis.*)

*Dikelocephalus minnesotensis* var. Hall, 1867, Trans. Albany Inst., Vol. 5, pl. 4, fig. 11; pl. 5, fig. 9. (Reprint of figures of 1863.)

*Dikellocephalus crassimarginatus* Whitfield, 1882, Geol. Wisconsin, Vol. 4, p. 344, pl. 27, fig. 14. (Describes and illustrates free cheek as type of species.)

*Dicellocephalus* ——— Chamberlin, 1883, Geol. Wisconsin (Survey of 1873-1879), Vol. 1, p. 129, text fig. 15. (Illustrates a nearly entire specimen from Prairie du Sac that is evidently this species.)

This fine species is generically related to *Saukia lodensis* (pl. 65, fig. 1). It differs specifically from it in having a broader border to the cephalon and pygidium, broader fixed cheeks, and smooth surface over the entire dorsal test. It also attains a larger size.

An entire specimen in the collection of the United States National Museum has a length of 9.7 cm., with a width of 6.8 cm. at the back of the cephalon. Other proportions are shown by figure 2, plate 66.

Several pygidia (pl. 65, fig. 9) resembling the pygidium of this species occur in the coarser Jordan? sandstone (**81, 81b**) near Devils Lake. The specific identification must remain doubtful until speci-

[1] See also page 378, second species under *Saukia fallax.*

mens of the cephalon are found. A similar pygidium occurs in the upper beds of sandstone near Trempealeau: (**83**[1]) Upper Cambrian: St. Lawrence formation; near Trempealeau, Trempealeau County, Wisconsin (Chas. Schuchert, 1893).

The western representative of this species is *Saukia coloradoensis*.

*Formation and locality.*—Upper Cambrian: St. Lawrence series; (**85**) at Prairie du Sac, Sauk County (Cooper Curtice, 1884); also (**85x**) beds near Mazomanie, Dane County (Chas. Schuchert, 1893); (**78b**) 50 feet (15.2 m.) above St. Croix River, near the landing at Osceola, Polk County (Cooper Curtice, 1884); and doubtfully (**81**) Jordan sandstone series, 1 mile (1.6 km.) east-northeast of Devils Lake, Sauk County (L. C. Wooster, 1883); (**81b**) Jordan? sandstone, near Devils Lake, Sauk County (Cooper Curtice, 1884), all in Wisconsin.

### SAUKIA FALLAX, new species

Plate 67, figs. 21, 21*a*, 22, 22*a*

This species is represented by specimens of the cranidium. The form of the glabella and frontal rim relate it to *S. pepinensis, S. leucosia,* and *S. pyrene,* all of which are illustrated on the same plate. It differs from the nearly related *S. pyrene* and *S. wardi* (pl. 69, fig. 3) by having a slightly tapering glabella and smoother surface.

*Formation and locality.*—Upper Cambrian: (**70a**) Wilberns formation, Baldy Mountain, near Morgans Creek, 8 miles (12.8 km.) northwest of Burnet, Burnet County, Texas (C. D. Walcott, 1884).

A second species from Texas, not unlike *Saukia coloradoensis* (p. 376), is shown by fragments occurring in a shale from San Saba County.

### SAUKIA JUNIA, new species

Text figure 17

This is a species allied to both *Saukia crassimarginata* (pl. 66) and *S. pepinensis* (pl. 67). It is represented by a broken cranidium

17

SAUKIA JUNIA, new species

FIG. 17. (Natural size.) Type specimen in limestone and side outline. U. S. National Museum, Catalogue No. 60677.

22 mm. in length. The frontal limb is proportionally longer than that of either of the above species, and there is a peculiar flattening of the frontal border in advance of the glabella with a narrow transverse ridge outlining the broad, downward sloping frontal margin. The glabella expands a little anteriorly.

Surface of test apparently smooth.

*Formation and locality.*—Upper Cambrian: (12g: 50 feet above 12j) Arbuckle limestone (lower part); Wichita Mountains, south side about 8 miles (12.8 km.) west of Fort Sill and in a small hill 2 miles (3.2 km.) southwest of Signal Mountain, Comanche County, Oklahoma. Fossil horizon No. 3 of E. O. Ulrich, 100 feet (30.4 m.) from base of hill. Collected October 9, 1901.

### SAUKIA ? ? LEPTÆNARUM (Wiman)

*Dicellocephalus ? leptænarum* Wiman, 1907, Arkiv för Zoologi, Bd. 3, No. 24, p. 5, pl. 2, figs. 1-3. (Described and illustrated as a new species.)

This species is founded on a small pygidium that resembles the pygidium of *Saukia leucosia* (pl. 67, figs. 13, 13*a*). It is possible but not probable that the pygidium belongs to a species of *Saukia.*

*Formation and locality.*—Ordovician: *Leptæna* limestone, west Baltic region, Sweden.

### SAUKIA LEUCOSIA, new species

Plate 67, figs. 14-17*a*

This fine species is represented by specimens of the cranidium, free cheeks, and possibly the pygidium. It differs from the associated *Saukia pyrene* (pl. 67, figs. 18-20) by having a broad, rounded frontal limb, a character that serves also to distinguish it from *S. pepinensis* (pl. 67, figs. 1-5) and *S. stosei* (pl. 69, fig. 3).

*Formation and locality.*—Upper Cambrian: St. Lawrence formation (78), quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin (L. C. Wooster, 1883).

Franconia formation (99), Minneiska (Miniska), on Mississippi River, near the line between Wabasha and Winona Counties, Minnesota (Cooper Curtice, 1884).

### SAUKIA LODENSIS (Whitfield)

Plate 65, figs. 1-3

*Dikellocephalus lodensis* Whitfield, 1880, Ann. Rept. Wis. Geol. Survey for 1879, p. 51. (Founds species on a free cheek.)

*Dikellocephalus lodensis* Whitfield, 1882, Geol. Wisconsin, Vol. 4, p. 188, pl. 10, fig. 14; p. 341; pl. 27, figs 12-13. (Reprints former description and illustrates free cheek, and on pl. 27, figs. 12 and 13, a nearly entire dorsal shield.)

*Dicellocephalus lodensis* Whitfield, CHAMBERLIN, 1883, Geol. Wisconsin, Vol. 1, p. 130, text figs. 16, 16*a-b*. (Illustrates nearly entire specimen of dorsal shield.)

The generic description of *Saukia* is based on this species; this with the figures on plate 65 gives a sufficiently complete conception of the species to furnish the student with the means for identifying and comparing it with other species. It differs from the other species referred to the genus by its strongly granulose surface and variations in details of form of the parts of the cephalon and pygidium.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (**85**) at Prairie du Sac, Sauk County (Cooper Curtice, 1884); (**86**) at Van Ness quarry, Gibraltar Bluff, Lodi, Columbia County (L. C. Wooster, 1883; Cooper Curtice, 1884), both in Wisconsin.

**SAUKIA MARICA (Walcott)**

Plate 64, figs. 6, 6*a*

*Dicellocephalus marica* Walcott, 1886, Monogr. U. S. Geol. Surv., Vol. 8, p. 44, pl. 10, fig. 13. (Described as below.)

Glabella and fixed cheeks subquadrate in outline, narrowing somewhat towards the front. Glabella subquadrangular and almost squarely truncate in front, which is not quite as wide as the base; strongly convex, and marked by three pairs of furrows, the two anterior pairs but slightly depressed and very short; the posterior pair extend obliquely inward one-third the distance across from each side, and are united by a slight transverse furrow; occipital ring strong and elevated; occipital furrow well defined; dorsal furrows strongly impressed; fixed cheeks moderately convex, narrow in front, widening at the palpebral lobes, and sloping away rapidly in front, and less so back of the eye lobes; eye lobes narrow, semicircular, and situated opposite the central portion of the glabella; frontal limb obsolete except the round, thick, marginal rim just in advance of the glabella; the posterior limbs are broken away at a little distance from the dorsal furrows.

Surface as seen under a strong magnifying glass, with fine inosculating, flattened lines surrounding minute round or irregularly oval spaces.

*Observations.*—This species is represented by one specimen of the cranidium. It resembles the cranidium of *Saukia pyrene* (pl. 67, fig. 18) and *S. fallax* (pl. 67, fig. 21), but differs in its frontal border. It occurs in the closing epoch of the Cambrian in association with a well-marked fauna (see locality **62**, p. 361).

*Formation and locality.*—Upper Cambrian (62) in thin layer of limestone in Dunderberg shale, in canyon immediately north of Adams Hill, Eureka District, Nevada[1] (C. D. Walcott, 1880).

### SAUKIA PEPINENSIS (Owen)

Plate 67, figs. 1-13, 13*a*

*Dikelocephalus pepinensis* OWEN, 1852, Rept. Geol. Surv. Wis., Iowa, and Minn., p. 574, pl. 1, figs. 9, 9*a-b*. (Describes and illustrates species.)

*Dikelocephalus pepinensis* Owen, HALL, 1862, Rept. Geol. Surv. Wis., Vol. 1, p. 22, text figs. 3, 4. (Illustrates cranidium and pygidium.)

*Dikelocephalus pepinensis* Owen, HALL, 1863, Sixteenth Ann. Rept. State Cab. Nat. Hist., p. 142, pl. 9, figs. 1-4; pl. 10, figs. 14-17. (Describes in detail and illustrates species. Fig. 13 does not appear to belong with this species.)

*Dicellocephalus pepinensis* Owen, WINCHELL, 1864, American Journ. Sci., 2d ser., Vol. 37, p. 229. (Comments on cranidium and describes an associated pygidium.)

*Dikelocephalus pepinensis* Owen, HALL, 1867, Trans. Albany Inst., Vol. 5, p. 122, pl. 4, figs. 1-4; pl. 5, figs. 14-17. (Republishes text and illustrations of 1863.)

*Dicellocephalus pepinensis* Owen, CHAMBERLIN, 1883, Geol. Wisconsin, Vol. 1, p. 130, figs. 16*c-f*, after Hall, 1863. (Copies figures of Hall without description.)

*Dicellocephalus pepinensis* Owen, WALCOTT, 1886, Bull. U. S. Geol. Survey, No. 30, p. 35, paragraph 66. (Notes occurrence of species in Highland Range, Nevada.)

*Dikelocephalus pepinensis* Owen, BRÖGGER, 1897, Nyt Mag. for Naturvid., Vol. 36, p. 175, fig. 9. (Illustrates pygidium after Hall.)

This species is readily recognized by its strong, flattened frontal rim and convex compact pygidium with a narrow, slightly flattened border. The description, given by Hall in 1863, is so detailed and accurate that it does not appear necessary to attempt to add to it.

Fragments of the species occur in great abundance in the shaly sandstones of the upper horizon of the St. Lawrence sandstones of Wisconsin.

Comparisons with other species referred to *Saukia* are given under observations on the genus.

Specimens of a cranidium and a pygidium that appear to be identical with those from Wisconsin occur in the Highland Range of Nevada in a limestone in association with fragments of a large trilobite that indicates a species which may be *Dikelocephalus minnesotensis*.[2]

[1] In Monograph 8 of the U. S. Geological Survey, p. 45, the locality of the type specimen is incorrectly given as just south of the Hamburg Mine. The geological horizon is correct but not the exact locality.

[2] Bull. U. S. Geol. Survey, No. 30, 1886, p. 35, paragraph 66.

*Formation and locality*.—Upper Cambrian: St. Lawrence formation; (**113**) at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County; also, (**132**) about 2 miles (3.2 km.) northwest of Lake City, on Lake Pepin, Wabasha County (Chas. Schuchert, 1893), all in Minnesota.

(**85x**) Near Mazomanie, Dane County, Wisconsin (Chas. Schuchert, 1893).

(**88**) Upper Cambrian: Hamburg formation (limestone), west side of Highland Range, 17 miles (27.2 km.) southwest of Pioche and 7 miles (11.2 km.) north of Bennetts Spring, Lincoln County, Nevada (C. D. Walcott, 1887).

A cranidium and free cheeks that may belong to a variety of this species occur in a friable sandstone with *Dikelocephalus* cf. *limbatus*, *Osceolia osceola* (Hall) and *Saukia leucosia* Walcott, near Devils Lake, Wisconsin. The parts are larger than in the typical specimens and it may be that another species is indicated.

Localities **81** and **81b**, Upper Cambrian: Jordan? sandstone: 1 mile (1.6 km.) east-northeast of Devils Lake, Sauk County, Wisconsin (L. C. Wooster, 1883; Cooper Curtice, 1884).

### SAUKIA PYRENE, new species

Plate 67, figs. 18-20

This species is represented by numerous fragments of the dorsal test including the cranidium, free cheeks and pygidium. At first sight the cranidium was referred to the Texas form of *Saukia fallax* (pl. 67, fig. 21), but closer comparison showed that its glabella was proportionally narrower and the sides more nearly parallel. The frontal rim is of the same character in the two species. The pygidium associated with *S. pyrene* (fig. 20, pl. 67) is unlike that associated with *S. fallax* in Texas (figs. 21, 21*a*, pl. 67).

*Saukia pyrene* differs from the associated *S. leucosia* (pl. 67, figs. 14-17) mainly in its rounded strong frontal limb. The frontal limb of *S. pepinensis* (pl. 67, figs. 1-5) is flattened and the glabella is proportionally wider than that of *S. pyrene*.

*Formation and locality*.—Upper Cambrian: St. Lawrence formation; (**78**) quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin (L. C. Wooster, 1883).

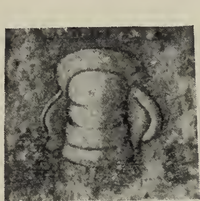
A somewhat similar form is indicated in the sandstone at Devils Lake by the presence of cranidia and free cheeks (**81b**): Jordan? sandstone; 1 mile (1.6 km.) east-northeast of Devils Lake, Sauk County, Wisconsin (L. C. Wooster, 1883; Cooper Curtice, 1884).

**SAUKIA RUSTICA, new species**

Text figures 18-20

The cranidium of this species is much like that of *Saukia lodensis* (pl. 65). It differs in its proportionally larger palpebral lobes, narrower glabella, and exterior surface of the test. The test of *S. lodensis* is covered with rather large, rounded pustules, and that of *S. rustica* with fine inosculating, irregular ridges that give it a roughened but not a pustulose appearance. The largest cranidium has a length of 7 mm. Small specimens 2 to 6 mm. in length show a narrowing of the glabella toward the rounded front.

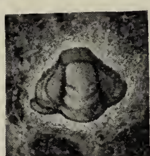
The associated pygidium has a smaller axial lobe than that of *S. lodensis.*



18

18 a

19



20

19 a

Saukia rustica, new species

Figs. 18, 18*a*. (× 4.) Type specimen of cranidium and side outline. U. S. National Museum, Catalogue No. 60678.

Figs. 19, 19*a*. (× 2.) Pygidium associated with fig. 18. U. S. National Museum, Catalogue No. 60679.

Fig. 20. (× 6.) Small cranidium. U. S. National Museum, Catalogue No. 60680.

The associated pygidium is much like that of *Saukia fallax* (pl. 67, fig. 21), and the cranidium is of the same general character.

*Eoorthis wichitaensis* Walcott and *Illænurus* sp. undt. are associated with *S. rustica.*

*Formation and locality.*—Upper Cambrian: (12j: 50 feet below 12g) Arbuckle limestone (lower part); Wichita Mountains, south side about 8 miles (12.8 km.) west of Fort Sill and in a small hill 2 miles (3.2 km.) southwest of Signal Mountain, Comanche County, Oklahoma. Fossil horizon No. 5 of E. O. Ulrich, 50 feet from base of hill. Collected October 9, 1901.

### SAUKIA STOSEI, new species

Plate 69, figs. 3-5; pl. 70, figs. 12, 12*a*

*Dikelocephalus hartti* Stose (on authority of Walcott), 1909, U. S. Geol. Survey Geol. Atlas, U. S., Folio No. 170, p. 6. (Name mentioned in list of fossils from Conococheague limestone.)

*Dikelocephalus* sp. undt. Stose (on authority of Walcott), 1909, idem, p. 6. (Mentioned with preceding species.)

This species belongs to the *S. pepinensis* form of *Saukia,* and is most nearly related to *Saukia fallax* (pl. 67, figs. 21, 21a), but it has a proportionately larger palpebral lobe. The associated pygidium (fig. 5, pl. 69) differs from the pygidium found with *S. fallax* in Texas in having a longer axial lobe, and the surface is strongly granulated instead of being smooth as in *S. fallax*.

The specific name is given in recognition of the fine work of Mr. George W. Stose, of the United States Geological Survey.

*Formation and locality*.—Lower Ozarkian (Ulrich): (**59n** and **59 o**) Conocheague limestone, about 800 feet (240 m.) above the base, that is, near the middle, of the formation in a quarry on point of spur northwest of Scotland Station, Franklin County, Pennsylvania (E. O. Ulrich; G. W. Stose, 1901). U. S. Geol. Survey Atlas, folio No. 170.

### SAUKIA WARDI, new species

Plate 69, figs. 1, 2

This species is represented by numerous casts of compressed, broken specimens that occur in a yellowish-colored shaly rock. The cranidium has the general character of that of *S. leucosia* (pl. 67, figs. 14, 16) and *S. pepinensis* (pl. 67, figs. 1, 4, 5), but it differs in being proportionately shorter. The frontal limb was gently rounded as in *S. leucosia* and not flattened as in *S. pepinensis*.

The free cheeks are rather broad. Thoracic segments of the type of those of *Saukia lodensis,* and the pygidium of the two species is somewhat similar except that of *S. wardi* is longer in proportion to its width. In this respect it has the outline of the pygidium of *S. pepinensis,* but not the narrow border of the latter. Surface not preserved.

The type specimens are in the Peabody Museum, Yale University, New Haven, Connecticut, and plastotypes in the U. S. National Museum, Nos. 58671 and 58672.

The species is named after Dr. Freeman Ward of Yale University, and I am indebted to Dr. Charles Schuchert for the opportunity to study and name the species.

*Formation and locality.*—Upper Cambrian: (346f) Beneath the Natural Bridge limestone; soft, shaly-yellow rock, probably a decomposed thin-bedded dolomitic limestone, east side of road about 1.5 miles (2.4 km.) north-northeast of Natural Bridge, south end of Rockbridge County, Virginia (Dr. Freeman Ward of Yale University, 1911).

### Genus **OSCEOLIA**, new genus

This genus is known only by the cranidium, associated free cheeks and pygidium of the type species. These parts occur together in the same layer of sandstone to such an extent that it seems reasonable to consider them as belonging to the species *Osceolia osceola* (pl. 68, figs. 4-10). The strong concave frontal limb, broadly conical glabella, and long palpebral lobe serve to distinguish the cranidium from that of *Dikelocephalus* (pls. 60-63), *Saukia* (pls. 65, 66) and *Calvinella* (pl. 70).

The pygidium is characterized by the very strong extension of the anterior segment (pl. 68, figs. 8-10), and in being shorter and more transverse than the pygidium of the three genera mentioned above.

All of the specimens of the typical species *O. osceola* occur in a rather friable sandstone so that little is known of the surface characters. As far as known the genus may be briefly characterized as follows:

Cephalon transversely semicircular with a broad convex frontal limb; genal angles extended into postero-lateral spines.

Glabella obtusely conical, with sides converging slightly to the rounded front. Occipital segment rounded and defined by a narrow, strong furrow from base of glabella. Posterior glabellar furrow strong and extending across the glabella.

Fixed cheeks very narrow; palpebral lobes elongate and extending back of the line of the occipital furrow. Facial suture back of the palpebral lobes extending almost directly outward well towards the genal spine so as to outline a very narrow postero-lateral limb; curving around the palpebral lobes they extend forward with a slight outward curve nearly across the frontal limb and then curve gently inward to the front margin. Free cheeks large.

Associated pygidium nearly twice as broad as long with strong median axis.

*Genotype.*—*Dikelocephalus osceola* Hall (1863).

*Osceolia* is represented by a single species that is readily distinguished by its strong, concave frontal limb, large palpebral lobes, narrow fixed cheeks and transverse pygidium with the great spinous extension of the pleuræ of the first segment.

### OSCEOLIA OSCEOLA (Hall)

Plate 68, figs. 4-10

*Dikelocephalus osceola* HALL, 1863, Sixteenth Ann. Rept., New York State Cab. Nat. Hist., p. 146, pl. 10, fig. 18; pl. 7, fig. 49. (Describes and illustrates cranidium and supposed free cheek and pygidium of this species.)

*Dikelocephalus osceola* HALL, 1867, Trans. Albany Inst., Vol. 5, p. 128, pl. 5, fig. 18; pl. 7, fig. 49 ?. (Reprint of paper of 1863.)

*Dicellocephalus osceola* Hall, WALCOTT, 1884, Monogr. U. S. Geol. Survey, No. 8, p. 40, pl. 9, fig. 25. (Identifies cranidium from Nevada and gives illustration. By error the field label was copied in description and the species referred to the Prospect Mountain limestone.)

*Conokephalina osceola* (Hall), BRÖGGER, 1886, Geol. Fören. i Stockholm Förhandl., Vol. 8, No. 101, p. 205. (Refers species to genus *Conokephalina.*)

The description given under the genus includes what is known of the species. It occurs in the friable St. Croix sandstone as casts, while in the limestones of Nevada and Texas the test is more or less well preserved. The outer surface of the test is nearly smooth, although there are slight indications that it may be minutely punctate.

The largest specimen of the cranidium has a length of 20 mm.

The original illustrations by Hall included a free cheek (1863, pl. 10, fig. 19) that is not the same as the cheek attached to the cranidium (this paper, pl. 68, fig. 7). The pygidium tentatively referred to the species by Hall (1863, pl. 7, fig. 49) probably belongs with it as a similar pygidium occurs with the cranidium in numbers when the only other cranidia are those of *Illænurus quadratus* Hall.

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; (**78**) quarry near St. Croix River, in suburbs of Osceola, Polk County (L. C. Wooster, 1883); (**83**[1]) upper horizon near Trempealeau, Trempealeau County (Chas. Schuchert, 1893); and doubtfully (**81b**) Jordan formation, near Devils Lake, Sauk County (Cooper Curtice, 1884), all in Wisconsin.

Upper Cambrian: (**66**) Dunderberg shale on the first ridge north of the Dunderberg mine, Eureka district, Eureka County, Nevada (C. D. Walcott, 1880).

Upper Cambrian: (**70a**) Wilberns formation, Baldy Mountain, near Morgans Creek, 8 miles (12.8 km.) northwest of Burnet, Burnet County, Texas (C. D. Walcott, 1884).

### Genus CONOKEPHALINA Brögger

*Conokephalina* Brögger, 1886, Geol. Fören. i Stockholm Förhandl., No. 101, Vol. 8, pt. 3, p. 206. (Names subgenus to include *Conocephalites ornatus* Brögger, 1877, *Dikelocephalus osceola* Hall, *D. misa* Hall, *D. spiniger* Hall, but does not define subgenus.)

*Conocephalina* Brögger, Grönwall, 1902, Danmarks Geol. Unders. Række 2, No. 13, p. 150. (Uses generic name, but does not define genus.)

*Conocephalina* Brögger, Lorenz, 1906, Zeitschr. deutsch. geol. Gesellsch., Bd. 58, Pt. 2, p. 64. (Revives genus *Conocephalites,* places *Conokephalina* Brögger in it, and takes a new type for *Conokephalina,* in *Conocephalites emmrichi* Barrande.)

*Conokephalina* Brögger, Walcott, 1913, Research in China, Carnegie Inst. Washington, 1913, Vol. 3, The Cambrian Faunas of China, p. 137, pl. 13. (Discussed as below.)

*Genotype.*—*Conocephalites ornatus* Brögger, 1877, Nyt Mag. Naturvid., Vol. 24, p. 37, pl. 3, fig. 5 (this paper, pl. 64, fig. 8, p. 400).

This genus as pointed out by Brögger occupies an intermediate position between forms referred to *Dikelocephalus* and *Ptychoparia* (*Conocephalites* as used by Brögger). He refers to *Conokephalina, Dikelocephalus osceola* Hall, *D. misa* Hall and and *D. spiniger* Hall.

In the present paper, *D. misa* is placed under *Conokephalina, D. osceola* is made the type of a new genus *Osceolia*, and *D. spiniger* the type of the new genus *Calvinella*.

*Conokephalina ornata* is illustrated on plate 64, figure 6, in order that it may be compared with *C. misa,* plate 68, figures 1 and 2. In my report on the Cambrian faunas of China[1] a number of species have been referred to *Conokephalina* and an illustration given of *Conocephalites emmrichi* Barrande (pl. 13, fig. 7), a form that may be closely related to *Conokephalina*. If this is correct, *C. misa* cannot be related to *Conokephalina.* We must wait for the discovery of entire specimens of *C. misa* and *C. ornata* before deciding to which family they may belong.

### CONOKEPHALINA MISA (Hall)

Plate 68, figs. 1-3

*Dikelocephalus misa* Hall, 1863, Sixteenth Ann. Rept. New York State Cab. of Nat. Hist., 1863, p.144, pl. 8, fig. 15; pl. 10, figs. 4, 5 (6, 7, 8 ?). (Describes and illustrates species.)

*Dikelocephalus misa* Hall, 1867, Trans. Albany Inst., Vol. 5, p. 126, pl. 3, fig. 15; pl. 5, figs. 4, 5 (6, 7, 8 ?). (Reprint of paper of 1863.)

*Conokephalina misa* (Hall), Brögger, 1886, Geol. Fören. i Stockholm Förhandl., Vol. 8, No. 101, p. 205. (Refers species to *Conokephalina.*)

*Dicellocephalus misa* Hall, Berkey, 1898, American Geol., Vol. 21, p 290, pl. 20, figs. 12, 13. (Not *C. misa.*)

[1] Research in China, Vol. 3, Carnegie Institution of Washington, Pub. No. 54, 1913, The Cambrian Faunas of China pl. 13.

The species is known only by the cranidium and fragments of associated pygidium that may belong to it. The cranidium differs from that of *Saukia lodensis* (pl. 65) in having a narrowing of the glabella from base to front and in its frontal limb and rim. With the specimens available for study the impression is that we may be dealing with a form more closely allied to *Conokephalina* Brögger than to *Saukia.* It differs from *Conokephalina* in the apparent direction of the facial sutures through the frontal rim of the cephalon; the form of the frontal limb and rim also differ in detail from those of *Conokephalina.* If the associated pygidium (fig. 3) belongs with the cranidia (figs. 1, 2) the provisional reference of the species to the Dikelocephalinæ is probably correct.

The largest cranidium in the collection has a length of 21 mm.

*Formation and locality.*—Upper Cambrian: Franconia formation; Green-sand horizon; ($83^3$) below the "fifth trilobite bed" of Owen, at Trempealeau, Trempealeau County (Chas. Schuchert, 1893), and (83b) Bluff Siding, Buffalo County (Collection of W. A. Finkelnburg, Winona, Minnesota), both in Wisconsin.

(99) Minneiska (Miniska), on Mississippi River, near the line between Wabasha and Winona Counties, Minnesota (Cooper Curtice, 1884).

### Genus CALVINELLA, new genus

*Calvinella* is founded on the cranidium of *Dikelocephalus spiniger* Hall and associated free cheeks, thoracic segments, and pygidium.

The cranidium (pl. 68, figs. 11, 13, 15) has the same general form as that of *Saukia leucosia* (pl. 67, figs. 14, 16) and, in addition, a strong occipital spine. The associated pygidium (pl. 68, figs. 18, 19) differs from the *Saukia leucosia* group of species (pl. 67, figs. 3, 12, 13, 17, 20) in having a broad flattened border comparable with that of the pygidium of *Dikelocephalus* (pl. 60, figs. 6, 7; pl. 63, fig. 6), but the cranidium of *Calvinella* is quite unlike that of *Dikelocephalus.* Further comparisons and remarks are given under observations on the family Dikelocephalinæ (p. 362).

*Calvinella* has a marked resemblance to some species referred to *Anomocare* from the Middle Cambrian. The type species of *Anomocare, A. læve* Angelin[1] has nearly the same form of glabella and palpebral lobes, but the frontal limb is dissimilar. The pygidium is essentially of the same character in the two genera.

The outer surface of all of the species of the genus is strongly granulose on the glabella, free cheeks, parts of the thoracic segments

[1] Research in China, Vol. 3, Carnegie Institution of Washington, Pub. No. 54, 1913, The Cambrian Faunas of China, p. 264, pl. 18, figs. 1, 1*b*.

and pygidium. This is finely shown by figures 1, 8, and 9, plate 70, and less distinctly by the casts of *C. spiniger* (pl. 68, figs. 11, 13, and 20).

A small cranidium occurs in a coarse sandstone near Devils Lake, Sauk County, Wisconsin (**81b**), that suggests by its large palpebral lobe, rounded frontal rim and strong posterior glabellar furrow, a form of *Calvinella* that differs from *C. spiniger* by having the glabella narrow gradually towards its rounded front. The specimen is a cast and it is too imperfect for specific identification.

*Genotype.*—*Dikelocephalus spiniger* Hall (1863) (this paper, p. 390).

*Stratigraphic range.*—Upper beds of Upper Cambrian and lower beds of the Ozarkian of Ulrich.

*Geographic distribution.*—Upper Mississippi valley in Missouri (*C. ozarkensis*) and Wisconsin (*C. spiniger*) ; Atlantic Basin region of New Jersey (*C. newtonensis*) ; Cordilleran region (*C. tenuisculpta*).

### CALVINELLA NEWTONENSIS (Weller)

Plate 70, figs. 7-11, 11*a*

*Dikelocephalus newtonensis* Weller, 1903, Geol. Surv. New Jersey, Rept. on Pal., Vol. 3. pp, 121-122, pl. 3, figs. 1-7. (Description and illustration.)

Specimens from the type locality now in the U. S. National Museum Collections show that this species has a well-marked occipital spine similar to that on specimens of *C. ozarkensis* from Missouri that appear to be almost identical with *C. newtonensis*. The former differs in having a more broadly rounded frontal rim, a more transverse frontal margin to the glabella and a larger occipital spine.

The specimens illustrated by Weller in the New Jersey Report are small and do not show the characters of the cranidium so fully as the large specimens in the National Museum Collections. Photographs of the type (fig. 7) and cotype (fig. 6) are given on plate 60, also an associated cranidium (fig. 8), free cheek (fig. 9), and pygidium (figs. 10, 10*a*).

*Formation and locality.*—Lower Ozarkian: (11c)[1] Lower part of Kittatinny limestone, O'Donnell and McManniman's quarry, Newton, Sussex County, New Jersey (H. E. Dickhaut, 1901).

### CALVINELLA OZARKENSIS, new species

Plate 70, figs. 1-6

This fine species is represented by the cranidium, free cheeks, and an associated pygidium. The cranidium is much like that of *Calvin-*

[1] By error locality 11c has "Hardyston Quartzite" for Kittatinny limestone in Monograph 51, U. S. Geol. Survey, 1912, pp. 178, 466, 539 and 784.

*ella newtonensis* (pl. 70, fig. 8). It differs most in the form of the frontal border. The associated pygidia differ in the form of the axial lobe (Compare figs. 2, 5 and 10).

The large cranidium (fig. 1, pl. 70) is from a locality 4 miles (6.4 km.) west of the town of Eminence, and the pygidium (fig. 2) from about a mile (1.6 km.) east of the town. They occur at about the same stratigraphic horizon and with the same fauna. Other fragments of cranidia and pygidia referred to this species occur in association at each locality.

The small cranidium (fig. 4) and associated pygidium (fig. 5) are probably from a young specimen, although they occur about 75 to 100 feet (22.8 m. to 30.4 m.) higher in the strata.

Dr. E. O. Ulrich collected the specimens in association with a strongly marked fauna that he refers to his Ozarkian group of formations. The fauna is mentioned in the introduction of this paper, p. 359.

*Formation and locality.*—Lower or Middle Ozarkian: Eminence formation; (102f) middle part of formation, 1 to 1.5 miles (1.6 to 2.4 km.) east of town of Eminence; also from (**100b**) same horizon as **102f** and near it at the Slater mine; also (**102h**), 4 miles (6.4 km.) west of Eminence; all in Shannon County; and locality **188y**, upper part of Eminence formation near town of Flat River, St. Francis County, all in Missouri.

The locality numbers cited above are those of Dr. E. O. Ulrich and are recorded in catalogues of the United States Geological Survey.

### CALVINELLA SPINIGER (Hall)

Plate 68, figs. 11-23*a*

*Dikelocephalus spiniger* Hall, 1863, Sixteenth Ann. Rept., State Cab. Nat. Hist., p. 143, pl. 10, figs. 1, 2, 3?. (Detailed description with illustration of cranidium and pygidium.)

*Dikelocephalus spiniger* Hall, 1867, Trans. Albany Inst., Vol. 5, p. 124, pl. 5, figs. 1, 2, 3?. (Reprint of paper of 1863.)

*Conokephalina spiniger* (Hall), Brögger, 1886, Geol. Fören. i Stockholm Förhandl., Vol. 8, No. 101, pp. 205, 206. (Refers *D. spiniger* to proposed new genus *Conokephalina.*)

The description by Hall (1863) is detailed, and there is little new to add to it that is not shown by the figures on plate 68. All of our specimens are casts in a fine-grained, rather compact sandstone. The outer surface of the test appears to have been slightly roughened by fine, raised irregular lines that occur on the glabella, fixed cheeks, border of cephalon, thoracic segments, and central parts of the pygidium.

The species is clearly separated by its occipital spine from *Saukia leucosia* (pl. 67, figs. 14, 16), the form nearest to it, and by the associated pygidia (Compare differences in figs. 18, 19, pl. 68, with figs. 17, 17*a*, pl. 67).

The pygidium recalls some of the pygidia referred to *Anomocare* from the Middle Cambrian of China.[1]

*Formation and locality.*—Upper Cambrian: St. Lawrence formation; ($83^1$, $83^2$, 135c, and 135d), Trempealeau, Trempealeau County, Wisconsin (Chas. Schuchert, 1893).

Locality $83^1$ is above the *Dikelocephalus minnesotensis* zone of $83^2$ (= 135c and 135d).

### CALVINELLA TENUISCULPTA, new species

Plate 64, figs. 7, 7*a*

This species is represented by a single cranidium that in proportions and most details approaches quite closely the cranidium of *Calvinella spiniger* (pl. 68). It differs in having a more convex border and slightly broader fixed cheeks in front of the palpebral lobes.

The test appears to be minutely punctate and to have obscure, irregularly arranged, fine flat ridges crossing and curving forward on the glabella.

The type specimen of the cranidium has a length of 11 mm.

*Formation and locality.*—Lower Ordovician (? Ozarkian): (201a) Pogonip limestone; east slope of the ridge east of Hamburg Ridge, Eureka district, Nevada (C. D. Walcott, 1882).

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[1] Research in China, Vol. 3, Carnegie Institution of Washington, Pub. No. 54, 1913, The Cambrian Faunas of China, pl. 18, figs. 1*b*, 4*c*.

[2] *Dikelocephalus*, species undetermined. Fragments of a large species of *Dikelocephalus* occur in collections from the Gallatin limestone on the west side of the Bridger Range, Gallatin County, Montana (locality 151, Upper Cambrian). The glabella of the cranidium is similar to that of *D. minnesotensis* and the associated pygidium appears to be similar to that of *D. ? limbatus.* (This note was added after the present paper was in page proof.)

## DESCRIPTION OF PLATE 60

PAGE

*Dikelocephalus minnesotensis* Owen. (See pls. 61, 62, and 66).......... 369

FIG. 1. (Natural size.) Cranidium flattened in shaly sandstone. (85.) U. S. National Museum, Catalogue No. 58594.

2. (Natural size.) Impression of outer surface of free cheek. (113.) U. S. National Museum, Catalogue No. 58595.

3. (One-half natural size.) Thoracic segment flattened in shaly sandstone. (85.) U. S. National Museum, Catalogue No. 58596.

4. (One-half natural size.) Segment from shaly sandstone. From locality 85x, Upper Cambrian: St. Lawrence formation near Mazomanie, Dane County, Wisconsin. U. S. National Museum, Catalogue No. 58597.

5. (One-half natural size.) Free cheek in shaly sandstone. (85.) U. S. National Museum, Catalogue No. 58598.

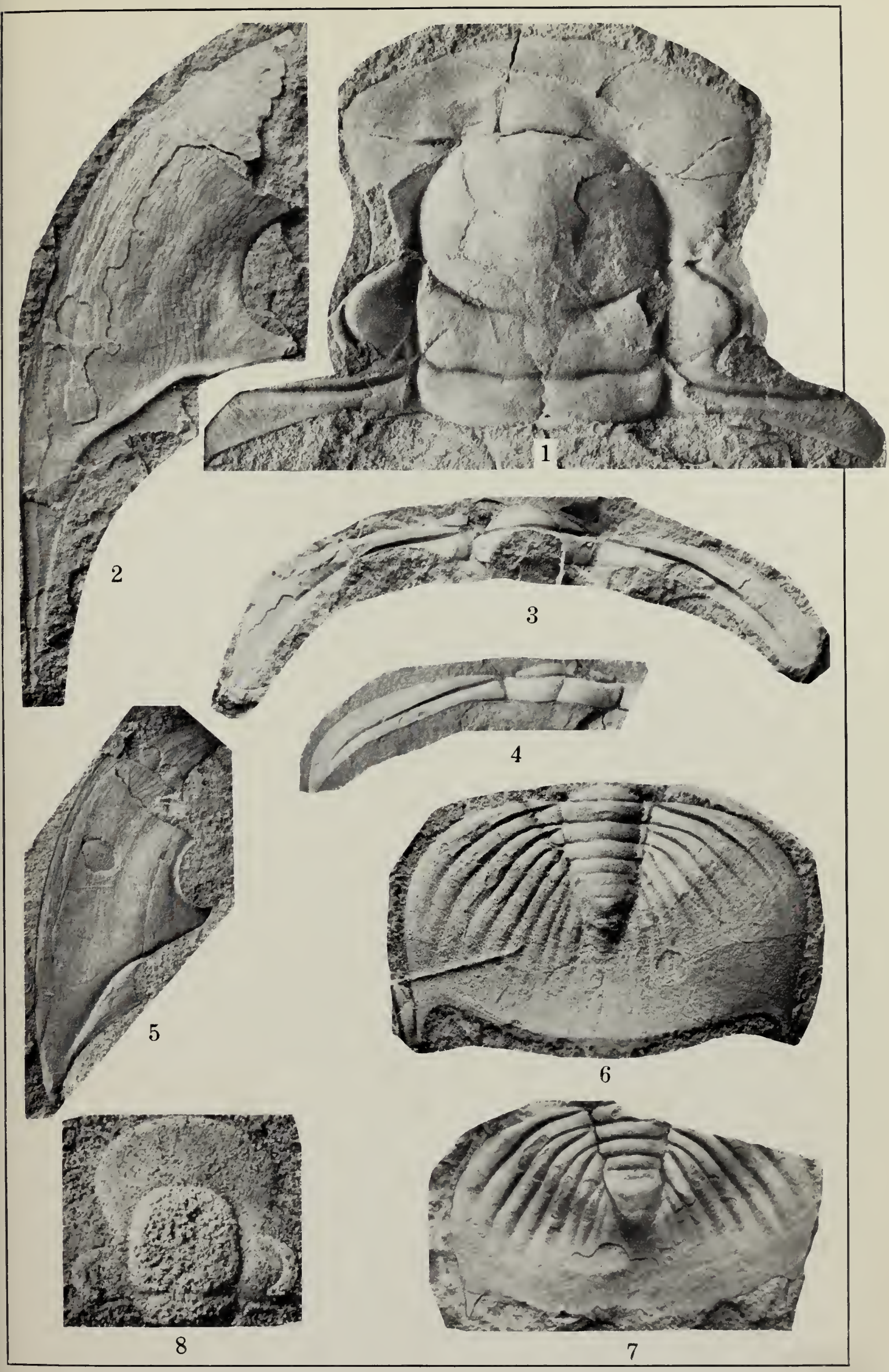
The specimens represented by figs. 1, 3, and 5 are from locality 85, Upper Cambrian: St. Lawrence formation at Prairie du Sac, Sauk County, Wisconsin.

6. (Natural size.) Pygidium flattened in shaly sandstone. (113.) U. S. National Museum, Catalogue No. 58599.

The specimens represented by figs. 2 and 6 are from locality 113, Upper Cambrian: St Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota.

7. (One-half natural size.) Pygidium preserving considerable of its natural convexity. From locality 86, Upper Cambrian: St. Lawrence formation at Van Ness quarry, Gibraltar Bluff, Lodi, Columbia County, Wisconsin. U. S. National Museum, Catalogue No. 58600.

8. (× 3.) Cephalon of young individual with very broad frontal limb. From locality $83^2$, Upper Cambrian: An upper horizon of the St. Lawrence formation near Trempealeau, Trempealeau County, Wisconsin. U. S. National Museum, Catalogue No. 58601.




DIKELOCEPHALUS MINNESOTENSIS Owen

## DESCRIPTION OF PLATE 61

PAGE

*Dikelocephalus minnesotensis* Owen. (See pls. 60, 62, and 66) .......... 369

FIG. 1. (One-half natural size.) Large cephalon flattened in shaly sandstone. (85.) U. S. National Museum, Catalogue No. 58602.

2. (Natural size.) Cranidium for comparison with fig. 5. (85.) U. S. National Museum, Catalogue No. 58603.

The specimens represented by figs. 1 and 2 are from locality **85**, Upper Cambrian: St. Lawrence formation at Prairie du Sac, Sauk County, Wisconsin.

3. (Natural size.) Hypostoma associated with this species in locality $83^1$, Upper Cambrian: Uppermost horizon of the St. Lawrence formation near Trempealeau, Trempealeau County, Wisconsin. U. S. National Museum, Catalogue No. 58604.

5 and 5*a*. (Natural size.) Dorsal and side views of a cranidium preserving most of its natural convexity. (113.) U. S. National Museum, Catalogue No. 58606.

The specimens represented by figs. 4 (below) and 5 are from locality **113**, Upper Cambrian: St. Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota.

6 and 6*a*. (Natural size.) Top and side views of a pygidium preserving its natural convexity. From locality (3747 U. S. N. M. records) Stillwater, Minnesota. U. S. National Museum, Catalogue No. 3747.

7. (One-half natural size.) Doublure of under side of cephalon with hypostoma in place. From locality **85x**, Upper Cambrian: Upper beds of the St. Lawrence formation near Mazomanie, Dane County, Wisconsin. U. S. National Museum, Catalogue No. 58607.

*Dikelocephalus minnesotensis* var. .................................. 371

FIG. 4. (Natural size.) Small pygidium with strong spines. (113.) U. S. National Museum, Catalogue No. 58605.

*Saukia crassimarginata* (Whitfield). (See pls. 65 and 66 ................ 377

FIG. 8. (Natural size.) Matrix of cranidium. This is illustrated by Owen, 1852, pl. 1, fig. 10, as *D.* (*minnesotensis ?*), locality La Grange Mountain, Minnesota (=113). Upper Cambrian: St. Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota. U. S. National Museum, Catalogue No. 58628.

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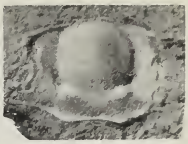

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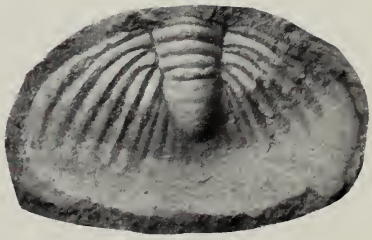

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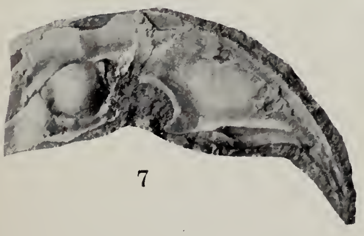

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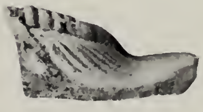

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DIKELOCEPHALINÆ

## DESCRIPTION OF PLATE 62

PAGE

*Dikelocephalus vanhorni* Walcott .................................... 373

FIG. 1. (Natural size.) Type specimen of cranidium.

2. (Natural size.) Thoracic segment associated with this species.

3. (Natural size.) Pygidium associated with the cranidium represented by fig. 1.

The three specimens represented by figs. 1-3 are from the Upper Cambrian: St. Lawrence formation, (346d) Hoka, Houston County, Minnesota. They are lot No. 14393, Walker Museum, University of Chicago. Plastotype U. S. National Museum, Catalogue No. 58608, *a, b, c*.

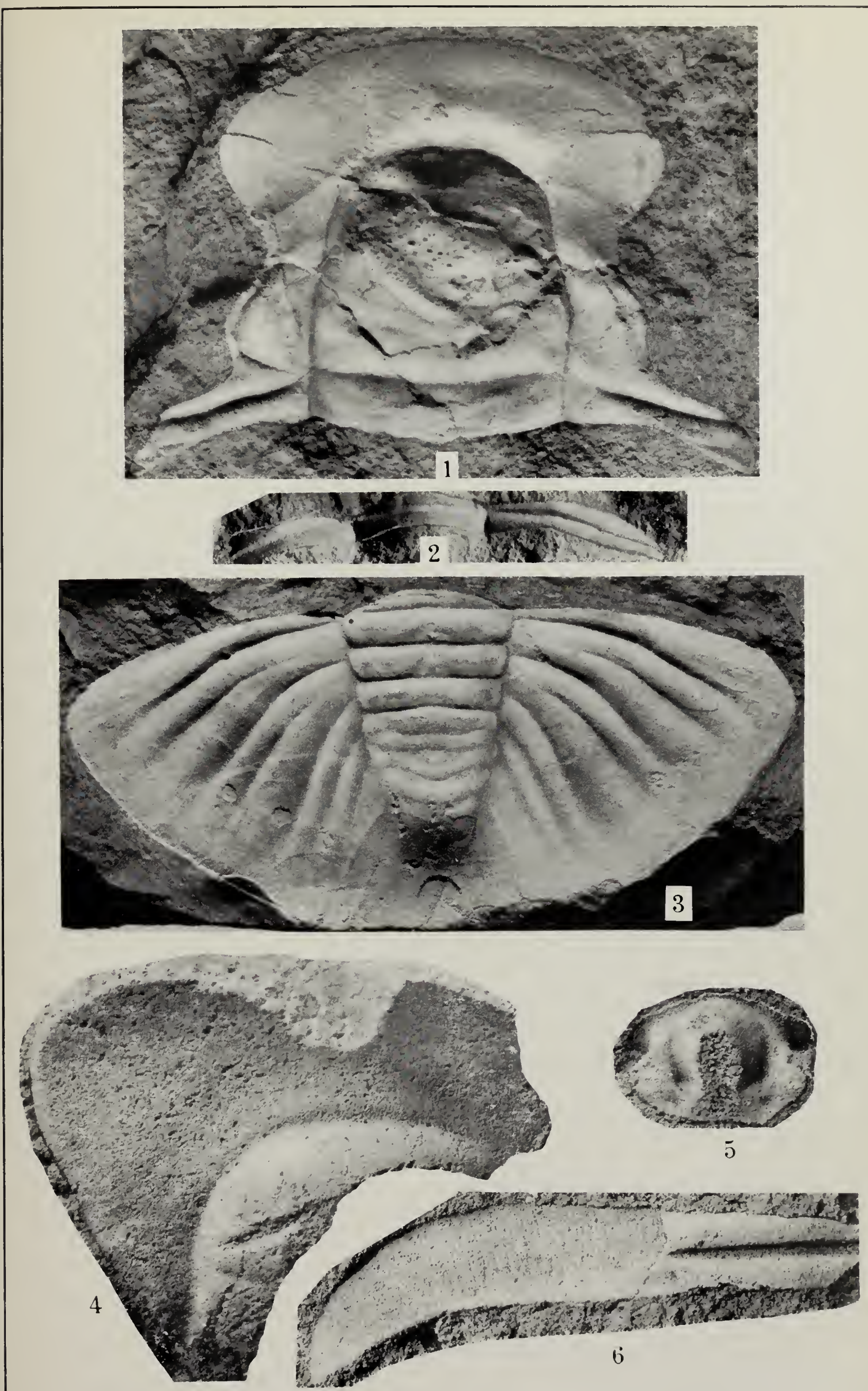
*Dikelocephalus minnesotensis* Owen ??. (See pls. 60, 61, 66) ............ 369

FIG. 4. (Natural size.) Fragment of cranidium. From locality **78b**, Upper Cambrian: St. Lawrence formation, 50 feet (15.2 m.) above the St. Croix River, near the landing at Osceola, Polk County, Wisconsin. U. S. National Museum, Catalogue No. 58609.

5. (Natural size.) Hypostoma from about the same horizon as fig. 4. (**78**.) U. S. National Museum, Catalogue No. 58610.

6. (Natural size.) Fragment of thoracic segment associated with fig. 5. (**78**.) U. S. National Museum, Catalogue No. 58611.

The specimens represented by figs. 5 and 6 are from locality **78**, Upper Cambrian: St. Lawrence formation; quarry near St Croix River, in suburbs of Osceola, Polk County, Wisconsin.




DIKELOCEPHALINÆ

## DESCRIPTION OF PLATE 63

PAGE

*Dikelocephalus hartti* (Walcott) .................................... 368

FIG. 1. (Natural size.) Wash drawing of a large cranidium. U. S. National Museum, Catalogue No. 58571.

2. (Natural size.) Wash drawing of free cheek associated with fig. 1. U. S. National Museum, Catalogue No. 58572.

3. (Natural size.) Dorsal view of a small cranidium, showing the proportional decrease in width of the frontal rim as compared with fig. 1. U. S. National Museum, Catalogue No. 58573.

4. (Natural size.) Wash drawing of partly restored thoracic segment, of which fig. 5 is a photographic reproduction of the specimen.

5. (Natural size.) Portion of thoracic segment. U. S. National Museum, Catalogue No. 58575.

6 and 6*a*. (Natural size.) Dorsal and side views of a large pygidium, illustrating the increase in width of the border as compared with the specimen represented by fig. 8. U. S. National Museum, Catalogue No. 58576.

7 and 7*a*. (Natural size.) Photographic reproduction and wash drawing of a small pygidium. U. S. National Museum, Catalogue No. 58577.

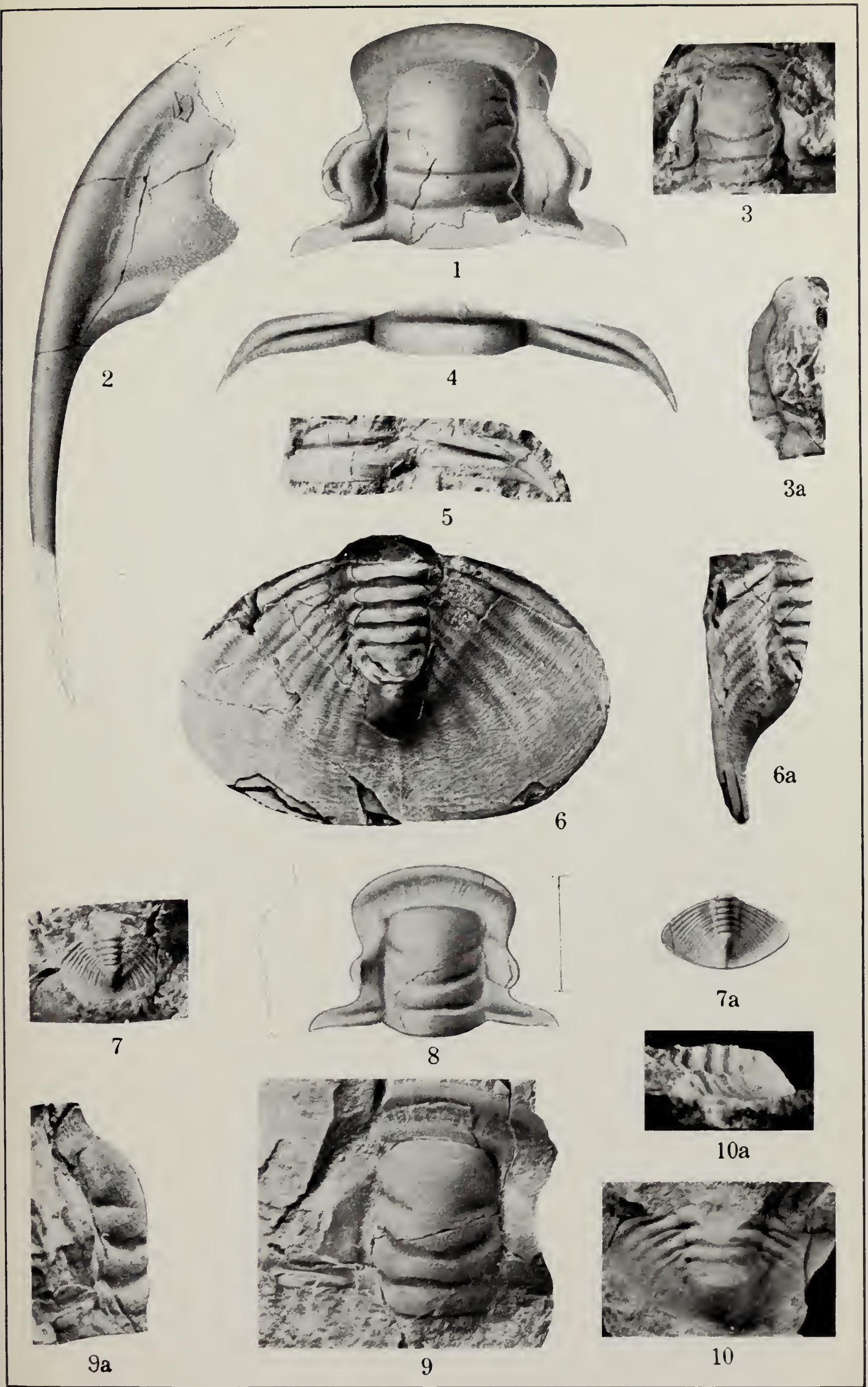
*Dikelocephalus ? tribulis* Walcott ........................................ 372

FIG. 8. (× 1.5.) Wash drawing of the specimen represented by fig. 9.

9 and 9*a*. (× 2.) Dorsal and side views of the type specimen of the cranidium of the species. U. S. National Museum, Catalogue No. 58578.

10 and 10*a*. (× 2.) Dorsal and side views of pygidium tentatively referred to this species. U. S. National Museum, Catalogue No. 58617.

The specimens represented by figs. 1-10 are from locality 76, Upper Cambrian: Hoyt formation; arenaceous limestone, Hoyts quarry, 4 miles (6.4 km.) west of Saratoga Springs, Saratoga County, New York.




DIKELOCEPHALINÆ

## DESCRIPTION OF PLATE 64



FIGS. 1 and 1*a*. (× 2.) Dorsal and side views of a nearly entire cranidium that shows the palpebral lobes to be about midway of its length. Plastotype. U. S. National Museum, Catalogue No. 60061.

2. (× 2.) A fragment of a cranidium with a nearly flat frontal limb that is more like the frontal limb of the typical *Dikelocephalus* than that of fig. 1. Plastotype. U. S. National Museum, Catalogue No. 60062.

3. (× 2.) Fragment of the pleural lobe of a thoracic segment. Plastotype. U. S. National Museum, Catalogue No. 60063.

4, 4*a*. (Natural size.) Dorsal and side views of pygidium illustrating the short axial lobe and broad flattened border. Plastotype. U. S. National Museum, Catalogue No. 60064.

5. (× 4.) Doublure of posterior portion of pygidium enlarged to illustrate imbricating lines. U. S. National Museum, Catalogue No. 60065.

The type specimens of this species are at Ottawa in the collection of the Geological Survey of Canada. From Upper Cambrian, British Columbia, Canada.



FIGS. 6 and 6*a*. (× 3.) Dorsal and side views of a cranidium which is the type specimen of the species. It was illustrated by fig. 13, pl. 10, Monogr. U. S. Geol. Surv., Vol. 8, 1884. From locality 62, Upper Cambrian, Dunderberg shales, Eureka District, Nevada. U. S. National Museum, Catalogue No. 24565.



FIGS. 7 and 7*a*. (× 2.) Dorsal and side views of a cranidium which is the type specimen of the species. From locality 201[a], Lower Ordovician (? Ozarkian): Pogonip limestone, Eureka District, Nevada. U. S. National Museum, Catalogue No. 60066.



FIG. 8. (Natural size.) Dorsal view of a cranidium. (After Brögger, Nyt Mag. for Naturvid., Vol. 24, 1877, pl. 3, fig. 5. From Middle Cambrian, Krekling, in Sandsvär, Norway.

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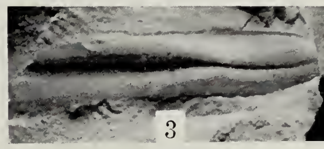

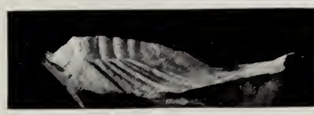

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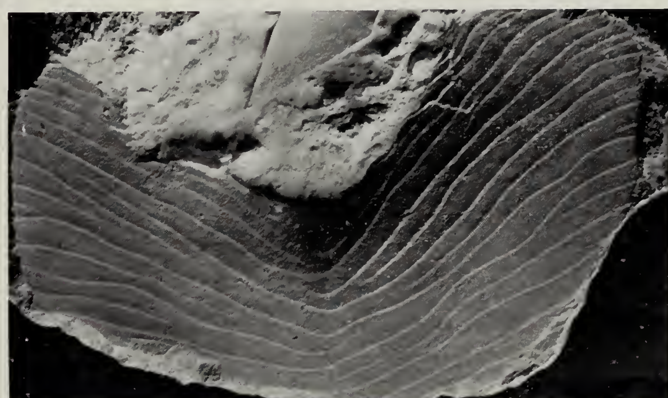

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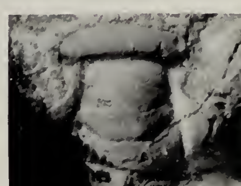

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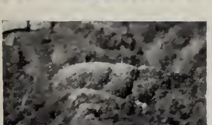

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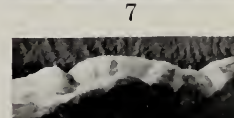

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DIKELOCEPHALINÆ

## DESCRIPTION OF PLATE 65

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*Saukia lodensis* (Whitfield) .......................................... 379

FIG. 1. (Natural size.) Entire dorsal shield flattened in shaly sandstone. Plaster cast. U. S. National Museum, Catalogue No. 58618. Original specimen in collection of Edgar E. Teller, Milwaukee, Wis.

2. (× 3.) Small cranidium with strong tubercles. U. S. National Museum, Catalogue No. 58619.

3. (Natural size.) Matrix of a dorsal shield flattened in shaly sandstone. Plaster cast. U S. National Museum, Catalogue No. 58620. Original specimen in collection of Edgar E. Teller, Milwaukee, Wis.

The specimens represented by figs. 1-3 are from locality **85**, Upper Cambrian: St. Lawrence formation at Prairie du Sac, Sauk County, Wisconsin.

*Dikelocephalus texanus* Walcott .......................................... 372

FIG. 4. (Natural size.) Portion of cranidium in limestone. From locality **70a**, Upper Cambrian: Wilberns formation; Baldy Mountain, near Morgans Creek, Burnet, Burnet County, Texas. U. S. National Museum, Catalogue No. 58621.

*Dikelocephalus ? limbatus* Hall .......................................... 369

FIG. 5. (Enlarged one-third.) Type specimen of cranidium of species. (**78b**.) U. S. National Museum, Catalogue No. 58622.

6. (Natural size.) Cranidium from a different layer but at about the same horizon in the section. (**78**.) U. S. National Museum, Catalogue No. 58623.

7. (Natural size.) Fragmentary pygidium associated with the cranidium represented by fig. 6. (**78**.) U. S. National Museum, Catalogue No. 58624.

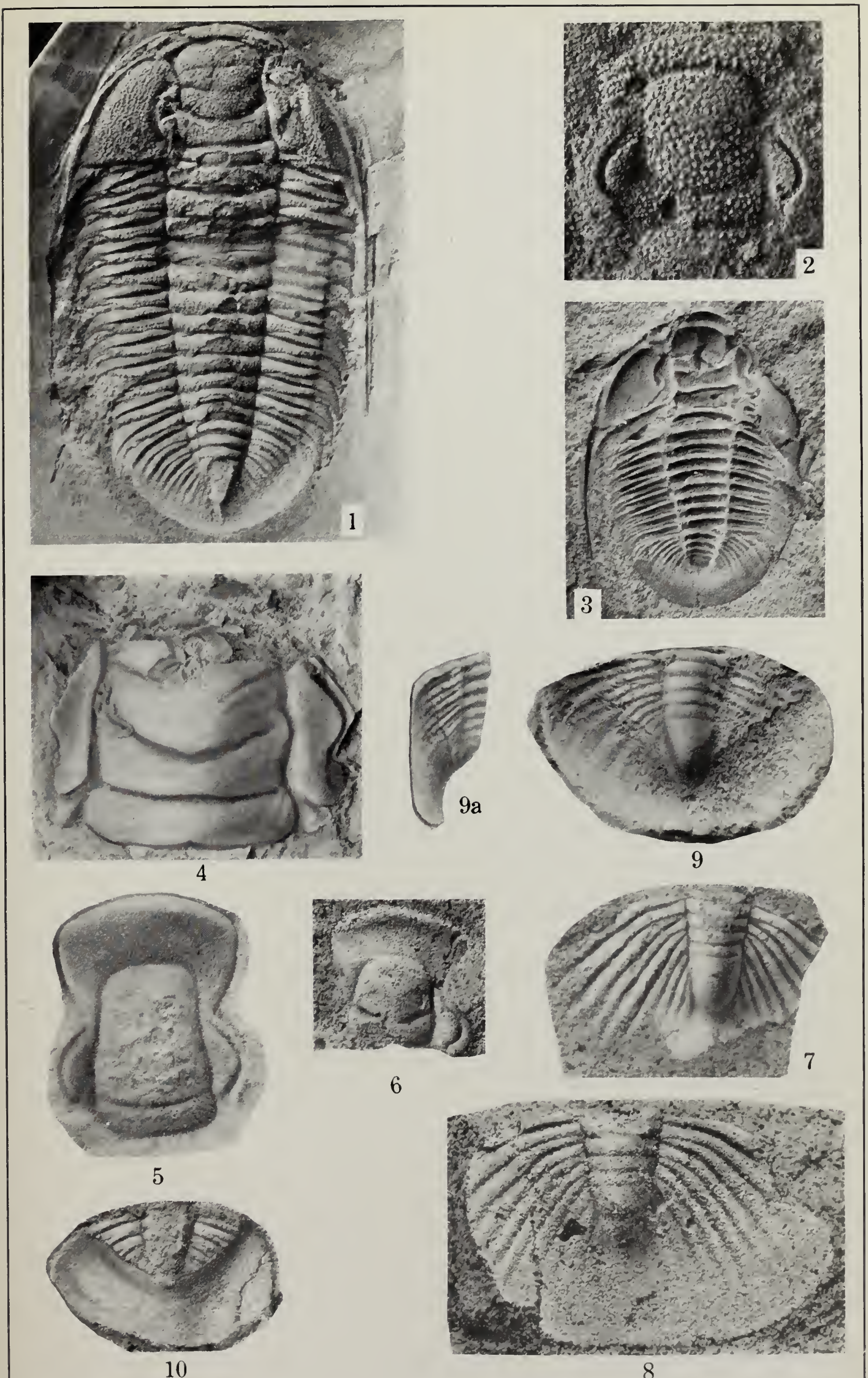
The specimens represented by figs. 6 and 7 are from localities **78** and **78b**, Upper Cambrian: St. Lawrence formation, quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin.

8. (× 2.) Pygidium of the same general type as that of fig. 7. From locality **81b**, Upper Cambrian: Jordan ? sandstone, near Devils Lake, Sauk County, Wisconsin. U. S. National Museum, Catalogue No. 58625.

*Saukia crassimarginata* (Whitfield) ? (See pls. 61 and 66) .............. 377

FIG. 9. (Natural size.) Dorsal and side views of a pygidium of the type of that of fig. 5, pl. 66. From locality **81b**, Upper Cambrian: Jordan ? sandstone near Devils Lake, Sauk County, Wisconsin. U. S. National Museum, Catalogue No. 58626.

10. (Natural size.) Cast of interior surface of pygidium from locality **83**[1], Upper Cambrian: An upper horizon of the St. Lawrence formation near Trempealeau, Trempealeau County, Wisconsin. This has the general character of the specimen represented by fig. 9. U. S. National Museum, Catalogue No. 58627.




DIKELOCEPHALINÆ

## DESCRIPTION OF PLATE 66

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*Dikelocephalus minnesotensis* Owen. (See pls. 60, 61 and 62) ............ 369

FIG. 1. (Natural size.) Matrix of free cheeks and frontal margin. From locality 113, Upper Cambrian: St. Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota. Plaster cast. U S. National Museum, Catalogue No. 58612. Original specimen in collection of Edgar E. Teller, Milwaukee, Wisconsin.

*Saukia crassimarginata* (Whitfield). (See pls. 61 and 65) .............. 377

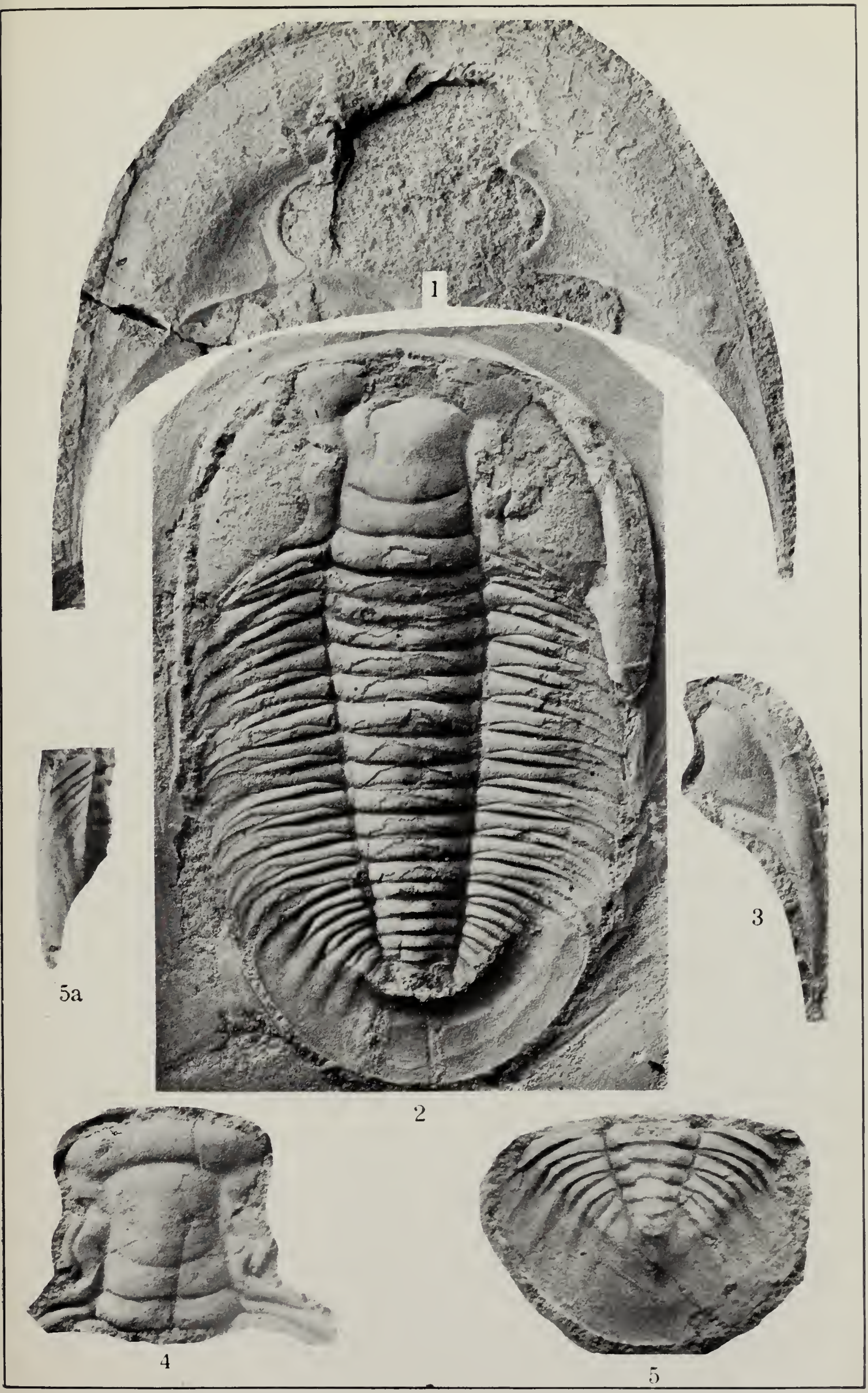
FIG. 2. (Natural size.) Entire dorsal shield flattened in shaly sandstone. U. S. National Museum, Catalogue No. 58613.

3. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58614.

4. (Natural size.) Cranidium. U. S. National Museum, Catalogue No. 58615.

5 and 5*a*. (Natural size.) Top and side views of a slightly flattened pygidium. U. S. National Museum, Catalogue No. 58616.

The specimens represented by figs. 2-5 are from locality 85, Upper Cambrian: St. Lawrence formation at Prairie du Sac, Sauk County, Wisconsin.

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## DESCRIPTION OF PLATE 67

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*Saukia pepinensis* (Owen) .......................................... 381

FIG. 1. (Natural size.) The type cranidium of Owen from La Grange Mountain, near Red Wing, Minnesota. U. S. National Museum, Catalogue No. 17868.

This specimen is figured by Owen, 1852, pl. 1, fig. 9*a*.

2 and 2*a*. (Natural size.) Dorsal and side views of pygidium from Owen's collection, associated with the cranidium represented by fig. 1. U. S. National Museum, Catalogue No. 58629.

3 and 3*a*. (Natural size.) Dorsal and side views of pygidium illustrated by Owen, 1852, pl. 1, fig. 9*b*. U. S. National Museum, Catalogue No. 17868.

4 and 4*a*. (× 1.5.) Dorsal and side views of a cranidium that is very slightly compressed. U. S. National Museum, Catalogue No. 58630.

5. (Natural size.) A flattened cranidium, varying slightly in outline of glabella and frontal rim from the type cranidium of the species, fig. 1. U. S. National Museum, Catalogue No. 58631.

6. (× 2.) Small pygidium enlarged for comparison with figs. 2 and 3. U. S. National Museum, Catalogue No. 58632.

7. (× 2.) Small cranidium enlarged for comparison with adults, figs. 1, 4, and 5. U. S. National Museum, Catalogue No. 58633.

8. (Natural size.) A large cranidium showing entire palpebral lobe. U. S. National Museum, Catalogue No. 58634.

9. (Natural size.) Matrix of free cheek with parts of doublure and genal spine. U. S. National Museum, Catalogue No. 58635.

10. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58636.

11. (× 2.) Thoracic segment. U. S. National Museum, Catalogue No. 58637.

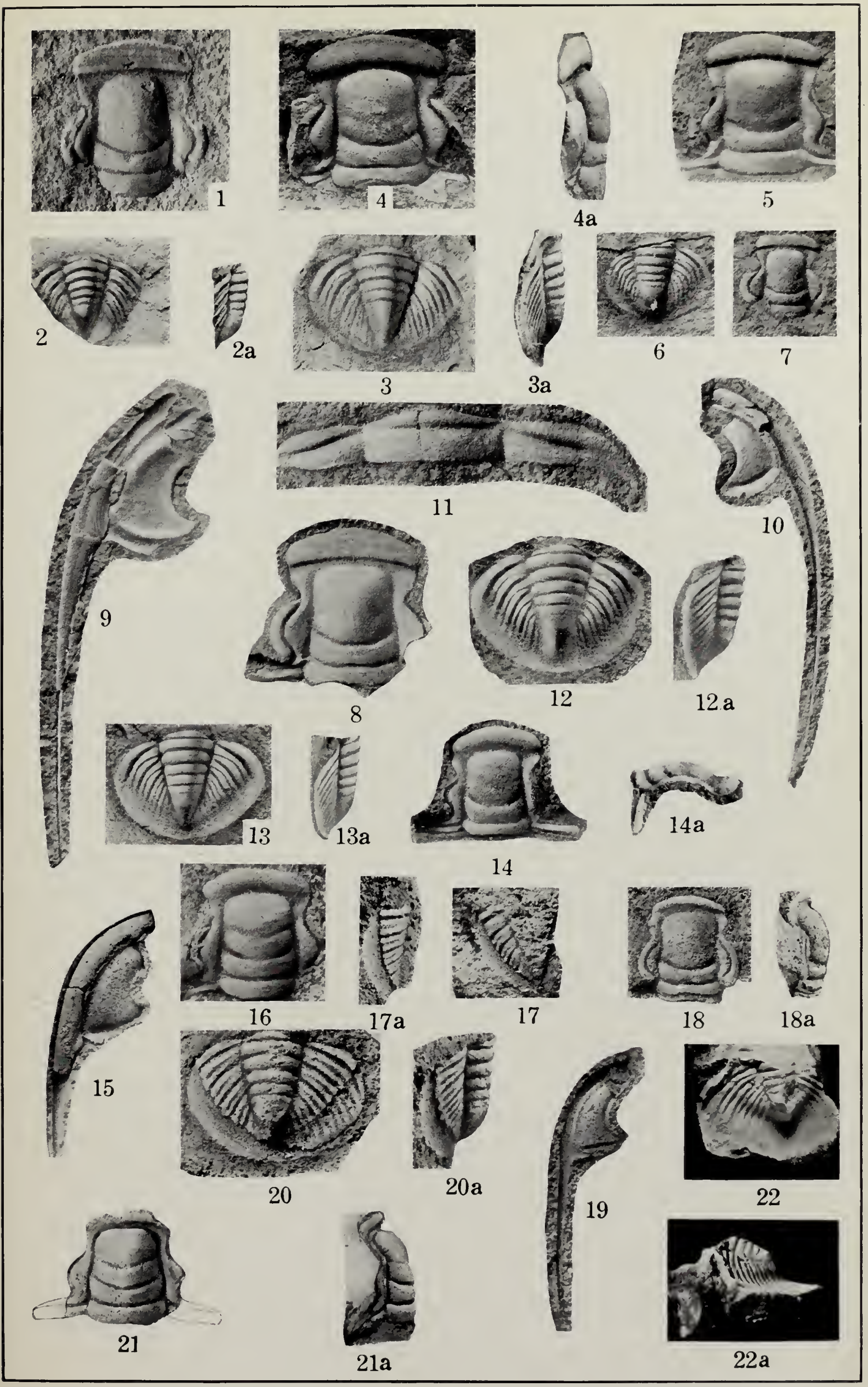
12, 12*a*, 13, and 13*a*. (Natural size.) Dorsal and side views of two unusually perfect pygidia that vary slightly in details from figs. 2 and 3. U. S. National Museum, Catalogue Nos. 58638 and 58639.

The specimens represented by figs. 1-13*a* are from locality 113, Upper Cambrian: St. Lawrence formation at La Grange Mountain (or Barn Bluff), near Red Wing, Goodhue County, Minnesota.

*Saukia leucosia* Walcott .......................................... 379

FIGS. 14 and 14*a*. (Natural size.) Dorsal and side views of the type specimen of the cranidium. U. S. National Museum, Catalogue No. 58640.

15. (Natural size.) Free cheek. U S. National Museum, Catalogue No. 58641.




DIKELOCEPHALINÆ

*Saukia leucosia* Walcott—Continued. PAGE

FIG. 16. (× 1.5.) View of a smaller cranidium than that of fig. 14. The photograph is from a wax impression taken from a natural matrix. U. S. National Museum, Catalogue No. 58642.

17 and 17*a*. (× 1.5.) Dorsal and side views of a fragmentary pygidium associated with the cranidia represented by figs. 14 and 16. U. S. National Museum, Catalogue No. 58643.

The specimens represented by figs. 14-17*a* are from locality 78, Upper Cambrian: St. Lawrence formation; quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin.

*Saukia pyrene* Walcott ........................................ 382

FIGS. 18 and 18*a*. (Natural size.) Dorsal and side views of type specimen of the cranidium. U. S. National Museum, Catalogue No. 58644.

19. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58645.

20 and 20*a*. (× 2.) Dorsal and side views of pygidium referred to this species. U. S. National Museum, Catalogue No. 58646.

The specimens represented by figs. 18-20 are from locality 78, Upper Cambrian: St. Lawrence formation; quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin.

*Saukia fallax* Walcott ........................................ 378

FIGS. 21 and 21*a*. (Natural size.) Dorsal and side views of a cranidium from locality 70a, Upper Cambrian: Wilberns formation, Baldy Mountain, near Morgans Creek, Burnet, Burnet County, Texas. U. S. National Museum, Catalogue No. 58647.

22 and 22*a*. (Natural size.) Dorsal and side views of a pygidium from the same locality (70a) as the specimen represented by figs. 21 and 21*a*. U. S. National Museum, Catalogue No. 60682.

## DESCRIPTION OF PLATE 68

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*Conokephalina misa* (Hall) .................................... 387

FIG. 1. (Natural size.) Fragment of a cranidium showing frontal limb and margin. U. S. National Museum, Catalogue No. 58661.

2. (Natural size.) A cranidium showing general characters of the species. U. S. National Museum, Catalogue No. 58662.

3. (Natural size.) Fragmentary pygidium associated with the cranidia represented by figs. 1 and 2. U. S. National Museum, Catalogue No. 58663.

The specimens represented by figs. 1-3 are from locality $83^3$, Upper Cambrian: Green-sand horizon in the Franconia formation below the "fifth trilobite bed" of Owen, at Trempealeau, Trempealeau County, Wisconsin.

*Osceolia osceola* (Hall) .................................... 386

FIGS. 4 and 4*a*. (× 1.5.) Dorsal and side views of cranidium. U. S. National Museum, Catalogue No. 58664.

5. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58665.

6 and 6*a*. (× 2.) Dorsal and side views of small cranidium. U. S. National Museum, Catalogue No. 58666.

7. (Natural size.) Cranidium with right free cheek attached. U. S. National Museum, Catalogue No. 58667.

8 and 9. (× 2.) Pygidia associated with cranidia represented by figs. 4 and 6. U. S. National Museum, Catalogue Nos. 58668 and 58669.

10. (Natural size.) Pygidium photographed from wax cast of natural matrix. U. S. National Museum, Catalogue No. 58670.

The specimens represented by figs. 4-10 are from locality 78, Upper Cambrian: St. Lawrence formation; quarry near St. Croix River, in suburbs of Osceola, Polk County, Wisconsin.

*Calvinella spiniger* (Hall) .................................... 390

FIG. 11. (Natural size.) Cranidium with slender occipital spine. ($83^2$.) U. S. National Museum, Catalogue No. 58648.

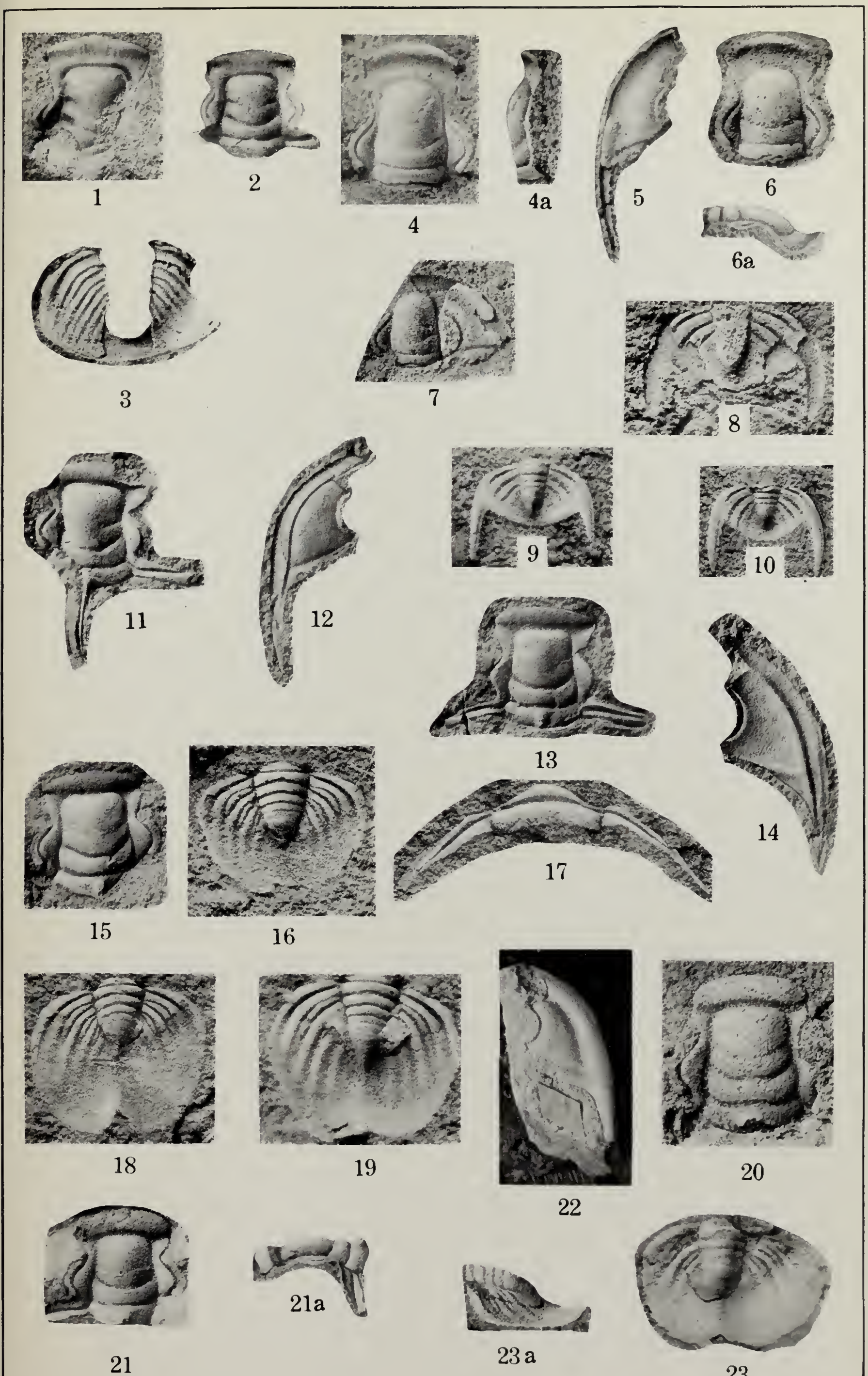
12. (Natural size.) Free cheek. ($83^2$.) U. S. National Museum, Catalogue No. 58649.

13. (× 1.25.) Nearly entire cranidium flattened in shaly sandstone. ($83^2$.) U. S. National Museum, Catalogue No. 58650.

14. (Natural size.) Matrix of free cheek. ($83^2$.) U. S. National Museum, Catalogue No. 58651.

15. (× 1.25.) Cranidium varying in details from figs. 11 and 13. ($83^2$.) U. S. National Museum, Catalogue No. 58652.

16. (× 1.25.) Pygidium flattened in shaly sandstone. (135d.) U. S. National Museum, Catalogue No. 58653.

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*Calvinella spiniger* (Hall)—Continued. PAGE

FIG. 17. (× 1.25.) Thoracic segment. (135d.) U. S. National Museum, Catalogue No. 58654.

18 and 19. (× 1.25.) Pygidia associated with the cranidia represented by figs. 11, 13, and 15. ($83^2$.) U. S. National Museum, Catalogue Nos. 58655 and 58656.

The specimens represented by figs. 11-19 are from localities $83^2$ and 135d, Upper Cambrian: St Lawrence formation; "fifth trilobite bed" of Owen, Trempealeau, Wisconsin.

20. (× 2.) Small cranidium in fine sandstone with strong frontal rim. U. S. National Museum, Catalogue No. 58657.

21 and 21*a*. (Natural size.) Cranidium preserving its natural convexity. U. S. National Museum, Catalogue No. 58658.

22. (Natural size.) Free cheek. U. S. National Museum, Catalogue No. 58659.

23 and 23*a*. (Natural size.) Dorsal and side views of a pygidium preserving its natural convexity. U. S. National Museum, Catalogue No. 58660.

The specimens represented by figs. 20-23*a* are from a fine-grained sandstone of locality $83^1$, Upper Cambrian; An upper horizon of the St. Lawrence formation near Trempealeau, Trempealeau County, Wisconsin.

## DESCRIPTION OF PLATE 69

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*Saukia wardi* Walcott........................................... 384

FIG. 1. (Natural size.) Small slab with cranidia, free cheeks, and pygidia. U. S. National Museum, Catalogue No. 58671.

2. (Natural size.) Small slab with matrices of cranidia and free cheeks, also pygidia and thoracic segments. U. S. National Museum, Catalogue No. 58672.

The specimens represented by figs. 1 and 2 are in the collection of the Yale University Museum, New Haven, Connecticut. The plastotypes in the U. S. National Museum bear the locality number **346f**, Upper Cambrian: Natural Bridge limestone, 1.5 miles (2.4. km.) north-northeast of Natural Bridge, Virginia, in calcareous shale in Shenandoah limestone.

*Saukia stosei* Walcott. (See pl. 70)................................. 384

FIG. 3. (× 3.) Surface of limestone with cranidia, free cheek, and pygidium weathered out in relief. U. S. National Museum, Catalogue No. 58673.

4. (× 3.) Side view of cranidium and free cheek of fig. 3.

5. (× 3.) Another view of the pygidium of fig. 3.

The specimens represented by figs. 3-5 are from locality **59 o**, Lower Ozarkian (Ulrich): Conocheague limestone, about 800 feet (240 m.) above the base of the formation in a limestone quarry on point of spur northwest of Scotland Station, Franklin County, Pennsylvania.

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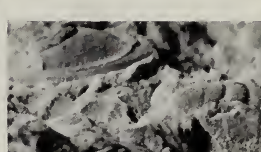

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## DESCRIPTION OF PLATE 70

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*Calvinella ozarkensis* Walcott........................................ 389

FIGS. 1 and 1*a*. (× 2.) Dorsal and side views of large cranidium. U. S. National Museum, Catalogue No. 58674.

2 and 2*a*. (Natural size.) Dorsal and side views of a large broken pygidium. U. S. National Museum, Catalogue No. 60055.

3. (Natural size.) Anterior portion of a cranidium with a slightly more convex frontal border than the specimen represented by fig. 1. U. S. National Museum, Catalogue No. 60056.

4 and 4*a*. (× 3.) Dorsal and side views of a small cranidium that is probably the young of this species. U. S. National Museum, Catalogue No. 58675.

5 and 5*a*. (× 2.) Dorsal and side views of a small pygidium from same rock as the cranidium represented by fig. 3. U. S. National Museum, Catalogue No. 58677.

6. (× 3.) Dorsal view of a small cranidium from a little higher horizon in the Eminence formation than the other specimens illustrated. U. S. National Museum, Catalogue No. 58676.

The specimens represented by figs. 1-5 are from Lower or Middle Ozarkian localities in the vicinity of Eminence, Shannon County; fig. 6 is from Flat River, St. Francis County, both in Missouri.

*Calvinella newtonensis* (Weller) ........................................ 389

FIG. 7. (× 2.) Cranidium with free cheek.

8. (× 2.) Type specimen of the cranidium of this species.

The specimens represented by figs. 7, 8, 11, and 11*a* are in the collections of the Museum of the State Geological Survey of New Jersey.

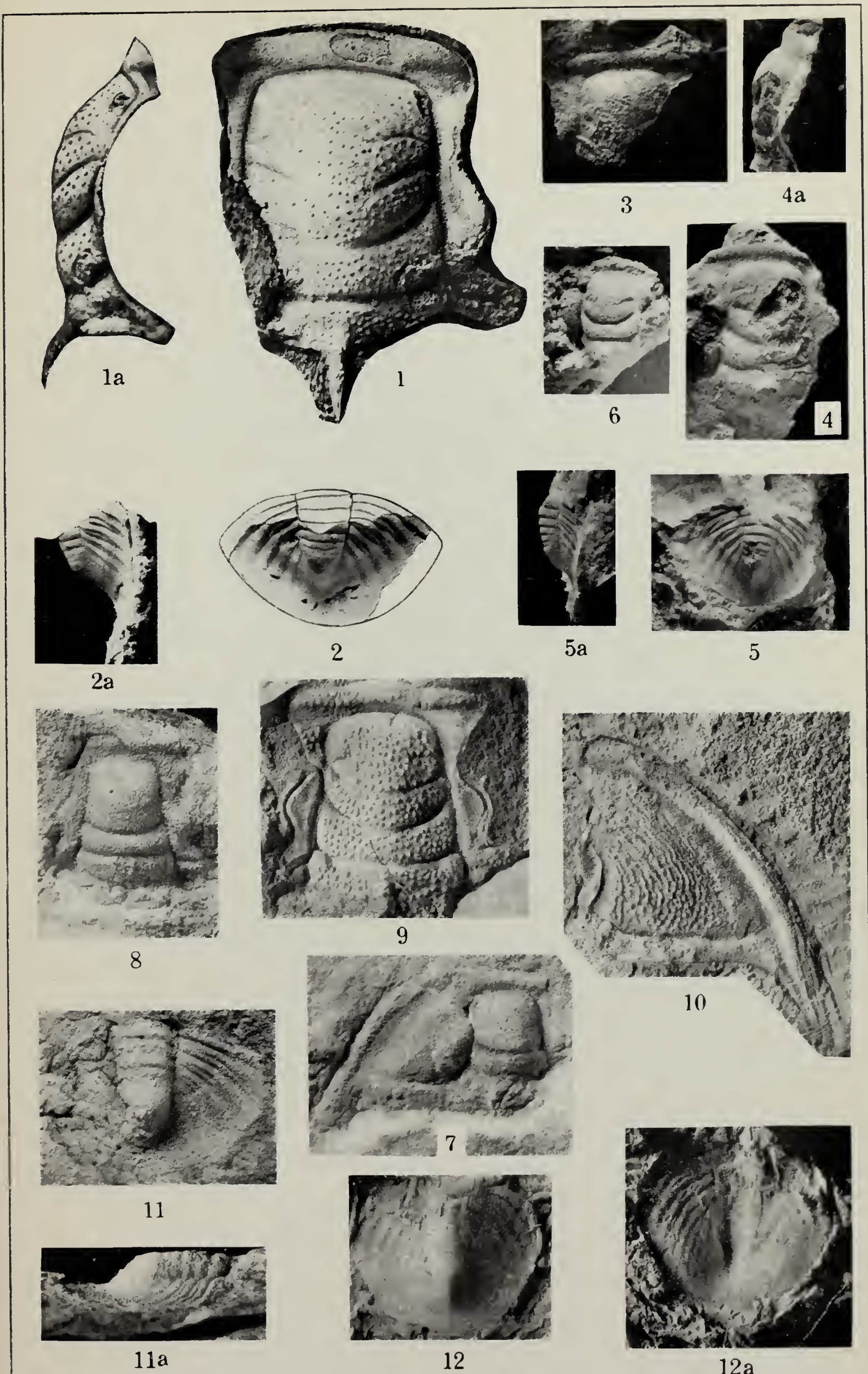
9. (Natural size.) Large cranidium from locality **11c**, Lower Ozarkian: Lower part of Kittatinny limestone, O'Donnell and McManniman's quarry, Newton, Sussex County, New Jersey. U. S. National Museum, Catalogue No. 58678.

10. (Natural size.) Free cheek associated with the cranidium represented by fig. 9. U. S. National Museum, Catalogue No. 58679.

11 and 11*a*. (× 2.) Dorsal and side views of pygidium associated with the cranidia represented by figs. 7 and 8.

*Saukia stosei* Walcott. (See pl. 69)........................................ 384

FIGS. 12 and 12*a*. (Natural size.) Matrix and cast from matrix of a crushed pygidium that may possibly be of this species. From locality **59n**, Lower Ozarkian (Ulrich): Conococheague limestone. Quarry at Scotland Station, Franklin County, Pennsylvania. U. S. National Museum, Catalogue No. 59680.

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# INDEX

The references in **heavy-faced** type refer to the locality numbers and the pages upon which the genera and species are described and figured.