SMITHSONIAN MISCELLANEOUS COLLECTIONS

VOLUME 75

CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

BY

CHARLES D. WALCOTT

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

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C. G. ABBOT,
Secretary of the Smithsonian Institution.

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V

No. 1.—GEOLOGICAL FORMATIONS OF BEAVERFOOT–BRISCO–STANFORD RANGE, BRITISH COLUMBIA, CANADA

(With Plates 1 to 8)

BY
CHARLES D. WALCOTT

(Publication 2756)

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INTRODUCTION

Late in the field season of 1922, I made a rapid reconnaissance along Sinclair Canyon from the Pass at its head on the crest of the Brisco-Stanford Range to the mouth of the canyon where it opens out on the east side of the Columbia River Valley, and during the field season of 1923 I studied more in detail the Sinclair section, and to the south the Stoddart-Dry Creek, the Fairmount and Canal Flats sections of the Stanford Range, and to the north the Vermilion and Harrogate sections of the Brisco Range, and the Kicking Horse Canyon section at the northern end of the Beaverfoot Range. I was accompanied by Dr. Edwin Kirk, of the United States Geological Survey, who studied the Upper Ordovician and Silurian formations, and Mrs. Walcott, who collected many Ozarkian and Cambrian fossils.

The three ranges grouped in the title are practically one continuous range on the eastern side of the Columbia River Valley that were given local names by the early settlers and surveyors. They are all more or less capped by the upturned hard, silicious, magnesian Silurian limestones that have resisted the agencies of erosion and now form high cliffs, sharp ridges and peaks, while the more readily disintegrated shales and thin-bedded limestones of the Ordovician, Ozarkian and Cambrian beneath have been deeply eroded since the close of Jurassic time.[1] On the west the great "Rocky Mountain Trench" developed, and on the east the deep valley of the Kootenay-Beaverfoot Rivers. Nearly all of the Devonian limestones and shales and Carboniferous limestones of pre-Jurassic time that may have been superjacent to the Silurian over the area between the Rocky Mountain Continental Divide and the Selkirk Mountains in British Columbia south of the main line of the Canadian Pacific Railway have disappeared in the millions of years since they were first subjected to erosion.[2]

For many years I wished to know more of the formations of the western ridges of the main range of the Rocky Mountains facing the Columbia River Valley, and I was delighted when the papers of Allan,[3] Schofield,[4] and Shepard[5] appeared with a more or less detailed

[1] Schofield, Trans. Roy. Soc. Canada, 3d Ser., Vol. 14, Sec. IV, 1921, pp. 90-97.

[2] In this connection the student should read Prof. S. J. Schofield's admirable paper on the "Origin of the Rocky Mountain Trench," *loc. cit.*, pp. 61-97.

[3] Allan, John A., Report Can. Geol. Surv. for 1912, Memoir Geol. Surv. Canada, No. 55, 1914, Geol. Ser. No. 46, pp. 94-102.

[4] Schofield, Stuart J., Trans. Roy. Soc. Canada, 3d Ser., Vol. 14, Sec. IV, 1920, pp. 61-86; Geol. Surv. Canada, Bull. 35, 1922, Geol. Ser. No. 42, pp. 1-15.

[5] Shepard, Francis P., Jour. Geol., Vol. 30, pp. 77-81, 89-99, 361-376.

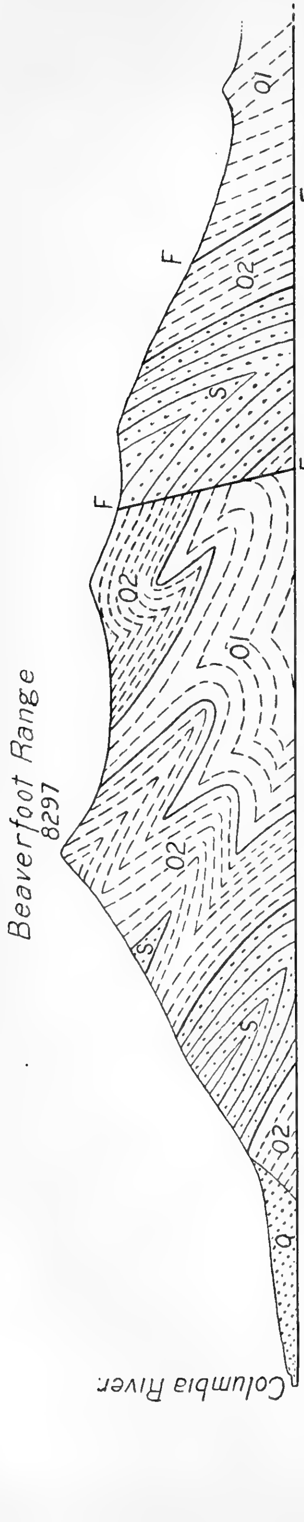

FIG. 1.—Allan section about 15 miles (24.1 km.) south of Golden. O.1 = Goodsir shales. O.2 = Graptolite beds (Glenogle shales). S. = Silurian Halysites beds (Beaverfoot formation).

account of the stratigraphy and structure of the Lower Paleozoic formations in and adjoining the "Rocky Mountain Trench."

The stratigraphic section of Allan, south of the Kicking Horse Canyon on the line of the Canadian Pacific Railway, crossed the Beaverfoot Range a few miles south of Golden, where he found Ordovician and Silurian [1] formations near the summit of the range overlooking the "Rocky Mountain Trench." The Silurian was identified by contained corals, and the Ordovician by the Glenogle graptolites. A diagrammatic section by Allan shows the complicated structure of the northern portion of the Beaverfoot Range. It is reproduced in outline in figure 1.

Schofield working to the south found Lower and Middle Cambrian and Devonian in the Elko district, and on the eastern side of the Trench at Canal Flats supposed Middle and Upper Cambrian overlain by Devonian.[2]

Shepard in connection with his study of the "Rocky Mountain Trench" examined several sections of the Beaverfoot-Brisco-Stanford Range on the western side and eastern wall of the Trench, and summarized his observations on the stratigraphic series as follows:

[1] *Loc. cit.*, p. 60 of Memoir; also Geol. Surv. Canada, 1913, Geol. Excursions Int. Geol. Congress, C. 1, Guide Book No. 8, pt. II. Colored structural section in pocket.

[2] Trans. Roy. Soc. Canada, 3d Ser., Vol. 14, Sec. IV, 1920, p. 76; also Geol. Surv. Canada, Geol. Ser. No. 42, Bull. 35, 1922, p. 15.

GENERALIZED SECTION OF SHEPARD

		Feet	Meters
Mississippian	Massive limestone	1,000 +	304.8
Devonian (Upper)	Thin-bedded limestone and shale	500 +	152.4
	Quartzite	500 +	152.4
	Massive limestone	2,500 +	762.
Silurian or Devonian	Calcereous shales	900 +	274.3
	Massive crystalline limestone	600	182.8
	Boulder bed	300	91.4
	Massive gray limestone	650	198.1
Richmond, Upper	Massive gray and black limestone	2,200	670.5
	Sandstone and quartzite	400	121.9
Richmond, Lower	Massive limestone	950	289.5
Ordovician (Lowest)	Thin-bedded limestones and shales	1,600 +	487.6
Cambrian (Upper)	Shales and thin-bedded limestone	1,000 +	304.8
	Massive pink weathered limestone	1,000 +	304.8
Cambrian (Upper or Middle).	Thin-bedded limestone	1,500	457.2
	Massive gray and black limestone	500	152.4
Cambrian and Pre-Cambrian.	Conglomerates, sandstones, shales and schists	5,000 +	1,524.

This section locates the "Silurian or Devonian," and beneath them the Upper and Lower Richmond, Lowest Ordovician, and Upper Cambrian.[1]

The formations included in this paper may be compared to those of the Shepard section as follows:

SHEPARD SECTION

Brisco = Upper Richmond, also boulder bed of "Silurian or Devonian."
Beaverfoot = Lower Richmond, also massive pink weathering limestone of Upper Cambrian.
Wonah Quartzite = Base of Upper Richmond.
Sinclair =[2]
Mons = Ordovician (Lowest), also shales and thin-bedded limestone of Upper Cambrian.
Lyell = Massive gray limestone of Silurian or Devonian.

Much in the Shepard section is necessarily theoretical, as he did not attempt to work out any one section thoroughly. He made a broad reconnaissance and added materially to the information in

[1] Jour. Geol., Vol. XXX, 1922, p. 364.

[2] Shepard apparently did not meet with the shales and sandstones of the Ordovician Sinclair formation carrying graptolites of the Beekmantown fauna. The formation is finely exposed in a number of places in the Stanford Range.

relation to the geology of the "Rocky Mountain Trench" from Golden to Canal Flats.

L. D. Burling (1922) in a paper "On a Cambro-Ordovician section in the Beaverfoot Range near Golden, British Columbia"[1] "offers new data regarding the stratigraphy of the upper part of the Cambrian and the Ordovician section." Two new formation names are proposed, Glenogle shales for the graptolite shales, and Beaverfoot formation for the Halysite beds.

In a paper published in March, 1923 (Smithsonian Miscellaneous Collections, Volume 67, No. 8, p. 463) I used the name Glenogle formation for the shales containing the graptolite fauna and referred it to the Ordovician; also the name Beaverfoot formation for the limestones, quartzites and interbedded shales on the crest of the Beaverfoot Range, as described by Allan. Reference should have been made to Burling's previous use of the names, but as I had used them in manuscript notes for several years, it was overlooked when the paper went to press.

The Burling section of the Beaverfoot Range was measured on the summit of the range (*loc. cit.*, p. 452) where it is crossed by the "Whiskey trail" about 15 miles (24.1 km.) southeast of Golden, and a small section of the Glenogle graptolite shales was measured at Glenogle Creek just north of the Kicking Horse Canyon.

Judging from Allan's section (*ante*, p. 4) of the north end of the Beaverfoot Range,[2] Burling crossed in his section an area of shales, limestones and quartzites where faults of large and small degree and sharp folds occur. His section appears very similar to that given in Allan's diagrammatic section for the eastern slope of the Beaverfoot Range where the section appears to be unbroken from the Silurian limestones down through the "Graptolite" beds into the Goodsir formation.

Messrs. Allan, Schofield, and Shepard furnished me with a list of the localities at which they found fossils, and with their published results in hand I enjoyed many advantages that were not available to them.

As my knowledge of the Silurian and Devonian faunas was only of a general character, I asked the Director of the U. S. Geological Survey to permit Dr. Edwin Kirk to accompany me in order that he might collect and identify the fossils in the field and correlate the formations and faunas locally and also with those in the great inter-

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[1] Geol. Mag., London, Vol. 69, 1922, pp. 452-461.

[2] Geol. Surv. Can., 1913, Guide No. 8, Pt. II, pl. of sections.

mountain area of western America from northern Alaska to the Gulf of Mexico. Dr. Kirk will publish the results of his field and office work; meantime he has given me data for use in this paper.

I now have in course of preparation an article on the Upper Cambrian and Ozarkian of western North America, in which a summary of this present paper will be incorporated and the relations of the "Rocky Mountain Trench" area and those to the north of the Bow Valley-Kicking Horse Canyon line more fully presented. At present the larger paper is waiting for the completion of the identification, description, illustration, and publication of the faunas of the various pre-Devonian formations.

The brachiopods included in the lists of this paper have been described, illustrated and published.[1] The genera of trilobites are now being prepared for publication, but most of the species are in course of study and illustration and will be published later.

Acknowledgments.—My indebtedness to Dr. Rudolf Ruedemann and Dr. Edwin Kirk for identification of Ordovician and Silurian fossils is mentioned in the text. Dr. Charles E. Resser has worked early and late on the collections from the Mons formation in connection with the study of the fragmentary trilobite remains so that generic names at least might be included in the lists of fossils. Dr. E. M. Kindle, of the Geological Survey of Canada, kindly gave all the information available to him in relation to the collections that had been made from the pre-Silurian formations of the Beaverfoot-Brisco-Stanford Range.

In all field-work during the past ten years, Mrs. Walcott has been an unfailing and most enthusiastic and effective assistant both in running the camp and pack outfit and collecting fossils. We have been greatly indebted to the officials and many employees of the Canadian Pacific Railway for many courtesies that have been of service in expediting and aiding the work. From the Superintendent of the Canadian National Parks, and the local officials and employees of the Rocky Mountains, Yoho, and Kootenay Parks we have received unfailing courtesy and assistance.

DESCRIPTION OF MAP, PLATE 1

This map represents rather crudely the area from the northern headwaters of the Saskatchewan River southeasterly along the Continental Divide for about 165 miles (265.5 km.). For the purposes of this paper only that portion between the line from Lake Louise,

[1] Smithsonian Misc. Coll., Vol. 67, No. 9, 1924.

Alberta, to Golden, B. C., is necessary, as the sections studied are within this area of approximately 95 miles (152.9 km.) between Kicking Horse Canyon and the line of Canal Flats. The full map will be used again in a paper discussing several sections between Glacier Lake, Alberta, and Canal Flats.

The base for this map is a large map of southern Alberta issued by the Department of the Interior, Ottawa, Canada. Scale 1 : 79200 or 12.5 miles (20.1 km.) to the inch. The true north and south is shown by the land survey lines.

The attached heavy faced letters A to O indicate the following localities:

A. Locality of lower Mons fossils between Beavermouth and Anzac on the Canadian Pacific Railway. Another locality is at Donald, 12 miles (19.3 km.) southeast of Beavermouth, B. C.

B. Area about the head of Glacier Lake where there is a fine geologic section that is located a little to the right and east of B.

C. Area about Mt. Wilson, the typical locality of the Wilson Quartzite.

D. Locality of a fine section on Siffleur River. Mt. Sedgwick is about 3 miles west of D.

E. Section Mountain is just above the right upper end of E, at the head of Clearwater River. The Clearwater section is about the upper part of the letter E.

F. Location of Fossil Mountain section. Baker Lake is at the lower end of the F.

G. Douglas Canyon section is at about the upper side of G at the northwest end of the Sawback range.

H. Location of Ranger Canyon section in Sawback range.

I. Area of Ghost River section on the west side of Ghost River where it turns south after passing out from its canyon.

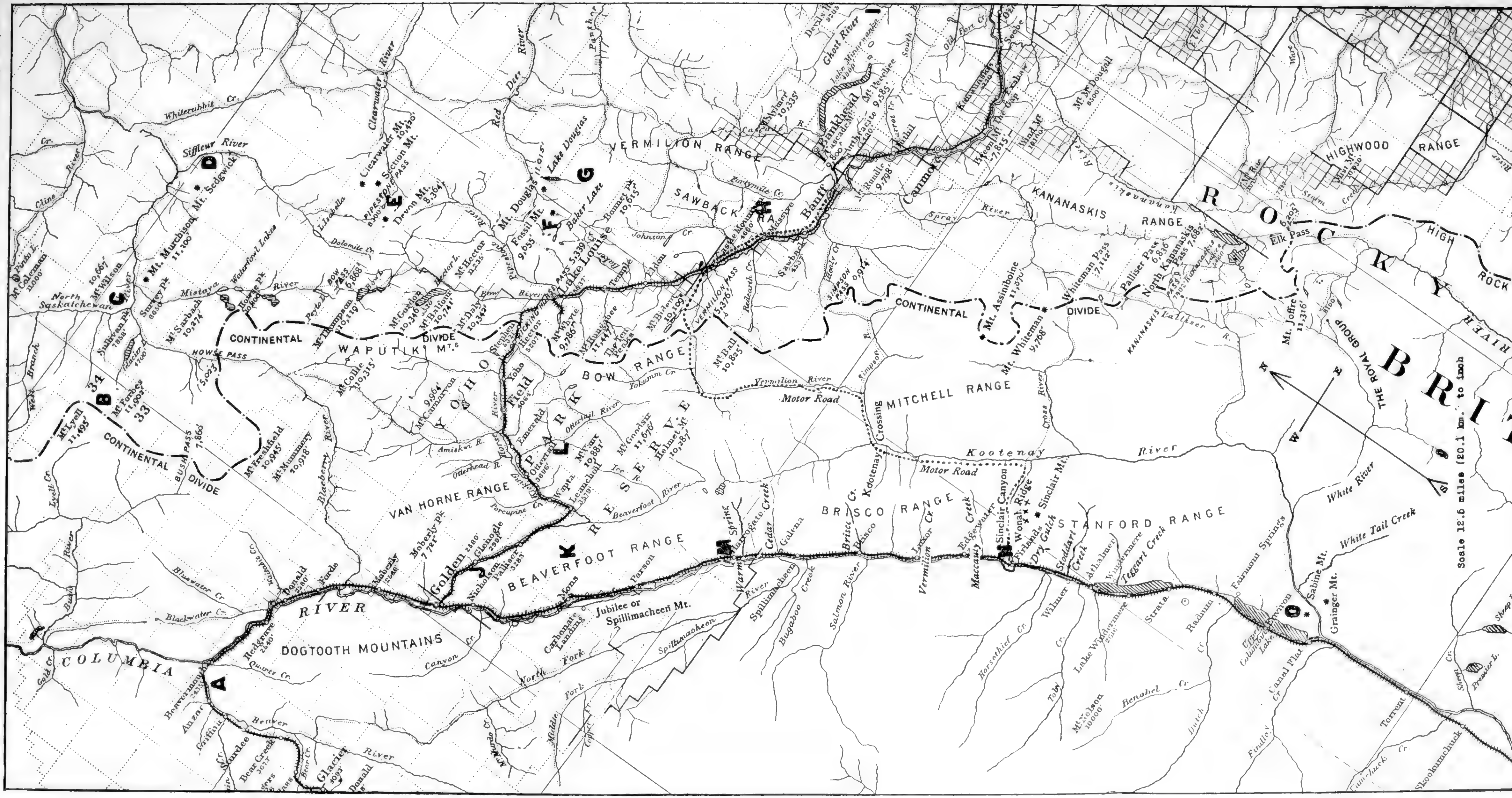
J. The location of the Glenogle graptolite beds is both east and west of Glenogle station on the Canadian Pacific Railway.

K. Type locality of the Beaverfoot formation on the Beaverfoot range is a little north of K.

L. Ottertail escarpment where the Upper Cambrian Ottertail limestone is well exposed along the river to the southeast.

M. Harrogate. Warm Spring Creek cuts back into the range but not as far as Cedar Creek 4 miles (6.4 km.) south, which was probably taken as the division line between the Beaverfoot and Brisco ranges.

N. Sinclair Canyon between the Brisco and Stanford ranges and the most important canyon between Golden and Canal Flats. The



Area from northern headwaters of Saskatchewan River southeasterly along Continental Divide for about 165 miles (265.5 km.).

Banff-Windermere motor road passes through it and the geological formations are cut across at nearly a right angle to the strike of the strata.

O. Sabine Mountain at the southwest end of Stanford Range.

STRATIGRAPHIC SECTIONS

SINCLAIR CANYON SECTION

The Sinclair section is taken as the standard section of the Brisco-Stanford Range. Sinclair Mountain is the first mountain south of Sinclair Pass and forms the north end of the Stanford Range, west of and above the Kootenay River Valley and east of the Columbia River Valley. The summit of the range at this point is formed of dark Silurian limestones. The section above the Ordovician was not measured or studied in detail at this place, and the thickness is based on estimate. The measured section extends down the northwest ridge (Wonah Ridge) into Sinclair Canyon. There is no indication of the Devonian above as it occurs in the Beaverfoot Range to the north. Sinclair Canyon broadens out in its upper portion, where it cuts through a broken dome of Silurian, Ordovician and Ozarkian strata. Erosion has cut deep into the central portions of the dome, exposing an almost continuous section on the northeastern side of Wonah Ridge[1] from the massive limestones of the Silurian well down into the Ozarkian. (See pl. 4. fig. 1). The canyon further down cuts through the southwestern side of the dome so as to expose parts of the same section as that on the slope of Wonah Ridge, but here it is broken by a fault that cuts out a considerable portion of the strata between the upper part of the Mons and the Wonah quartzite. To the northwest and southeast deep broad canyons lead up from Sinclair Canyon to the encircling ridges which are largely covered by débris and forest growth.

The best horizon marker in the great amphitheater is Wonah quartzite which occurs around the southwest upper slopes of Sinclair Mountain and on the high ridge on the northeast side. (See fig. 1, pl. 4.) The quartzite is cut by the canyon east of a fault just above bridge No. 5 on the Banff-Windermere motor road. At this point it dips to the southwest 50° to 60° with the Silurian Beaverfoot formation above and the Ordovician Sinclair formation beneath. Passing down the canyon and up in the section the Silurian above

[1] Name given to the northwest ridge of Sinclair Mountain south of Sinclair Pass, the southwest slope of which rises above Kootenay Park Warden Cabin No. 2 on the Banff-Windermere motor road.

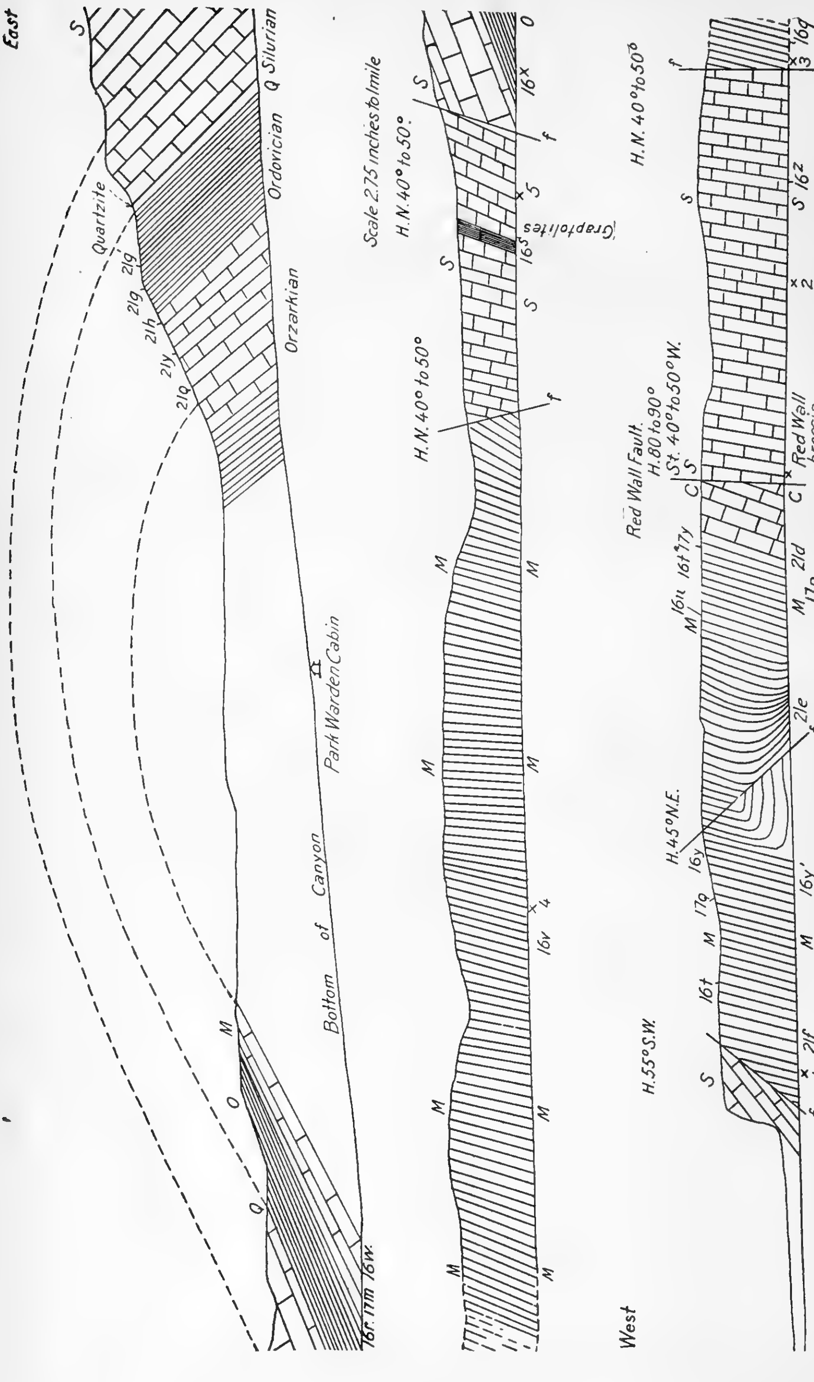
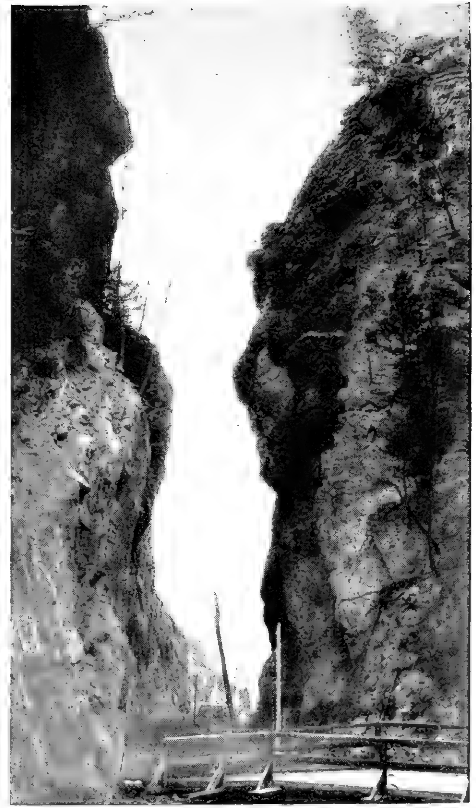
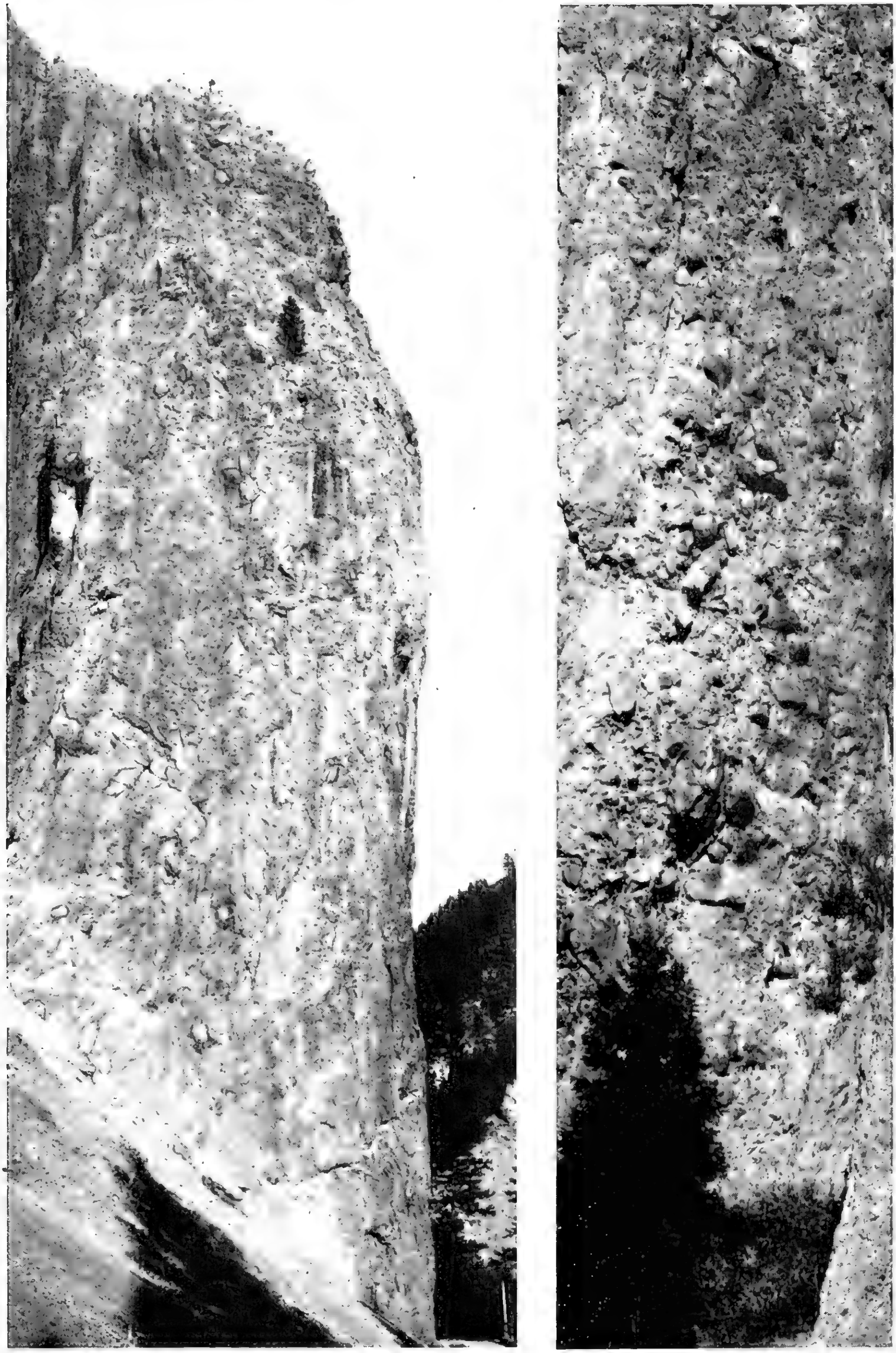


FIG. 2.—Diagrammatic section in Sinclair Canyon from summit of Wonah Ridge above Sinclair Pass to mouth of the canyon. Scale 2.75 miles (4.4 km.) to inch (2.5 cm.). The first five bridges crossing Sinclair Creek are indicated by a cross and number. The approximate hade of the principal faults is indicated and their strike when known. S = Silurian formations, Beaverfoot and Brisco; O = Ordovician, Sinclair formation; Q = Wonah quartzite; M = Ozarkian, Mons formation; C = Cambrian, Lyell formation. Localities of fossils indicated by numbers, which are locality numbers recorded in the U. S. National Museum catalogue.

1. Silurian Beaverfoot formation limestones of the upper cliffs of the Gates of the Canyon, showing thick layers and picturesque character of the canyon as seen from below.



2. Gates of the Canyon above the entrance to Sinclair Canyon from Columbia River Valley. The outer cliffs are formed of the Silurian Beaverfoot formation limestones west of the Gates of the great fault. (See pl. 5.) The highly inclined thin-bedded limestones of the Mons are shown on the left side in the cliff above the bridge and in the ledge on which the bridge rests. The *Hungaia* fauna occurs in a layer of this ledge. (Photo by C. D. and Mary V. Walcott, 1922.)



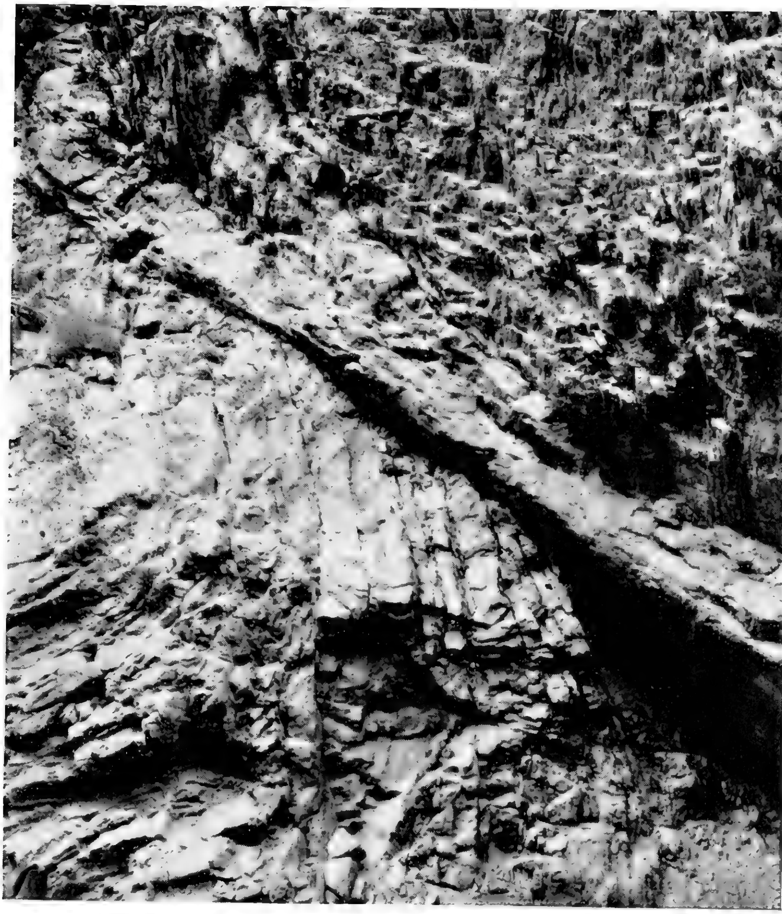
West face of Red Wall Fault Breccia facing fault line, on north side of Sinclair Canyon above Banff-Windermere motor road, one-half mile (.8 km.) above Radium Hot Springs. (Photo by Walcott, 1922.)

1. Southwest face of Sinclair Mountain above Sinclair Canyon. The dark limestone above includes the Silurian Brisco and Beaverfoot formations with the light colored Wonah Quartzite forming a white band beneath. Below the quartzite the shales and sandstones of the Sinclair formation, and subjacent to this the Mons limestones shown in the Wonah Ridge on the left.

B = Brisco limestone.
Br. = Beaverfoot limestone.
Q = Wonah Quartzite.
S = Sinclair shales.
M = Mons limestones.

2. Limestone boulders of Red Wall Fault Breccia. The size of the boulders is indicated by the large hat lying on the right side. (See pl. 3.)

Gates of the Canyon fault above the entrance on the north side of Sinclair Canyon. To the right of the main fault on the right the thin-bedded hard limestones of the Mons formation are in a nearly vertical position. On the left of this fault and also above the branch fault the thick-bedded, massive, pink weathering Silurian limestones of the Beaverfoot formation are dipping to the southwest. (Photo by C. D. and Mary V. Walcott, 1922.)



Fault in Mons limestones, Sinclair Canyon, about 1,500 feet (457.2 m.) east of Gates of the Canyon, Hade 45° N. E. (Photo by Walcott, 1922.)

the quartzite extends to where a northwest-southeast fault brings the upper beds of the Ozarkian (Mons formation) against it. The first faunule found in the Mons, going down, was just below bridge No. 4, and this faunule is repeated (16q, p. 17) just above bridge No. 3, which is 5,400 feet (1,645.9 m.) down the canyon from No. 4. The layers of limestone and shale are highly inclined and it is quite possible that an anticline occurs between bridges 3 and 4. Below bridge 3 the Silurian extends down the canyon about 4,400 feet (1,341.1 m.) to the cliffs of Red Wall Fault Breccia. (See pl. 3.) West of the Red Wall Fault a thick-bedded, cliff-forming magnesian limestone of possible Upper Cambrian age occurs that is subjacent to a series of shales and interbedded layers of limestone that contain the lower Mons fauna, and the sequence of the Mons faunules is continuously upward until the upper middle Mons faunule (21f) or *Hungaia* faunule is met with just east of the pink weathering Silurian limestone forming the Gates of Sinclair Canyon. (Pl. 2, fig. 2.)

The Sinclair Canyon section beginning at the summit of Sinclair Mountain and passing down to the lowest beds exposed is necessarily made up of parts occurring in the canyon between the great faults. The greater portion of the Mons formation is found between the Radium Hot Springs and the Gates of the Canyon. A concealed portion of the upper Mons formation is inserted from the Stoddart-Dry Creek section as it occurs 5 miles (8 km.) to the south.

SILURIAN

Brisco Formation:

	Feet	Meters
1. Thick-bedded (2 to 6 feet, .6 to 1.8 m.) dark gray rough weathering and more or less silicious magnesian limestones forming cliffs and high points. (Estimate).....	1,200	365.8

Fauna.—The fauna in the basal portion of the Brisco (Silurian) is scant, consisting mainly of very poorly preserved cyathophylloid corals. However, within 50 feet above the top of the Beaverfoot (Richmond) in the Windermere Creek section *Pentamerus* was found. Slightly higher stratigraphically but below the *Monograptus* horizon *Virgiana* was found in abundance in Sinclair Canyon. In the upper portion of the Silurian a more abundant fauna was collected near the head of Windermere Creek which included (E. Kirk):

Halysites sp.
Syringopora sp.
Favosites sp.
Atrypina sp.
Spirifer sp.
Stropheodonta sp.

Silurian graptolite beds.—In the upturned Silurian, Brisco bluish black limestones about 5 miles (8 km.) below Sinclair Pass on the south side of the canyon, an intercalated band of black argillaceous shale carries an abundant graptolite faunule which Dr. Rudolf Ruedemann correlates with the Clinton formation graptolite faunule of the Silurian, which places it above the Beaverfoot (Richmond) coral fauna and in the Brisco limestone of the Silurian. Dr. Kirk located this shale in Sinclair Canyon section at about 300 feet (91.4 m.) from the base of the Brisco limestone formation. We did not find it elsewhere either to the north or south.

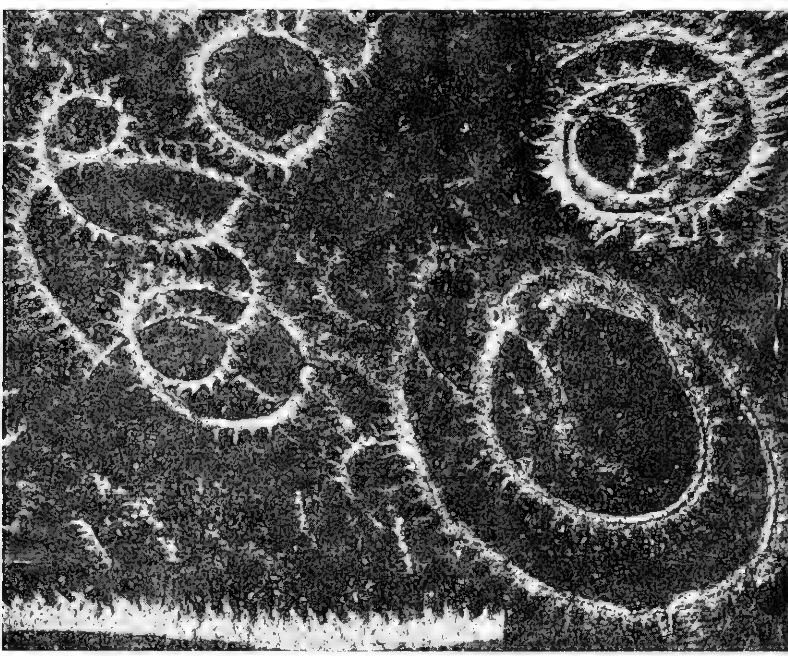


FIG. 3.—Illustration of occurrence on surface of shale of Silurian graptolites in Sinclair Canyon.

Monograptus cf. *Spiralis* Geinitz
Monograptus sp.

Dr. Ruedemann reported on the graptolites as follows:

The faunule consists of:

Monograptus sp. nov. This form is closely related to *Monogr. spiralis* (Geinitz).

Monogr. marri Perner. This form is practically identical with the European species.

Retiolites (*Gladiograptus*) *geinitzianus* Barrande, which is the same as *R. venosus* Hall from our Clinton. These three species, *M. spiralis*, *marri* and *Retiolites geinitzianus*, are all Gala-Tarannon forms of Great Britain and occur also in Bohemia, etc. The faunule from Sinclair Canyon in British Columbia is hence fairly safely correlated with that of the Gala-Tarannon beds of Britain, and also with the Clinton graptolite shale of New York. (Williamson shale.)

The Idaho faunule is characterized by *Monograptus cf. marri* Perner (probably the identical form).

M. cf. pandus Lapworth (also so far not distinguishable).

Cyrtograptus murchisoni Carruthers.

M. marri and *pandus* are Gala-Tarannon forms, while *Cyrtograptus murchisoni* characterizes the base of the Wenlock in Britain.

The Idaho fauna may therefore be a little younger than the Sinclair Canyon fauna, but it is in general of the same age.

Beaverfoot Formation:

	Feet	Meters
1. Gray, compact, hard, cliff-forming limestone with considerable gray chert in nodules, stringers and thin sheets or irregular layers. (Estimate)	400	121.9

Fauna.—No fossils were collected on Sinclair Mountain but at a locality a mile (1.6 km.) west and down the canyon the following fauna was found in a few layers of light colored, fine-grained limestone superjacent to the Wonah Quartzite:[1]

Columnaria alveolata Goldfuss
Columnaria (*Paleophyllum*) cf. *stokesi* (Edwards and Haime)
Favosites sp.
Streptelasma rusticum Billings
Rhynchotrema argenturbica (White)
Zygospira cf. *recurvirostris* Hall
Plectambonites cf. *saxeus* (Sardeson)
Hebertella cf. *occidentalis* (Hall)
Dinorthis cf. *subquadrata* (Hall)

As the result of his study of the formation, Dr. Kirk reports as follows:

The Beaverfoot (Richmond) is composed in the main of heavy bedded dolomitic limestones, weathering brownish to lead colored. It seems to vary in thickness in different sections. In the Upper Columbia Lake and Windermere Creek sections it apparently does not exceed 200 feet in thickness. In the Sinclair Canyon sections higher beds are present, consisting of thinner-bedded, purer limestones, and here it attains a thickness of about 400 feet. The fauna is identical with that of the upper Bighorn of Wyoming, of the upper portion of the Fremont of Cañon City, Colorado, and of the Richmond of Stony Mountain, Manitoba.

Beatricea sp.
Receptaculites sp.
Paleofavosites sp.
Streptelasma trilobatum Whiteaves
Columnaria alveolata Goldfuss
Columnaria (*Paleophyllum*) cf. *stokesi* (E. and H.)
Halysites sp.
Rhynchotrema cf. *capax* (Conrad)
Rhynchotrema argenturbica (White)
Zygospira cf. *recurvirostris* Hall
Plectambonites cf. *saxeus* (Sardeson)
Hebertella occidentalis (Hall)
Dinorthis subquadrata (Hall)
Maclurina sp.
Endoceras sp.

[1] As identified by Mr. Edwin Kirk.

WONAH QUARTZITE:

	Feet	Meters
1. Light gray to white compact quartzite in layers 3 to 10 feet (.9 to 3 m.) thick. (Estimate)	110	33.5
Strike N. 35° W.		
Dip 50° N. 55° E.		

A section measured about a mile to the northwest of Sinclair Mountain gave the following:

	Feet	Meters
1. Massive-bedded, white and light gray quartzite. The basal layer is a more or less cross-bedded indurated white sandstone 2.5 feet (.7 m.) thick. The layer above is 18 to 22 feet (5.5 to 6.7 m.) thick, with another similar layer above it; these two layers are almost homogeneous and were evidently formed of clear, white beach sand.		
Total thickness where measured	42	12.8

Strike N. 65° W. Dip about 30° N. 25° E.

No traces of fossils were found at any of the exposures of the quartzite.

DISCONFORMITY:

There is no physical evidence of unconformity beneath the quartzite, but the Glenogle black shale formation of the Kicking Horse Canyon section with its strongly marked Middle Ordovician graptolite fauna has not been recognized.

ORDOVICIAN

SINCLAIR FORMATION:

	Feet	Meters
1a. Thin layers of gray, reddish brown weathering sandstone passing into arenaceous shale 330 feet (100.5 m.) down.	474	144.5
Fauna.—Numerous annelid trails and borings on and in some of the thin layers of sandstone.		
Strike N. 55° W. Dip 40° N. 35° E.		
1b. Gray, hard, thin-bedded sandstone	43	13.1
1c. Dark grayish black slightly and finely arenaceous shale	106	32.3
1d. Light gray quartzite weathering buff gray	7	2.1
Total of 1	630	192.0
2a. Dark finely arenaceous and silicious shale with occasional thin layers of hard, dark arenaceous earthy rock and a few lenticular concretionary nodules carrying graptolites	707	215.5
Fauna.—Noted fragments of graptolites 102 feet (31.0 m.) below the summit in association with *Caryocaris curvilatus* Gurley; also at 417 feet (127.1 m.) and 572 feet (174.3 m.). At 517 feet (157.5 m.) the following species		

	Feet	Meters
(locality 21g) were readily identified by Dr. R. Ruedemann as extremely closely related if not identical species to:		
Trigonograptus ensiformis (Hall) *Didymograptus caduceus nanus* Ruedemann *Phyllograptus anna ultimus* Ruedemann cf. *Dichograptus octobrachiatus* (Hall); only fragment of branch *Caryocaris curvilatus* Gurley		
A mile to the northwest a small collection from the same bed of shale but probably a lower zone than that of 21g included the following genera and species as identified by Dr. Ruedemann. (Locality 16x.)		
Didymograptus cf. *spinosus* Ruedemann *Didymopraptus* sp. (fragment) *Phyllograptus* (cf.) *ultimus* Ruedemann *Glossograptus* cf. *hystrix* Ruedemann *Climacograptus* cf. *pungens* Ruedemann *Diplograptus* cf. *dentatus* Brongniart		
"Of the species cited above, all occur in my bed 7 of the Deepkill section (top of the Deepkill shale) except *Did. spinosus* which is found in a lower horizon at the Ashkill quarry at Mount Moreno near Hudson, N. Y. This bed belongs to the base of the zone with *Dipl. dentatus.* The form from the Sinclair Canyon zone is a larger and probably different species." (Ruedemann.)		
In the lower portion of the Sarbach formation at Fossil Mountain, 8.7 miles (13.9 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, a few graptolites were found in a compact hard gray limestone. Dr. Rudolf Ruedemann identified two forms, *Phyllograptus ilicifolius* Hall var. *major* Ruedemann, *Didymograptus* sp. nov. (*pacificus* Ruedemann). He wrote that the faunule may be of Beekmantown (Canadian) age.		
2b. Band of dark silicious, impure, almost black, limestone that breaks down on weathering slopes into shales and very thin layers	28	8.5
2c. Arenaceous and silicious shale that gradually passes about 55 feet (16.7 m.) above the base into grayish black argillaceous shale with thin interbedded layers of limestone	290	88.4
Total of 2	1,025	312.4
Total of Sinclair formation	1,655	504.4

See Sinclair formation, p. 34.

Observations.—In thin-bedded gray and more or less arenaceous and silicious limestones that occur near a fault about half way between the second and third bridges from the mouth or Gates of Sinclair Canyon, a fauna occurs that corresponds to the lower zone of the Sarbach formation of the Clearwater River section, and which may represent the fauna near the base of 2b of this section. The fauna includes (locality 16z):

Receptaculites
Obolus sp. undt.
Obolus sp. undt.
Protorthis iones Walcott
Asaphus ?

A mile to the northwest beneath the shale carrying the graptolites noted under 2a, there is a series of light gray, more or less ferruginous, brown weathering, thin-bedded silicious cherty layers with annelid borings running through them in all directions; the borings are filled in with a dark brown, fine arenaceous material that disintegrates more readily than the matrix, leaving many holes and cavities.

	Feet	Meters
Estimated thickness	250	76.2

It is probable that these beds represent a local development below the base of 2a.

The Wonah Ridge portion of the Sinclair Canyon section supplements the upper portion (p. 21) of Stoddart-Dry Creek section and gives a definite limit to the upper horizon of the Mons formation, also the thickness of the Ordovician Sinclair shales between the Mons and the Wonah quartzite.

OZARKIAN

Mons Formation:

	Feet	Meters
1. More or less irregular dove gray limestone in layers and bands varying in thickness from a few inches (1 to 10, 2.5 to 25.4 cm.) to 2 to 6 feet (.6 to 1.8 m.) and interbedded at irregular intervals in a gray calcareous impure shale	545	166.1

Strike near base of exposure above talus slope. Strike N. 45° W., Dip N. 20° N. E.

Fauna.—At summit (21h):

Obolus sp.
Lingulepis cf. *acuminata* (Conrad)
Xenostegium 2 sp.
Fragments of trilobites

Just above the talus slope on Wonah Ridge, about 500 feet (152.4 m.), below summit of 1, fragments and sections of *Ozarkispira leo* Walcott occur in a hard dove colored layer of limestone.

A thin layer of hard gray limestone a little below the *Ozarkispira leo* layer afforded a few cranidiæ and a pygidium of *Hystricurus* sp. (Locality 21q.)

Note.—I did not find in Sinclair Canyon that portion of the Mons formation that occurs between the *Ozarkispira leo* zone of the Wonah Ridge section and the *Hungaia* faunule zone that occurs in the highest beds exposed of the Mons formation, east of the great fault, as found at the first bridge near the mouth of Sinclair Canyon; the missing strata in the interval are filled in from the Stoddart-Dry Creek section 5 miles (8 km.) to the south where the strata that occur between the two faunules are 356 feet (108.5 m.) in thickness.

	Feet	Meters
2. Mons limestones and shales concealed by débris on Wonah Ridge	356	108.5
The measured section is taken up again just below the first bridge at the eastern end of the Gates of Sinclair Canyon, where a fault with a hade to the west brings the massive limestones of the Beaverfoot formation against and partly over the limestones and shales of the *Hungaia* zone of the Mons. (See pl. 5.)		
3. The upper portion is formed of compact, hard gray and steel gray limestones in rather thin layers with bands of calcareous shaly partings varying in thickness from a millimeter up to several feet. About 200 feet (60.9 m.) from the top the limestone is in layers from 2 inches (5 cm.) to 2 or 3 feet (.6 or .9m.) thick and largely composed of small irregular oval lumps and small bits of limestone in a hard compact calcareous matrix, the whole forming a typical intraformational conglomerate.	1,030	313.9

Fauna.—At 170 feet (51.8 m.) below the top the *Hungaia* faunule occurs in a layer of hard gray limestone, and it was found to continue down through 168 feet (51.2 m.) of shales and interbedded limestones. I found a single pygidium of *Hungaia* in the upper layer where Dr. E. M. Kindle of the Canadian Geological Survey collected considerable material that includes two species of *Hungaia* (21e).

At the base of the *Hungaia* zone as now known, 168 feet (51.2 m.) below 21e, the faunule includes (locality 21f):

Lingulella ibicus Walcott
Eoorthis putillus Walott
Hungaia sp.
Symphysurina sp.
Apatokephalus ? sp.
Xenostegium ? sp.
Hystricurus sp.

At 405 feet (123.4 m.) below the top the *Symphysurina* fauna is abundant but badly broken up. Near the base the following faunule was found (loc. 16q):

Obolus ion Walcott
Obolus sp. undt.
Lingulepis nabis Walcott
Lingulella ibicus Walcott
Lingulella nepos Walcott
Syntrophia perilla Walcott
Acrotreta sp. undt.
Billingsella coloradoensis (Shumard)
Eoorthis putillis Walcott

Feet Meters

Protorthis porcias Walcott
Cyrtolites mystes Walcott
Agnostus sp.
Hystricurus briscoensis n. sp.
Hystricurus cinctus n. sp.
Hystricurus dorsatus n. sp.
Hystricurus venustus n. sp.
Symphysurina 3 sp.
Kingstonia sp.

The base of 3 is an arbitrary line selected owing to the presence of a fault having a hade of 50° north 25° east. The displacement of the beds is not great although the layers are upturned and more or less contorted on the southwestern side. (See pl. 6.) Comparing the section with the Stoddart-Dry Creek section 5 miles (8 km.) to the south it is probable that about 250 feet (76.2 m.) of strata have been duplicated by the fault.

3a. Strata duplicated by fault, estimated, 250 feet (76.2 m.).

3b. Layers of limestone varying in thickness from one or two inches (2.5 or 5. cm.) to two or three feet (.6 or .9m.), alternating with beds of calcareous shale, the limestones predominating. The limestones are usually dark gray in color, compact, dense and tough except where they take the form of intraformational conglomerate. An occasional layer of lighter gray softer limestone carries many fragments of trilobites and brachiopods. Thickness, 925 feet (281.9 m.) less 250 feet (76.2 m.) duplicated by fault 675 205.8

Fauna.—Near the summit of 3b the *Syntrophia* and *Symphysurina* faunules similar to those of the Stoddart-Dry Creek section occur and they may also be found southwest of the fault in the base of 3 (locality 21e).

Obolus cf. *tetonensis* Walcott
Eoorthis putillus Walcott
Syntrophia cf. *calcifera* Walcott
Symphysurina
Hystricurus
cf. *Isoteloides*

4. The change between the base of No. 3 and the summit of No. 4 is in the increased proportion of the shales and the thinning of the layers of limestone. These shales with their interbedded layers of limestone continue up the canyon with an average dip of 70° to 80° west to southwest. In the lower portion dirty gray argillaceous shales predominate and have only a few thick (6 to 15 inches, 15.2 to 38.1 cm.) interbedded layers of hard, finely semi-crystalline gray limestone with some intraformational conglomerate and near the base a few thin, almost shaly, layers of compact, fine-grained, dove colored limestone.

	Feet	Meters
The shales at the base are in direct contact with the massive magnesian limestones beneath.		
Total measured thickness of No. 4	1,220	371.9
Near the base the strata strike north 25° west and dip 70° south 25° east.		

Fauna.—From 30 to 75 feet (9.1 to 22.8 m.) above the base, just below the hot springs, a small and characteristic fauna occurs in the shales and thin layers of limestone. (Locality 21d.)

Lingulella cf. *similis* Walcott
Lingulella cf. *desiderata* Walcott
Eoorthis cf. *iophon* Walcott
Taenicephalus sp.
Ptychostegium sp.
Ptychoparia sp.

At about this horizon on the opposite side of the canyon 450 feet (137.1 m.) above the canyon bottom there was found (locality 17p):

Obolus cf. *leda* Walcott
Agnostus cf. *josepha* Hall
Agraulos sp.
Ptychaspis sp.
Irvingella ? sp.
Saratogia cf. *wisconsinensis* Owen
Briscoia opimius Walcott

About 500 feet (152.4 m.) above the canyon bottom and 400 feet (121.9 m.) above the base of No. 4 in the section the *Briscoia* fauna occurs in thin layers of limestone through 50 feet (15.2 m.) or more of the shale. (Locality 16t′)

Obolus 2 sp. undt.
Lingulella cf. *desiderata* Walcott
Agnostus
Briscoia dalyi Walcott
Saukia sp.
Saukia maurus Walcott
Saukia numenia Walcott
Briscoia sinclairensis Walcott
Briscoia superlata ? Walcott
Kingstonia sp. a
Platycolpus sinclairensis
Plethopeltis ? sp.

In a band of interbedded layers of dove gray limestone 30 inches (76.2 cm.) thick 600 feet (182.8 m.) from the base of No. 4, a small, strongly marked *Symphysurina* faunule occurs. (Locality 16u.)

Obolus cf. *tetonensis* Walcott
Lingulella ibicus Walcott
Billingsella archias Walcott
Eoorthis ochus Walcott
Syntrophia cf. *isis* Walcott
Syntrophia cf. *calcifera* Billings
Platyceras
Straparollus
Agnostus sp.
Symphysurina ? sp.

SUMMARY OF SECTION OF MONS IN SINCLAIR CANYON SECTION

	Feet	Meters
1. Limestone with shaly partings	545	166.1
2. Concealed (estimated)	356	108.5
3. Limestone and shales	1,705	519.7
4. Shales with little limestone	1,220	371.9
Total Mons	3,826	1,166.2

UPPER CAMBRIAN

Lyell ? Formation (See p. 39):

Beneath the base of the Mons at the Radium Hot Springs bathing pool there is a thick-bedded, coarse, steel gray limestone that differs in character from the Silurian and all other limestones in the Sinclair Canyon section. It is similar to a limestone at the base of the Mons in the Stoddart-Dry Creek section 5.5 miles (8.8 km.) to the south, and in the Sabine Mountain section 34 miles (54.7 km.) further south at the south end of the Stanford Range. The stratigraphic position of this limestone is referred to on page 39.

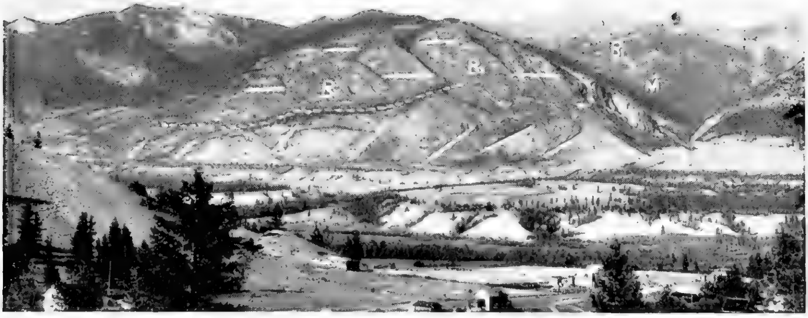
	Feet	Meters
1. Massive rough weathering cliff-forming semi-crystalline gray magnesian limestone in layers 2 to 20 feet (.6 to 6. m.) in thickness	860	262.1

Strike N. 15° W. Dip 45° S. 75° W.

The lowest layers exposed strike N. 5° W. and dip 50° E.

This limestone is here cut off below by a great fault that brings the Red Wall Breccia of presumably Silurian age against it. The fault is vertical and strikes N. 15° W., which causes it to cut obliquely across the Lyell limestone and into the lower Mons shales a short distance north of the canyon.

Note.—The hot springs originate on the line of the Red Wall fault and the water running through breaks in the upper beds of the Lyell ? limestone comes out on the contact between the limestone and the lower Mons shales just above the bathing pool.



1. Looking across Columbia River Valley to the west face of Stanford Range between Stoddart Canyon on right and Dry-Creek Canyon on left. At the mouth of Stoddart Canyon the Upper Cambrian Lyell ? limestones (L.) form a low cliff and to the left of the canyon foothills of Mons shales and limestones (M.) abut against the cliffs of Silurian Brisco (B.) and Beaverfoot (Br.) limestones. The strike of the Mons and the Silurian strata is indicated by short lines and the position of the fault between the Mons and the Brisco limestones by a dotted line. A second block of the Mons and Silurian further up Stoddart Canyon is indicated by the letters M., Br. The Red Wall fault and breccia are shown on the face of the high cliffs to the left, which are a short distance south of Sinclair Canyon. (Photo by Walcott, 1923.)

2. Southwest end of Sabine Mountain. The Silurian Brisco and Beaverfoot limestones form the higher cliff beneath which the lower Mons shales and limestones (M) slope down to contact with the Upper Cambrian Lyell ? limestone (L). The position of the fault that has brought the lower limestones against the Lyell ? is indicated by a dotted line. (Photographed by Walcott, 1923, from bluff above Kootenay River bridge.)

A larger scale view of the formations adjoining Sinclair Canyon. Lettering same as plate 7, figure 1.

SUMMARY OF THE SINCLAIR SECTION

	Feet	Meters
Silurian:		
Brisco	1,200	365.8
Beaverfoot	400	121.9
Ordovician:		
Wonah Quartzite	110	33.5
Sinclair	1,655	504.4
Ozarkian:		
Mons	3,826 [1]	1,166.2
Cambrian:		
Lyell ?	860	262.1
Total section	8,051	2,453.9

STODDART-DRY CREEK SECTION

Section between Stoddart and Dry Creeks. The mouth of Stoddart Creek Canyon is on the eastern side of the Columbia River Valley, 7 miles (11.2 km.) north of Lake Windermere and 5.5 miles (8.8 km.) south of Sinclair Canyon.

The mouth of the canyon is flanked on either side by a cliff of massive-bedded, rough weathering, finely semi-crystalline, arenaceous magnesian limestone. The dip on the north side is to the northeast and on the south side slightly to the west-southwest. This limestone dips beneath the shales and interbedded limestones of the lower Mons formation, which extends to the north about one mile (1.6 km.), forming foot-hills up to the high cliffs of massive Silurian limestones that constitute the eastern wall of the valley and the western lower face of the Stanford Range. (See pl. 7, fig. 1.) The shales and limestones of the Mons dip to the northeast so that higher and higher strata abut diagonally and successively against the Silurian (Beaverfoot) limestones. They are separated from the latter by a fault which is a portion of a major fault line along the western side of the Stanford Range. The Mons limestones and shales are a portion of a large block that formerly extended far to the westward prior to the erosion of the "Rocky Mountain Trench." It is about 1 mile (1.6 km.) in length, north and south, and includes the Mons section from near its upper limit down to the *Briscoia* zone at the base. The basal Mons is superjacent to a massive-bedded limestone that occupies the stratigraphic position and has the character of the Upper Cambrian Lyell limestone of the Bow and Saskatchewan Valley sections to the north. West of the measured section, the Mons is buried beneath the high Terrace drift gravels of the Columbia River Valley. (See pl. 7, fig. 1.)

[1] In the Stoddart-Dry Creek section 5 miles (8 km.) south, the Mons is given a thickness of 3,666 feet (1,117.3 m.).

OZARKIAN

	Feet	Meters
MONS FORMATION:		
1. The highest beds exposed are two bands of hard gray intraformational conglomerate limestone some 6 feet (1.8 m.) in thickness separated by 3 feet (.9 m.) of gray silicious shale. (Dip 80° N. 65° east. Strike N. 25° west.)		
Below, there are single layers and bands of hard, silicious steel gray limestone with stringers and very thin layers of gray chert and layers of irregular intraformational limestone conglomerate made up of small lumps of what appears to have originally been calcareous mud, also thin irregular bits of gray limestone with angular or rounded edges, all of which are interbedded with gray silicious shale in which occur thin layers of limestone .25 inch to 2 inches (.6 to 5. cm.) thick. Thickness of 1	705	214.9
Fauna.—Many bits of comminuted tests of trilobites and fragments of shells occur at several horizons but the only recognizable forms found were near the top and consist of a single ventral valve of *Syntrophia* cf. *isis* Walcott, a whorl of a small depressed gasteropod, and a fragment of the test of a trilobite.		
2. Hard, steel gray, fine grained, compact magnesian limestone in layers 12 to 30 inches (30.4 to 76.2 cm.) thick, with much included light gray weathering chert in thin layers .5 to 2 inches (1.2 to 5. cm.) thick, and numerous irregular cherty nodules	83	25.3
A silicious or finely arenaceous shale forms parting between some of the layers.		
Fauna.—No fossils observed.		
3. Alternating bands of calcareous and silicious shale with layers of gray limestone of varying thickness and character; the limestone may be dove colored, compact with conchoidal fracture, hard dark gray with silicious shale in thin irregular laminations, irregular nodules of small size scattered through or mainly composing it, and a few thin layers of soft, gray, more or less finely crystalline limestone crowded with broken and rolled fragments of the tests of trilobites	648	197.5
In the upper 100 feet (30.4 m.) there are a few thin layers of light gray weathering chert running along irregularly with the bedding of the limestone and shale.		
The strike of the beds in the upper two or three hundred feet (60.9 or 91.4 m.) is N. 15° west, and dip 70° N. 75° east.		
Fauna.—In a layer of hard, dove colored to gray limestone 30 inches (76.2 cm.) thick that occurs 113 feet (34.4 m.)		

	Feet	Meters
from the top of No. 3, a number of gasteropods and other fossils were found. These include (locality 17z): *Cyrtolites* sp. *Ozarkispira* *Raphistoma* ? *Agnostus* sp. *Hystricurus* sp. *Bellefontia* sp.		
At 125 feet (38.1 m.) above the base of No. 3, a compact, hard, gray limestone (17y′) contains fragments of the *Hungaia* faunule, and they continue nearly to the base. About 50 feet (15.2 m.) above the base the faunule included (locality 17y): *Obolus tetonensis* Walcott *Lingulella remus* Walcott *Hungaia* sp.		
In a broken section on the north side of Dry Creek this zone gave (locality 17w): *Obolus* sp. undt. *Eoorthis putillus* Walcott *Hungaia* sp.		
At the base of the *Hungaia* zone of this section, about 125 feet (38.1 m.) below 17w, afforded (17w′): *Obolus* sp. *Agnostus* sp. cf. *Conaspis* sp. *Hungaia* sp.		
4. A thick layer of hard, dove colored limestone 6 to 8 feet (1.8 to 2.4 m.) thick on the line of the section, was assumed to mark the base of No. 3; below it there is a thick series of alternating bands of shale and limestone, the latter mostly small irregular nodules and bits of rolled limestone shale (intraformational conglomerate). Thin, even layers of hard, gray limestone also occur irregularly in the shale and with the thicker layers. There is much similarity between the layers above No. 3 and this series	875	266.7
Fauna.—Fragments of the tests of trilobites are abundant in many of the layers of limestone, but it was only in the lower part that recognizable species were collected. These indicate the basal beds of the *Symphysurina* zones of the Sinclair Canyon section.		
A local sigmoid flexure occurs in the strata of this series (4), but by carrying the section east of it, duplication of beds was considered to be avoided.		
5. Alternation of thick (18 to 30 inches, 45.7 to 76.2 cm.) and thin (.25 to 3 inches, .6 to 7.6 cm.) layers of hard, close grained, dark gray limestone..................	195	59.4
6. Greenish argillaceous shale with a few interbedded layers of dark gray limestone...........................	45	13.7

	Feet	Meters
7. Medium gray limestone in layers varying from one to six inches (2.5 to 15.2 cm.) in thickness, with occasional layers 12 to 30 inches (30.4 to 76.2 cm.)	250	76.2
Fauna.—About 80 feet (24.3 m.) below the top of 7, a well marked faunule occurs that contains many specimens of *Syntrophia*. (17x.)		
Eoorthis cf. *putillus laeviuscula* Walcott		
Syntrophia nonus Walcott		
8. Alternating bands of gray limestone and drab gray argillaceous shale	390	118.8
Fauna.—Fragments of trilobites (*Xenostegium* sp.) in limestone about 190 feet (57.9 m.) from the top. (17 o.)		
9. Thick-bedded, dark gray limestone with a few oolitic layers	18	5.5
Fauna.—None observed.		
10. Argillaceous shale with a few interbedded layers of hard bluish gray, more or less intraformational conglomerate limestone	340	103.6
Fauna.—At 170 feet (51.8 m.) below the top numerous fragments of the *Briscoia* faunule occur. (17n.)		
Obolus ion Walcott		
Lingulella ibicus Walcott		
Lingulepis nabis Walcott		
Acrotreta sp. undt.		
Eoorthis cf. *putillus* Walcott		
Briscoia sinclairensis Walcott		
Concealed by débris	117	35.7
Total Mons exposed	3,666	1,117.3

UPPER CAMBRIAN

Lyell Formation (See p. 39):

Below the lowest exposure a drift-covered slope extends down to a cliff formed of a thick-bedded, rough weathering, semi-crystalline, magnesian limestone dipping to the north N. E. 30°. It is unlike any of the limestones above the Mons and corresponds in position to the magnesian limestone beneath the Mons near Fairmount Hot Springs, and at the southern end of Stanford Range on Sabine Mountain east of Canal Flats and east of the Radium Hot Springs beneath the base of the Mons in Sinclair Canyon. (See pp. 20 and 28.)

The thickness of this supposed equivalent of the Lyell limestone is about 125 feet (38.1 m.) down to the level of Stoddart Creek.

SUMMARY OF SECTION OF MONS IN STODDART-DRY CREEK SECTION

	Feet	Meters
1. Limestone with shaly partings	788	240.2
2. Alternating bands of limestone and shale	648	197.5
3. Limestone and shales	1,115	339.8
4. Limestone	250	76.2
5. Shales with little limestone	748	227.9
Concealed by debris	117	35.7
	3,666	1,117.3

Comparison with the Mons of Sinclair Canyon shows that there is an increase of the proportion of limestone in this section and that it will be difficult to compare the details of the two sections without a very close study of the lithology and succession of faunules.

SABINE MOUNTAIN SECTION

Sabine[1] Mountain rises as a bold dark mass between the terraces of Kootenay River on the east and south and the plain of Canal Flats at the head of Columbia Lake on the southwest and west. It forms the southern end of the Stanford Range which extends from Sinclair Canyon 34 miles (54.7 km.) south. The higher ridges and summits of the range are formed of the thick-bedded, hard silicious limestones of the Silurian Beaverfoot and Brisco formations, and it may be that remnants of Devonian limestones occur on the higher points somewhere along the Stanford Range. Professor S. J. Schofield mentions the Devonian in his Canal Flats section.[2] He says: "The eastern wall rises abruptly out of a flat drift-covered floor (Canal Flats). At the base of the wall, the Elko formation (Middle Cambrian) outcrops and is overlain conformably by the fossiliferous Upper Cambrian (Sabine) formation which in turn is overlain by the Devonian limestone." As we found an abundant Silurian fauna in the limestones above the beds referred to the Upper Cambrian, it seems that Schofield identified the "Devonian" on Sabine Mountain by lithologic resemblance to the Devonian of the southern end of the Purcell Range where he found abundant Devonian fossils correlated with the Jefferson limestone fauna of Montana, Idaho and Wyoming.

Shepard mentions the Canal Flats locality of Schofield and cites Schofield, giving a reference to Memoir 76, Geological Survey of Canada, 1915, pages 48, 53-55, but Schofield there refers to the Devonian of the Purcell Range and does not speak of its presence on Sabine Mountain at Canal Flats.

Shepard notes fossiliferous Devonian strata a mile east of Harrowgate in the Beaverfoot Range[3] and Dr. Kirk collected a few finely preserved high middle Devonian fossils from the locality.

We did not find the Devonian on Sabine Mountain and no attempt was made to measure the thickness of the Silurian limestones. The lower, light colored limestones of the Beaverfoot formation has an

[1] Named in honor of Major General Sir Edward Sabine, 1788-1883, physicist and astronomer, President Royal Society 1861-1871, by Palliser.

[2] Trans. Roy. Soc. Canada, 3d Ser., Vol. 14, Sec. IV, 1920, p. 76.

[3] Jour. Geol., Vol. 30, No. 5, 1922, p. 366.

abundant fauna (Richmond), and it is strongly defined by its light gray color for a long distance in the southern cliffs of the mountain.

The contact between the Mons shales and superjacent light gray, buff weathering silico-magnesian Silurian limestone is about 2 miles (3.2 km.) N. 5° W. of Kootenay River bridge (Canal Flats) north of a northeast and southwest fault that cuts across Sabine Mountain from Columbia Lake to the Kootenay River Valley.

The general relations of Sabine Mountain, and an outline of the stratigraphic section are shown by plate 7, figure 2 and text figure 7.

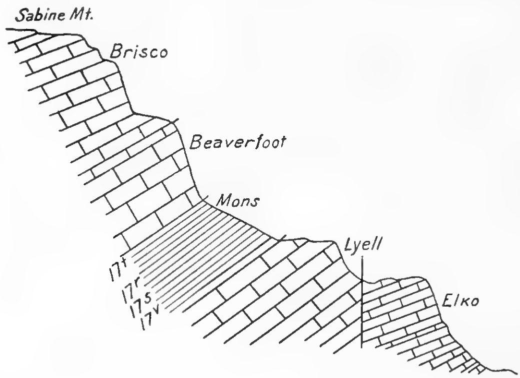


FIG. 4.—Diagrammatic profile section of southwest slope of Sabine Mountain above Canal Flats.

SILURIAN

BRISCO FORMATION:

	Feet	Meters
1. Thick-bedded, dark gray, coarse magnesian limestones. Estimate	1,800	548.6

Fauna.—(See p. 11.)

BEAVERFOOT FORMATION:

	Feet	Meters
1. Compact, light gray magnesian limestones in layers 6 inches (15.2 cm.) to 3 feet (.9 m.) thick, with more or less cherty and silicious matter. Estimate	400	121.9

At the base there is a band of highly silicious light gray limestone about 100 feet (30.4 m.) thick that gives the impression that it is a white quartzite when lighted up by the afternoon sunlight.

Fauna.—(See p. 13.)

DISCONFORMITY:

The Silurian limestones appear to be conformable with the dark, hard, argillaceous shales of the Mons formation beneath. The Wonah Quartzite, 110 feet, (33.5 m.), Sinclair formation, 1,655 feet (504.4 m.), upper and middle portions of the Mons formation, 3,175 feet (967.7 m.), having a combined thickness of 4,940 feet (1,505.7 m.), in the Sinclair section, are not present. There does not appear to be any evidence of the faulting out of these formations or of their removal by erosion prior to the deposition of the Silurian. It appears to be an example of non-deposition and the overlap of the Silurian on the lower Mons in this area.

On the southwest angle of Sabine Mountain the hard upper shales of 1a of the Mons form a dark colored cliff above the softer, light gray shales beneath. In the face of the cliffs on the south face of the mountain there appears to be an unconformity between the Mons and the superjacent Silurian, but this may be only a local upturning of the Mons shale against the massive-bedded Silurian limestone; usually the shales and limestone appear to be conformable.

OZARKIAN

Mons Formation:	Feet	Meters
1a. Dark, compact, argillaceous shales with interbedded irregular layers of hard, compact, gray limestone in stringers and a few layers 3 inches (7.6 cm.) to 12 inches (30.4 cm.) thick	156	47.6
Fauna (near top locality 17t.) *Billingsella* origen Walcott *Huenella juba* Walcott Fragments of trilobites		
1b. Compact, hard, gray limestone	6	1.8
1c. Somewhat softer, dark gray shale with occasional interbedded, more or less irregular layers of dark gray limestone	54	16.5
1d. Massive-bedded thin layers hard gray limestone with parting of gray shale	48	14.6
Fauna (locality 17r.) *Obolus* sp., fragment *Eoorthis iophon* Walcott *Eoorthis* cf. *wichitaensis* Walcott *Agnostus* cf. *josepha* Hall *Ptychaspis* 2 sp. *Conaspis* cf. *anatina* Hall Cf. *Saratogia wisconsinensis* Owen		
1e. Compact, hard, gray, buff weathering limestone in layers 6 to 14 inches (15.2 to 35.5 cm.) thick	4	1.2
Strike N. 20° W., Dip 40° N. 70° E.		
1f. Gray shale with layers of buff weathering gray limestone .25 inch (.6 cm.) to 6 inches (15.2 cm.) thick that at 17 feet (5.2 m.) down form a solid band of layers, the shale having disappeared	29	8.8
Total	297	90.5

Fauna (locality 17s.)

Obolus sp. undt.
Agnostus cf. *josepha* Hall
Ptychaspis sp.
Cf. *Saratogia wisconsinensis* (Owen)

The section was here followed south along the southwest face of Sabine Mountain to where the rise in dip brought lower beds above the débris slope, and where at the southwest angle of the mountain the section of the Mons is exposed from the disconformity at the base of the Silurian to the contact with a massive magnesian limestone below, which is assumed to be the equivalent of the Lyell of the Glacier Lake section.

	Feet	Meters
1g. Just below the limestone of 1f, shale with interbedded stringers and thin layers and flat nodules of limestone appear which contain the *Briscoia* fauna, which also occurs in thin pieces of limestone on the débris slope of the section of 1f above..........................	170	51.8
Strike N. 25° W., Dip 50° N. 65° E.		
Fauna.—Fragments of *Briscoia* cf. *sinclairensis* Walcott similar to those of locality 17s were found in the upper portion of 1g. (Locality 21p.)		
1h. Buff colored arenaceous shale weathering reddish buff brown with a few interbedded layers of gray limestone. The shales become slightly coarser at 200 feet (60. 9 m.) down	275	83.8
Fauna.—A small fauna occurs in a thin interbedded layer of soft gray limestone 54 feet (16.5 m.) below the summit of 1h that contains the following species (locality 17v):		
Obolus cf. *leda* Walcott		
Acrotreta sp. undt.		
Agnostus sp.		
Ptychaspis sp.		
Ellipsocephalus ? sp.		
Total Mons	742	226.1

The distinction between 1g and 1h is a gradual decrease of limestone and argillaceous shale and an increase of fine arenaceous sediment. As seen in cliffs there is very little change indicated except by the color.

UPPER CAMBRIAN

Lyell ? Formation:

	Feet	Meters
The Mons shales are superjacent to an outcrop of thick-bedded, semi-crystalline, gray magnesian limestone that I have referred to the Upper Cambrian and correlated with the Lyell formation of the Saskatchewan-Glacier Lake area 139 miles (223.6 km.) to the north.[1] Thickness	400	121.9

A fault here cuts across the lower southwest end of the mountain (pl. 7, fig. 2) that has displaced a mass of bedded magnesian limestone so that it forms a high knoll with a southwestward facing cliff the base of which is nearly on the plain of Canal Flats. The upper 300 feet (91.4 m.) of this cliff and knoll is formed of thick beds of limestone similar to those beneath the

[1] See p. 39.

Mons shale above but below this portion the layers are more even and gradually became thinner and the limestone is more silicious, finer grained and not at all semi-crystalline. This limestone may possibly represent a part of the Elko formation as seen at Grainger Mountain on the west side of the Kootenay Valley, 3 miles (4.8 km.) east of Sabine Mountain or it may be the lower part of the Lyell ? limestone.

GRAINGER MOUNTAIN SECTION

The term Grainger Mountain is here applied to a mountain that rises from the Kootenay Valley where the valley bends west to merge into the "Rocky Mountain Trench" opposite Canal Flats. It is about 3 miles southeast of Sabine Mountain and is outlined on the north and east by the canyon of Whitetail Creek, and to the south it extends as a ridge that merges into the high ridges between Kootenay River and Sheep Creek. Its summit is about 4 miles (6.4 km.) east-northeast of Kootenay River bridge.

The name Grainger is derived from the old Grainger ranch which is located at the west foot of the mountain on Kootenay River.[1]

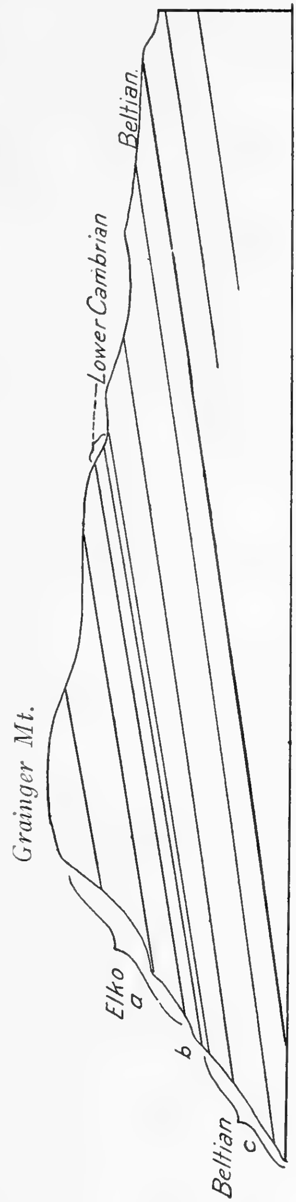


Fig. 5.—West face of Grainger Mountain facing Kootenay River bridge and Canal Flats, British Columbia, Canada. (*a*) Elko (Cathedral) formation. Light gray magnesian limestone in thick layers. Upper Cambrian. 1800 feet. (548.6 m.) (*b*) Mt. Whyte. Mesonacidæ fauna. Impure limestone and arenaceous shales. Lower Cambrian. 400 feet. (121.9 m.) (*c*) Beltian.

Between the Lower Cambrian limestone and the base of the Elko (Cathedral) there is a covered space of about 500 feet (152.4 m.) in thickness of beds, which may form the Middle Cambrian Burton formation. The limestones dip steeply to the northeast and eastern sides of the mountain.

At the summit of the mountain and on the north slope there is a great thickness of gray magnesian limestone that was presumably overlain by shale or thin-bedded limestone, as on

[1] Name approved by the Geographic Board of Canada, November, 1923.

all sides the limestone is the surface rock and the superjacent beds have been removed by erosion so as to form deep canyons.

The west face of the mountain shows the Beltian beneath, with Lower Cambrian Mt. Whyte formation resting on it. The section was hurriedly examined with the following result.

CAMBRIAN

Elko Limestone:	Feet	Meters
1. Thick-bedded, hard, gray magnesian limestone in ledges and broken down cliffs. (Estimate)	1,800	548.6
Concealed by débris	500	152.4
The débris may cover the shales and limestones of the Middle Cambrian, Burton formation.		

LOWER CAMBRIAN

Mt. Whyte ? Formation:		
1. Silicious and arenaceous shales with some calcareous layers in the upper part	400	121.9

Fauna.

Micrometra (P.) *labradorica* Billings
Kutorgina cingulata Billings
Nisusia festinata (Billings)
Wanneria sp.
Olenellus cf. *argenta* Walcott
Olenellus cf. *fremonti* Walcott
Olenellus ? sp.
Corynexochus fieldensis Walcott

Prof. Schofield found in addition to the above *Stenotheca rugosa* Hall and an *Agraulos*-like cranidium of a small trilobite.

Sandstone with many small white quartz pebbles. (Estimate)	125	38.1
Disconformity.		

BELTIAN

Reddish brown argillites, hard sandstones, and fine conglomerate. Estimate	1,000 +	304.8

The above section is introduced here as it is the nearest to the Beaverfoot-Brisco-Stanford Range in which undoubted Cambrian occurs. Prof. S. J. Schofield discovered Lower Cambrian fossils at the north end of Grainger Mountain and sent them to me for examination and published a list of the genera and species in 1922[1] with my comments on the fauna as follows:

The various species mentioned above are characteristic of the Lower Cambrian Mount Whyte formation of the section at McArthur Pass and 3 miles east of Field, B. C. There is nothing to suggest a Middle Cambrian fauna

[1] Geol. Surv. Canada, Geol. Series No. 42, Bull. No. 35, 1922, p. 14.

except such forms as *Ptychoparia* and *Agraulos*. If the typical Burton is of Middle Cambrian age, then this formation is not to be correlated with the Burton but with the Mount Whyte formation.

The section of the Burton near Elko, B. C., as published in 1914, indicated that 5 of the section is to be compared with Ptarmigan formation (Middle Cambrian) and 4, 3, 2 with the Mount Whyte formation (Lower Cambrian) of the section at Kicking Horse Pass, east of Field, B. C.

Mrs. Walcott and I collected a number of species that are listed in the section (*ante*, p. 30), but we were unable to find any fossils in the great limestone tentatively referred to the Elko. This limestone occupies the stratigraphic position of the Middle Cambrian Cathedral limestone of the Mt. Stephen section 92 miles (148 km.) to the north, and may possibly be a southern continuation of it. A study of the area eastward of Grainger Mountain to and including the formations at the head of Palliser River will probably be necessary before a satisfactory correlation can be made.

NOTES ON GEOLOGICAL FORMATIONS OF THE WESTERN SIDE OF THE BEAVERFOOT-BRISCO-STANFORD RANGE

This mountain range has had three names given to it as follows: Beaverfoot for the northern section between Kicking Horse Canyon east of Golden and Harrogate Canyon 33 miles (53 km.) to the south; Brisco for the middle section from Harrogate to Sinclair Canyon 31 miles (49.9 km.), and Stanford for the southern section between Sinclair Canyon and the end of the range where the Kootenay Valley enters the "Rocky Mountain Trench" 36 miles (57.9 km.), thus burdening geographic nomenclature with two unnecessary names for a continuous range topographically and structurally having a length of 100 miles (160.9 km.). It is delimited on the east by the deep Beaverfoot-Kootenay River trench, and on the west by the great "Rocky Mountain Trench" in which the Columbia River rises and flows to the north. These remarks serve to explain why I use the composite name for the range and the letters B. B. S. for it in these notes.

DEVONIAN

The most recent geological formation known to occur in the B. B. S. Range is the Devonian limestone corresponding in position to the Pipestone formation of the Clearwater Canyon area (p. 51), 20.5 miles (32.9 km.) north of Lake Louise Station on the Canadian Pacific Railway. The Devonian limestones of Harrogate Canyon were examined by Dr. Edwin Kirk who estimated that there was about 500 feet (152.4 m.) in thickness exposed between two faults.

He collected a few fossils corresponding in age to those of the Pipestone formation. A preliminary examination gave

Heliophyllum sp.
Schizophoria maçfarlani Meek
Martinia meristoides Meek
Atrypa reticularis Lin.
Spirifera cf. *compactus* Meek
Productella cf. *lachrymosa* (Con.)

This fauna is referable either to the uppermost Middle Devonian or to the Upper Devonian. (Kirk.)

SILURIAN

The Silurian limestones form the higher summits and ridges of the range from Kicking Horse Canyon to Sabine Mountain. They are grouped under the Brisco and Beaverfoot formations and described in the Sinclair section (p. 11), where the Brisco is assigned a thickness of 1,200 feet (365.8 m.) and the subjacent Beaverfoot 400 feet (121.9 m.). The fauna of the Brisco is about middle Silurian (see p. 11) and that of the Beaverfoot low in the Silurian (Richmond) (see p. 13).

Wonah Quartzite:

This quartzite is subjacent to the Beaverfoot and superjacent to the Sinclair formation which is of lower Ordovician (Beekmantown) age. It was deposited in the interval between the close of the Sinclair and the beginning of the deposition of the Beaverfoot limestones. It may have been deposited by the transgressing Silurian sea or during late Ordovician time. A quartzite at about this horizon in the Beaver Mountains section in northern Utah contains fossils referred to the lower Ordovician (see p. 43).

The Wonah Quartzite has a thickness of 110 feet (33.5 m.) at the Sinclair Canyon section, and a quartzite 800+ feet (243.8+ m.), thick, 60 miles (96.5 km.) northwest on the north end of the Beaverfoot Range (Allan) may possibly be of the same age.

ORDOVICIAN

Glenogle Formation:[1]

This formation is known only from its occurrence near Glenogle station on the Canadian Pacific Railway in Kicking Horse Canyon, and in the north end of the Beaverfoot Range to the south of the

[1] See *ante*, p. 6.

Canyon (Allan). It may be that when the formations of the B. B. S. Range are studied and areally mapped, that the Glenogle shales with their included graptolite fauna will be found further to the south. I looked for it in the Sinclair section on Sinclair Mountain but failed to find its characteristic graptolite faunule. In a collection made by L. D. Burling for the Geological Survey of Canada in a railway cut just west of Glenogle station, Dr. Rudolf Ruedemann identified the following species:

Loganograptus logani mut. *tardus* Ruedemann
Didymograptus serratulus Hall
Didymograptus sagitticaulis Gurley
Didymograptus sp. nov. aff. D. *forcipiformis* Ruedemann
Didymograptus sp. nov. aff. D. *filiformis* Tullberg
Didymograptus spinosus Ruedemann
Cryptograptus tricornis (Carruthers)
Climacograptus antiquus Lapworth
Diplograptus cf. *teretiusculus* Hisinger
Lasiograptus sp. nov.
Glossograptus horridus Ruedemann

His comments on this faunule are as follows:

There may be also two or more other species of *Diplograptus* in the material but they are not well enough preserved to distinguished them readily.

This fauna is a new association of forms indicating a horizon between the Deep Kill and Normanskill shales. This is especially well shown by the presence of such Normanskill types as *Didymograptus sagitticaulis* and *D. serratulus.* together with a later mutation of *Loganograptus logani.* Two of the species here noted were so far known only from the Ashkill quarry faunule (at Mt. Moreno near Hudson, New York; see Graptolites of New York, Mem. 11, p. 25) namely: *Didymograptus spinosus* and *Did. forcipiformis.* (The Glenogle type is somewhat coarser.)

The faunas published by Lapworth from Kicking Horse Pass (1886) and Dease River (1889), contain the most common forms of the present fauna, as *Cryptogr. tricornis, Climacogr. antiquus* (equals *C. caelatus* of Lapworth's list), *Glossogr. horridus* (equals *G. ciliatus* of Lapworth's list), *Diplogr. euglyphus* (variety of *D. teretiusculus*) and *D. teretiusculus, Didymogr, sagitticaulis* (equals *sagittarius*); and therefore belong to the same general horizon as the one collected by Burling.

The locality mentioned by Dr. Lapworth as Kicking Horse Pass should be lower Kicking Horse Canyon, as the collection was made near Glenogle station.

Other localities of the Glenogle graptolite shale probably occur in the folded and faulted shales, but as far as known no one has attempted to make a systematic survey of the numerous exposures in the canyon and the tributary gulches. The Sinclair shale graptolitic faunule (of the Sinclair Canyon section) occurs 3.5 miles (5.6 km.)

below Glenogle, but their stratigraphic relations to the Glenogle shales have not been determined. The evidence of the graptolitic faunules, however, is that the Glenogle shales are superjacent to the Sinclair shales.

SINCLAIR FORMATION:

This is described in detail in the Wonah Ridge section on Sinclair Mountain (p. 14). It should include an extension of the Glenogle graptolitic shales, and the upper part may be equivalent to the latter, but at present we do not know of an unbroken section where the faunas of the two formations occur. It will presumably be found in Kicking Horse Canyon or vicinity, as the Glenogle shale occurs near Glenogle station, and 3.5 miles (5.6 km.) west of there, on both sides of Kicking Horse Canyon. A little below tunnel No. 31-08 on the Canadian Pacific Railway, a thin band of black argillaceous shale is crowded with graptolites on some of its surfaces. In a small collection Mrs Walcott and I made there, Dr. Ruedemann identified the following (locality 21k):

Clonograptus sp. nov. cf. *tenellus* (Linnarsson)
Loganograptus logani Hall
Tetragraptus similis (*bigsbyi*) Hall
Tetragraptus sp. nov. aff. *fruticosus* Hall
Tetragraptus (*Etagr.*) cf. *lentus* Ruedemann
Phyllograptus cf. *typus* Hall (gigantic form)
Didymograptus cf. *extensus* Hall
Didymograptus bifidus Hall
Didymograptus sp. nov. aff. *gracilis* Törnquist

He wrote as follows:

This fauna is decidedly older than the one Lapworth published from the Kicking Horse Pass (=Glenogle). It is a distinct Deep Kill fauna, belonging to the *Didymograptus bifidus* horizon, but containing also some older elements, as the *Clonograptus*, *Tetragraptus* aff. *fruticosus* and *Didymograptus* cf. *extensus*, which suggest a mixture with the preceding horizon.

There is a considerable thickness of brownish gray arenaceous shales above and below the black graptolite shales that are twisted and folded and thrust over westward onto limestones of the Ozarkian Mons formation. The locality is about 3.5 miles (5.6 km.) west of the typical locality of the formation just west of Glenogle. A further study of this section and that of the norh end of the Beaverfoot Range may disclose the relations of the Glenogle shales to the Sinclair shales beneath and the superjacent Wonah quartzite, which appears to be present in the section, or if it is not, to the limestones of the Beaverfoot formation.

Dr. E. M. Kindle wrote me under date of May 10, 1924, "The graptolites which Professor Merle F. Bancroft secured from the Windermere Creek locality were reported upon by Dr. Rudolph Ruedemann, who states that they indicate an horizon near the top of the Deep Kill shale."

This corresponds to the horizon of 2a of the section of the Sinclair Formation on Wonah Ridge above Sinclair Canyon which is 12 miles (19.3 km.) north of Windermere Creek.

Sarbach ? Formation:

The Sarbach formation of the Saskatchewan-Glacier Lake section[1] appears to be represented in the Sinclair Canyon section west of a fault above and east of the fourth bridge by a thickness of 350 to 400 feet (106.6 to 121.9 m.) of thin-bedded, hard silicious limestone and a few thin layers of gray limestone containing a small fauna similar to that occurring at the base of the Sarbach in the Clearwater Canyon section of Alberta. The fauna includes (locality 16z):

Receptaculites sp.
Protorthis ? iones Walcott
Obolus 2 sp. undt.
Asaphus ? sp.

It is possible that the silicious limestone near the base of the Sinclair formation of the Wonah Ridge section may represent the Sarbach. There is too little now known, however, of it in Sinclair Canyon to correlate it definitely but on the evidence of the contained fauna it may be referred to tentatively as representing the lower Sarbach of the Glacier Lake and Clearwater Canyon sections.

The Ordovician as now known includes:	Feet	Meters
Glenogle formation (estimate)	1,700	518.2
Sinclair formation	1,655	504.4
Sarbach ? formation	400	121.9
	3,755	1,144.5

OZARKIAN

Mons Formation:[2]

This formation has an average thickness of 1400 feet (426.7 m.) in the Glacier Lake-Sawback Range area and contains four characteristic faunules *Ozarkispira leo, Hungaia, Symphysurina, Briscoia*. The occurrence of the Mons in Sinclair Canyon[3] was discovered in 1922 but it was not until the middle of the field season of 1923 that

[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15. Idem, Vol. 67, No. 8, 1923, p. 459.

[2] *Idem,* Vol. 72, No. 1, 1920, p. 15; *Idem,* Vol. 67, 1923, pp. 459, 470.

[3] *Idem,* Vol. 74, No. 1, 1923, p. 17.

a full appreciation of the development of the formation in the Brisco-Stanford Range was obtained. It was found that the formation has a maximum thickness of 3,800 feet (1,158.2 m.), and the same four faunules that occurred in it to the north are also present. The extent and character of the formation and of its contained fauna is presented in a preliminary manner in the account of the Sinclair Canyon and Stoddart-Dry Creek sections.

The fine exposures of the formation in the Beaverfoot-Brisco-Stanford Range are the result of faulting and subsequent erosion of the blocks delimited by the faults. On the west side of the range Mons limestones and shales occur west of a major fault that occurs between the several areas of the Mons and the Silurian limestones of the westward facing cliffs of the range. One of the most important of these exposures is that between Stoddart and Dry Creek Canyons (see p. 21). Another is the long, narrow area at Brisco and the outcrops from south of Harrowgate to the Kicking Horse Canyon at Golden. All of these outcrops undoubtedly represent remnants of what was originally a continuous outcrop of Mons from Golden to Canal Flats, and which probably now extend far to the westward beneath the Pleistocene floor of the Columbia River Valley ("Rocky Mountain Trench").

Other major faults occur within the range to the eastward that have delimited long strips of Silurian limestones on the east of the western strip of Mons, also a second north and south strip of the Mons east of the Silurian that extends over 5,000 feet (1,524 m.) up the Sinclair Canyon with a dip of 60° to 80° before it is cut off by the great "Red Wall breccia" fault. Another strip of the Mons occurs east of the Silurian of the "Red Wall breccia" that has an exposure of nearly 6,000 feet (1,828.8 m.) along the canyon, with a high dip (70° to 90° west). How much duplication of strata occurs by faulting and folding in these great exposures of the Mons is not definitely known.

In all known sections the Mons is superjacent to a massive cliff-forming limestone beneath which a strongly developed Upper Cambrian fauna occurs in thin-bedded and shaly limestones. The Mons is succeeded by limestones containing a fauna of lower Ordovician age, unless they are absent by nondeposition as is quite frequently the case. The lower Mons (Briscoia) faunule is strongly related to that of the Upper Cambrian, and the upper faunule has a large proportion of genera of an Ordovician facies. The discussion of the Mons fauna will be taken up after the study of the collections is further advanced and critical comparisons can be made with the Upper Cambrian and lower Ordovician faunas.

The four faunal zones of the Mons are characterized, as far as known, by some one genus that attains its greatest development in each zone (see figs. 6, 7, 8 and 9, p. 38).

The upper zone has *Ozarkispira leo* (fig. 6, p. 38) and a considerable group of other gasteropods associated with it.

The *Hungaia* zone (fig. 7, p. 38) is marked by a great development of that genus.

The *Symphysurina* zone (fig. 8, p. 38) has the greatest vertical range, as representatives of it occur in the basal beds of the *Hungaia* zone and for about 1,400 feet (426.7 m.) beneath.

The *Briscoia* zone (fig. 9, p. 38) ranges through the lower part of the Mons, but is usually confined to a limited thickness of beds.

In considering these zones it must be borne in mind that they are based on limited study and collecting, and that future discovery may extend and combine them or more clearly limit their range.

OZARKISPIRA LEO Walcott n. sp.

Fig. 6. (× 2.) Side view and view of spire from above

This is the type species of the genus.

Locality.—64t, Ozarkian, Mons formation. Fossil Mountain, 8.7 miles (13.9 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

HUNGAIA BILLINGSI Walcott n. sp.

Fig. 7. (Nat. size.) Diagrammatic outline of the cephalon, thoracic segments, and pygidium

This is the type species of the genus.

Locality.—61q, Ozarkian, Chushina formation. Billings Butte (Extinguisher), Robson Peak District, British Columbia, Canada.

SYMPHYSURINA WOOSTERI Ulrich n. sp.

Fig. 8. (× 2.) Diagrammatic outline of cephalon and pygidium

This is the type species of the genus.

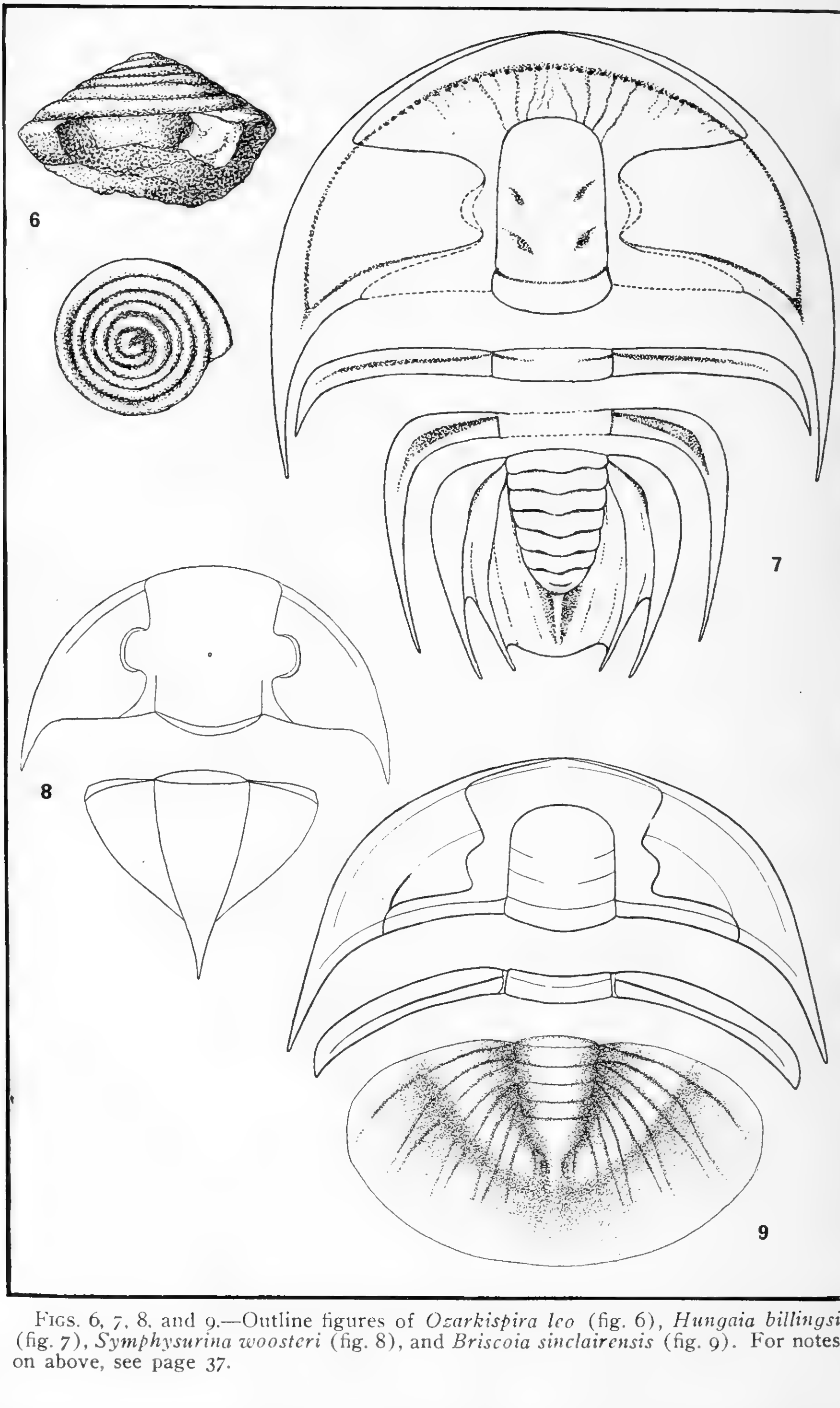
Locality.—193, Ozarkian, Oneota Dolomite. Trempealeau, Wisconsin.

BRISCOIA SINCLAIRENSIS Walcott n. sp.

Fig. 9. (Nat. size.) Diagrammatic outline of a cephalon, thoracic segment, and pygidium

This is the type species of the genus. Fragments of this species occur that indicate individuals more than twice as large as the above figures.

Locality.—16t′, Ozarkian, Mons formation. North side of Sinclair Canyon above Radium Hot Springs. South end of Brisco Range, British Columbia, Canada.



FIGS. 6, 7, 8, and 9.—Outline figures of *Ozarkispira leo* (fig. 6), *Hungaia billingsi* (fig. 7), *Symphysurina woosteri* (fig. 8), and *Briscoia sinclairensis* (fig. 9). For notes on above, see page 37.

UPPER CAMBRIAN

LYELL ? FORMATION:[1]

In the absence of fossils it is a venture to correlate formations that are separated by a distance of from 100 miles (160.9 km.) to 132 miles (212.4 km.) and on opposite sides of the Rocky Mountain Continental Divide, but in the case of the Lyell limestone there is a superjacent fossiliferous formation that contains a similar lower Ozarkian fauna and the lithologic and stratigraphic characters are quite similar. At each locality there is a thick-bedded, semi-crystalline, cliff-forming magnesian limestone subjacent to the shales and interbedded limestones of the Mons formation. The Lyell ? limestone is unlike the Silurian and Devonian limestones of the Beaverfoot-Brisco-Stoddart Range and unlike the Elko Middle ? Cambrian limestone of the ranges to the south and southwest. Under these conditions a tentative reference of the limestone to the Upper Cambrian as a probable representative of the Lyell formation to the north of the Bow Valley-Kicking Horse Canyon valleys seems to be justified. (See pp. 20, 24.)

MIDDLE AND LOWER CAMBRIAN

In Grainger Mountain, a few miles southeast of Sabine Mountain and on the southeast side of the Kootenay Valley, strata of Lower and possibly Middle Cambrian age occur which are described on page 30. Unfortunately there is no section known to me where the relation of the Elko Middle ? Cambrian limestone to the limestone beneath the Mons is shown. That such a section exists east or southeast of the Kootenay Valley is quote probable. When found it may be that some of the Upper Cambrian formations of the Bow Valley-Kicking Horse Canyon sections will be discovered or their absence by nondeposition established.

About 100 miles (160.9 km.) to the north-northwest of Grainger Mountain in the Dogtooth Mountains, at a locality about 4 miles (6.4 km.) west of Golden and 2 miles (3.2 km.) from the mouth of Canyon Creek Canyon, beside an old logging railway, a belt of quartzites occurs with shales, in which calcareous nodules occur, interbedded or above them; these nodules contain many fragments of trilobites and brachiopods of the Lower Cambrian Mt. Whyte formation, and I have identified the following (68d):

Micromitra (Paterina) labradorica (Billings)
Obolus cf. *damo* Walcott
Acrotreta cf. *sagittalis taconica* Walcott
Acrotreta sp.
Callavia ? *nevadaensis* Walcott

[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15. *Idem*, Vol. 67, No. 8, 1923, p. 460.

This fauna is essentially the same as that at the northern foot of Mt. Stephen on the Canadian Pacific Railway and near Cranbrook where Col. C. H. Pollen has collected such fine specimens.

SUMMARY

	Feet	Meters
Devonian:		
Limestones (only a portion)	400 +	121.9 +
Silurian:		
Brisco / Beaverfoot limestones	1,600 +	487.7 +
Wonah Quartzite	110 +	33.5 +
Ordovician:		
Shales { Glenogle	1,700 +	518.2 +
Shales { Sinclair	1,655 +	504.4 +
Limestones (Sarbach ?)	400 +	121.9 +
Ozarkian:		
Mons limestones and shales	3,826 +	1,166.2 +
Upper Cambrian ?:		
Limestones	860 +	262.1 +
Total thickness as measured and estimated	10,551 +	3,215.9 +

NOTE ON THE EXTENSION OF PRE-DEVONIAN FORMATIONS OF THE BEAVERFOOT-BRISCO-STANFORD RANGE NORTH OF KICKING HORSE CANYON

Silurian.—The most recent pre-Devonian formations met with are the Beaverfoot and Brisco limestones of the Silurian, which as far as known to me are not present in the sections at Glacier Lake, the Van Horne or Sawback Ranges. The " Silurian," as mapped by Dr. J. A. Allan, extends some distance north of Kicking Horse Canyon[1] but how far has not been determined.

Ordovician.—The Ordovician Glenogle graptolite shales extend a short distance north across the Kicking Horse Canyon along with the Silurian, but a part of the Sarbach Ordovician limestone and included fauna occur in the Sinclair Canyon section where the shales of the Sinclair formation carry graptolites that may be compared with those found in the Sarbach limestones on the eastern side of the Continental Divide at Fossil Mountain and Glacier Lake; also the fauna of the lower portion of the Sarbach at Clearwater Canyon section may be compared with that of the lower Sinclair in Sinclair Canyon. The Sarbach and Sinclair formations are lithologically dissimilar and unlike in character, which prevents my using the name Sarbach for the strata of about the same geological age in the Brisco and Stanford mountains.

[1] Guide Book No. 8, pt. II, Transcontinental Excursion C. I. Geol. Surv. Can., 1913, Route map between Banff and Golden, p. 189.

Ozarkian.—The comparison with the Mons formation at the type locality at Glacier Lake with the Sinclair Canyon section more than 100 miles (160.9 km.) to the south shows the two to be similar both in lithology and faunas, except that the Sinclair Canyon section is nearly 2.5 times as thick. The character of the limestones and shales and the succession of the sub-faunas is the same, also the stratigraphic position.

Cambrian.—The Mons shales are superjacent to a thick series of magnesian limestones (Lyell) at Glacier Lake and other sections north of the Bow Valley, and the same conditions appear in the Stanford Range at Sinclair Canyon, Fairmount Hot Springs, and Sabine Mountain.

I think we are justified in extending the names Mons and Lyell of the northern sections to similar formations south of the Kicking Horse Canyon into the Beaverfoot-Brisco-Stanford Range.

The continuity in the Cordilleran sea of the sediments now constituting these formations in the " Rocky Mountain Trench " appears to have been along its western side in British Columbia, which is now west of the Continental Divide.

ORDOVICIAN-SILURIAN BOUNDARY

I had not given much attention to the discussion over the " Ordovician-Silurian Boundary " prior to my present study of the formations of the Beaverfoot-Brisco-Stanford Range, but when I found in the Sinclair Canyon section that a quartzite was superjacent to an arenaceous shale (Sinclair) containing graptolites of lower Ordovician (Beekmantown) age and that superjacent to the quartzite a massive limestone (Beaverfoot) contained a large and representative Richmond fauna, I realized that I was at the parting of the ways and must include the Beaverfoot in the Ordovician and thus agree with the " conservatives " in the controversy, or place it in the Silurian and agree with the " progressives." Not having any great interest for or against any particular interpretation, I returned to the field in 1923 with the desire to discover more of the record of what happened prior to the deposition of the Beaverfoot formation with its contained " Richmond " fauna. The section in Sinclair Canyon was re-examined and the line of contact of the Beaverfoot with the formations above and below observed wherever accessible in the Brisco-Stanford Range for 60 miles (96.5 km.) or more. In all sections there appeared to be a conformable contact between the Beaverfoot and superjacent Brisco formations. The Beaverfoot limestones are of a lighter gray color than those of the Brisco but both indicate somewhat similar conditions of sedimentation. We did not find any physical evidence of a systemic break at the upper limit of the Beaverfoot formation. Beneath the Beaverfoot the Wonah Quartzite of the Sinclair Canyon section is formed of a clean wave-washed beach sand more or less cross-bedded and varying in thickness in relative short distances. Subjacent to the quartzite the shales and sandstones of the Sinclair formation of the lower Ordovician were found to be over 1,600 feet (487.7 m.) in thickness, and beneath them occur the limestones and shales of the Ozarkian Mons formation, more than 3,800 feet (1,158.2 m.) thick. At Sabine Mountain 34 miles (54.7 km.) south of Sinclair Canyon the Beaverfoot is superjacent to the lower portion of the Mons. The Wonah Quartzite Sinclair formation and over 3,000 feet (914.4 m.) of the Mons are absent, presumably from nondeposition.

On returning from the field I looked up the occurrence of the Richmond horizon to the south in northern Utah and found that the Fish Haven Dolomite with a Richmond fauna is superjacent to the Swan Peak Quartzite, which in turn rests on the Garden City limestone containing a lower Ordovician (Beekmantown) fauna and beneath the latter the St. Charles formation with a lower Ozarkian (Mons) fauna.

I found that the evidence from the Cordilleran area is in favor of including the Beaverfoot with its Richmond fauna in the Silurian, and the same seems to be true from the diastrophic or physical view wherever a formation carrying the Richmond fauna is superjacent to an Ordovician or pre-Ordovician formation.

The evidence of the faunas has been well presented by Dr. E. O. Ulrich [1] who holds that the break between the Richmond fauna and that of the Maysville of the Cincinnatian is probably greater than that at the summit of the Richmond.

With the physical (diastrophic) record in the Cordilleran Province and the character of the "Richmond" fauna on which to form a conclusion, the Beaverfoot formation of this paper is placed in the Silurian. This is based on the presence of a great disconformity and unconformity at the base of formations carrying a Richmond fauna that is wide-spread on the North American Continent, and the change in the fauna between the Maysville fauna of the Cincinnatian (Ordovician) and the basal fauna of the Silurian (Richmond).

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[1] The Ordovician-Silurian Boundary. Congrès Geol. Int. Compte-Rendu de la XII" Session Toronto 1913, pp. 593-667.

DISCONFORMITY AT THE BASE OF THE SILURIAN BEAVERFOOT FORMATION

The Wonah Quartzite (pl. 4, fig. 1) beneath the Beaverfoot formation is now assumed to represent the initial beach sands of the Silurian (=Richmond) transgression in the same manner that the Mount Wilson[1] quartzite represents the beach sands of the Devonian transgression as it occurs at the headwaters of the Clearwater and Saskatchewan Rivers in Alberta.

Dr. Allan found on the crest of the Beaverfoot Range 15 miles (24.1 km.) southeast of the Canadian Pacific Railway, a quartzite 800 feet (243.8 m.) in estimated thickness that was quite free of impurities and formed of angular colorless quartz grains. This quartzite appeared to be conformably superjacent to the dark argillaceous shales of the Glenogle formation and subjacent to a massive-bedded gray dolomite carrying fossil corals. This fauna is presumably the same as that of the Beaverfoot formation (*ante*, p. 13), to the south in the Sinclair Canyon section.

Fifty-two miles (83.6 km.) to the south in the Sinclair Mountain-Wonah Ridge section, the Glenogle graptolite shales are absent beneath the Wonah Quartzite, and at Sabine Mountain 36 miles (57.9 km.) still further south the Wonah quartzite, Glenogle and Sinclair shales and over 3,000 feet (914.4 m.) in thickness of the Mons formation are absent, the massive Beaverfoot limestones resting conformably along several miles of outcrop on the shales of the lower portion of the Mons formation.

Similar conditions as those in the Sinclair Canyon section exist far to the south in northern Utah[2] where the Swan Peak Quartzite, 500 feet (152.4 m.) in thickness is superjacent to the Garden City limestone in which an Ordovician (Beekmantown) fauna occurs. Above the Quartzite the Fish Haven dolomite, 500 feet (152.4 m.) in thickness, contains a fauna (Richmond) that may be compared with that of the Beaverfoot limestone. Above the Fish Haven dolomite there is a Silurian (Laketown) dolomite, 1,000 feet (304.8 m.) thick, that corresponds to the Brisco formation of the Sinclair section. To complete the correlation between the two widely separated sections, the St. Charles formation beneath the Ordovician Garden City limestone is known to contain essentially the same fauna as the Mons formation.

The Swan Peak Quartzite carries a fauna referred to the lower Ordovician[3] (Chazy ?) which indicates that the transgressing sea

[1] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 464.

[2] Amer. Jour. Sci., 4th Ser., Vol. 86, 1918, pp. 406-411.

[3] Loc. cit., p. 409.

that deposited it was of lower Ordovician age, which may possibly but not probably have been the age of the Wonah Quartzite of the Sinclair Canyon section, as that is superjacent to shales carrying a Beekmantown faunule.

To the north of the Bow Valley-Kicking Horse Canyon section I have not met with any formation of Silurian age. In the Sawback Range and the Main Range along the Continental Divide the Devonian is superjacent to the Ordovician Sarbach formation (Beekmantown), or it may rest directly on the Mons, or there may be the Ghost River or Mount Wilson[1] quartzite, representing the beach sands of the transgressing pre-Devonian sea.

The Beaverfoot-Brisco and early Devonian seas do not appear to have extended into this eastern and northern area. Probably, however, they extended north of the Kicking Horse Canyon along the western side of the Cordilleran sea, west of the Continental Divide, as the same type of Silurian faunas occur in Alaska, where they may have migrated southward.

VARIATION IN THICKNESS OF FORMATIONS

Dr. J. A. Allan, in describing the Ottertail limestone of the Upper Cambrian which occurs on the eastern side of the Beaverfoot canyon valley opposite and northeast of the Beaverfoot Range, states that the formation has a thickness of about 1,640 feet (499.8 m.) on the south slope of Ottertail Valley, and 5 miles (8 km.) south on Limestone Peak north of Washmawapta snowfield it has an approximate thickness of 2,450 feet (746.7 m.), indicating a thickening of over 800 feet (243.8 m.) in a distance of less than 5 miles (8 km.).[2]

Examples of the variation in the thickness of formations similar to that of the Ottertail limestone are found the entire length of the Beaverfoot-Brisco-Stanford Range from Kicking Horse Canyon to its southern end, a distance of about 100 miles (160.9 km.). The Glenogle shale with its Ordovician graptolite fauna appears to thin out and disappears somewhere between Kicking Horse Canyon and Sinclair Canyon. The lower Ordovician Sinclair formation, which has a thickness of 1,655 feet (504.4 m.) at Sinclair Canyon, is not present in the Sabine Mountain section 34 miles (54.7 km.) south; the Wonah Quartzite 110 feet (33.5 m.) thick in Sinclair Canyon, is absent at Sabine Mountain, and on the northern end of the Beaverfoot Range it may be 800+ feet (243.8+m.) thick. The Mons formation 742 feet

[1] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, pp. 463, 464.

[2] Geol. Surv. Canada, No. 46, Geol. Ser., Memoir 55, 1914, p. 86.

(226.2 m.) thick at Sabine Mountain is 3,826 feet (1,166.2 m.) at Sinclair Canyon and 1,480 feet (451.1 m.) at Glacier Lake, 100 miles (160.9 km.) north-northwest.

The above examples serve to indicate the irregular areal deposition of sediments in this section of the " Cordilleran Trough," and others will be given in a future paper dealing with the pre-Devonian formations to the northwest of Bow River Valley.

PRE-PLEISTOCENE FORMATIONS OF THE FLOOR OF THE COLUMBIA RIVER VALLEY ("ROCKY MOUNTAIN TRENCH") FROM CANAL FLATS TO GOLDEN

From our present information it is probable that the Ozarkian Mons formation is subjacent to the greater part of the present Pleistocene deposits of the Valley, and that the pre-Pleistocene Valley from Canal Flats to Golden and north was mainly eroded:

(1) In folded, plicated and faulted Devonian and Silurian limestones.

(2) The subjacent Lower Ordovician grapolite shales of the Glenogle and Sinclair formations.

(3) The shales and interbedded limestones of the Ozarkian Mons formation.

Usually on the western side of the valley the pre-Cambrian Beltian strata are subjacent to the Pleistocene deposits, but in Spillimacheen Mountain a block of Silurian limestone has been dropped by faulting and left by subsequent erosion so that now it adjoins the Beltian on the west and northwest of the north end of Spillimacheen Mountain and stands out as a reminder that the Silurian sea extended over and probably beyond the western limits of the location of the " Rocky Mountain Trench."

The Mons limestones and shales outcrop at intervals on the east side of the valley from Sabine Mountain above Canal Flats at the head of Columbia Lake on the south to and beyond Golden and Kicking Horse Canyon, but they are only remnants that have been left by pre-Pleistocene erosion abutting against the cliffs of massive Silurian limestone or out-cropping from beneath them, as at Sabine Mountain and the northern portion of the Beaverfoot Range; sometimes conformably but more frequently upturned and displaced.

On the west side of the valley, the lower Mons (Briscoia zone) occurs where canyon of Canyon Creek 5 miles (8 km.) south of Golden cuts through the plicated and folded shales and interbedded limestones and these beds continue to the northwest to and beyond Beavermouth and south probably to Spillimacheen Mountain. The few fossils found west of Parson and Donald and heretofore regarded as of Upper Cambrian age, came from the limestones interbedded in the lower Mons shales. The Upper Cambrian is presumably repre-

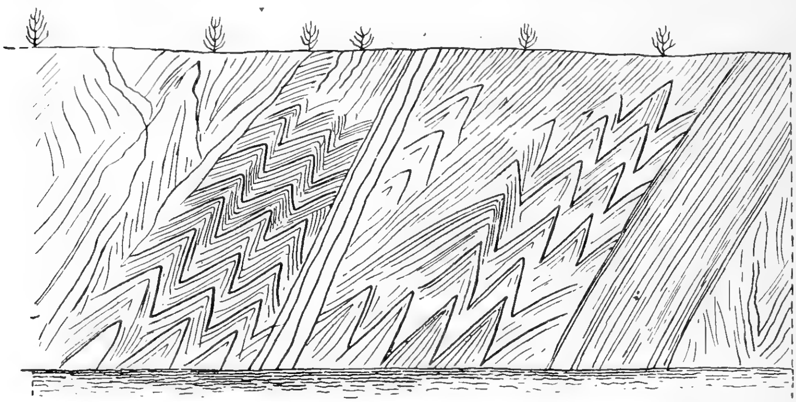

FIG. 10.—Sketch of plicated shales and thin interbedded limestones in cliff near mouth of Canyon Creek canyon.

sented by the massive semi-crystalline magnesian limestones that occur beneath the Mons at Sabine Mountain, Fairmount Hot Springs, Stoddart Creek, and east of the Radium Hot Springs in Sinclair Can-

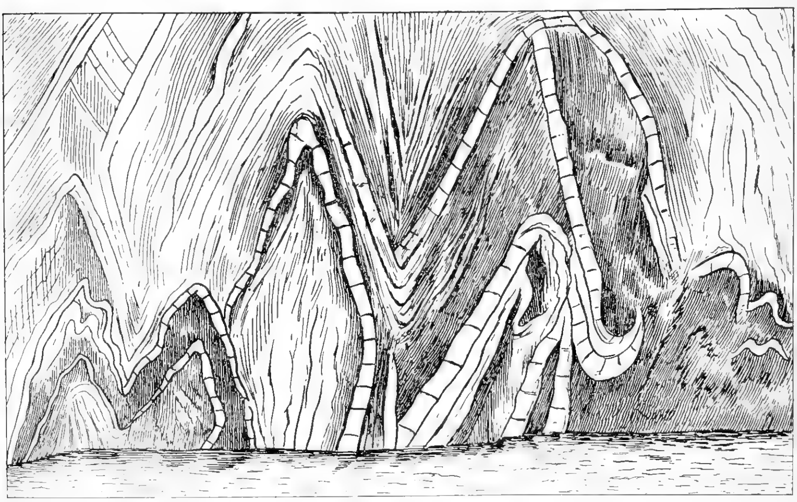

FIG. 11.—Enlarged sketch of plications near those shown by fig. 10.

yon. No fossils have been found in this lower limestone that corresponds in stratigraphic position to the massive Upper Cambrian Lyell limestone of the Glacier Lake and Clearwater sections. The true Upper Cambrian fauna is found beneath the massive Lyell limestone and not above it in all sections north of Bow River Valley in Alberta. The supposed equivalent of the Lyell limestone has not been seen on the western side or projecting from beneath the floor of the Columbia River Valley.

East of Golden in Kicking Horse Canyon the lower Mons shales and interbedded limestones are folded, faulted and upturned for about 3.5 miles (5.6 km.) to where a fault brings them in contact with the graptolite shales of the Glenogle ? formation. Fossils were found in a hurried trip up the Canyon at two zones in the lower Mons.

In the upper, eastern end of Sinclair Canyon the orderly succession from the upper Mons through the lower Ordovician Sinclair graptolite beds to the Wonah Quartzite at the base of the Silurian is preserved; the Glenogle shales have not been identified. (See note on pp. 32-34.)

Conclusion.—From the present position of the pre-Devonian formations in the Beaverfoot-Brisco-Stanford Range and their remnants in the Columbia River Valley from Beavermouth to Canal Flats, it is quite probable that all of the formations extended westward over the area now occupied by the Columbia River Valley and thinned out against a pre-Cambrian land area now included in the Dogtooth and Purcell Mountains.

NEW FORMATION NAMES

SILURIAN

Brisco Formation

Locality.—Upper southwest slope of Sinclair Mountain south of Sinclair Pass and along the western cliffs of the Brisco-Beaverfoot-Stanford Range facing the Columbia River Valley, British Columbia, Canada.

Derivation.—From Brisco Range.

Character.—Dark, rough weathering, finely arenaceous and magnesian limestones. Band of black argillaceous graptolite-bearing rock 100+ feet (30.4+ m.) thick.

Thickness.—Estimated at 1,200 feet (365.8 m.) on Sinclair Mountain, but probably it will be found to be thicker when the upper limits of the formation are determined.

Organic remains.—Brachiopods and graptolites of Silurian age. (Lists on pp. 11-13.)

Observations.—During the field season of 1923, Dr. Edwin Kirk of the U. S. Geological Survey accompanied me in the field and made a detailed study of the Silurian limestones of the Brisco and Stanford Ranges, which are the southern continuation of the Beaverfoot

Range. Prior to this I found in September, 1922, in Sinclair Canyon at the south end of the Brisco Range, a limestone [1] carrying abundant specimens of corals (Halysites, Palæofavosites, etc.) and beneath it a quartzite that occupied an equivalent position to the quartzite at the base of the "Silurian" described by Allan. This limestone is now placed in the Beaverfoot formation and the great limestone above, carrying a Silurian fauna, is placed in the Brisco. Above these Silurian limestones at the north end of the Beaverfoot Range there appears to be a quartzite that possibly may be at the base of the Devonian. In Sinclair Canyon, a band of thick layers of a hard black argillaceous rock occurs interbedded in the massive magnesian limestones. The layers 2 to 3 feet (.6 to .9 m.) thick break down into thin layers on weathering, and these split into shaly pieces, on the surface of which numerous graptolites of Silurian age are abundant. (See p. 12.)

Dr. Edwin Kirk reported on the Silurian Brisco as follows:

"The most complete section of the Silurian seen in the upper portion of Windermere Creek gave a thickness of between 1,000 feet and 1,200 feet. The section is incomplete in its upper portion, being faulted against the Ordovician. The Silurian consists in the main of grayish to brownish fine grained limestones, some layers being slightly dolomitic.

"The fauna in the basal portion of the Brisco (Middle Silurian) is scant consisting mainly of very poorly preserved cyathophylloid corals. However, within 50 feet above the top of the Beaverfoot (Richmond) in the Windermere Creek section, *Pentamerus* was found. Slightly higher stratigraphically but below the *Monograptus* horizon, *Virgiana* was found in abundance in Sinclair Canyon. In the upper portion of the Silurian a more abundant fauna was collected near the head of Windermere Creek, which included:

Halysites sp.
Syringopora sp.
Favosites sp.
Atrypina sp.
Spirifer sp.
Stropheodonta sp."

Beaverfoot Formation [2]
(redefined)

Type locality.—Crests of Beaverfoot Range east of Columbia River Valley and south of Canadian Pacific Railway line in Kicking Horse

[1] Smithsonian Misc. Coll., Vol. 74, No. 5, 1923, p. 17.

[2] Burling, Geol. Mag. London, Vol. 59, 1922, p. 454. Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 463.

Canyon, also westward facing cliffs of the Brisco and Stanford Ranges and the sections exposed near the head of and in Sinclair Canyon, British Columbia, Canada.

Derivation.—Name derived from Beaverfoot Range.

Character.—Thick-bedded, cliff-forming, rather coarse, gray dolomites, weathering to a light gray color and rough surface.

Thickness.—Estimated to average 400 feet (121.9 m.).

Organic remains.—Lists on p. 13.

Observations.—This formation is a fine horizon marker from the north to the south ends of the Beaverfoot-Brisco-Stanford Range, a distance of over 100 miles (160.9 km.). Burling in his section assigns numbers 1-13 to the Beaverfoot, but it is quite evident that he has included strata (9-13) that belongs elsewhere (*ante,* p. 6).

Dr. Kirk's report on the Beaverfoot (Richmond) fauna is given *ante,* p. 13.

Sabine Formation

(A SYNONYM OF MONS FORMATION)

Prof. S. J. Schofield suggests the name Sabine[1] "for the fossiliferous Upper Cambrian formation that conformably overlies the Elko formation," on Sabine Mountain, which is in turn overlain by the Devonian limestone. I found the fauna of the fossiliferous formation (Sabine) to be that of the lower Mons formation of the Ozarkian[2] and that of the limestones above to be Silurian and not Devonian, also that the probabilities are that the "Elko" formation is not the true Middle Cambrian Elko of Schofield but the representative of the Upper Cambrian Lyell formation of the region north of the Bow Valley-Kicking Horse Canyon area.

The identification of the fossils, found by Schofield, as of Upper Cambrian age is in agreement with their general character, but at the time the strong resemblance of the lower Mons fauna to that of the Upper Cambrian was unknown. The name Sabine appears to be a synonym of Mons.

Wonah Quartzite

Type locality.—Southwest slope of Wonah Ridge of Sinclair Mountain above Sinclair Canyon, at the northern end of the Stanford Range, British Columbia, Canada.

Derivation.—Name derived from Wonah Ridge.

Character.—Thick-bedded, white to grayish-white quartzite.

[1] Trans. Roy. Soc. Canada, 3d Ser., Vol. 14, Sec. IV, 1920, p. 76.

[2] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.

Thickness.—Variable as it ranges from 42 feet (12.8 m.) to over 100 feet (30.4 m.) in a distance of 2 miles (3.2 km.).

Organic remains.—No fossils found. A quartzite (Swan Peak) in the Bear River Range of Northern Utah, occupying about the same stratigraphic position, contains fossils that indicate its age as lower Ordovician and probably Chazyan. (See p. 43.)

Observations.—The Wonah Quartzite appears to represent the beach sands of the transgressing waters at the beginning of Silurian time in this area of the Cordilleran sea. It may be compared tentatively with the quartzite described by Allan that occurs above the Glenogle graptolite shales and beneath the Silurian limestones at the northern end of the Beaverfoot Range.[1]

ORDOVICIAN

Sinclair Formation

Type locality.—Sinclair Canyon.

Derivation.—Name derived from Sinclair Canyon.

Character.—Thin layers of sandstone and arenaceous shale with bands of silicious impure limestone in lower portion.

Thickness.—At Wonah Ridge on Sinclair Mountain, the only locality where the entire section was observed, 1655 feet (504.4 m.)

Organic remains.—See p. 15.

Observations.—It is not improbable that in No. 1 of the Sinclair formation, the Glenogle shale graptolite fauna may be found. If it is, then the 630 feet (192 m.) of No. 1 should be referred to the Glenogle formation and the Sinclair correspondingly reduced in thickness.

DEVONIAN

Messines Formation

MIDDLE DEVONIAN

Type locality.—Head of Glacier Lake Canyon valley above the Mons Glacier and on the slopes of Mount Messines which rises above the Mons icefield on the Continental Divide about 3 miles (4.8 km.) southeast of Mount Mons, which is about 50 miles (80.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Mount Messines.

Character.—Dark, rough weathering, thick-bedded, cliff-forming, magnesian limestone.

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[1] Geol. Surv. Canada, No. 46, Geol. Ser. Memoir No. 55, 1914, pp. 101, 102.

Thickness.—Estimated for the Mons-Messines section, 1,000 feet (304.8 m.). In the Clearwater Canyon section 33 miles (53.1 km.) east-southeast the measured section is 663 feet (202 m.).

Organic remains.—Middle Devonian. At Glacier Lake Canyon:

Stromatopora sp.
Cyathophyllum sp.
Atrypa reticularis (Linn)

At Clearwater Canyon the collection from 100 to 105 feet (30 to 32 m.) above the base gave:

Stromatopora sp.
Crinoid columns
Gomphoceras sp.
Atrypa reticularis (Linn)
Stropheodonta sp.
Palaeoncilo sp.
Identified by Dr. Edwin Kirk.

Observations.—Systematic collecting at the Clearwater Canyon locality would add a number of species not in the small collection that was hurriedly made when measuring this part of the Devonian section.

Pipestone Formation

UPPER DEVONIAN

Type locality.—Section on northeastern side of Pipestone Pass down over the slopes of Devon Mountain to the level of Clearwater Canyon, about 2 miles (3.2 km.) from the head of the canyon. Pipestone Pass is 9 miles (14.4 km.) north of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

Derivation.—From Pipestone Pass at the head of Pipestone River.

Character.—Compact light gray limestone in thin layers with some silicious cherty stringers and nodules and silicified fossils.

Thickness.—At the type locality there is about 1,200+ feet (365.8+ m.) between the Banff shale above and the Messines formation below.

Organic remains.—Upper Devonian corals as follows:

Pachyphyllum woodmani (White)
Cyathophyllum sp.
Heliophyllum sp.
Striatopora sp.
Cladopora sp.
Romingeria sp.
Atrypa reticularis (Linn)
Identified by Dr. Edwin Kirk.

Observations.—The exposure of the strata at Pipestone Pass and over Devon Mountain to Clearwater Canyon is an unusually complete and fine one, and a large collection of fossils could readily be made by a competent collector.

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

No. 2.—CAMBRIAN AND LOWER OZARKIAN TRILOBITES

(WITH PLATES 9 TO 14)

BY
CHARLES D. WALCOTT

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(With Plates 9 to 14)

INTRODUCTION

The field work of the past decade has resulted in the accumulation of extensive collections of fossils from the Cambrian and Lower Ozarkian formations. In order to aid in the delimitation of geological formations preliminary studies were made of portions of the material and names assigned to supposedly new genera and species. A few of these have been used in published lists and the study of the brachiopods published.[1] Realizing that the publication of generic and specific names of the trilobites without description and illustration was of little service it was decided to print from time to time the new genera and species. In this paper are presented in an outline form characterizations of those genera which were ready for preliminary publication. These are presented at this time to meet the needs recently expressed by a number of field workers. No attempt has been made to group the genera in biological or geological order.

Dr. E. O. Ulrich has been studying the faunas of the Upper Cambrian and Ozarkian formations, especially of the Mississippi province for many years, giving special attention to the trilobites. When unpublished genera and species were found in the collections that he had already identified and named his work was accepted, which explains the reference to unpublished species and genera by Ulrich.

It was thought that outline drawings of the type species would present in the most concise manner possible the characters of the genera. These drawings are to be regarded as preliminary and subject to correction as better material becomes available.

AMECEPHALUS new genus

Pl. 9, fig. 1. (Nat. size.) Diagrammatic outline of the type species as restricted.

Amecephalus includes those forms with the wide frontal border that were formerly referred to the type species.

[1] Smithsonian Misc. Coll., 67, No. 8, 1923, and 75, Nos. 1 and 9, 1924.

Genotype.—*Ptychoparia piochensis* Walcott (Bull. U. S. Geol. Surv., 30, 1886, p. 201, pl. 26, fig. 2 and pl. 28, figs. 1 and 2).

Range.—Middle Cambrian of Great Basin and Rocky Mountains.

ANORIA new genus

Pl. 9, fig. 2. (Nat. size.) Diagrammatic outline of the type species.

Anoria is characterized by the absence of a frontal border.

Genotype.—*Dolichometopus tontoensis* Walcott (Smithsonian Misc. Coll. 64, 1916, p. 373, pl. 51, fig. 1).

Range.—Upper Cambrian, Grand Canyon.

ARMONIA new genus

Pl. 10, fig. 1. (Nat. size.) Diagrammatic outline of type species.

Armonia differs from *Elrathia* in the characters of the frontal limb and the relatively larger pygidium.

Genotype.—*A. pelops* Walcott, new species.

Range.—Upper Cambrian, Southern Appalachians.

BELLEFONTIA

Ulrich (MSS.) New genus, pl. 9, figs. 3, 4 and 5. (Nat. size.) Diagrammatic outlines of the cranidium and pygidium of the type species and of *Niobe frontalis* (Dalman) and *Hemigyraspis affinis* (McCoy), the types of the respective genera.

Bellefontia differs from the similar genera in the characters of the pygidium and the absence of a dorsal furrow.

Genotype.—*Hemigyraspis collieana* Raymond (Carnegie Mus., Annals, vol. 7, no. 1, 1910, p. 41, pl. 14, figs. 9-13).

Range.—Canadian, Central Pennsylvania, Ozarkian of the Rocky Mountains.

BURNETIA new genus

Pl. 10, fig. 2. Diagrammatic outline of the cranidium.

This genus is characterized by the peculiar wide frontal limb. Other parts of this trilobite unknown but possibly included in the large unworked collections from the type locality.

Genotype.—*Ptychoparia* (?) *urania,* Walcott (Proc. U. S. Nat. Mus., 13, 1890, p. 274, pl. 21, figs. 10, 11).

Range.—Upper Cambrian of Texas.

BYNUMIA new genus

Pl. 14, fig. 3. Diagrammatic outline of cranidium.

Bynumia differs from *Ucebia* and *Kingstonia* in the deeper dorsal furrow and prolonged frontal limb.

Genotype.—*B. eumus,* new species.

Range.—Upper Cambrian, British Columbia.

CEDARIA new species

Pl. 10, fig. 6. (Nat. size.) Diagrammatic outline of the type species.

Cedaria is characterized by the proparian-like course of the facial suture The free cheeks commonly have long genal spines and are often attached sufficiently strongly to remain a unit with the cranidium.

Genotype.—*C. prolifica* new species.

Range.—Upper Cambrian, Appalachians, Wisconsin.

CHANCIA new genus

Pl. 10, fig. 4. (Nat. size.) Diagrammatic outline of the type species.

Chancia differs from *Elrathia* in its wider fixed cheeks and wider rim, but more particularly in its small pygidium. It differs from *Amecephalus* in the frontal rim, wide fixed cheeks and occipital furrow.

Genotype.—*C. ebdome* new species.

Range.—Middle Cambrian, Rocky Mountains in Idaho.

CORBINIA new genus

Pl. 10, fig. 5. (Nat. size.) Outline drawing of the cranidium and associated pygidium.

Corbinia resembles *Eurekia* in several characteristics but differs in the absence of glabellar furrows, the structure of the frontal limb and size and position of the eyes.

Genotype.—*C. horatio* new species.

Range.—Ozarkian. Mons formation, Alberta.

CRUSOIA new genus

Pl. 10, fig. 7. (× 1½.) Diagrammatic outline of the type species.

Crusoia is characterized by the peculiar upturned front of the cephalon, the small eyes situated far forward, and the minute pygidium.

Genotype.—*C. cebes* new species.

Range.—Middle Cambrian. Woolsey shale, Montana.

DOKIMOCEPHALUS new genus

Pl. 11, fig. 1. (× ½.) Restoration of the cephalon of the type species.

Dokimocephalus is characterized by the long, pointed frontal limb, the deep dorsal and glabellar furrows and the elaborate surface ornamentation. Thorax and pygidium as yet unknown, but possibly represented in the extensive unworked collections from the type localities.

Genotype.—*Ptychoparia pernasuta* Walcott (Mon. U. S. Geol. Surv., 8, 1884, p. 49, pl. 10, fig. 8).

Range.—Upper Cambrian. Nevada and Missouri.

DUNDERBERGIA new genus

Pl. 11, fig. 2. (Nat. size.) Outline drawings of cranidium and pygidium.

Dunderbergia includes a number of forms which have formerly been assigned to *Ptychoparia* (unrestricted). This genus is characterized by the absence of glabellar furrows and the rounded, bordered pygidium. It differs from *Modocia* in its narrower fixed cheeks and the direction of the facial suture.

Genotype.—Crepicephalus (*Loganellus*) *nitidus* Hall and Whitfield (Geol. Expl. 40th Parallel, vol. 4, 1877, p. 212, pl. 2, figs. 8-10).

Range.—Upper Cambrian. Rocky Mountains and Basin Ranges.

ELKIA new genus

Pl. 10, fig. 8. (Nat. size.) Diagrammatic restoration of the cranidium.

Elkia is characterized by the extended frontal rim and very narrow fixed cheeks. The palpebral lobes appear to be considerably elevated. Other parts of the trilobite unknown.

Genotype.—Dicellocephalus nasutus Walcott (Mon. U. S. Geol. Surv., 8, 1884, p. 40, pl. 10, fig. 15).

Range.—Upper Cambrian. Eureka District, Nevada.

ELRATHIA new genus

Pl. 11, fig. 4. (Nat. size.) Outline drawing of the type species. Pl. 11, fig. 5 (medium sized specimen) diagrammatic outline of *Ptychoparia striata* (Corda), the type of the genus, introduced for comparison.

Elrathia is erected to include many forms hitherto assigned to *Ptychoparia*. It is characterized by the wide frontal limb, the wide fixed cheeks and the large, flat, furrowed pygidium.

Genotype.—Conocoryphe (*Conocephalites*) *kingii* Meek (Proc. Acad. Nat. Sci. Philadelphia, 1870, p. 63).

Range.—Middle Cambrian, mainly. Cordilleran area and possibly elsewhere.

ELVINIA new genus

Pl. 11, fig. 3. (Nat. size.) Restoration of cephalon and pygidium of the type species.

Elvinia includes many species widely distributed, formerly referred to *Ptychoparia*. This genus is characterized by the first pair of glabellar furrows which distinguishes it from similar forms.

Genotype.—Dikelocephalus roemeri Shumard (Amer. Jour. Sci., 2d ser., vol. 32, 1861, p. 220).

Range.—Upper Cambrian and Ozarkian, New York, Pennsylvania, and generally west of the Mississippi River.

EUREKIA new genus

Pl. 12, fig. 1. (Nat. size.) Diagrammatic restoration of the cephalon and pygidium of the type species.

Eurekia is characterized by the upturned, frontal limb, the moderately large eyes situated far back, narrow fixed cheeks and the high axis of the pygidium. Pygidium with spines sometimes long and slender, at other times with peculiar hook-like blunt ends.

Genotype.—*E. granulosa,* new species.

Range.—Upper Cambrian, Great Basin, Rocky Mountains, Mississippi Valley.

HARDYIA new genus

Pl. 12, fig. 5. (× 2.) Outline drawing of type cranidium.

Hardyia is a small trilobite with wide fixed cheeks, narrowing rapidly forward, with large occipital ring and very short, faintly indicated glabellar furrows.

Genotype.—*H. metion* new species.

Range.—Ozarkian. Canadian Rockies.

HOLTERIA new genus

Pl. 13, fig. 7. (Nat. size.) Diagrammatic restoration of the cranidium and pygidium of the type species.

The genus *Holteria* is based primarily on the unusual pygidium. The associated cranidium is indistinguishable generically from that of *Neolenus inflatus* Walcott. The pygidium, however, is radically different because of the fusion of the pleura and the reduction of the number of spines.

Genotype.—*Ogygia ? problematica* Walcott (Mon. U. S. Geol. Surv., 8, 1884, p. 63, pl. 10, fig. 2).

Range.—Upper Cambrian, Great Basin.

HOUSIA (Walcott)

Pl. 12, fig. 4. (Nat. size.) Outline drawing of the type species.

Housia was first described as a subgenus of *Dolichometopus,* due to a portion of the specimen being obscured by the matrix and thus overlooked in making the illustration. The generic name *Sodalitia* (Smithsonian Misc. Coll., 67, 1922, p. 471) was proposed for forms belonging to this genus.

Housia is characterized by the absence of the dorsal furrow and the large frontal limb. The pygidium of the British Columbia forms was first referred to *Ceratopyge* because of the marginal spines. It differs, however, from *Ceratopyge* in that the spines of *Housia* are simply the ends of a thoracic segment attached to the posterior smooth portion of the pygidium.

Genotype.—*Dolichometopus* (*Housia*) *varro* Walcott (Smithsonian Misc. Coll., 64, 1916, p. 374, pl. 65, fig. 1).

Range.—Ozarkian. British Columbia and Great Basin.

IDAHOIA new genus

Pl. 14, fig. 1. (Nat. size.) Outline drawing of the type cephalon and associated pygidium.

Idahoia is characterized by the broad frontal limb, which is composed of a border, a wide rim and the rim of the free cheeks. Suture entirely intramarginal. Occipital furrow absent. Pygidium concave on the pleural portions.

Genotype.—*I. serapio* new species.

Range.—Upper Cambrian. Idaho.

IDDINGSIA new genus

Pl. 12, fig. 6. (Nat. size.) Outline of the cranidium.

Iddingsia is represented by the cranidium only, although other parts may be present in the extensive collections.

Genotype.—*Ptychoporia similis* Walcott (Mon. U. S. Geol. Surv., 8, 1884, p. 52, pl. 10, fig. 10).

Range.—Upper Cambrian. Eureka District.

IRVINGELLA Ulrich and Resser MSS new genus

Pl. 10, fig. 3. (Large specimen.) Diagrammatic drawing of the type cranidium.

Irvingella is characterized by its very large eyes, narrow fixed cheeks and exceedingly narrow free cheeks. It is a very large genus.

Genotype.—*I. major* Ulrich and Resser MSS.

Range.—Upper Cambrian and Ozarkian. Appalachians, Mississippi Valley, Rocky Mountains and Nova Zemlya.

ISOTELOIDES Raymond

Pl. 13, fig. 6. (Nat. size.) Outline drawing of the genotype, *I. whitfieldi* Raymond.

The genus *Isoteloides* is represented in many of the Upper Ozarkian and Canadian collections of the Rocky Mountains.

KINGSTONIA new genus

Pl. 14, fig. 2. (×4.) Outline drawing of the genotype.

Kingstonia is a small trilobite characterized by the practical absence of the dorsal furrow. Many undescribed species belonging to this genus are in our collections. It resembles in certain features *Illaenurus* Hall (pl. 14, fig. 7), *Symphysurina* Ulrich (Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 37) and *Tsinania* (pl. 14, fig. 6).

Genotype.—*Kingstonia apion* new genus.

Range.—Upper Cambrian, Appalachians, Missouri, Oklahoma, Cordillera of Canada and United States.

MALADIA new genus

Pl. 12, fig. 2. (Nat. size.) Outline drawing of the type cephalon and associated pygidium.

Maladia exhibits certain relationships to *Eurekia* but differs in the course of the facial suture and structure of the pygidium.

Genotype.—*M. americana* new species.

Range.—Upper Cambrian or Ozarkian, Idaho and Grand Canyon.

MODOCIA new genus

Pl. 12, fig. 7. (Nat. size.) Outline drawing of the type cranidium.

The genus *Modocia* is established to include species with wide fixed cheeks which were formerly referred to six different genera.

Genotype.—*Arionellus* (*Crepicephalus*) *oweni* Meek and Hayden (Proc. Acad. Nat. Sci., Phila., 1861, p. 436).

Range.—Upper Cambrian, Black Hills, Rocky Mountains.

MOOSIA new genus

Pl. 14, fig. 9. (Nat. size.) Outline drawing of the type species.

Moosia resembles *Olenus* but differs in the course of the facial suture and backward direction of the eye lines.

Genotype.—*M. grandis* new species.

Range.—Ozarkian, Rocky Mountains.

MOXOMIA new genus

Pl. 12, fig. 3. (× 3.) Outline drawing of dorsal and side views of type cranidium.

Moxomia is characterized by the quadrate glabella and cranidium and the small eyes situated far forward

Genotype.—*M. hecuba* new species.

Range.—Ozarkian. British Columbia.

TAENICEPHALUS Ulrich and Resser MSS. new genus

Pl. 13, fig. 1. (Nat. size.) Diagrammatic drawing of type cephalon and associated pygidium.

Taenicephalus includes those forms assigned by Hall to *Conaspis,* which are congeneric with *C. shumardi.*

Genotype.—*Conocephalites shumardi* Hall (16th Ann. Rept. New York State Cabinet Nat. Hist., 1863, p. 154, p. 7, figs. 1, 2).

Range.—Upper Cambrian. Mississippi Valley and Rocky Mountains.

TOSTONIA new genus

Pl. 13, fig. 2. (× 2.) Outline drawings of type cranidium and associated pygidium.

Tostonia is another of the forms which resembles *Olenus* and *Triarthropsis.* It differs in width of the fixed cheeks and course of the facial suture and in the spinose pygidium.

Genotype.—*Dicellocephalus iole* Walcott (Mon. U. S. Geol. Surv., 8, 1884, p. 43, pl. 10, fig. 19).

Range.—Upper Cambrian. Eureka District, Nevada.

UCEBIA new genus

Pl. 14, fig. 4. (×3. Outline drawing of type species.

Ucebia is closely allied to *Kingstonia*, but differs by having a shallow dorsal furrow.

Genotype.—*U. ara* new species.

Range.—Upper Cambrian. Appalachians, Rocky Mountains.

UTIA new genus

Pl. 13, fig. 3. (×2.) Restoration of type cranidium.

Utia is a very curious trilobite in which the frontal limb stands vertically, with wide fixed cheeks, furrowed by peculiar longitudinal depressions. Specimens with a portion of thorax in the collections.

Genotype.—*U. curio* new species.

Range.—Middle Cambrian. Spence shale, Idaho.

WILBERNIA new genus

Pl. 13, fig. 4. (Nat. size.) Outline drawings of dorsal and side views of the type cranidium.

Wilbernia includes among its numerous species the well-known *Ptychoparia diademata* (Hall).

Genotype.—*P. pero* Walcott (Proc. U. S. Nat. Mus., 13, 1890, p. 274, pl. 21, fig. 6).

Range.—Upper Cambrian. Mississippi Valley and Rocky Mountains.

XENOSTEGIUM new genus

Pl. 13, fig. 5. (Nat. size.) Outline drawing of the type species.

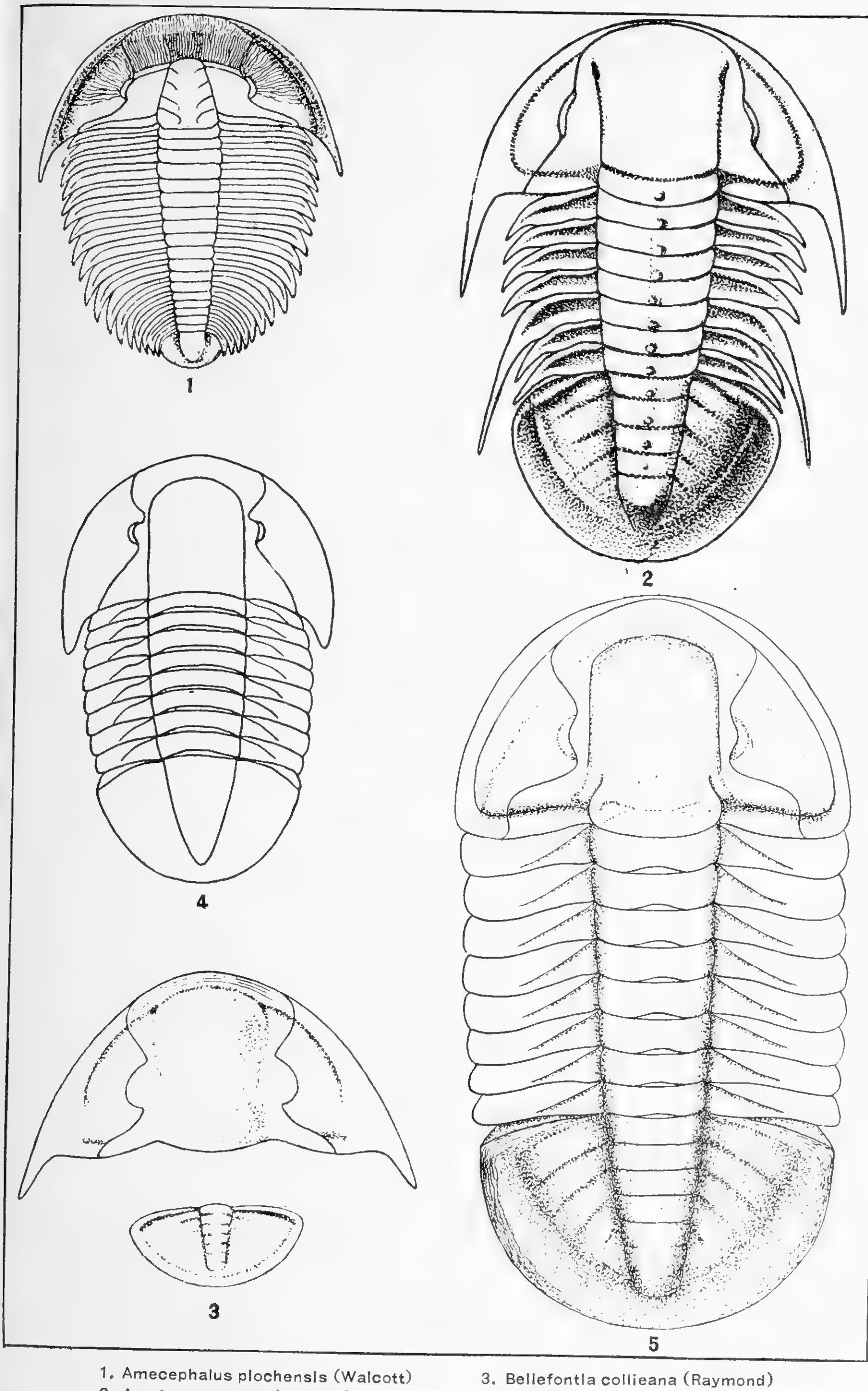
Xenostegium contains many species, some of which were formerly referred to *Megalapis*. It is characterized by the spined pygidium.

Genotype.—*Asaphus* (*Megalapis ?*) *goniocercus*, Meek (6th Ann. Rept., U. S. Geol. Surv. Territories, 1873, p. 480).

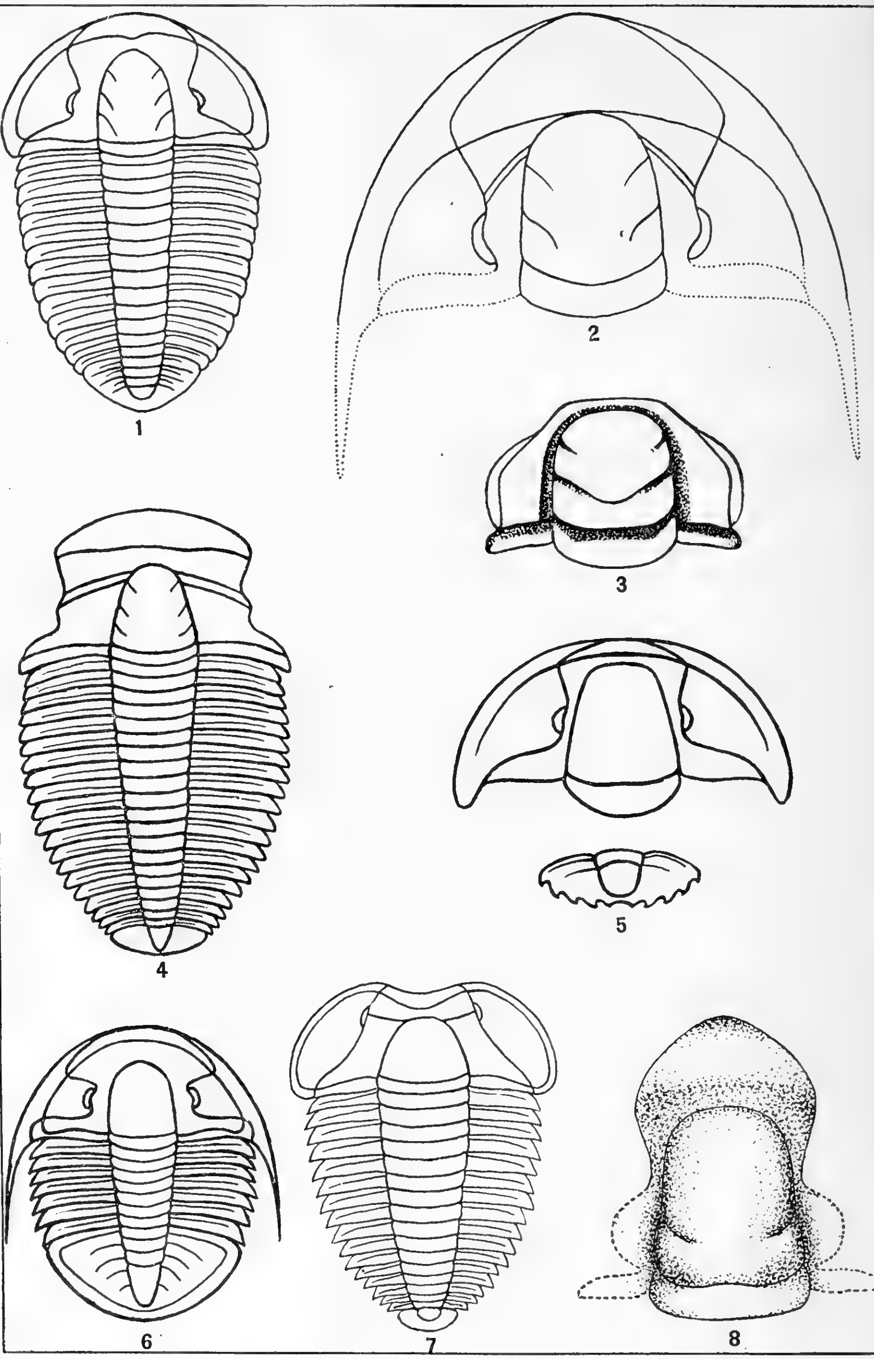
Range.—Upper Ozarkian and possibly Canadian, Cordilleran region.

PLATYPELTIS Calloway. PSILOCEPHALUS Salter

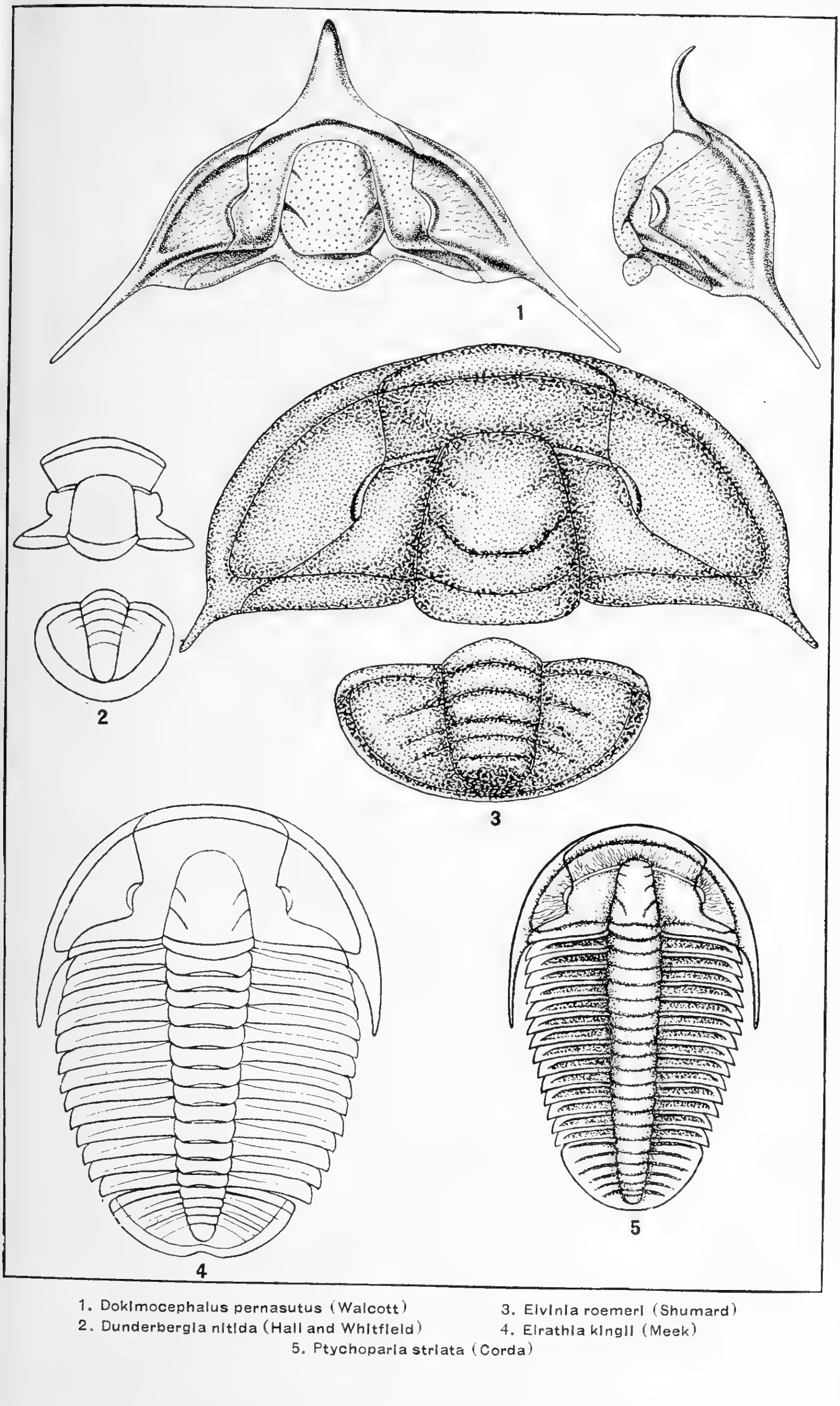
Pl. 14, figs. 5 and 8. Outline drawings of the genotypes. *Platypeltis croftii* and *Psilocephalus innotatus* were introduced for comparison with *Symphysurina*. (Smith. Misc. Coll., vol. 75, no. 1, 1924, p. 38.)



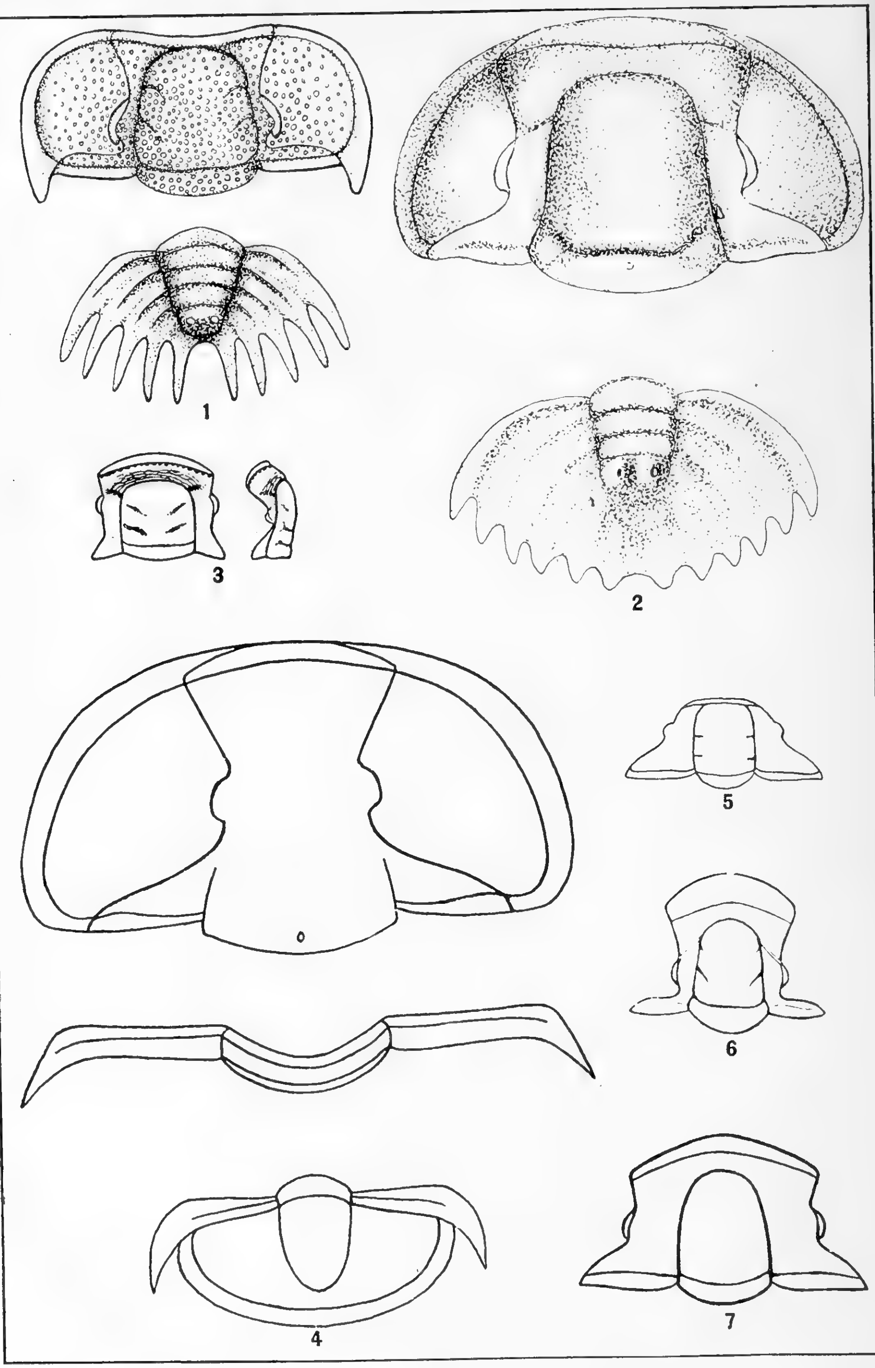
1. Amecephalus piochensis (Walcott)
2. Anoria tontoensis (Walcott)
3. Bellefontia collieana (Raymond)
4. Hemigyraspis affinis (McCoy)
5. Niobe frontalis (Dalman)



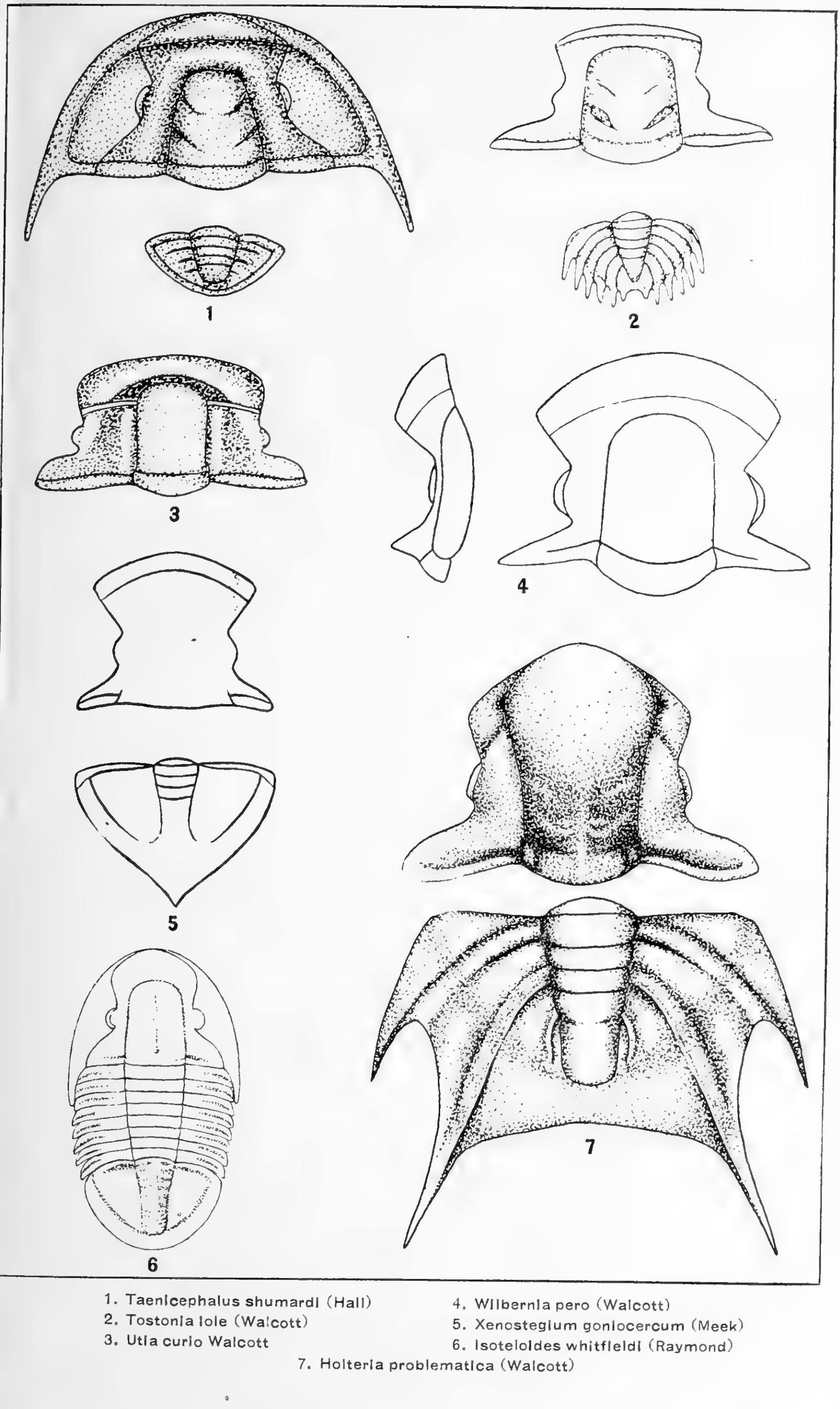
1. Armonia pelops Walcott
2 Burnetia urania (Walcott)
3. Irvingella major Ulrich and Resser
4. Chancia ebdome Walcott
5. Corbinia horatio Walcott
6. Cedaria prolifica Walcott
7. Crusoia cebes Walcott
8. Elkia nasuta (Walcott)



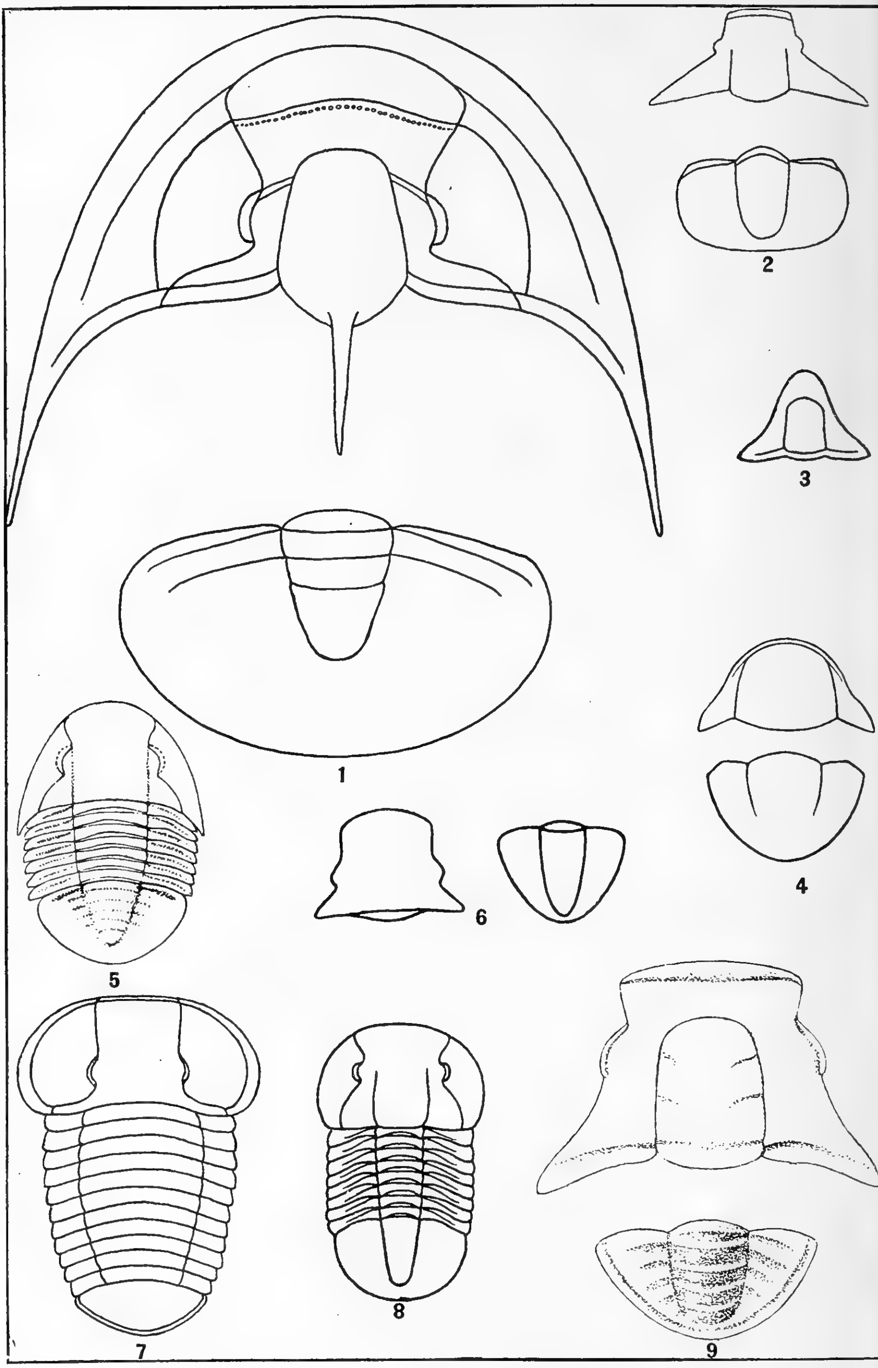
1. Dokimocephalus pernasutus (Walcott)
2. Dunderbergia nitida (Hall and Whitfield)
3. Elvinia roemeri (Shumard)
4. Elrathia kingii (Meek)
5. Ptychoparia striata (Corda)



1. Eurekia granulosa Walcott
2. Maladia americana Walcott
3. Moxomia hecuba Walcott
4. Housia varro (Walcott)
5. Hardyia metion Walcott
6. Iddingsia similis (Walcott)
7. Modocia oweni (Meek and Hayden)



1. Taenicephalus shumardi (Hall)
2. Tostonia iole (Walcott)
3. Utia curio Walcott
4. Wilbernia pero (Walcott)
5. Xenostegium goniocercum (Meek)
6. Isoteloides whitfieldi (Raymond)
7. Hoiteria problematica (Walcott)



1. Idahoia serapio Walcott
2. Kingstonia apion Walcott
3. Bynumia eumus Walcott
4. Ucebia ara Walcott
5. Platypeltis croftii (McCoy)
6. Tsinania cleora (Walcott)
7. Illaenurus quadratus (Hall)
8. Psilocephalus innotatus Salter
9. Moosia grandis Walcott

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 75, NUMBER 3

CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

No. 3.—CAMBRIAN AND OZARKIAN TRILOBITES

(With Plates 15 to 24)

BY
CHARLES D. WALCOTT

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INTRODUCTION

The collections of invertebrate fossils in the United States National Museum from the Cambrian and Ozarkian formations of the United States and Canada contain a large and varied series of trilobites, many of which are undescribed, while others have been given only provisional study and publication.

These collections have accumulated during the past 25 years, largely as the result of my studies of the various formations of the Cambrian and Ozarkian in western America. In the actual collecting, I have been aided by several assistants, notably Dr. Cooper Curtice, Mr. F. B. Weeks, Dr. L. D. Burling, Dr. Charles E. Resser, my two sons, Sidney and Stuart, and their mother, and during the past 10 years, Mrs. Mary Vaux Walcott has been most helpful in assisting me in gathering the faunas of the lower Ozarkian and Cambrian in the Canadian Rockies. During this period over 65,000 specimens have been deposited in the Museum from collections made in the Cordilleran area alone. Many specimens have been contributed and loaned by local collectors, and the generous cooperation of the Geological Survey of Canada has been of great service through assistance in my field-work and in loaning specimens for study. Dr. E. O. Ulrich has gathered a great quantity of material from the Lower Paleozoic formations of the Appalachians and the Mississippi Valley, in connection with his field studies as a member of the U. S. Geological Survey. From time to time he has made many intensive studies of the fragmentary trilobites but refrained from publication in order to obtain a more comprehensive knowledge of the faunas and the formations in which they occur. I pursued a somewhat different course, as it was essential that a few at least of the fossils occurring in the great Cordilleran sections should be made known to the geologist. This has led to much preliminary study and publication, since otherwise the entire work would have been delayed for many years. Now, thanks to the enthusiastic work of Dr. Charles E. Resser, aided and checked by Dr. Ulrich, the great collections are being systematically worked, studied and prepared for future publication.

At the present time Dr. Ulrich is actively engaged in preparing descriptions of the Ozarkian fossils together with a volume on the stratigraphy. It is expected that portions of both volumes will be ready for the press within a few months. Dr. Ulrich and Dr. Resser are also carrying forward their studies of the Cambrian faunas of the Mississippi Valley. Prof. B. F. Howell of Princeton University and Dr. Resser also have under way a monographic study of the

Agnostidae, from which it is hoped much data will be obtained for more exact correlation of the older beds. Several of the studies listed above will be published in parts, which together with descriptions to be published by me from time to time, will in the near future equip the worker in Cambrian stratigraphy so that more detailed and more correct stratigraphic conclusions can be reached.

The genera described and illustrated in this paper were recognized and prepared for study at various times during the past 10 years. Diagrammatic outline sketches of most of them were published in 1924,[1] and the names given many have been used in connection with description of formations and geological sections.[2] In the preparation of descriptions of genera, free use was made of Dr. Ulrich's notes on some; also the observations of Dr. Resser.

The dorsal tests of the trilobites are usually dismembered and often only a single head or tail of a species is found; then again the rock may be almost made up of various parts of many species crowded together in great disorder. The most skillful manipulation is required to work out identifiable specimens and then the interpretation of the probable relations of the various parts requires patient study and a wide acquaintance with the fauna.

Mr. J. A. Mirguet did much of the preliminary working out of the fossils from their matrix. Miss Sara Evans has assisted Dr. Resser, and Miss Frances Wieser and Miss Doris Cochran have made outline sketches and retouched the photographs where necessary.

DESCRIPTION OF GENERA AND SPECIES

Genus AMECEPHALUS Walcott

Amecephalus Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, pp. 53, 54.

Description.—The genus *Amecephalus* was established to include the forms with a wide frontal border that were formerly placed in *Ptychoparia piochensis* (Walcott) (s. l.).

The broad, flat border is characteristic of the genus. Cranidium wide with the glabella occupying only about one-half the length of the head and well defined by the dorsal furrow. There are three sets of glabellar furrows that are usually moderately impressed and which turn sharply backward as they approach the middle of the head where most of the specimens of the type species have a more or less

[1] Smithsonian Misc. Coll., Vol. 75, Nos. 1 and 2, 1924.
[2] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923; Vol. 75, No. 1, 1924.

pronounced longitudinal keel. Fixed cheeks wide, with strong ocular ridges crossing them. Palpebral lobes rather small and slightly upturned. The broad frontal limb and border in front of the eye-lines is marked by irregular inosculating lines. There is a tendency toward the formation of a boss immediately in front of the glabella, a feature which seems to occur in a greater or less degree in nearly all trilobites with a wide frontal limb. The present incomplete study indicates a possibility that several of the American species now referred to the European genus *Acrocephalites* may ultimately be included in *Amecephalus*.

The free cheeks are of moderate size and of the usual shape. They have a very narrow border with a tendency to turn up somewhat into a wire edge. A comparatively wide doublure is present under the cheeks and possibly maintains its width across beneath the cranidium. The facial suture is intramarginal for about one-third the distance in front of the cranidium. The broad frontal border has a very narrow rim which is usually not apparent in the flattened specimens.

The thorax in the type species has 19 segments. Those toward the rear of the body have relatively longer spines that partly envelop the small pygidium.

Pygidium small, smooth, and definitely three-lobed. The axial lobe is considerably larger than the side lobes and extends to the posterior margin; it has two or three transverse furrows that do not appear to extend out on the pleural lobes.

Derivation of name.—Αμη = shovel or spade; Κεφαλη = head.

Genotype.—*Ptychoparia piochensis* Walcott, as restricted.

Range.—Middle Cambrian of the Great Basin, Nevada, etc.

AMECEPHALUS PIOCHENSIS (Walcott)

Plate 15, figs. 8-10

Ptychoparia piochensis Walcott, 1886, U. S. Geol. Surv. Bull. 30, p. 201, pl. 26, figs. 2, 2a, b; pl. 28, figs. 1, 2-2e. (Described and illustrated.) Pack, 1906, Journ. Geol., Vol. 14, p. 297, pl. 2, figs. 4-4c. (Added notes and illustrated.) Grabau and Shimer, 1910. N. A. Index Fossils, Vol. 2, p. 276, fig. 1575. (Illustrated.)

Liostracus piochensis Lorenz, 1926, Zeits. d. d. geol. Gesell., bd. 58, heft 1, p. 61. (New generic reference with notes.)

Amecephalus piochensis Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 9, fig. 1.

Observations.—The original description includes the forms with an extra wide frontal border and 19 segments which here are restricted to this specific name. The specimens included under this generic and specific name do not show intergradations relative to size of border as stated in the original description, but, as can be seen from the illustrations, large and small maintain the same relative proportions.

Formation and locality.—Middle Cambrian: (31) Chisholm formation. Chisholm mine, southwest slope of Ely Mountains, 3 miles (4.8 km.) northwest of Pioche, Lincoln County, Nev.

Genus ANORIA Walcott

Anoria Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54.

Description.—Dorsal shield broadly oval in outline, moderately convex, with a strong axial lobe. Cephalon with a large glabella outlined by strong dorsal furrows on the sides that terminate anteriorly in slight pits: a very slight depression separates the glabella from a narrow rounded frontal rim: the sides of the glabella diverge from about midway of its length towards the front: posterior glabellar furrows slightly defined: occipital furrow well marked and occipital ring strong with a node at its center.

Fixed cheeks are narrow in front of the palpebral lobes and widening posteriorly to merge into rather short postero-lateral limbs that have a well-defined intermarginal furrow. Palpebral lobes narrow with posterior end slightly back of the transverse median line of the cranidium; ocular ridge extending across the cheek to the dorsal furrow.

Free cheeks moderately large with a furrow defining a wide border beginning near the suture at the front and curving inward to join the posterior edge of the postero-lateral limb. Genal spines long and strong. A wide doublure extends forward from the genal angle and thickens as it passes beneath the cranidium, and apparently without a median suture. The general course of the facial suture diverges from the front of the cephalon to the occipital margin; is entirely intramarginal, rounds off the corners of the glabella, passes outward around the comparatively straight palpebral lobes, and behind the eyes diverges more rapidly, cutting the posterior margin at a distance from the glabella equal to about one-third the length of it, thus leaving broadly triangular postero-lateral limbs.

Thorax in the type species with seven segments. Axis wide, each segment having a median tubercule and a faintly impressed furrow. The pleuræ are short, increasing in length relative to the width of the axis posteriorly; each pleura has a deep and wide furrow dying out rapidly near the end where the pleura begins to taper to a blunt spine. The third segment from the posterior end of the thorax is continued laterally into a long, backward extending spine.

Pygidium semi-circular in outline. The axis is somewhat narrower than the thoracic axis and is more nearly semi-cylindrical, standing considerably higher than the side lobes. No rim is apparent except in the specimens compressed in shale when the doublure leaves an impression on the upper surface: the border flattens out and is slightly concave. Three or four axial furrows and rings are usually discernible, but they become successively fainter until indistinguishable. Those near the anterior edge have median tubercles similar to those on the thoracic segments. Several pleural furrows are very faintly visible on the lateral lobes back of the strong anterior one, the margin of which is slightly thickened.

Derivation of name.—Ανευ = without; Ορια = border.

Genotype.—*Dolichometopus tontoensis* Walcott.

Range.—Upper Cambrian.

Observations.—*Anoria* differs from *Dolichometopus,* the genus to which the type species was first referred, in several important respects. The glabella of *Dolichometopus* is definitely separated from the fixed cheeks and frontal limb by a dorsal furrow passing all the way around. The course of the facial suture is different. In *Dolichometopus* it diverges in front of the eyes as well as behind and here more rapidly than in *Anoria.* It is also not intramarginal except possibly for a short distance. The eyes of *Dolichometopus* are relatively larger and more curved than in *Anoria.*

The pygidia of the two genera are quite similar in general appearance. *Dolichometopus* always has a distinct border. The axial furrows are also distinctive in their course, which is straight across the flattened axis and not curved as in *Anoria.*

ANORIA TONTOENSIS (Walcott)

Plate 18, figs. 15-28

Dolichometopus tontoensis Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, No. 5, p. 373, pl. 51, figs. 1, 1 a-h. (Description and illustration of species.)

Anoria tontoensis Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 9, fig. 2.

The original description with the generic description and illustrations present all that we know of the species.

Formation and locality.—Upper Cambrian: (74e) Bright Angel shale. Indian Garden Spring: (74) Nunkoweap Valley, Grand Canyon, Arizona.

Genus ARMONIA Walcott

Armonia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54.

Description.—*Armonia* is characterized by a conical glabella with only traces of furrows. The wide frontal limb is composed of a wide rim and border and the dividing furrow turns back in the center, narrowing the border almost one-half in the genotype. The facial suture diverges moderately in front of the eyes, but rapidly back of them, thus making wide triangular postero-lateral limbs. Free cheeks small and without genal spines in the genotype.

Thorax of the type species with 14 segments which resemble those of *Chancia* and *Elrathia.*

Pygidium relatively large, with three or four axial rings and several pleuræ which continue nearly across the pleural lobes.

Observations.—*Armonia* differs from *Elrathia* in its frontal limb, absence of glabellar furrows and relatively larger pygidium.

Genotype.—*Armonia pelops* Walcott.

Range.—Upper Cambrian: Southern Appalachians.

ARMONIA PELOPS Walcott

Plate 17, figs. 28-31

Armonia pelops Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 10, fig. 1.

The illustrations and notes on the genus present all known features of the species.

Formation and locality.—Upper Cambrian: (95) Conasauga formation. One-half mile (0.8 km.) above Center Road Ford, Cowan Creek, Cherokee County, Alabama.

Genus BELLEFONTIA Ulrich

Bellefontia Ulrich, in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54.

Quotation from Dr. Ulrich's manuscript: "*Hemigyraspis* was proposed by Raymond[1] as a subgenus of *Niobe* Angelin, *Asaphus affinis* McCoy, a British Upper Tremadoc species being cited as the type. In my opinion *A. affinis,* as figured by Salter,[2] belongs to a genus quite distinct from *Niobe* which has a well-developed neck ring and a of the Asaphidae. The general aspect of *A. affinis,* on the other hand, is decidedly asaphid. In fact, so far as I can see, it differs in no

[1] Raymond, P. E. Annals Carnegie Mus., Vol. 7, No. 1, p. 41, 1910.

[2] Salter, J. W. Monogr. Brit. Trilobites, p. 164, p. 24, figs. 13, 14, 1864.

essential feature from *Platypeltis* Galloway except that its eyes are smaller. *Hemigyraspis,* as based on McCoy's species, may be a subgenus of *Platypeltis,* or perhaps of *Symphysurus,* but not of *Niobe.* Again, *Hemigyraspis affinis* seems a close relative of *Asaphellus* with which it agrees in every generic character, except that the facial suture in the former cuts the anterior edge of the cephalon in front of the eye, whereas in the typical species of *Asaphellus* the suture remains on the dorsal side to the middle of the anterior edge. In view of these facts it is difficult to decide as to which of these suggested alliances is the closest. Personally, I doubt very much that we know enough of these trilobites to warrant any definite conclusion. For the present, therefore, I prefer to view *Hemigyraspis* as a distinct genus, and would refer to it only those species that are unquestionably congeneric with the type species.

"Thus restricted it becomes questionable whether the genus is truly represented in American deposits. Raymond refers here Matthew's *Asaphellus ? planus,*[1] but that Bretonian species is described as having an unlobed pygidium, on which account its reference to *Hemigyraspis* seems very doubtfully warranted. He describes also two new species, one of which, *H. mcconnelli,*[2] from the vicinity of Golden, British Columbia, is based on specimens too imperfect for exact determination. The other is founded on separated pieces of a trilobite collected at Bellefonte, Pa., from near the top of the Stonehenge limestone, which is the lowest of four alternating limestone and dolomite formations into which the great development of the Canadian system in central Pennsylvania has been divided. Raymond[3] applied the name *Hemigyraspis collieana* to this Bellefonte species.

"Unfortunately, the specimens on which Raymond based this species, especially that, or those of the cranidium, are so imperfect that he failed entirely to observe certain important characters that are quite at variance with those assigned to his genus *Hemigyraspis.* Thus, in *H. collieana* the glabella is clearly outlined in front—as well, indeed, as in any asaphid; and in front of it the cranidium incloses a fairly wide flat border. The facial suture does not cut the front edge of the cephalon, as in *H. affinis,* but, as shown by the anterior

[1] Matthew, G. F., 1902, Bull. New Brunswick Nat. Hist. Soc. No. 20, p. 419, pl. 18, fig. 11; Geol. Survey Canada Ann. Rept. 1903, Cambrian Rocks Cape Breton, p. 237, pl. 18, fig. 11.

[2] Raymond, P. E., 1913, Victoria Mem. Mus. Bull. No. 1, p. 40, pl. 4, fig. 4.

[3] Raymond, P. E., 1910, Annals Carnegie Mus., Vol. 7, p. 41, pl. 14, figs. 9-13.

extensions of the free cheeks remains on the dorsal surface well within the edge. Finally, the eyes are not 'nearly halfway to the front of the cephalon' but wholly behind the midlength of the cranidium. The hypostoma, when the anterior wings are entirely uncovered, is much wider than long. In most other respects also it resembles the hypostoma of *Symphysurina,* the only differences of any consequence being that the anterior wings are more quadrate in form and pointed at the outer front extremity, and the depression at the middle of the anterior edge much shallower.

"In none of the features mentioned is *H. collieana* like *H. affinis.* They cannot belong to the same genus. So far as the cephalon is concerned, the former is much nearer *Ogygia corndensis*, a British Llandeilo Flags species figured by Salter in his monograph, and for which Raymond[1] has proposed the new designation *Ogyginus.* The similarity and apparent relation to the latter extends to the hypostoma; but the neck and glabellar furrows, even though imperfectly developed, together with a strongly segmented pygidium, are essential characters of *Ogyginus* whose absence in the species *collieana* will not permit its unqualified reference to that genus. As the peculiarities of the latter species do not seem to be covered by any established genus, the new generic term *Bellefontia* is proposed for it.

"It is this *Bellefontia collieana* that is above referred to as a close ally of *Symphysurina.* It seems to me a derivative of some species of this genus, differing from its ancestors in the development of a flat border in front of the glabella. At the same time, and perhaps largely in consequence of the growth of the border, the facial suture became intramarginal. These departures approximate to conditions usually found in typical Asaphidae. But this seems a case of parallel tendencies in the development of different lines and not one of orthogenesis."

Genotype.—*Hemigyraspis collieana* Raymond.

Range.—Ozarkian: Mons formation. Alberta, Canada. Rocky Mountains. Canadian: Stonehenge, Bellefonte, Pennsylvania.

Observations.—This genus has many species in the Ozarkian and so far as the studies have gone only a few pass into the Canadian. The study of the group, however, is too little advanced to be altogether certain of its complete range.

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[1] Raymond, P. E., 1912, Roy. Soc. Canada, Proc. and Trans., 3d ser., Vol. 5, sec. 4, p. 117.

BELLEFONTIA COLLIEANA (Raymond) Ulrich

Plate 23, figs. 1-6

Asaphus marginalis Collie (not Hall), 1903, Bull. Geol. Soc. Amer., Vol. 14, p. 413. (Listed only.)

Hemigyraspis collieana Raymond, 1910, Annals Carnegie Mus., Vol. 7, No. 1, p. 41, pl. 14, figs. 9-13.

Bellefontia collieana (Raymond) Ulrich, in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 9, fig. 3.

Raymond's description of the species is as follows:

" Cephalon short and wide, glabella smooth, not outlined, no glabellar furrows. Neck-furrow shallow, hardly visible. Eyes nearly halfway to the front of the cephalon, large, very far apart. Between the eyes is a small median tubercle. Free cheeks short, wide, with long narrow spines at the genal angles. Facial suture entirely intramarginal. There is a narrow depressed border on the front of the cranidium.

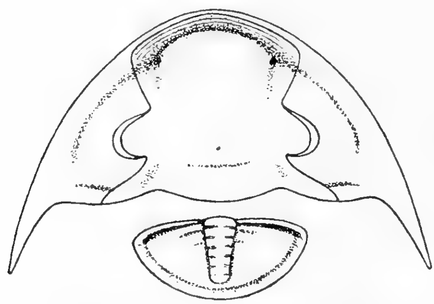

FIG. 12.—*Bellefontia collieana* (Raymond). Corrected drawing of the genotype.

" Axial lobe of thorax one-third the total width; pleura grooved. Pygidium short, wide, semi-circular in outline. Axial lobe narrow, rather prominent, showing traces of two or three rings. Pleural lobes convex, without traces of ribs. Border narrow, concave; doublure narrow, convex."

It is to be noted that Raymond places the eyes too far forward in his illustrations.

Formation and locality.—Canadian: (271r) Lower Stonehenge. Bellefonte, Pennsylvania.

BELLEFONTIA NONIUS (Walcott)

Plate 23, figs. 7-11

Niobe ? nonius Walcott, 1923, Smithsonian Misc. Coll., Vol. 67, No. 8, p. 473. (Listed under locality 65y.)

This species averages larger in size than *B. collieana.* In the cranidium the greatest difference between the two species lies in the slightly different front. *B. nonius* has a flatter rim, but the glabella is marked off in much the same way except that it is more expanded anteriorly. The head is less convex in longitudinal cross-section and the palpebral lobes are also slightly smaller.

The free cheek (fig. 9) assigned to *B. nonius* has preserved the extension of the doublure for a considerable distance beyond the cheek. The suture is intramarginal.

The pygidia associated with *B. nonius* are not unlike those of *B. collieana,* except that the axial and pleural ribs are less well developed.

Formation and locality.—Ozarkian: Mons formation. (65y) north side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.8 km.) in an air line north, 2° west, of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

This species occurs in 1c of the Clearwater section, 426 feet (129.8 m.) above the base of the Mons formation and 970 feet (295.7 m.) below the summit.

BOWMANIA, new genus

Description.—Only the glabella of the type species is known. Due to the meager material the following generic description must be regarded as tentative.

The glabella is cylindrical, rounded in front and a little less than half the length of the head. Two pairs of very short glabellar furrows are present. Eyes small, situated back of the middle of the glabella. Ocular ridges strong. Frontal border wide, convex, with a narrow rim, and covered with fine, irregular lines.

Facial suture unknown. The frontal rim is of an even width throughout, which proves that the suture was not intramarginal.

Genotype.—*Arethusina americana* Walcott.

Range.—Upper Cambrian.

BOWMANIA AMERICANA (Walcott)

Plate 15, figs. 15, 16

Arethusina americana Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 62, pl. 9, fig. 27. (Described and illustrated.) Brögger, 1886, Geol. Foren. Stockholm Fornhandl., bd. 8, p. 206. (Mentioned.)

Harpides ? americanus Frech, 1897, Leth. geog., th. 1, Leth. Pal., 2, p. 44, footnote. (Generic reference changed.)

Aulacopleura americana Raymond, 1913, Ottawa Nat., Vol. 26, p. 6. (Generic reference changed.)

See original description for details.

Formation and locality.—Upper Cambrian: (66) Hamburg limestone? On first ridge north of the Dunderberg Mine, Eureka District, Nevada.

Subfamily DIKELOCEPHALINÆ Beecher

Dikelocephalinæ Beecher, 1897, Amer. Journn. Sci., 4th Ser., Vol. 3, p. 192.

In a paper on *Dikelocephalus* and other genera of the Dikelocephalinæ[1] I included in this subfamily:

Dikelocephalus Owen 1852.
Conokephalina Brögger 1886.
Calvinella Walcott 1914.
Osceolia Walcott 1914.
Saukia Walcott 1914.

To the above five genera there is now added *Briscoia* Walcott which occurs in the lower beds of the Mons formation of the Ozarkian of Alberta and British Columbia, and the Lower Ozarkian of Devils Lake and Mendota formations of Wisconsin and Hoyt limestone of New York. The non-spinose species belonging in the Upper Cambrian are also included.

BRISCOIA Walcott

Briscoia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 1, p. 37.

Briscoia is founded on the cranidium, free cheeks, fragments of thoracic segments and entire pygidia of a large trilobite that occurs in the lower portion of the Mons formation.

Observations.—*Briscoia* differs from *Dikelocephalus* in its elongate glabella, frontal limb and course of the facial sutures in front of the glabella, and in the latter the suture is intramarginal to the center while in *Briscoia* the suture appears to be intramarginal for a less distance: the most strongly marked difference, however, is the presence of the characteristic postero-lateral spine on the pygidium of *Dikelocephalus.* The thoracic segments are essentially the same.

Genotype.—*Briscoia sinclairensis* Walcott.

Stratigraphic range.—Ozarkian, lower portion of the Mons formation. Hoyt limestone of New York. Upper Cambrian of Wisconsin and Minnesota.

Geographic distribution.—Cordilleran area of Alberta and British Columbia, from Glacier Lake to Mount Sabine at the southern end of the Stanford Range; Saratoga County, New York; Devils Lake sandstone and Mendota limestone areas of Wisconsin.

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[1] Smithsonian Misc. Coll., 1914, Vol. 57, No. 13.

The species now referred to the genus from the Mons formation, in the present stage of the study, are:

Briscoia glaucus Walcott.
B. onophas Walcott.
B. opimius Walcott.
B. sinclairensis Walcott.
B. splendens Walcott.
B. zebina Walcott.

There should also be included:

B. limbatus (Hall) = *Dikelocephalus ? limbatus* Hall (Walcott).[1]
B. coloradoensis Walcott = *Saukia coloradoensis* Walcott.[2]

BRISCOIA SINCLAIRENSIS Walcott

Plate 20, figs. 1-10

Briscoia sinclairensis Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 1, p. 37, fig. 9.

Description.—This is the largest species of the genus although *B. splendens* is close to it in size. The material representing the cephalon is far from satisfactory, but by combining data from several specimens a fairly satisfactory outline is obtained. Glabella with nearly parallel straight sides and broadly rounded front; rather strongly convex and marked by a distinct narrow occipital furrow that bends slightly forward towards the ends; the first furrow is narrow and distinct; it slopes forward from near the center and terminates just within the lateral margin, not entering the dorsal furrow; the second furrow is represented by a short furrow on each side corresponding to the lateral third of the second furrow; the anterior lobe of the glabella is smooth, sloping rather abruptly down to the faint dorsal furrow between it and the frontal limb; the first and second lobes are rather slightly convex and a little wider than the occipital lobe which is flattened and without a node at its central posterior margin. Dorsal furrow beside the glabella narrow and distinct; both the glabella and fixed cheeks rise abruptly from it.

Fixed cheeks narrow, expanding in front to merge into the frontal limb and posteriorly widening a little as they join the narrow posterior limbs; palpebral lobes nearly one-third the length of the cranidium, narrow and with a well-defined furrow within the outer margin; frontal limb broad, about one-fifth the length of the cranidium; it is nearly flat but rises slightly towards the slightly convex frontal rim

[1] Smithsonian Misc. Coll., 1914, Vol. 57, No. 13, pl. 65, figs. 5-8.
[2] Loc. cit., p. 376, text figs. 14-16.

which is delimited by a very gentle smooth furrow from the frontal limb. The facial sutures curve outward and forward from the base of the eye and recurve abruptly inward so as to cut across the frontal rim at a very slight angle; their course in front is unknown.

Free cheeks broad, large and terminating in a strong, long spine.

The few fragments of the thorax were found which indicate that the segments were similar in form to those of *B. splendens.*

The associated pygidium has a strong axial lobe crossed by four narrow sharp furrows that separate four strong, slightly convex segments and a terminal portion that is nearly as long as the segmented portion. The axis is a little more than one-half the length of the pygidium and merges into it at the end of a very steep slope; the lateral lobes slope rapidly from near the axis down to the broad planulate margin that extends from the anterior margin entirely around the lateral and posterior margins; the transverse furrows of the axis extend diagonally backward and fade out on the margin along with the pleural furrow of each segment represented in the pygidium.

Surface marked by very fine, raised, irregular inosculating lines.

An associated hypostoma is illustrated by figure 7, plate 20. It is not unlike that of *Dikelocephalus minnesotensis* Owen[1] but varies in details.

Dimensions.—The largest cranidium has a length of about 50 mm. and pygidium of 50 mm.

Observations.—This species differs from *D. splendens* in the character of the frontal limb and rim, and in the proportions of the glabella. The pygidia associated with the cranidiæ of the two species are much alike, but the axial lobe of *B. splendens* is more slender.

Formation and locality.—Ozarkian: (16t′) Mons formation. Thin layers of limestone interbedded in gray argillaceous shale, Brisco Range, north side of Sinclair Canyon about 500 feet (152.4 m.) above creek and a little west of Radium Hot Springs.

(17n) Thin layer gray nodular limestone interbedded in argillaceous shale, at north side of Stoddart Creek Canyon near its mouth, 6 miles (9.6 km.) south of Sinclair Canyon, Stanford Range, on east side of Columbia River Valley, British Columbia, Canada.

Ozarkian. (64n) Mons formation (Lower). Near base of 1e of field section. Cliff on southeast side of Mons Glacier, above head of Glacier Lake Canyon valley about 50 miles (80.5 km.) northwest of Lake Louise Station on Canadian Pacific Railway, Alberta, Canada.

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[1] Smithsonian Misc. Coll., 1914, Vol. 57, No. 13, pl. 81, fig. 3.

Fragments that may belong to this species occur in the lower part of the Mons at locality 21p: Ozarkian: Mons formation: Gray limestone interbedded in shale of 1g of section and a little below faunal horizon of 17s. West slope Sabine Mountain 500 feet (152.4 m.) above south end of Columbia Lake, 2 miles (3.2 km.) north of Kootenay River bridge and about 2 miles (3.2 km.) northeast of Canal Flats Station on Canadian Pacific Railway, British Columbia, Canada.

Genus BURNETIA Walcott

Burnetia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 10, fig. 2.

Description.—A single cranidium and a free cheek assigned to it are the only parts of this trilobite thus far obtained.

This form is peculiar in several respects. It is characterized by a strongly convex high glabella which arches rapidly from the occipital furrow to the anterior margin. The occipital and the posterior pair of glabellar furrows are fairly well marked, and a second pair of short anterior furrows is faintly outlined. The dorsal furrow is strongly defined all around. The wide, flaring, steeply inclined, smooth border is slightly concave in front and forms a notable character of the cranidium.

Fixed cheeks narrow: palpebral lobes and eyes moderately large, and the posterior portion of the palpebral lobe extends to a point in line with the occipital ring: ocular ridges clearly outlined. Free cheek elevated and with a wide border. The facial suture may possibly be intramarginal to the apex.

Surface of the type species granulose.

Genotype.—*Ptychoparia ? urania* Walcott.

Range.—Upper Cambrian: Texas.

BURNETIA URANIA (Walcott)

Plate 17, figs. 1-3

Ptychoparia ? urania Walcott, 1890, Proc. U. S. Nat. Mus., Vol. 13, p. 274, pl. 21, figs. 10, 11. (Original description.)

Burnetia urania Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 10, fig. 2.

The original description outlines what is known of the species.

Formation and locality.—Upper Cambrian: (68) Cap Mountain formation. Packsaddle Mountain, Llano County, Texas.

Genus BYNUMIA Walcott

Bynumia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54.

Observations.—*Bynumia* is a small trilobite closely related to *Kingstonia* and several undescribed genera. In the shape and obscure definition of the glabella and in the general configuration of the posterior portion of the cranidium, it agrees almost exactly with *Kingstonia*. It differs in the following points: (1) The eyes are situated just about opposite the middle of the glabella and farther back than in *Kingstonia*. (2) The front of the cranidium is narrower and more produced in the middle varying from obtusely angular to narrowly rounded in outline. (3) The cranidium lacks a frontal rim. The last character suggests that the rim is on the free cheeks and that the suture is intramarginal.

No pygidium that can be referred with this head has been discovered in the collections containing the type cranidium, but with other species there is associated a form not very unlike the pygidium of *Kingstonia*, which may belong to this genus.

Genotype.—*Bynumia eumus* Walcott.

Range.—The type species occurs in the Upper Cambrian Lyell formation of British Columbia. Two other species are known, one from the Maryville limestone of Tennessee and a second from the Lower Ozarkian of St. Albans, Vermont.

BYNUMIA EUMUS Walcott

Plate 17, figs. 4-6

Bynumia eumus Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 54, pl. 14, fig. 3.

The illustrations exhibit the known characters of this species.

Formation and locality.—Upper Cambrian: (66m) Lyell formation. Second canyon northwest of Mt. Edith, 4.75 miles (7.6 km.), Sawback Range. (64b) Lyell formation, Head of Glacier Lake, Canyon valley, about 48 miles (77.2 km.) northwest of Lake Louise, Alberta, Canada.

Genus CEDARIA Walcott

Cedaria Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55.

Description.—The genus *Cedaria* includes a number of species which have long been known in the collections but of which only one has been described (*Agraulos woosteri* Whitfield).

Cephalon semi-circular in outline. Glabella smooth, tapers slightly to rounded front, a little more than half the length of the cranidium. Occipital furrow present, dorsal furrow strongly impressed. Frontal limb consists of a border and a fairly wide rim. The course of the facial suture is unusual: back of the eye it turns directly outward and somewhat forward, making a postero-lateral limb that is wider at its outer extremity than immediately below the eye. In front of the eye the suture turns outward very sharply as does the posterior portion. It is intramarginal for about half the distance between the anterior corners of the cranidium and the center. A cranidium viewed with the free cheek separated exhibits the characters of a Proparian trilobite, in which the facial suture cuts the margin anterior to a rounded genal angle. When, however, this free cheek with its long genal spine is studied, its true course, which is illustrated by figure 24, plate 17, becomes clear. It is also not unlike that of the Hypoparian *Trinucleus* in the manner of rounding the genal angle. The facial suture is usually so tight in most species that the free cheeks are seldom separated.

The thorax of the genotype has seven segments.

The pygidium is nearly as large as the cephalon. It is semi-circular in outline and has a sloping border: axis convex with four or five segments that continue across the pleural lobes to merge into the border.

Surface smooth or slightly roughened by fine depressed granulations.

Genotype.—*Cedaria prolifica* Walcott.

Range.—Upper Cambrian: Appalachians, Wisconsin.

CEDARIA PROLIFICA Walcott

Plate 17, figs. 18-21

Cedaria prolifica Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55, pl. 10, fig. 6.

The generic characterization together with the figures present the features of this species.

Formation and locality.—Upper Cambrian: (91) Conasauga formation. Cedar Bluff, Cherokee County, Alabama.

CEDARIA TENNESSEENSIS, new species

Plate 17, figs. 22-25

Observations.—This species differs from *C. prolifica* in the wider postero-lateral limbs and the wider frontal limb of the cranidium.

The facial suture diverges less both before and behind the eye, making the free cheek more triangular and less quadrangular in outline.

The pygidium has a wider border than *C. prolifica.*

Formation and locality.—Upper Cambrian. Nolichucky shale (Loc. 107a): Bull Run Ridge, 11 miles (17.6 km.) northwest of Knoxville, Tennessee.

Genus CHANCIA Walcott

Chancia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55

Description.—*Chancia* is characterized by a wide cephalon and thorax. Fixed cheeks at the narrowest point nearly as wide as the glabella on the same line. Palpebral lobes moderately small and connected with the dorsal furrow near its front by an ocular ridge. Frontal limb wide, and marked by a strong transverse furrow that divides the wide rim from the border. Glabella tapering, marked by a rounded median ridge and apparently faint glabellar furrows, whose position and direction are similar to those of *Ptychoparia.*

Free cheeks undetermined.

Thorax with numerous segments, 20 in the genotype and 24 in *C. evax.* The pleural furrows are similar to those of *Elrathia.*

Pygidium small, trilobed and faintly segmented.

Observations.—*Chancia* resembles *Elrathia,* but differs in its wider fixed cheeks and wider rim, but most strongly in the small pygidium. From *Amecephalus* it differs in the presence of a wide frontal rim, wider fixed cheeks and occipital furrow. The pygidium, while small and unsegmented as in *Amecephalus,* is wider and the trilobation is less pronounced, due to a lower axis. The thoracic segments of *Chancia* are blunt compared to the slender spines of the posterior portion of the thorax in *Amecephalus.*

Genotype.—*Chancia ebdome* Walcott.

Range.—Middle Cambrian: Rocky Mountains of Idaho.

CHANCIA EBDOME Walcott

Plate 17, fig. 26

Chancia ebdome Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55, pl. 10, fig. 4.

The illustration of this species presents its characters quite clearly.

Formation and locality.—Middle Cambrian: (55c) Spence shale: Danish Flat, six miles (9.7 km.) southwest of Liberty, Bear Lake County, Idaho.

CHANCIA EVAX, new species

Plate 17, fig. 27

Observations.—*C. evax* differs from *C. ebdome* in having at least 24 thoracic segments instead of 20, the uncertainty as to number being due to the incompleteness of the posterior portion of all specimens in the collection. *C. evax* has a wider rim in proportion to the border, but is essentially the same in other respects.

Formation and locality.—Middle Cambrian: (55c) Spence shale: Danish Flat, six miles (9.7 km.) southwest of Liberty, Bear Lake County, Idaho.

Genus CORBINIA Walcott

Corbinia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55.

Description.—*Corbinia* is founded on the cranidium and associated free cheek and pygidium. The cranidium has a strongly defined, slightly subconical, truncated glabella, strong occipital ring, very narrow fixed cheeks and a flattened frontal border that turns up somewhat as does the frontal border of *Eurekia* (fig. 13, pl. 16). The associated pygidium is small, with a very strong axial lobe marked by one furrow and the pleural lobes have about five short, broad spines on the margin.

A second species, *C. valida* Walcott (fig. 18), is represented by a single cranidium.

Corbinia differs by the form of its frontal limb and border from nearly all genera except *Eurekia*. (For comparisons see p. 89.)

Genotype.—*Corbinia horatio* Walcott.

Range.—Ozarkian: Mons formation, Clearwater Canyon, Alberta.

CORBINIA HORATIO Walcott

Plate 16, figs. 19-22

Corbinia horatio Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55, pl. 10, fig. 5.

The illustrations and brief notes under the genus give all that we know of the species.

Formation and locality.—Ozarkian: (65x) Mons formation. North side of Clearwater Canyon, two miles (3.2 km.) from the divide at head of Canyon, about 21 miles (33.8 km.) in an air line north of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

CORBINIA VALIDA, new species

Plate 16, fig. 18

Of this species only the cranidium illustrated is known. It differs in details of the outline of the glabella, occipital ring and frontal limb and border, from *C. horatio*.

Formation and locality.—Same as that of *C. horatio*.

Genus CRUSOIA Walcott

Crusoia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55.

Description.—This genus is characterized by the peculiar upturned front of the head, the small glabella and the extremely small pygidium.

The cranidium is wide at the base and narrowed in front. The frontal border is turned up quite sharply in the middle. Eyes are extremely small, situated at the end of an eye-line at a point opposite the anterior end of the glabella. Glabella about two-thirds as long as the entire cranidium and rounded conical in shape. A pair of posterior glabellar furrows, triangular in outline, is faintly visible on some specimens.

Free cheeks small, without genal spines. They have a definite rim and a doublure of uniform width.

Thorax with about 16 segments. The axis is convex and relatively wide; pleural segments with a narrow, nearly straight furrow within a high posterior marginal rim and a narrow depressed anterior border.

The character of the pygidium is uncertain. There are several entire individuals in the collections, but the pygidium is not clearly defined on any of them. It is certainly very small.

Genotype.—*Crusoia cebes* Walcott.

Range.—Middle Cambrian: Wolsey shale, Montana.

CRUSOIA CEBES Walcott

Plate 15, figs. 5-7

Crusoia cebes Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55, pl. 10, fig. 7.

This species is fairly abundant at the type locality.

The generic description together with the illustrations clearly defines the characters of the species.

Formation and locality.—Middle Cambrian: (4g) Wolsey shale. Five miles (8 km.) northeast of Logan, Montana.

DESMETIA, new genus

There is barely sufficient material to allow a description of the genus, but because it is unusual in several respects, it is included in this preliminary work.

The glabella is rounded with minute recurved glabellar furrows. Fixed cheeks and frontal limb wide and convex. Eyes small and far forward.

Observations.—At first sight it seems as if *Desmetia and Raymondina* Clark[1] are synonymous, and the insufficiency of material will not now allow a solving of this question. Clark's figure, according to imperfect casts, is incorrect in the unusual rearward extension of the postero-lateral limbs. The forward turning of the occipital furrow on the fixed cheeks argues strongly for the Proparian nature of *Raymondina* and the straight course of the same suture in *Desmetia* would seem to indicate a difference. *Desmetia* also seems to lack a frontal border.

Genotype.—*Ptychoparia ? annectans* Walcott.

Range.—Ozarkian: Nevada.

DESMETIA ANNECTANS (Walcott)

Plate 15, figs. 24, 25

Ptychoparia ? annectans Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 94, pl. 12, fig. 18. (Described and illustrated.)

See original description.

Formation and locality.—? Ozarkian: (201) Goodwin formation. East slope of the ridge east of Hamburg ridge, Eureka District, Nevada.

Genus DOKIMOCEPHALUS Walcott

Dokimocephalus Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 55.

Observations.—This genus is characterized by the great extension of the frontal border and large convex glabella. It may be compared with *Burnetia* (pl. 17, figs. 1-3) and *Elkia* (pl. 18, figs. 1-3).

Proampyx Frech, based on *Anomocare acuminatus* Angelin, and to which the genotype had been referred, is too uncertain to be used. It has a nasute extension of the frontal border but differs in glabella, occipital ring, and frontal limb.

Two species have been referred to the new genus, *D. pernasutus* (Walcott) and *D. gregori*, new species. Free cheeks similar to the one assigned to *D. pernasutus* are present in collections from several

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[1] Clark, Bull. American Pal., Ithaca, N. Y., 1924, Vol. 10, No. 41, p. 35, pl. 4, fig. 8.

localities in which no cranidia have yet been noted. It is also hoped that further study, particularly of the collections from Loc. 11e, will permit the assignment of a pygidium to this head.

Genotype.—*Ptychoparia pernasuta* Walcott.

Range.—Upper Cambrian, Nevada.

DOKIMOCEPHALUS GREGORI, new species

Plate 16, figs. 32, 33

Observations.—This species differs from *D. pernasutus* in details of the cranidium, the only part available for comparison. A comparison of figures 29, 30 and 32, 33 of plate 16 shows the stronger occipital ring, broader glabella and shorter frontal limb of *D. gregori.*

Formation and locality.—Upper Cambrian: (11e): Southwest of Potosi, Missouri.

DOKIMOCEPHALUS PERNASUTUS (Walcott)

Plate 16, figs. 29-31

Ptychoparia ? pernasutus Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 49, pl. 10, figs. 8, 8a, b. (Description and illustration of species.)

Proampyx ? pernasutus Walcott, 1913, Research in China, Vol. 3, Cambrian Faunas of China, p. 145. (Generic reference.)

Dokimocephalus pernasutus Walcott, 1924, Smithsonian Misc. Coll., Vol. 75. No. 2, p. 55, pl. 11, fig. 1.

The original description and new figures include what is known of this species. It is a rare form in the Cordilleran area and only one allied species, *D. gregori,* is known from elsewhere.

Formation and locality.—Upper Cambrian: (61) Secret Canyon shale. A little north of Hamburg Mine, Eureka District, Nevada.

Genus DUNDERBERGIA Walcott

Dunderbergia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56.

Observations.—*Dunderbergia* was proposed to include a group of species numbering perhaps 20 or more, all formerly assigned to *Ptychoparia* or closely related genera. The original description of the genotype and the figures of the cranidium and associated pygidium give all that is known of this genus.

Dunderbergia differs from *Modocia* in its narrower fixed cheeks, and in the direction of the facial sutures across the frontal border being intramarginal to the center.

Genotype.—*Crepicephalus* (*Loganellus*) *nitidus* Hall and Whitfield.

Range.—Upper Cambrian; Secret Canyon shale, Cordilleran area; Eureka District, Nevada.

DUNDERBERGIA NITIDA (Hall and Whitfield)

Plate 16, figs. 4-7

Crepicephalus (*Loganellus*) *nitidus* Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Paral., Vol. 4, p. 212, pl. 2, figs. 8-10. (Original description and illustrations.)

Ptychoparia nitidus Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 57.

Dunderbergia nitida Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56, pl. 11, fig. 2.

There is nothing to be added to the original description.

Formation and locality.—Upper Cambrian: Secret Canyon shale: (61) Adams Hill. South of Hamburg Mine, Eureka District, Nevada.

Genus ELKIA Walcott

Elkia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56.

Description.—The outstanding characters of *Elkia* are the very narrow, fixed cheeks together with the extended frontal limb. Glabella large, convex, outlined all around and slightly tapering: occipital furrow narrow and deeply impressed. There is one pair of glabellar furrows which bend backward but very slightly and do not unite across the middle; by turning some specimens carefully in the light additional faintly defined anterior pairs may be seen.

The eyes are beneath a large and apparently flattened palpebral lobe. None of the specimens is well preserved in this area due to the fact that the fixed cheeks stand nearly vertical and are quite easily broken away. The shape and size of the postero-lateral limbs are also unknown.

The facial sutures diverge in passing forward and then converge to the median line of the head, thus outlining an unusual triangular frontal limb, separated by a very slight, transverse furrow from a narrow frontal limb. Remaining parts unknown.

Genotype.—*Dicellocephalus nasutus* Walcott.

Range.—Upper Cambrian: Eureka District, Nevada.

ELKIA NASUTA (Walcott)

Plate 18, figs. 1-3

Dicellocephalus nasutus Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 40, pl. 10, fig. 15. (Original description and illustration.) Matthew, 1893, Trans. Roy. Soc. Canada, Vol. 10, sec. 4, p. 11, footnote.

Proampyx nasutus Walcott, 1914, Smithsonian Misc. Coll., Vol. 57, No. 13, p. 352. (Refers species to *Proampyx*.)

Elkia nasuta Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56, pl. 10, fig. 8.

The original description includes what is known of the species, no new material being available.

Formation and locality.—Upper Cambrian: (60, 64, 54) Secret Canyon shale ?, Richmond Mine, Adams Hill, and New York Canyon, Eureka District, Nevada.

Genus ELRATHIA Walcott

Elrathia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56.

Observations.—The genus *Elrathia,* based on *Ptychoparia kingii* Meek, will include many of the forms hitherto assigned to *Ptychoparia,* which genus was used as a sort of dumping ground for a large series of species that had the general characters formerly assigned to that genus. It is not an easy task to separate them into distinct genera, even though several quite independent groups can be readily determined. *Ptychoparia* (restricted), so far as the present study has gone, is possibly absent from American Cambrian beds, and may be confined to the Bohemian Basin. It has much wider fixed cheeks and the sutures diverge much more in front of the eyes than in *Elrathia.* They also cut the frontal rim in a different manner. In *Elrathia* the suture is intramarginal to the center. This results in a widening of the frontal rim anteriorly. In *Ptychoparia,* on the other hand, the suture is marginal. Both genera have ocular ridges but that of *Ptychoparia* is much the stronger.

Ptychoparia has a very pronounced striation of the forward parts of the head, beginning at the eyes and ocular ridges. *Elrathia* also possesses a striation, but less pronounced and not beginning so definitely at the ocular ridges, and in some species, it is absent.

The thoracic segments of the two genera are quite distinct. In *Ptychoparia* the pleural furrows maintain an even width from their origin at the axis out nearly to the end of the pleura, dividing each segment into an anterior and posterior ridge. In *Elrathia* the pleural furrow divides the segment into two unequal parts; the anterior one is narrow next to the axis and widens out toward the outer end; the posterior one is wide next to the axis and narrows outward, but less rapidly than the anterior one and unites with the latter in forming the blunt terminal spine.

The pygidium of *Ptychoparia* shows the same peculiarity as the thorax in that the edges of two segments are fused to form the ridges that appear, on first sight, to be the pleural segments and not as they are—made of the anterior ridge of one, and the posterior ridge of the next. The separating depressions are not between segments, therefore, but pleural furrows. The pygidium of *Elrathia* has under-gone much less fusion and the individual segments can readily be distinguished. A more definite rim is also present.

Dimensions.—Average length of large specimens, four cm.

Genotype.—*Conocoryphe* (*Conocephalites*) *kingii* Meek.

Stratigraphic Range.—Middle Cambrian, mainly.

Geographic Distribution.—Cordilleran area and possibly elsewhere.

Many species of the genus will be described and illustrated as the study of the trilobites of this type progresses. One of them is the *Crepicephalus* (*C.*) *haguei* Hall and Whitfield, from the Secret Canyon shale of the Eureka District, Nevada. The types come from the White Pine District. (Geol. Expl. 40th Paral., Vol. 4, p. 210, pl. 2, figs. 14, 15, 1877.)

ELRATHIA KINGII (Meek)

Plate 15, figs. 1-4

Conocoryphe (*Conocophalites*) kingii Meek, 1870, Proc. Acad. Sci. Philadelphia, p. 63. (Description of species.)

Conocoryphe (*Ptychoparia*) *kingii* Meek, 1873, 6th Ann. Rept. U. S. Geol. Surv. Terr., p. 487. Referred U. S. Geol. Expl. 40th Paral., 1877, Vol. 4, p. 20, pl. 1, fig. 4. White, 1877, Rept. U. S. Geogr. Surv., West 100th Merid., Vol. 4, p. 40, pl. 2, figs. 2a-c. (Described and illustrated.)

Liostracus kingii Brögger, 1886, Geol. Foren. Stockholm Forhandl., bd. 8, p. 205. (Generic reference changed.)

Ptychoparia kingii Walcott, 1886, U. S. Geol. Surv. Bull. 30, p. 193, pl. 27, figs. 4, 4a. (Described and illustrated.) Research in China, 1913, Carnegie Inst., Vol. 3, pl. 12, fig. 6. (Illustrated.) Beecher, 1895, Amer. Geol., Vol. 16, p. 171, pl. 8, figs. 5-7. (Noted and illustrated.) Grabau and Shimer, 1910, N. A. Index Fossils, Vol. 2, p. 275, fig. 1573. (Illustrated.)

Elrathia kingii Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56, pl. 11, fig. 4.

Meek's very elaborate description gives the essential characters of the species, even though he included more than one form.

Formation and locality.—Middle Cambrian: (3w, 10y, 10z, 30g) Marjum formation. 1c of section. In cliff two miles (3.2 km.) southeast of Marjum Pass, House Range, Utah.

(3y) Marjum formation. Shaly limestones forming 1d of section, 2.5 miles (4 km.) east of Antelope Springs, in ridge east of Wheeler Amphitheater, House Range, Utah.

(4) Wheeler formation. Drift below cliffs near Antelope Springs, House Range, Utah.

(15b) Wheeler formation. Near Swazey Spring, House Range, Utah.

Genus ELVINIA Walcott

Elvinia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56.

Description.—A large number of closely related species belonging to this genus is present in the National Museum collections. Some are definitely in the Upper Cambrian while others are Ozarkian. The specific assignment of the various body parts seems fairly correct.

The principal character that distinguishes the genus is the first pair of glabellar furrows, which is strongly impressed, the lateral parts sloping backward and united by a straight horizontal furrow. Another very short and faint pair can sometimes be distinguished farther forward. An occipital furrow is present but often so shallow as to be distinguished with difficulty. Dorsal furrow strong and definite.

Fixed cheeks fairly wide. Ocular lines present, usually in the form of an escarpment-like edge of the more elevated portion of the fixed cheek lying back of this line. Eyes of moderate size and situated opposite the forward half of the glabella.

The facial suture diverges slightly in front of the eyes and is intramarginal for about half way. Back of the eyes it passes rapidly outward in a gentle curve, thus giving a wide base to the cranidium. Free cheeks wide, with a well-defined rim. Genal spines usually long.

The pygidium of *Elvinia* is characterized by its clearly defined rings on the axis and the broad, but more shallow, pleural furrows. The axis is convex, cylindrical to sub-cylindrical in form, and it usually extends nearly to the posterior margin. The pygidia of many species have a wire-like raised edge which widens and thickens toward the anterior angles and joins the larger segment, usually the first.

Genotype.—*Dikelocephalus roemeri* Shumard.

Range.—Upper Cambrian—Ozarkian: New York and Pennsylvania, and numerous localities west of the Mississippi River.

ELVINIA ROEMERI (Shumard)

Plate 17, figs. 9-13

Dikelocephalus roemeri Shumard, 1861, Amer. Journ. Sci., 2nd ser., Vol. 32, p. 220. (Original description.)

Ptychoparia roemeri Walcott, 1914, Smithsonian Misc. Coll., Vol. 57, No. 13, p. 352. (Generic reference.)

Elvinia roemeri Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 56, pl. 11, fig. 3.

Observations.—The cephalon here illustrated has been chosen as most nearly representing Shumard's description of the species. It is necessary to make several species from among the numerous specimens from Texas. It will be noted that a different pygidium has here been assigned to this than that given by Shumard. It is true that the pygidium apparently referred to in Shumard's description occurs with the heads of *Elvinia,* but at other localities, some far removed from Texas, only the type of pygidium here illustrated is associated with these heads wherever they occur.

Formation and locality.—Upper Cambrian: (68) Cap Mountain formation. Packsaddle Mountain, Llano County.

(70) Baldy Mountain, Morgans Creek, eight miles (12.9 km.) northwest of Burnet, Burnet County, Texas.

Genus EUREKIA Walcott

Eurekia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, pp. 56, 57.

Description.—*Eurekia* is represented by numerous specimens of the cranidium, free cheeks and associated pygidium. The strongly convex glabella with its deep dorsal furrows, the narrow upturned frontal border, narrow fixed cheeks and palpebral lobes, combine to give the cranidium a very distinctive character as does the associated pygidium (pl. 16, fig. 17). As at present constituted the genus includes species both with and without glabellar furrows. It may be that as the study of this group advances beyond its present incomplete stage, the species without glabellar furrows will adhere to *Corbinia* rather than to *Eurekia,* but the structure of the frontal rim and of the pygidium seems to prevent this. The eyes of *Corbinia* are also smaller than in *Eurekia.*

There are several described species that appear to belong to the genus.

Dicellocephalus ? angustifrons Walcott, 1884, Monogr. Geol. Surv., Vol. 8, p. 42, pl. 10, figs. 1, 1a, 1b.

Ptychoparia (Euloma) dissimilis Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 51, pl. 9, fig. 28.

Conocephalites eos Hall, 1863, 16th Ann. Rept. State Cabinet Nat. Hist., p. 151, pl. 7, fig. 24, pl. 8, figs. 8, 9.

Conocephalites binodosus Hall, 1863, 16th Ann. Rept. State Cabinet Nat. Hist., p. 160, pl. 7, fig. 47. Hall did not associate any head with this species but later collections have furnished numerous examples. It has recently been described by Clark[1] as *Bayfieldia finkelnburgi.*

Genotype.—*Eurekia granulosa* Walcott.

Range.—Upper Cambrian: Great Basin, Rocky Mountains and Mississippi Valley (north and south).

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[1] Clark, 1924, Bull. American Pal., Vol. 10, No. 41, p. 32, pl. 4, fig. 7.

EUREKIA DISSIMILIS (Walcott)

Pl. 16, fig. 12.

Ptychoparia (*Euloma ?*) *dissimilis* Walcott, 1884, Monogr. U. S. Geol. Surv., 8, p. 51, pl. 9, fig. 28.

Eurekia dissimilis Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, p. 409. (Generic reference.)

The original description of this imperfect cranidium suffices to indicate the species, although the structure of the frontal limb is better shown in specimens obtained more recently.

Observations.—*E. dissimilis* differs from *E. granulosa* in the longer and less quadrate glabella, the more posterior position of the occipital furrow and ring and the less granulose surface. The frontal limb is insufficiently preserved to allow a knowledge of its details.

Formation and locality.—Upper Cambrian: (54) Secret Canyon shale, New York Canyon, Eureka District, Nevada.

EUREKIA GRANULOSA Walcott

Plate 16, figs. 13-17

Eurekia granulosa Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57, pl. 12, fig. 1.

All that is known of this species is shown by the illustrations. It apparently has a wide geographic distribution and may be one of the Mississippi Valley forms that occurs in the Cordilleran area of Nevada.

Formation and locality.—Upper Cambrian, Hamburg ? formation: (88) West side of Highland Range, 17 miles (27.4 km.) southwest of Pioche, Lincoln County, Nevada. Apparently also present in the Mississippi Valley, but further study is required to be certain that these forms are conspecific.

Genus HARDYIA Walcott

Hardyia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57.

Description.—The glabella is rectangular in outline extending to the front of the head. Two sets of very short glabellar furrows are faintly indicated. The neck furrow and ring are rather large for so small a trilobite.

Fixed cheeks wide, particularly back of the eyes. Eyes small, situated well forward. A narrow straight rim immediately in front of the glabella.

Other portions of this trilobite unknown, and the material available for study of the cranidium is not very satisfactory.

Genotype.—*Hardyia metion* Walcott.

Range.—Ozarkian; Canadian Rockies.

HARDYIA METION Walcott

Plate 18, fig. 9

Hardyia metion Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57, pl. 12, fig. 5.

The illustration and generic description include the known specific characters.

Formation and locality.—Ozarkian: (66k) Mons formation. Ranger Canyon, Sawback Range, Alberta.

Genus HOLTERIA Walcott

Holteria Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57.

Description.—The genus is based primarily on the pygidium. It is fairly certain that the head and tail assigned to the genotype belong together, but the cranidia of *Holteria problematica* and of *Neolenus inflatus*[1] Walcott are indistinguishable generically while the pygidia assigned to the two species are quite unlike.

The cranidium is characterized by the large prominent glabella, which expands toward the front. There is no frontal limb, thus causing the glabella to occupy the full length of the cranidium, which has three sets of very faint glabellar furrows; the posterior pair being broad and somewhat interrupted by small elevations within them.

Fixed cheeks narrow in front, widening out rapidly posteriorly, due to the contracting glabella and the diverging suture. Eyes a little less than medium size, situated about opposite the middle of the glabella. The facial suture diverges somewhat in passing forward from the eye leaving a flat area at the front corners; it may possibly be intramarginal, a point that cannot be determined in the absence of a rim and since the free cheeks are unknown. At the point where the margin of the glabella turns toward the front, there are pit-like depressions, a character very prominent in some of the related genera. Back of the eye the facial suture turns suddenly outward outlining rather long and broad postero-lateral limbs.

The pygidium is very distinctive. It is broad and flat with a well-defined axis extending more than three-fourths of the distance to the posterior margin. The axis is relatively narrow and tapers to a slight broadening at the end. The five axial furrows are not deep and the posterior ones are barely discernible.

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[1] See *Neolenus*, 1908, Smithsonian Misc. Coll. Vol. 53, No. 2, pls. 4-6.

The lateral portions of the pygidium are flat, tapering off to terminate in two long spines on each side. These spines appear to be the extension of two very broad and furrowed pleuræ, fused together by the flat areas between.

Observations.—A preliminary review has recently been made in connection with the erection of the genus *Holteria,* of the related genera. It was ascertained that all of the species previously referred to *Olenoides* (Bull. U. S. Geol. Surv. No. 30, 1886, pp. 180-190) are not congeneric with the genotype, of which only the single specimen originally described has ever been found. This fragment is made distinct by the course of the pleural furrows. It might well be that additional material, if it could ever be found, would prove this specimen to be erratic and not typical. The species of *Olenoides* all fall quite readily into *Neolenus* and *Kootenia.* The cranidia of

Fig. 13.—*Holteria problematica* (Walcott).
Side outline of the cranidium illustrated in figure 17, plate 15.

the 40 or more species of *Kootenia* and the dozen or more species assigned to *Neolenus,* together with those assigned to *Holteria,* form an almost unbroken series from the one extreme to the other and in the absence of the distinctive pygidia could well be retained in one genus. The pygidia, however, are quite distinct in plan. *Holteria* has a well-fused pygidium with two spines arising from a flat border on either side. *Neolenus* lacks the flat border, has the individual pleuræ separate enough to be readily distinguishable and from three to nine spines on either side. *Kootenia* is distinguished by the fusion of the pleuræ to the extent that the boundary between them is only rarely discernible, and then with great difficulty. The pleural furrows, as in the foregoing genera, are quite deep. *Kootenia* has usually four or five spines to a side, but they may vary in length from mere scallops to long, heavy spines equal to the length of the pygidium.

Genotype.—*Ogygia ? problematica* Walcott.

Range.—Upper Cambrian: Great Basin, Nevada.

HOLTERIA PROBLEMATICA (Walcott)

Plate 15, figs. 17-21

Ogygia ? problematica Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 63, pl. 10, figs. 2a, b, 4. (Original description and illustration.)

Holteria problematica Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57, pl. 13, fig. 7.

See original description of the species.

Formation and locality.—Upper Cambrian: (58) Secret Canyon shale. East side of New York and Secret Canyons, Eureka District, Nevada.

Genus HOUSIA Walcott

Ceratopyge Walcott, 1912, Smithsonian Misc. Coll., Vol. 57, No. 7, p. 233.

Housia Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, No. 5, p. 374. (Subgenus of *Dolichometopus:* type *D.* (*Housia*) *varro* Walcott.)

Sodalitia Walcott, 1923, Smithsonian Misc. Coll., Vol. 67, No. 8, p. 471. (In lists.)

Housia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57.

Description.—The type species when first described was made a subgenus of *Dolichometopus,* the cranidium being incorrectly drawn because a portion of the specimen was obscured in the matrix. The generic name *Sodalitia* was proposed in lists[1] for forms now known to belong to this genus.

Cranidium long and narrow. Glabella not separated from fixed cheeks. Eyes rather small situated opposite the middle and narrowest part of the cephalon. Postero-lateral limbs long and narrow with a shallow intermarginal furrow. The cranidium slopes down rapidly a short distance in front of the eyes and flattens out again, somewhat, into the frontal rim and border, which is moderately wide. Facial suture intramarginal. A central keel-like line is faintly visible on most specimens of the glabella and some have a tubercle directly between the eyes and another in the occipital region. Glabellar furrows none or very faint on upper surface. Three sets visible on some casts of the interior. The front set consists merely of two dots and is situated in front of the eyes. The other two sets increase in size, until the third one, beginning at a point opposite the hindermost edge of eyes and extending obliquely backward, attains considerable length.

Free cheeks with a wide border, with or without a genal spine. Those without a spine become quite circular in outline. A doublure of even width passes entirely around the cephalon and is apparently of one piece.

[1] See Synonymy.

Thorax contains 10 segments in all species of which entire specimens are known, all with a narrow median pleural furrow and ending abruptly in a blunt spine.

Pygidium consists of two parts, the posterior one being a welded shield somewhat like the tail of *Asaphiscus* and the anterior one a pleura-like segment extending into long spines, but attached firmly to the more solid shield. In some species two or more rings are visible on the axis and several lateral furrows at the front edge of this shield. Border or pygidium quite broad in some species. Apparently a doublure as wide as the border, occurs under it.

Derivation of name.—House Range, Utah.

Genotype.—*Dolichometopus* (*Housia*) *varro* Walcott.

Range.—Upper Cambrian, Cordilleran area of Canada and the United States.

Observations.—*Housia* differs from *Ceratopyge forficula* Sars, the type of the latter genus, in many important respects. In *Ceratopyge* the glabella is distinctly separated by a strong dorsal furrow, passing all the way around. There is also no wide frontal border and rim. There is a very narrow rim, almost wire-like, in which the suture could not have been intramarginal in the same manner as in *Housia*. The suture also diverges a little more in *Ceratopyge*. The glabellar furrows are definite, extending straight across and not oblique to the glabella.

The pygidia of the two genera are quite different. That of *Ceratopyge* is completely fused. There is no wide rim but simply a wire-like one. Axis relatively high and annulated. The two lateral spines of the *Ceratopyge* tail are not the definite segments as in *Housia,* but arise from the second or third segment and are fused with the rim.

In addition to the two described species of *Housia* there are two from the Goodsir formation that will be published in a future paper.

HOUSIA CANADENSIS (Walcott)

Plate 22, figs. 10, 11

Ceratopyge canadensis Walcott, 1912, Smithsonian Misc. Coll., Vol. 57, No. 7, p. 233, pl. 35, figs. 17, 20, 21 (not figs. 13-16, 18, 19, 22).

Observations.—The figures of *Housia canadensis* published in 1912 are all of more or less distorted specimens which have now been referred to three species. Entire individuals are available for most of the species and so the reference of the various cheeks and pygidia to the cranidia is much more certain than where entire specimens are lacking.

Housia canadensis is one of the species with a genal spine. The illustration of the head in figure 11, plate 22, is the cast of the under side of the test. The striations shown on the frontal rim, which is here less distinct than on the dorsal side, are possibly not impressed on the upper surface.

In several of the pygidia the border is broken away exposing the striated doublure. The test of this trilobite apparently was smooth, except possibly radiating irregular lines on the free cheek, a feature found in another better preserved species.

H. canadensis differs from *H. varro* in the presence of the genal spine, which results in a less circular outline for the free cheeks. The facial suture diverges a little more. The pygidium of *H. canadensis* has more clearly marked axial and pleural furrows. The rim is also relatively wider.

Formation and locality.—Upper Cambrian, Goodsir formation. Ice River Valley about six to eight miles (9.7 to 12.9 km.) southeast of Leanchoil Station; Moose Creek; and Mount Goodsir, British Columbia.

HOUSIA VARRO (Walcott)

Plate 18, figs. 4-8

Dolichometopus (*Housia*) *varro* Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, No. 5, p. 374, pl. 65, figs. 1, 1a-e.

Housia varro Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 57, pl. 12, fig. 4.

The original description, together with the generic diagnosis, gives the character of this species.

Formation and locality.—Upper Cambrian: (30y) Orr formation. Orr Ridge, south of Marjum Pass, House Range, Utah.

Genus IDAHOIA Walcott

Idahoia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58.

Description.—The genus *Idahoia* is characterized by the unusual development of the frontal limb. The glabella occupies only about half the length of the cranidium and has no glabellar nor occipital furrow. The broad occipital segment bears a strong occipital spine that is nearly as long as the glabella. Dorsal furrow well-marked and transverse in front of the glabella, which tapers slightly. The facial sutures delimit long and narrow postero-lateral limbs and diverge rapidly in front of the eyes and are entirely intramarginal. The frontal limb is composed of three wide parts. On the cranidium there is the border and rim and in front of this the free cheeks add a narrow part that merges into the front of the border.

Free cheeks wide, with long strong genal spines: they appear somewhat unusual because of the extra furrow necessitated in order to fit on the front of the head.

Associated pygidium large with the high, strong axis occupying about half its length: border concave and considerably upturned in some species. Three axial rings and three to four pleuræ are outlined that merge into the broad border.

Genotype.—*Idahoia serapio* Walcott.

Range.—Upper Cambrian: Rocky Mountains of Idaho.

Observations.—*Idahoia,* during its study, was first regarded as a relative of *Saratogia,* but the absence of glabellar and occipital furrows, the wider fixed cheeks, the intramarginal suture and the frontal limb give the genus very distinctive characters.

IDAHOIA MALADENSIS, new species

Plate 19, figs. 13, 14

Observations.—This species is represented by considerably less material than *I. serapio.* It differs from the latter in the greater convexity of the border and rim. The glabella is also lower, with a hint of two pairs of short glabellar furrows.

The associated pygidium assigned to this species differs from that assigned to *I. serapio* in its somewhat broader, even more concave, border and fewer pleural segments.

Formation and locality.—Same as for *Idahoia serapio.*

IDAHOIA SERAPIO Walcott

Plate 19, figs. 1-12

Idahoia serapio Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58, pl. 14, fig. 1.

Observations.—The generic description, together with figures, present most of the characters of the species. None of the free cheeks is sufficiently well preserved to give a complete representation of the anterior portion. The width of the doublure is indicated in figure 4, where the upper shell is broken away.

Formation and locality.—Upper Cambrian: (54w) Ovid formation. On the north side of Two Mile Canyon, two miles (3.2 km.) southeast of Malad, Oneida County, Idaho.

Genus IDDINGSIA Walcott

Iddingsia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58.

Description.—*Iddingsia* is based on the cranidium and includes a small group of species present in the Great Basin and eastward.

The cranidium of *Iddingsia* is distinguished by its nearly flat, sloping, equally divided frontal border, strongly developed glabella and narrow fixed cheeks. It differs from *Dunderbergia* and *Modocia*, with which it is associated, in the equal width of its border and rim. The ocular ridges are also quite prominent.

The other parts are unknown.

Genotype.—*Ptychoparia similis* Walcott.

Range.—Upper Cambrian, Eureka District, Nevada.

The generic name is in memory of Dr. Joseph P. Iddings, geologist, who was my associate in the survey of the Eureka District in 1880.

IDDINGSIA ROBUSTA (Walcott)

Plate 16, figs. 10, 11

Ptychoparia similis robustus Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 53, pl. 1, figs. 9, 9a. (Original description and illustrations.)

This species varies slightly from *I. similis* in the relative proportions of the parts of the cranidium, sufficiently to warrant regarding it as a full species rather than a variety.

Formation and locality.—Same as for *I. similis*.

IDDINGSIA SIMILIS (Walcott)

Plate 16, figs. 8, 9

Ptychoparia similis Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 52, pl. 10, fig. 10. (Original description and illustration.)

Iddingsia similis Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58, pl. 12, fig. 6.

The original description and figures 8 and 9 give all that is known of this species.

Formation and locality.—Upper Cambrian: (60) Secret Canyon shale, near Richmond Mine. (61) Near Hamburg Mine, Eureka District, Nevada.

Genus IRVINGELLA Ulrich and Resser

Irvingella Ulrich and Resser in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58.

Description.—Glabella large, the dorsal and occipital furrows very strong and usually rather wide; the posterior pair of glabellar furrows is always present and is usually united across the glabella; a second pair is usually short, but sometimes deep and extending entirely across the glabella. Fixed cheeks wide, with very large palpebral lobes in most of the species. In the type species they are more than three-fourths as long as the glabella. Most of the species of *Irvingella* have a narrow transverse frontal border but no rim.

Free cheeks very narrow, in most species being little more than a band passing around the eyes and filling in the notch anterior to them and meeting the very short, and usually blunt, postero-lateral limbs. So far as known the free cheeks have long genal spines.

Thorax unknown except for isolated segments, in which the elevation of the axis usually agrees with that of the transverse section of the head.

The pygidium has a high, wide and long axis and flat sides. Several rings are usually present in the axis. The sides may or may not have pleuræ indicated. Border often turned up into a wire-like rim.

Derivation of name.—Proposed in honor of the late Professor J. D. Irving.

Genotype.—*Irvingella major* Ulrich and Resser.

Range.—Upper Cambrian and Ozarkian: Appalachians and Mississippi Valley, Rocky Mountains, and Nova Zemlya.

Observations.—*Irvingella* resembles *Chariocephalus* very closely; in fact the two genera approach so nearly that it is almost necessary to draw an arbitrary line separating them. *Irvingella* is distinguished by its larger eyes, usual presence of glabellar furrows—sometimes, however, not any more visible than in *Chariocephalus*—larger fixed and smaller free cheeks and the better definition of the axis of the pygidia.

More than 25 species have been determined in about one-half of the collections in the National Museum from the Upper Cambrian and Ozarkian, in which the genus is widely distributed.

IRVINGELLA MAJOR Ulrich and Resser

Plate 15, figs. 26-29

Irvingella major Ulrich and Resser in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58, pl. 10, fig. 3.

The illustrations, particularly figure 26 which has been carefully restored, show the characters of this species. All the specimens, about 20 in number, both complete cranidia and fragments, are contained in a single hand specimen.

Formation and locality.—Upper Cambrian: (80n) Micaceous shale member of the Franconia formation, Ableman, Wisconsin.

ISOTELOIDES

Isoteloides Raymond, 1910, Ann. Carnegie Mus., 7, No. 1, pp. 36, 67; 1910, 7th Rep. Vermont State Geol., p. 223; 1912, Trans. and Proc. Roy. Soc. Canada, 5, 3d ser., sec. 4, p. 115.

Observations.—This genus appears to be characteristic of the Beekmantown and Ordovician, occurring over a wide area in the northern Rocky Mountains, in the Garden City limestone and beds of similar age. Its presence in the upper Mons suggests the possibility of the uppermost beds here and there being referable to the Beekmantown, but like *Bellefontia* it may occur in greater numbers in the Ozarkian.

ISOTELOIDES LAUTUS, new species

Plate 24, fig. 25

Observations.—This cranidium and free cheek which may belong together are referred to *Isoteloides* with reservation since the head is quite narrow and has very narrow fixed cheeks.

Formation and locality.—Ozarkian: (66v) Mons formation. Upper Johnson Creek Canyon about one mile (1.6 km.) below divide on east side of canyon, Sawback Range, 21 miles (33.8 km.) northwest of Banff, Alberta, Canada.

ISOTELOIDES ? MALADENSIS, new species

Plate 24, fig. 27

Observations.—With better preserved specimens this species may be transferred to *Xenostegium.* The cranidium resembles that of *X. kirki* and does not seem to be an *Isoteloides* because of its expanded front. The pygidium appears to belong to the latter genus, but it is broken away posteriorly so that the presence or absence of a spine is uncertain.

Formation and locality.—Upper Ozarkian ?: Near Malad, Idaho.

ISOTELOIDES OCCIDENTALIS, new species

Plate 24, fig. 26

Observations.—The cranidium and pygidium associated on a fragment of rock appear to have the essential characters of *Isoteloides.* The species differs from *I. whitfieldi* Raymond mainly in its wider cranidium, and the pygidium, so far as its characters are ascertainable, is very little different from the one assigned to that species.

Formation and locality.—Ozarkian ?, Mons formation (67h) North fork Saskatchewan River, 3 miles (4.8 km.) south of Wilcox Pass, Alberta, Canada.

ISOTELOIDES ? sp. undt.

Plate 24, fig. 24

This small fragmentary cranidium is presented here in order to illustrate a group of trilobites that occurs occasionally, but of which the material thus far is so poor that the characters cannot yet be determined. The fragment bears a superficial resemblance to this genus and on that account may be tentatively referred to it.

Formation and locality.—Ozarkian: (67h) Mons formation. Head north fork Saskatchewan River, three miles (4.8 km.) south of Wilcox Pass, Alberta, Canada.

KAINELLA, new genus

Hungaia Walcott, 1913, Smithsonian Misc. Coll., Vol. 57, No. 12, p. 336 (listed); idem, 1924, Vol. 75, No. 1, p. 37.

Kainella Walcott, 1925, Smithsonian Misc. Coll., Vol. 77, No. 2, p. 14. (New name proposed.)

This genus is clearly defined by the unusual direction of the facial suture, together with the peculiarities of the associated pygidium. No entire specimens have yet been found of any species belonging to it.

Glabella rectangular in outline, slightly rounded in front, relatively flat in cross-section. Two sets of glabellar furrows are present in front of the occipital furrow. The anterior set consists of two oblique depressions, while the posterior ones are similar, though longer, and are connected across the glabella by a very shallow furrow.

Eyes large and situated about the midlength of the glabella.

Fixed cheeks very narrow.

Facial suture outlining long narrow postero-lateral limbs, passes around the eyes and a short distance beyond, turns outward almost at right angles to the glabella. The distance from this angle to the frontal rim equals two-thirds or more of the length of the glabella. The suture is intramarginal to the center.

Frontal rim and border wide. Border between the glabella and rim marked by rather pronounced, peculiar ridges, slightly irregular in course and size. In the different species, these radiate from the front of the glabella in groups of varying numbers. The stronger ones usually start from two points of origin near the front inner corners of the glabella and extend to and merge into the rim. The weaker ones, originating in front and back and along the sides of the glabella almost to the eyes, for the most part fail to reach the rim. A row of deep pits, somewhat irregularly spaced, occur in the frontal furrow immediately back of the frontal rim.

Free cheeks large, extending into a strong and long genal spine. Their shape is somewhat peculiar due to the unusual direction taken by the facial suture. A wide doublure extends from the genal angles forward, maintaining practically an even width from a point anterior to the occipital furrow to the center of the head. Thus far none of the specimens has permitted the determination as to whether this doublure is continuous and uninterrupted across the front of the cephalon, or whether there is a median suture, or finally whether there is an epistoma. As now known, specimens suggest a continuous doublure. The pleuræ near the front of the thorax are long, to accord with the wide cranidium. They have a rather deep, narrow pleural furrow, that has a slightly oblique direction, but yet approximately bisecting the pleuræ and extending out to about the point where the pleura begins to bend backward. The pleuræ near the posterior end are shorter in a transverse direction, with wider furrows, which bend backward with the pleura. The pleuræ here are as long as those in the anterior portion of the thorax, but bend backward much sooner and are extended into a long slender spine. The posterior pleuræ must have enveloped the pygidium.

Pygidium large and flat, with a definite, large, high axis. The axis consists of from four or five to seven or more rings. The axial furrows do not pass straight across but are as illustrated in figure 4. The axis proper terminates some distance from the posterior edge, dropping steeply off to the flat border, but with a median ridge extending to the posterior edge, such as would be made by pinching the axis with the fingers if it were made of some plastic material. There are two definite pleuræ in the tail outside of the flat areas, which lie on either side of the axis and which vary in relative size in the different species and in some, one or more additional pleuræ, differentiated by additional shallow furrows, may be distinguished. The outer pleuræ always extend beyond the border into sharp spines. They are unfurrowed and the interpleural furrows are characterized by their wavy course.

Derivation of name.—Named in honor of Conrad Kain, Swiss guide and explorer of the Canadian Rockies.

Genotype.—*Hungaia billingsi* Walcott.

Range.—Ozarkian: Cordilleran area of Canada and the United States, Province of Quebec at Point Levis and possibly Vermont in Champlain Valley.

KAINELLA BILLINGSI (Walcott)

Plate 22, figs. 1-7

Hungaia billingsi Walcott, 1913, Smithsonian Misc. Coll., Vol. 57, No. 12, p. 336 (listed only); idem, 1924, Vol. 75, No. 1, p. 37, fig. 7.

Observations.—This species, known only from the dissociated parts, is the largest of six species determined from the locality. The presence of so large a number of species makes it impossible to be altogether certain that the pleuræ, pygidium, and free cheeks here assigned to this cranidium actually belong together. Most species of this genus have been founded on the pygidium, one of which (*H. flagricaudus*) was long ago described by White, as these parts are more readily distinguishable one from the other than the cranidia. All that can be said with respect to the grouping of the parts here assigned to *K. billingsi* is that it seems most natural after a study of the available material.

The illustrations, together with the generic diagnosis, give the characters of the species.

Specific name is given in honor of Elkana Billings, a pioneer paleontologist of the Geological Survey of Canada.

This is a widely distributed genus in the Cordilleran area of western Canada and the United States. Thus far it has been found only in dismembered fragments of the dorsal shield, but usually in great quantities of one or two species. Altogether 20 species have thus far been differentiated.

The Kainella zone is a well-marked horizon in the lower part of the upper third of the Mons formation and thus far it has been found to be a serviceable unit in comparing stratigraphic sections. It has a known vertical range from a few feet up to 130 feet (39.6 m.).

The described species referred to the genus are:

Dicellocephalus ? flagricaudus White, 1874. See U. S. Geol. Surv. Bull. 30, 1886, p. 185, pl. 25, fig. 4.

Dicellocephalus inexpectans (Walcott), 1884. Monogr. U. S. Geol. Surv., Vol. 9, p. 90, pl. 1, fig. 10.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness, one or two layers quite ferruginous. In Billings Butte (Extinguisher) at end of west spur of Mount Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

Genus KINGSTONIA Walcott

Kingstonia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58.

Description.—Cephalon semi-circular in outline, without genal spines; nearly uniformly convex, all furrows weak or quite invisible externally, but the dorsal and occipital furrows more or less plainly indicated on inner surface of test; a very thin rim usually striated, around middle half of head. Glabella subquadrate, rounded in front, not extending to the frontal groove, but leaving a wide invariably undefined brim between it and the rim. Fixed cheeks rather wide, eyes very small, situated nearly opposite but always behind the anterior extremity of the glabella. Suture extending almost directly forward from the eyes and cutting the rim abruptly. Behind the eyes it runs diagonally backward and outward, ending just within the genal angles. Free cheeks small, narrow.

Pygidium relatively large, externally unsegmented without border, varying in outline from subtriangular to transversely suboblong, with convex, steeply descending and often thick edge. Axis rather narrow, long, usually clearly, though never deeply, outlined on sides and behind. Where the shell is removed traces of segments usually observable on both the axis and pleural lobes.

Genotype.—*Kingstonia apion* Walcott.

Range.—Small trilobites belonging to *Kingstonia, Ucebia,* and five or six related genera have been noted in the older collections for many years, but more recently many species and hundreds of individuals have come to light. *Kingstonia* occurs in the upper Cambrian formations of the southern Appalachians, central Pennsylvania, and throughout the Rocky Mountains. A single species occurs in the Ozarkian in northern Vermont. *Kingstonia* appears in faunas of Atlantic and Arctic waters.

KINGSTONIA APION Walcott

Plate 16, figs. 27-28a

Kingstonia apion Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 58, pl. 14, fig. 2.

This trilobite was considered at first to be a small species of *Illaenurus,* but comparison with specimens of the latter led to its being taken as the type of a new genus. The generic description and figures present its more prominent characters.

Formation and locality.—Upper Cambrian: (127) Maryville formation. Five miles (8 km.) west of Cleveland, Tennessee.

Genus **LEIOSTEGIUM** Raymond

Leiostegium Raymond, 1913, Bull. No. 1, Victoria Memorial Museum, p. 68.

Observations.—The genus *Leiostegium* founded by Raymond on Billings' *Bathyurus quadratus* hitherto has had a few species referred to it. At the present time in the study of the Ozarkian faunas 22 additional species have been determined or referred to the genus. Furthermore, three new genera have been erected to include the many forms grouping themselves about characters not belonging to *Leiostegium*. The name *Ptychostegium* appeared in certain published faunal lists, but further study proved that the characters used in the preliminary determinations were not of sufficient importance to be of generic rank.

LEIOSTEGIUM MANITOUENSIS, new species

Plate 23, figs. 12-19

Observations.—This species is characterized by its quadrate glabella with the two pits at each side in front, together with the size and position of the eyes and the small frontal border. Free cheeks fairly wide, all with a long genal spine. Facial suture intramarginal for a short distance. The doublure of the free cheeks is a continuous piece of even width across the front of the head.

The associated pygidium is not very unlike that of *Bellefontia* (see figs. 10, 11, pl. 23), but it can be distinguished by its more definite border, definite rings on the axis and by its more subtriangular outline.

Formation and locality.—Ozarkian: (187) Basal Manitou limestone, two miles (3.2 km.) below Manitou Park Hotel, Colorado: Chushina formation, Mt. Extinguisher near Mt. Robson, British Columbia (61q).

Genus **MALADIA** Walcott

Maladia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59.

The cranidium of *Maladia* is somewhat quadrate in shape. The glabella is outlined by the dorsal furrow and a wide, deep occipital furrow. Eyes large. Free cheeks rounded and without genal spines. Pygidium with spinose border, with a very high axis. Pleuræ are well fused.

This genus with its strongly defined cranidium and associated pygidium (same at several localities) is related by the course of its facial sutures, free cheeks, and pygidium with *Eurekia*, and to a much less extent with *Corbinia*, but is clearly not congeneric with either.

Genotype.—*Maladia americana* Walcott.

Range.—Upper Cambrian: Ovid formation, Idaho. Grand Canyon, Arizona.

MALADIA AMERICANA Walcott

Plate 16, figs. 23-26

Maladia americana Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59, pl. 12, fig. 2.

The illustrations present practically all that is known of this species.

Formation and locality.—Upper Cambrian: (54x) Ovid formation. Sixty feet (18.3 m.) from top of bed 4, north side of Two Mile Canyon near its mouth, two miles (3.2 km.) southeast of Malad, Idaho.

Genus MODOCIA Walcott

Modocia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59.

The genus *Modocia* is based on the cranidia of a species known for more than 60 years that has been referred to six different genera by authors. It does not fall strictly within any described genus and to avoid further confusion a new name is proposed for it.

The cranidium of *Modocia* is characterized by its strong, subconical glabella without definite glabellar furrows; occipital furrow clearly defined and extending across the fixed cheeks within their posterior margin; occipital segment rather narrow: fixed cheeks broad and merging into strong postero-lateral limbs and the frontal limb which is of medium width: frontal border rounded, narrow at the ends and broadening very gradually to the center owing to the course of the facial outline which cuts the border on a line with the eyes and then curves sharply and continues obliquely across the border nearly to the center and possibly the two branches meet at the center, but the material in hand does not prove this: palpebral lobes small and located just back of the line of the longitudinal center of the cranidium. The fixed cheeks must have been of medium size. An associated pygidium was illustrated by Walcott.[1]

Genotype.—*Arionellus* (*Crepicephalus*) *oweni* Meek and Hayden.

Range.—Upper Cambrian: Black Hills, South Dakota, Big Horn Mountains, Wyoming, and probably in the Cordilleran area of western North America.

Observations.—The cranidium of *Modocia* suggests that of species which have been referred to *Crepicephalus, Blountia, Bathyuriscus, Asaphiscus,* etc. The cranidium, however, differs in the direction of the facial sutures through the frontal border and the very broad fixed cheeks.

[1] Monogr. U. S. Geol. Surv., 1884, Vol. 8, pl. 10, fig. 3a.

MODOCIA OWENI (Meek and Hayden)

Plate 16, figs. 1-3

Arionellus (*Crepicephalus*) *oweni* Meek and Hayden, 1861, Proc. Acad. Nat. Sci. Philadelphia, p. 436. (Original description of species.)

Arionellus ? oweni Meek and Hayden, 1862, Amer. Journ. Sci. Arts, ser. 2, Vol. 33, p. 74, fig. 4. (Description and illustration.)

Agraulos oweni Meek and Hayden, 1865, Pal. Upper Missouri, Smithsonian Contr. Knowl., Vol. 14, No. 172, p. 9, figs. a-c. (Change of generic reference.)

Crepicephalus (*Loganellus*) *centralis* Whitfield, 1877, Prelim. Rept. Pal. Black Hills, U. S. Geol. Surv., p. 10. (Description.)

Crepicephalus centralis Whitfield, 1880, Rept. Geol. Res. Black Hills, U. S. Geogr. and Geol. Surv., p. 341, pl. 2, figs. 21-24. (Description and illustration.)

Ptychoparia oweni Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 55, pl. 10, figs. 3, 3a. (Change of generic reference.) Grabau and Shimer, 1910, N. A. Index Fossils, Vol. 2, p. 277. (Mentioned.)

Crepicephalus oweni Miller, 1889, North Amer. Geol. Pal., p. 540. (Generic reference.)

Anomocarella oweni Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, No. 3, p. 204. (Generic reference.)

Modocia oweni Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59, pl. 12, fig. 7.

The generic description and the illustrations give all we know of this species.

Formation and locality.—Upper Cambrian: Deadwood formation. Castle Creek and Deadwood, Black Hills, South Dakota. Powder River, Big Horn Mountains, Wyoming.

Genus MOOSIA Walcott

Moosia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59.

Observations.—The genus *Moosia* is very much like *Olenus* in many respects. The glabellar and dorsal furrows are very similar in position, size and amount of depression. The eyes are also in very nearly the same position and of the same relative size. The three characters of *Moosia* which exclude it from *Olenus* are, first, the slight tapering of the glabella; second, the slightly greater divergence of the facial suture anterior to the eyes; and third, the eye-lines which here slope back whereas in *Olenus* they always run straight out from the glabella or even forward.

The pygidium associated with *Moosia* agrees in general appearance with that of *Olenus,* but differs in the greater width of the axis and character of furrows.

Genotype.—*Moosia grandis* Walcott.

Range.—Upper Cambrian: at present known only from the Rocky Mountains of southeastern British Columbia.

MOOSIA GRANDIS Walcott

Plate 23, figs. 20, 21

Moosia grandis Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59, pl. 14, fig. 9.

This species is founded on a few cranidia and one associated pygidium. Free cheeks unknown.

The illustrations and the generic description present the essential characters of the species.

Formation and locality.—Upper Cambrian: Goodsir formation. Moose Creek, British Columbia.

Genus MOXOMIA Walcott

Moxomia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59.

Glabella quadrate, two sets of glabellar furrows present, not joined across the glabella. Dorsal furrow deep and glabella clearly marked off all around.

Eyes small, situated well forward. Palpebral lobes not elevated as high as the glabella. Fixed cheeks about one-quarter the width of the glabella. A steep frontal border with a narrow rim present. Just inside of rim a row of pits. Rim ornamented by a series of fine, irregular lines running in a transverse direction. Facial suture diverges only slightly in front of the eye and apparently intersects the margin near the point where it joins the rim: *i. e.*, intramarginal for a short distance. Occipital furrow present.

Genotype.—*Crepicephalus* (*Bathyurus?*) *angulatus* Hall and Whitfield.

Range.—Ozarkian: Eureka District, Nevada; Robson Peak District, British Columbia.

MOXOMIA ANGULATA (Hall and Whitfield)

Plate 22, figs. 8, 9

Crepicephalus (*Bathyurus* ?) *angulatus* Hall and Whitfield, 1877, U. S. Geol. Expl. 40th Paral., Vol. 4, p. 220, pl. 2, fig. 28.

Ptychoparia ? *angulatus* Walcott, 1884, Monogr. U. S. Geol. Surv., 8, p. 269 (Generic Reference).

Ptychoparia (*Emmrichella*) *angulatus* Walcott, 1916, Smithsonian Misc. Coll., Vol. 64, p. 204 (Generic Reference).

Moxomia hecuba Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59, pl. 12, fig. 3.

The generic description indicates all the known characters of this species.

Formation and locality.—Ozarkian: (61q) Chushina formation. Gray limestone in beds of varying thickness one or two layers quite ferruginous. In Billings Butte (Extinguisher), at end of west spur of Mt. Lynx, above Hunga Glacier and east of Robson Peak, Robson Park, northwest of Yellowhead Pass, in eastern British Columbia, Canada.

SYMPHYSURINA Ulrich

Symphysurina Ulrich in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 1, p. 37.

Quotation from Dr. Ulrich's manuscript:

Description.—"Cephalon strongly convex, a quarter-sphere in form. Cranidium subquadrate, usually longer than wide, excepting the more or less produced post-lateral extremities, bordered in front with a narrow striated rim. Palpebral lobes situated either midway between the anterior and posterior angles or somewhat behind the midlength of the cranidium, the length of the lobes equaling one-sixth to one-fourth the length of the cranidium, and between one-fourth and one-third the distance between their bases. Eyes moderate in size and prominence, facetted as in the Asaphidae. Median tubercle small but constantly present, situated between the eyes, hence far from the posterior edge. Glabella large, unfurrowed, convex, not defined in front of the eyes and usually but faintly outlined behind them; fixed cheeks narrow. Neck furrows and neck ring practically indistinguishable. Sutures nearly straight and commonly diverging slightly anteriorly from the eyes, reaching the edge of the cephalon which they follow in passing around the front of the cranidium. Free cheeks large, rounded triangular to subquadrate in outline, the posterior edge curving forward to the genal angle which is broadly obtuse, sharply pointed, or drawn out into a spine. Surface of cheeks with or without a wide, undefined, depressed border, and more generally a striated raised rim that increases in prominence as it approaches the anterior angle of the cranidium. This rim is the dorsal edge of the doublure which continues its course beneath the front edge of the cranidium until it meets the similar extension from the opposite cheek.

"The associated hypostoma is broadly alate anteriorly, with a deep pit at the middle of the anterior edge making this part appear bilobed, median portion strongly swollen; posterior margin rounded, with two concentric, partly interrupted ridges. The marginal ridge dies out forward on the posterior part of the anterior wings.

"Thorax known only from fragments of the segments; the axis approximately one-third the width. An imperfect specimen suggests that the segments were nine in number, rather wide, and grooved as in *Asaphus*.

"Associated pygidia referred to the genus semi-elliptical to triangular, always much wider than long, with a fairly distinct axis that may or may not reach the margin, and in others prolonged posteriorly into a spine. Segmentation imperfect, usually obsolete except for one or two ribs at the anterior edge, or with as many as four segments on the axis but never more than two on the pleura, that latter being for the greater part smooth. Surface gently convex to the edge or with an obscurely defined, wide, marginal depression. Doublure rather wide, about as in *Asaphus*."

Dimensions.—The known species range in length from less than one inch to perhaps three inches (2.54 to 7.62 cm.).

Genotype.—*Symphysurina woosteri* Ulrich.

Stratigraphic range.—Lower or Middle to Upper Ozarkian.

Geographic distribution.—Quebec, upper Mississippi Valley, Nevada, Alberta and British Columbia.

Observations.—"As defined *Symphysurina* is remarkable in that it includes species with and others without genal spines; also species in which the axis of the pygidium fails to reach the posterior margin, and others in which it is prolonged posteriorly in a long spine. In some the pygidium has a flattened or concave border and in others the slope of the pleural lobes continues convex to the edge. Such differences are often regarded as of generic significance, but in *Symphysurina* the cranidial characters are so constant that they do not appear to be of more than specific importance. Besides, the associated pygidia of the various species exhibit among them every gradation from the condition obtaining in *S. illaenoides,* in which the end of the axis is blunt and one-fourth its length from the margin, to the long-spined condition observed in *S. spicata* and *S. goniura.* The progressive chain formed by the pygidia of *S. illaenoides, S. billingsi, S. striatifrons, S. eurekensis, S. obtusa, S. woosteri, S. spicata* and *S. goniura,* while probably not altogether genetic, is yet too gradual in the differentiation of its limits to encourage one in drawing even a subgeneric boundary between any two of them. And it is much the same with respect to the genal spines and the submarginal grooves. Apparently *Symphysurina* affords here merely another illustration of the unstability of the Ozarkian trilobites in characters that were developed more regularly in the preceding Cambrian and succeeding Canadian and later periods.

"Two species of this new genus have been referred to *Symphysurus* by Brögger and Raymond, the former having done this for *S. eurekensis* (Walcott) and the latter for *S. illaenoides* (Billings). Indeed, the cranidium in the new genus is considerably like that of such typical species of *Symphysurus* as *S. angustatus* and *S. palpebrosus*. Carefully compared, however, certain differences appear: the eyes are larger and situated nearer the front in *Symphysurus;* the dorsal furrows are deeper and in front of the eyes follow the suture, there being in this part no fixed cheek. In *Symphysurina,* on the contrary, there is always—even though the dorsal furrow is shallow—some space left on the antero-lateral parts of the cranidium that may be called a fixed cheek. As for the posterior fixed cheeks, these are relatively larger in *Symphysurus,* while the opposite is true of the free cheeks. The free cheeks show another, probably more important, difference in the extension of the doublure beneath the front of the cranidium. As described by Brögger and others these extensions from the opposite cheeks unite in the middle of the head of typical species of *Symphysurus* and *Nileus* without leaving a suture where they join. The two cheeks thus are united into a single piece. In *Symphysurina,* however, this never occurs, the two cheeks being separated by a suture precisely like that found in all of the true Asaphidae.

"On the other hand, as already indicated, the cephalon of *Symphysurina* is not greatly different from that of *Nileus* and *Symphysurus*. However, only the latter requires close comparison because *Nileus* is distinguished readily enough by its evenly convex, unlobed and unsegmented pygidium, very wide thoracic axis, and larger eyes.

"Regarding *Symphysurus* so far as shown by the collections in the U. S. National Museum, this genus is not represented in American deposits. Raymond[1] has on two occasions referred American species to it. They do not appear to belong to *Symphysurus* but to Walcott's *Tsinania*. The name of the New Jersey species, therefore, becomes *Tsinania columbiensis* (Weller), while that from the Valley of New York becomes *T. convexus* (Cleland), providing Whitfield's *Illaenurus convexus* is not congeneric.

"The reference of *Illaenurus eurekensis* Walcott[2] to *Symphysurus* by Raymond[3] had been anticipated by Brögger's[4] suggestion. Raymond in the same paper refers also *Asaphus illaenoides* Billings to

[1] Annals Carnegie Mus., Vol. 7, 1910, pp. 42-44. Roy. Soc. Canada, Proc. and Trans., 3d ser., Vol. 5, 1912, sec. 4, p. 117.

[2] Paleontology of the Eureka District: Monogr. U. S. Geol. Surv., Vol. 8, 1884, p. 97, pl. 12, figs. 4, 4a.

[3] Annals Carnegie Mus., Vol. 7, 1910, p. 144.

[4] Ueber die Verbreit. der Euloma-Niobe Fauna: Nyt. Mag. for Naturvidensk., Vol. 36, 1898, pp. 189, 228, Christiania.

the same genus. But neither of these species has the essential characters of *Symphysurus*. Both fall definitely into the new genus *Symphysurina*.

"Taking into account both the hypostoma and the dorsal surface of the trilobite, the relationship of *Symphysurina* to *Platypeltis* Calloway[1] is perhaps as close as to any other established genus. The differences lie in the cephalia of the two genera, especially in the course of the facial sutures and consequent distinctions in the forms of the cranidia, free cheeks, and eyes. Judging from the form of the cranidium and the general shape and construction of the cephalon, *Platypeltis* represents a younger stage in the evolution of the asaphid trilobites than is represented by *Symphysurina*.

"One other British genus may be mentioned as probably related to *Symphysurina*, namely, *Psilocephalus* Salter, based on a Lower Tremadoc species. Critically compared, the latter proves to have a relatively much larger cranidium, with broader fixed cheeks, this difference being particularly notable in the posterior limbs. The course of the facial suture in *Psilocephalus* also is quite different, the curves both in front and behind the eyes, as shown by the outlines of the cranidium, being decidedly convex instead of nearly straight to distinctly concave.

"Of American genera, *Platycolpus*, proposed a few years ago by Raymond[2] for species of the type of *Bathyurus capax* Billings, agrees in certain respects closely with *Symphysurina*, but the margin of the palpebral lobes in *Platycolpus* is less convex, especially in the anterior half, and is provided with a raised rim. Another constant difference is to be noted at the anterior edge of the cranidium. This is bordered by a simply thickened, generally finely striated rim in *Symphysurina*, whereas in *Platycolpus* the rim expands into an oblique or vertical flattened coarsely striated area.

"As a rule the dorsal furrows are more distinct and the glabella correspondingly better outlined in *Platycolpus* than in *Symphysurina*. But a more striking difference is noted in comparing the posterior parts of the cranidia. In *Platycolpus*, namely, the neck furrow and neck ring are usually more or less clearly developed, which is never the case in *Symphysurina*. The postero-lateral limbs also are much nearer the genal angles than in *Symphysurina*. Another important difference is in the location of the small median tubercle which is found on the glabella between the eyes in *Symphysurina* and on the neck ring in *Platycolpus*.

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[1] Quart. Journ. Geol. Soc., Vol. 33, 1887, p. 664, pl. 25, figs. 2, 2a.

[2] Victoria Mem. Mus. Bull. No. 1, 1913, p. 63.

"Comparison of the thoracic segments brings out another difference. Thus, while these segments in *Symphysurina* are broadly furrowed lengthwise, those of *Platycolpus* are more deeply and narrowly furrowed. In other words, the thoracic segments in the former genus are essentially like those in *Megalaspis*. In the latter genus, on the contrary, they are marked much the same as in the Dikelocephalinae.

"Despite certain similarities the two genera appear to be widely distinct genetically, *Platycolpus* being derived from a Cambrian genus allied to *Dikelocephalus*, while *Symphysurina* descended from an *Illaenurus*-like type.

"Finally, it remains to compare the new genus with the older *Illaenurus* Hall, and the younger American species of *Hemigyraspis* Raymond, to both of which it seems to be closely allied. In fact these three genera represent stages in a single genetic line. The cranidium of *Illaenurus* is scarcely distinguishable from that of *Symphysurina*, except that in the latter a tendency to develop genal spines is commonly manifested that has not been observed in the Upper Cambrian species of *Illaenurus*. The real differences between the two types are found in the thorax and pygidium. In *Illaenurus*, namely, the thoracic axis is much broader and less distinctly separated from the pleura, while the pygidium is relatively smaller and shorter, evenly convex, and without a sign of an axis."

Among the species now referred to *Symphysurina* are:

S. ? entella Walcott.
S. eugenia Walcott.
S. eurekensis (Walcott).
S. illaenoides (Billings).
S. spicata Ulrich.
S. woosteri Ulrich.

In addition there are also at least 20 species in process of illustration and description.

SYMPHYSURINA ? ENTELLA, new species

Plate 21, figs. 19-24, 30

Observations.—This species should perhaps be referred to *Symphysurina* with reservation since it departs considerably from the other species referred to the genus. Compared with *S. woosteri* Ulrich, the facial suture of *S. entella* diverges considerably more and takes a much more convex course anterior to the eyes. It is intramarginal almost to the center. The eyes themselves are a bit smaller. The median tubercle is also situated farther back. No dorsal furrows are apparent, their position being indicated by depressions where the postero-lateral limbs join the glabella, and connecting them is a shallow furrow which causes a slight up-turning of the occipital edge. The free cheeks of *S. entella* are larger than in *S. woosteri*. They are not nearly so much thickened in front of the glabella, but have a wide, striated doublure. The genal spine is long and slender.

The pygidium assigned to *S. entella* also departs from that of the genotype. It has no trace of an axial furrow, its position being marked only by notches similar to those marking the position for the dorsal furrow in the cranidium. The shape of the pygidium and the existence of a long spine agree with the same characters in *S. woosteri*.

Formation and locality.—Ozarkian: (65w) Mons formation, 1d of section. North side of Clearwater Canyon, two miles (3.2 km.) from divide at head of canyon and about 21 miles (33.8 km.) in an air line north 2° west of Lake Louise Station, on the Canadian Pacific Railway, Alberta, Canada.

SYMPHYSURINA EUGENIA, new species

Plate 21, figs. 25-29, 31, 32

Observations.—This species agrees in all essential respects with the genotype and is about of average size. All the available material is more or less fragmentary.

Cranidium usual size and shape and differs very little from that of *S. spicata* Ulrich, being a little more square across the front. Free cheeks without genal spines. Spine on pygidium shorter than in *S. spicata*.

Formation and locality.—Ozarkian: (65v): Mons formation. Same as *Symphysurina entella* in 1e of section.

SYMPHYSURINA SPICATA Ulrich (MSS.)

Plate 21, figs. 12-18

Ampyx ? Walcott, 1884, Pal. Eureka District, Monogr. U. S. Geol. Surv., Vol. 8, pl. 12, fig. 19. (Pygidium only, not described.)

Quotation from Dr. Ulrich's manuscript:

"Trilobite small, the typical variety probably not exceeding 25 mm. in length. Cranidium relatively a little longer than the average for the genus, moderately convex, arching (in longitudinal direction) uniformly from the posterior edge to within a fifth of the length from the anterior edge where the profile straightens and finally becomes concave as it passes through the hollow, frontal border; sutural edges diverging very slightly and almost straight in the first halves of their courses forward from the eyes, then turning inward around the antero-lateral angles which, therefore, are broadly rounded; front part of outline slightly angulated medially, the outer part of the flat border with a delicately tri-striated band forming a barely raised rim; dorsal furrows moderately impressed between the posterior edge and the eyes, obsolete forward; neck furrow unrecognizable exteriorly, but a very narrow neck ring is suggested on interior casts; palpebral lobes of medium size, drooping but slightly, situated entirely behind the midlength; posterior limbs short and not much attenuated laterally.

"Free cheeks, subtriangular, depressed convex, without elevated border; but having a long genal spine which is directed more outward than backward. The anterior edge of the cheek is bent near its middle and nearly straight on either side, the outer of the straight halves extending to the tip of the genal spine, the other to the facial suture. Here the edge passes to the doublure, the direction at the same time having to bend a little forward so as to conform with the obtusely angular frontal edge of the cranidium.

"Thoracic segments narrow, nearly smooth or at least not deeply furrowed, the axial and pleural parts approximately equal in width, the extremities tapering almost to a point without recurving.

"Pygidium, exclusive of spine, broadly triangular, fully twice as wide as long, unsegmented exteriorly; axis convex though obscurely defined exteriorly, fairly well defined and with traces of three or four segments in casts of the interior, extending to the posterior edge beyond which it is prolonged as a slender and relatively long spine; pleural lobes gently convex, divided obliquely into subequal parts by an obscure linear depression or groove, otherwise smooth."

Observations.—"Intimately associated with the typical form of the species are two other kinds of cranidia, but only one other kind of pygidium has been observed with them. Though distinguishable, this pygidium and at least two of the cranidia seem too closely allied to warrant specific discrimination with the material in hand. Provisionally, then, I propose to distinguish them as varieties. The third is so much shorter and more convex than the others as to suggest a distinct, though doubtless allied, species. However, as only a single example has been observed, it seems advisable to recognize it provisionally as another variety.

"The rock in which the type specimens occur is a light-gray, laminose limestone, filled with fossils. The same layer contains *Apatokephalus finalis* (Walcott)."

Formation and locality.—Ozarkian: (201a) Goodwin formation. East slope of the ridge east of Hamburg Ridge, Eureka District, Eureka County, Nevada.

SYMPHYSURINA WOOSTERI Ulrich (MSS.)

Plate 21, figs. 1-11

Symphysurina woosteri Ulrich in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 1, p. 37, fig. 8. (Illustrated but not described.)

Quotation from Dr. Ulrich's manuscript:

" Carapace of medium size, approximately three cm. in length and two cm. in width.

" Cranidium strongly convex, arching uniformly from front to back, with a low median ridge, the outline expanding decidedly forward from the eyes, the sutural edge here making a gently sigmoid curve; anterior edge moderately accurate in both dorsal and front views, distinctly rimmed by a marginal furrow: palpebral lobes of medium size, contracted behind, situated mostly behind the midlength, convex in the inner part, then concave, and finally curving upward to the edge: posterior limbs small, narrowly tapering and declining outward: neck ring narrow, obscurely defined in casts of the interior and perhaps unrecognizable on the exterior: dorsal furrows moderately deep near the posterior edge, quite obsolete in passing the palpebral lobes, but reappearing faintly impressed in front of them, thus obscurely separating the glabellar region from the anterior fixed cheeks.

" Free cheeks sub-triangular, terminating outwardly in a strong compressed genal spine: inner area moderately convex, separated by a narrow furrow from the outer border, which is narrow and wire-like at the front, but widens and flattens rapidly in approaching the genal angle, beyond which it becomes obsolete before reaching the posterior edge: eye prominent, rising abruptly out of a flattened or slightly concave area, the minutely ocellated band at the top comprising less than half of the rounded ocular elevation: anterior edge thick, especially in the part that projects under the front of the cranidium, the thinner lateral part with nine pits for the reception of the ends of the thoracic segments.

" Pygidium rounded sub-triangular, rather strongly convex, the axis prominent, distinctly outlined by the dorsal furrows, extending to the posterior edge where it tapers rapidly and is further produced as a slender sharply pointed free spine: tip of spine rising to the level of the axis and reaching a point one-fourth or less of the total length of the pygidium behind its margin: pleural lobes convex in the inner parts, thence sloping somewhat steeply, and commonly through an obscurely developed marginal concavity, to the edge: segmentation obsolete or very obscurely indicated excepting the first rib inside of the anterior edge. A second and occasionally a third rib may be observed on the interior of the axis, especially in young specimens.

" Surface of test smooth or very minutely punctate."

Observations.—Named after L. C. Wooster, the Wisconsin geologist, who collected most of the material from which this species was worked out.

Of all the known species, *S. eurekensis* (Walcott), doubtless agrees best with *S. woosteri.* For comparisons see the description of the Nevada species.

Formation and locality.—Ozarkian: (193) Oneota dolomite, in partly decomposed white chert, about 15 feet (4.6 m.) above the base, in Rudolph's quarry, at Trempealeau, Wisconsin.

TAENICEPHALUS Ulrich and Resser

Taenicephalus Ulrich and Resser in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59.

This genus has been established to incude those forms which Hall assigned to his genus *Conaspis,* that are congeneric with *Conaspis shumardi* (Hall).

The genus is characterized by the presence of glabellar furrows, eye lines, medium-sized eyes situated well forward toward the front of the glabella. Posterior to the eyes the suture diverges quite rapidly, giving a broad base to this head. The suture diverges much less rapidly in front of the eyes, and is intramarginal.

Free cheeks are fairly large with a border more or less well defined.

Pygidium with axial and pleural furrows, and a narrow rim.

Derivation of name.—Greek Ταινια=bound with a fillet; and Κεφαλη=head.

Genotype.—*Conocephalites shumardi* Hall.

Range.—Upper Cambrian: Mississippi Valley and Rocky Mountains.

Observations.—*Taenicephalus* differs from *Conaspis*[1] in that the fixed cheeks, palpebral lobes and border surround the glabella, which is cut off square in front, as an elevated ridge. The facial suture is intramarginal to the center, whereas it cuts the margin half way in *Conaspis.* In *Conaspis* the posterior pair of glabellar furrows are united across the glabella. The pygidium assigned to *Taenicephalus* differs from that of *Conaspis* by having a flat rim, and this also occurs along the outer edge of the free cheeks.

[1] Hall, 1863, 16th Ann. Report New York State Cab. Nat. History, p. 152. Walcott, 1914, Smithsonian Misc. Coll., Vol. 57, No. 13, p. 357.

TAENICEPHALUS SHUMARDI (Hall) Ulrich and Resser

Plate 17, figs. 15-17

Conocephalites shumardi Hall, 1863, 16th Ann. Rept. New York State Cab. Nat. Hist., p. 154, pl. 7, figs. 1, 2; pl. 8, figs. 32, 19?. 1867, Trans. Albany Inst., Vol. 5, p. 138, pl. 2, figs. 1, 2; pl. 3, figs. 32, 19?.

Conaspis shumardi Hall, 1863, 16th Ann. Rept. New York State Cab. Nat. Hist., p. 152. Walcott, 1914, Smithsonian Misc. Coll., Vol. 57, No. 13, p. 357. (List.)

Ptychoparia shumardi Miller, 1889, North American Geol. and Pal., p. 565. (Generic reference.)

Taenicephalus shumardi Ulrich and Resser in Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 59, pl. 13, fig. 1.

Hall's original description of this species is quite complete, so that nothing need be added for the present.

Formation and locality.—Upper Cambrian: Franconia formation, Trempealeau, Wisconsin.

Genus TOSTONIA Walcott

Tostonia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, pp. 59, 60.

Description.—Of this genus, only a few specimens of the cranidium and an associated pygidium have been found. The cranidium, by its almost quadrate outline, strong dorsal furrows, subquadrate glabella with two pairs of oblique furrows, narrow frontal limb and rim, small palpebral lobes and narrow fixed cheeks, relates the genus to *Olenus.* The associated pygidium has a strong convex axis, and pleural lobes with distinctly outlined segments that terminate in points without an intervening rim much as in the pygidia referred to *Apatokephalus.*

Genotype.—*Dicellocephalus iole* Walcott.

Range.—Upper ? Cambrian: Hamburg limestone, Eureka District, Nevada.

TOSTONIA IOLE (Walcott)

Plate 18, figs. 10-14.

Dicellocephalus iole Walcott, 1884, Monogr. U. S. Geol. Surv., Vol. 8, p. 43, pl. 10, fig. 19. (Description and illustration of cranidium.)

Tostonia iole Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60, pl. 13, fig. 2.

The original description outlines the characters of the cranidium.

Formation and locality.—Upper ? Cambrian: (64) Hamburg limestone, near the Bullwhacker Mine, Eureka District, Nevada.

Genus UCEBIA Walcott

Ucebia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60.

Description.—The cranidium of *Ucebia* has a general resemblance in outline of that of *Kingstonia,* but differs in important respects; it lacks a frontal limb, as the glabella extends forward to the frontal rim. Another important difference is that both the dorsal and occipital furrows are more clearly impressed so as to be readily determinable on the exterior of the test. The suture follows about the same course as in *Kingstonia,* passing very nearly through the genal angles. The eyes are also small and hold about the same position with respect to the anterior and posterior ends of the suture, but not as regards the anterior extremity of the glabella.

Genotype.—*Ucebia ara* Walcott.

Range.—Upper Cambrian: Warrior limestone, central Pennsylvania.

UCEBIA ARA Walcott

Plate 17, figs. 7, 8

Ucebia ara Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60, pl. 14, fig. 4.

The illustrations and generic comparisons give the principal characters of this species.

Formation and locality.—Upper Cambrian: (107k) Warrior limestone, two miles (3.2 km.) north of Benore Post Office, Center County, Pennsylvania.

Genus UTIA Walcott

Utia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60.

Description.—This is a very peculiar trilobite, of which only the cephalon and a portion of the thorax of the type species are known.

The cranidium is subquadrate in shape with the glabella marked off by a deep dorsal furrow: the latter is rectangular in outline and a little more than three-fourths the length of the cranidium. There are no apparent glabellar furrows, but the occipital furrow is strongly impressed.

Fixed cheeks as wide as the glabella: on some of the specimens there is a fairly strong ocular ridge. Eyes small, and situated about opposite the middle of the glabella. An unusual feature of this trilobite consists of the peculiar depressions in the fixed cheeks which run parallel to the dorsal furrow and the glabella. These depressions begin just back of the ocular ridge and widen out posteriorly. The slope of the side toward the glabella is much steeper than the one on the outside. Surface covered with fine, irregular lines.

The frontal border is quite distinct. It is wide in reality but appears narrower than it is, due to the fact that it first rises sharply from the frontal portion of the dorsal furrow into a ridge, then drops off very steeply, which results in the unusual appearance of this trilobite. Viewed from the front there is only a vertical band. In some specimens a narrow, poorly defined rim seems to be indicated.

Free cheeks unknown.

About nine segments of the thorax are preserved on one specimen. The pleural furrows are fairly deep and seem to divide the pleuræ into two approximately equal portions.

Pygidium unknown at present, but futher investigation of the large collections from the type locality may result in its determination as well as of the free cheeks.

Genotype.—*Utia curio* Walcott.

Stratigraphic range.—Middle Cambrian: Spence shale member of the Ute formation.

Geographic distribution.—In a ravine 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

Observations.—The characters of the type species of the genus as far as known are given in the specific description of *Utio curio* Walcott. The rectangular glabella, tumid frontal limb, and its great downward extension in front give an assemblage of characters unknown to me in any other trilobite. The small palpebral lobe and strong ocular ridge with the rectangular glabella suggest *Inouyia capax* Walcott,[1] but the downward extension of the frontal border is unlike anything referred to *Inouyia.*

The only known species is a small one, indicating a size for the genus about the same as for *Agraulos* and *Inouyia.*

UTIA CURIO Walcott

Plate 15, figs. 11-14

Utia curio Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60, pl. 13, fig. 3.

Dorsal shield.—Dorsal shield small, regularly elliptical in outline, the breadth more than two-thirds the length. Axial lobe moderately wide, strongly convex, rising well above the pleural lobes which were

[1] Research in China, Carnegie Inst. of Washington, Vol. 3, 1913, p. 151, pl. 14, f. 11.

probably flattened even before compression in the shaly matrix in which they are preserved.

Cephalon.—Cephalon relatively large, more than half as long as the entire shield. Cranidium only preserved, broadly convex, rudely semi-circular in outline, the relative proportions varying quite widely with the degree and direction of compression. Glabella about three-fourths as long as the cranidium, subrectangular in outline; dorsal furrows rather broad but deeply impressed, converging very slightly toward the front; anterior furrow transverse not quite so deep as the dorsal; antero-lateral margins of glabella sharply rounded; glabellar furrows obscure and often obliterated, the posterior pair inclined to the axis at an angle of about 45° and persisting almost, but not quite, to the occipital groove, the medial and anterior pair even more obscure than the posterior and more nearly at right angles to the axis, all three pairs of furrows disappearing rather abruptly so that the unsculptured medial portion of the glabella is of approximately the same width as the grooved lateral areas; a fourth pair of glabellar furrows perceptible in some individuals between the anterior extremity and the third pair counting from the occipital ring; occipital groove deep and quite wide, persistent across the crest of the glabella, the anterior margin of the groove more steeply cut than the posterior; occipital ring rather narrow, slightly expanded medially, apparently not nodose. Fixed cheeks broad and flattened, the distance from the palpebral lobe to the dorsal furrow equal approximately to the width of the glabella; postero-lateral lobe short, and sagittate in outline, the obtusely angulated extremity slightly inclined posteriorly; posterior groove deeply channeled and quite broad, its inner termination in line with the posterior portion of the occipital ring; posterior margin conspicuously elevated opposite the palpebral lobe, wedging out toward the axis. Palpebral lobe short, narrow, somewhat arcuate, about one-third as long as the glabella exclusive of the occipital groove and ring, placed rather far back opposite the lobe between the posterior and medial glabellar furrows. Ocular ridge narrow, cordate, arching obliquely across from the anterior extremity of the lobe and intercepting the dorsal furrows as the origin of the fourth pair of glabellar furrows. Frontal limb wide, sharply elevated in front of the glabella, and then abruptly turned down so as to form a semi-circular ridge that extends back beyond the ocular ridges. The fine venation radiating from in front of the glabella passes over the ridge and down the nearly perpendicular front slope to the narrow frontal border, which is a little thickened and but slightly defined from the frontal limb. A narrow transversely lined doublure extends back beneath the frontal border.

Thorax.—Posterior extremity of thorax imperfectly known, so that the number of component segments cannot be definitely determined; nine are preserved on one specimen. Axial lobe not so wide as the flattened pleura, sharply defined both by the abrupt elevation and the lateral furrows: annulation rather coarse. Pleural segments slender, elongated, obtusely angulated at their extremities; pleural furrows linear and sharply incised.

Pygidium.—Pygidium not preserved, but from the narrowing of the thorax undoubtedly small.

Dimensions.—Length of dorsal shield, 7.1 mm.; greatest width of dorsal shield exclusive of the free cheeks, 5.0±mm.; length of cranidium, 3.7 mm.; length of glabella, 2.7 mm.

Surface.—Apparently nearly smooth.

Formation and locality.—Middle Cambrian: (55c) Spence shale member of the Ute formation; about 50 feet (15.2 m.) above the Brigham quartzite, and 2,755 feet (839.7 m.) below the Upper Cambrian, in a ravine running up into Danish Flat from Mill Canyon, about six miles (9.7 km.) west-southwest of Liberty and 15 miles (24.2 km.) west of Montpelier, Bear Lake County, Idaho.

VISTOIA, new genus

Vistoia is proposed for a small trilobite from the lower portion of the Middle Cambrian limestones near the southwestern base of Robson Peak. The cranidium and thorax suggest *Corynexochus stephenensis* Walcott,[1] but the pygidium is more of the type of that of *Eodiscus punctatus* (Salter) with the transverse furrows omitted from the axial lobe. The presence of five thoracic segments also seems to distinguish it from *Corynexochus,* which has from 7 to 11 segments. *Eodiscus,* as far as known, has three thoracic segments.

Genotype.—*Vistoia prisca,* new species.

Dimensions.—The only entire specimen known has a length of 13 mm.

Range.—The one known species occurs in the lower portion of the Middle Cambrian of Robson Peak, British Columbia, Canada.

Observations.—All that is known of the genus is included in the description of the genotype.

[1] Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pp. 324, 325, pl. 55, fig. 5.

VISTOIA PRISCA, new species

Plate 17, fig. 14

Dorsal shield convex and strongly trilobed, elongate, elliptical in outline. The facial sutures cut the anterior margin almost directly in front of the sides of the expanded front of the glabella and then curve a little outward and backward to the anterior end of the eye; passing around and above the eye they then slope outward and backward with a gentle curve to the posterior margin so as to leave a strong postero-lateral limb. Glabella elongate, clavate in outline, expanded in front and narrowing gradually from about midway to the occipital ring, without glabellar furrows; occipital ring strong and separated from the glabella by a broad shallow furrow which is continued out across the postero-lateral limbs; its posterior margin rises at the center and may have carried a spine. Palpebral lobes elongate, prominent and nearly one-half the length of the cranidium. Fixed cheeks of medium width. Free cheeks unknown.

Thorax with five (5) segments; strongly trilobed and convex; pleural lobes narrow; pleural segments short with rather blunt backward curving ends; pleural furrows broad, straight out to the geniculation where they begin to narrow and curve backward with the end of the pleura.

Pygidium with a strong convex axial lobe extending nearly its entire length; an anterior ring is outlined by a faint narrow furrow that also extends across the lateral lobes just within the anterior margin; no other transverse furrows have been observed.

Dimensions.—Dorsal shield, length 13 mm., width about 6 to 7 mm., length of cephalon 5 mm., thorax 4 mm., pygidium, .4 mm.

Surface of outer test appears smooth.

Observations.—The type and only specimen of this species occurs in a calcareous shaly rock; it is slightly compressed laterally which makes it more than naturally convex. The expanded glabella, large eyes and narrow free cheeks suggest *Corynexochus*[1] as do the thoracic segments, but the pygidium with its elongate outline and smooth axial and pleural lobes gives the impression of a pygidium of *Eodiscus* with a smooth axial lobe.

Other specimens of this species will undoubtedly be found when the shales and limestones above the Lower Cambrian sandstones of the Robson District are searched for fossils.

[1] Smithsonian Misc. Coll., Vol. 64, No. 5, 1916, pls. 55-57.

Formation and locality.—Middle Cambrian: (62f) Chetang formation. Shaly bed in bluish gray limestones; Southwest base of Robson Peak about 600 feet (182.9 m.) from base and 300 feet (91.4 m.) above Lake Kinney, Robson Park, British Columbia, Canada.

Genus WILBERNIA Walcott

Wilbernia Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60.

The glabella is about three-fourths as long as the cranidium and rectangular in outline, rounded in front. Two pairs of glabellar furrows are usually visible on the inner surface of the test, but are faint or absent on the outer surface. The occipital ring is fairly wide, and the furrow is usually strongly defined.

Fixed cheeks about one-third as wide as the glabella in advance of the eyes. Ocular ridges present or indicated on most specimens. Eyes moderately large, and the mid point is back of the middle of the glabella. The palpebral lobes have a tendency to rise above the fixed cheeks, and in some species they are raised into a boss-like protuberance.

The facial suture diverges considerably in front of the eyes and is intramarginal for some distance. The postero-lateral limbs are long and narrow.

Cranidium with a wide frontal limb, in which the border and rim occupy relatively varying portions of the whole. The rim is always wide and well defined by a shallow furrow.

Free cheeks with long genal spines and a rim as wide as that of the cranidium. A doublure of equal width extends all the way across beneath the head. No epistoma nor median suture has been seen.

The pygidia of the species of this genus have a high, very convex axis, and approximately flat sides. The axial rings clearly marked by deep furrows. The axis extends back more than three-fourths the length of the tail, and often widens out with a tendency toward the formation of small nodes at the end. A descending, narrow ridge connects the posterior end of the axis proper with a flattened border. Its width increases toward the anterior margins. Four or more lateral pleuræ are visible in the tail. They are closely fused but have the dividing furrows well marked. The pleural furrows are wide and clearly impressed.

Derivation of name.—Wilberns formation.

Genotype.—*Ptychoparia pero* Walcott.

Range.—Upper Cambrian: Mississippi Valley and Rocky Mountains.

Observations.—There are many species of the genus *Wilbernia* and all parts of the tests are known, but only the cranidium of the type species has been definitely identified in the preliminary study of the Texas collections. The best known species of the genus is Hall's *Ptychoparia diademata* from the Franconia formation of Wisconsin.

WILBERNIA PERO (Walcott)

Plate 15, figs. 22, 23

Ptychoparia pero Walcott, 1890, Proc. U. S. Nat. Mus., Vol. 13, p. 274, pl. 21, fig. 6. (Described and illustrated.)

Anomocare pero Walcott, 1912, Monogr. U. S. Geol. Surv., Vol. 51, p. 212. (Generic reference.)

Wilbernia pero Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60, pl. 13, fig. 4.

More material of this species will be available after the collections from the type locality are more fully studied.

Formation and locality.—Upper Cambrian: (70) Wilberns formation. Morgans Creek, Burnet County, Texas.

Genus XENOSTEGIUM Walcott

Xenostegium Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60.

The genus *Xenostegium* includes a number of trilobites which have long been known, usually being assigned to *Megalaspis*.

The cranidium expands in front and often at the same time increases in convexity. It is distinguished by this swelling rather than by any definite dorsal furrow. Border always present, usually a simple concave rim. Glabellar furrows absent. Occipital furrow absent unless represented by two pits. Fixed cheeks narrow. Palpebral lobes usually more or less erect. Free cheeks undetermined.

This type of pygidium, generally placed in the genus *Megalaspis*, is characterized by its triangular outline and median posterior spine; the axis is often not delimited at the posterior end by the dorsal furrow as it, after outlining the axis along the sides, turns slightly outward and usually disappears, a slight swelling carrying the axis back to the base of the terminal spine. A flattened border is defined by a shallow depression between it and the slope of the pleural lobe. Several transverse furrows are usually developed sufficiently to permit the recognition of several segments. Very faint pleural furrows are occasionally outlined at the anterior end.

Genotype.—*Megalaspis belemnurus* White.[1]

Range.—Ozarkian and possibly Canadian. Western Cordillera.

The narrow border on the cranidium places this group nearer the Asaphidae than to the family including *Megalaspis.* None of the pygidia assigned to *Xenostegium* possesses the pleural furrows characteristic of the species belonging to *Megalaspis.*

XENOSTEGIUM ALBERTENSIS, new species

Plate 24, figs. 10, 11

Observations.—Only a pygidium of this form has been thus far found in the collections. It differs from *X. goniocercum* in its greater general convexity and the strongly convex axis. No trace of axial or pleural furrows.

Formation and locality.—Ozarkian: (66v) Mons formation. Upper Johnson Creek Canyon, Sawback Range, Alberta, Canada.

XENOSTEGIUM BELEMNURUM (White)

Plate 24, figs. 3, 4

Megalaspis belemnurus White, 1877 (Rept. 1874, p. 11), Rept. U. S. Geol. Surv., West 100th Merid., War Dept., Vol. 4, p. 59, pl. 3, fig. 9. Miller, 1889, N. A. Geol. Pal., p. 556, fig. 1030.

Xenostegium goniocercum (Meek) Walcott, 1924, Smithsonian Misc. Coll., Vol. 75, No. 2, p. 60, pl. 13, fig. 5.

Observations.—A cranidium was discovered in the matrix lying quite close to the pygidium, which is the hologenotype. It is assumed that this cranidium belongs to the same animal as the pygidium (fig. 4) since it agrees quite closely with others at distant localities associated with pygidia congeneric with this one.

Formation and locality.—Canadian ? (67i) Queen Spring Hill, just south of Schellbourne Pass, Nevada.

XENOSTEGIUM DOUGLASENSIS, new species

Plate 24, figs. 22, 23

Observations.—This species resembles the genotype more closely than any other in the collections. The cranidium is a little more

[1] For several years *Megalaspis belemnurus* White and *Asaphus (M.) goniocercus* Meek were labeled as one species, in the collections of the National Museum, and the genus was published last year before completing the critical study, hence the older established name was chosen as the genotype, but the drawing was based on the proper specimen.

expanded and the associated pygidium is wider and less triangular. The axis is also outlined farther back.

Formation and locality.—Ozarkian: (67q) Mons formation. Douglas Lake Canyon Valley, Sawback Range, Alberta, Canada.

XENOSTEGIUM EUCLIDES, new species

Plate 24, figs. 13, 14

Observations.—The pygidium of *X. euclides* is readily distinguishable from *X. albertensis* which occurs in the same beds, being less convex and robust. The axis extends nearer to the posterior margin and both axial and pleural furrows are traceable on the anterior portion.

X. euclides differs from the genotype in its more sharply triangular outline, and longer, more slender median axis.

The associated hypostoma assigned to *Xenostegium* must be regarded as tentative, as it indicates the kind of hypostoma it may have had.

Formation and locality.—Ozarkian: (66v) Mons formation. Upper Johnson Creek Canyon, Sawback Range, Alberta, Canada.

XENOSTEGIUM ? EUDOCIA, new species

Plate 24, fig. 12

Observations.—The cranidium on which this species is founded is unusual. It is referred tentatively to *Xenostegium,* as the one fragmentary specimen will not permit of an accurate determination. It departs from the genotype of *Xenostegium* in characters that might give it a different generic reference if better material were available. It may possibly be congeneric with *X. ? sulcatum* (fig. 9, pl. 24) from the same locality. The cranidium is long and narrow. A shallow dorsal furrow outlines the slightly expanded glabella; the frontal limb is concave as in *X. goniocercum* but it is shaped differently. Fixed cheeks very narrow. The greatest peculiarities in this strong cranidium are the depression occupying the position of the posterior pair of glabellar furrows and the occipital furrow. Between them lies a very pronounced swelling, and on the ridge between them is a median tubercle.

X. eudocia departs from typical forms of *Xenostegium* in the less expanded glabella, the narrowness of the cranidium and the peculiar furrow pits.

Formation and locality.—Ozarkian: (55z) St. Charles formation. Blacksmith Fork Canyon, 10 miles (16 km.) east of Hyrum, Cache County, Utah.

XENOSTEGIUM GONIOCERCUM (Meek)

Plate 24, figs. 5-8

Asaphus (Megalaspis) goniocercus Meek, 1873, 6th Ann. Rept. U. S. Geol. Surv., Terr., p. 480.

Observations.—Several additional specimens and the original types are figured for the first time, no previous illustrations of this species having even been published. This species, of which only the pygidium is known, differs from *Xenostegium belemnurum* with which it was regarded as synonymous for several years, mainly in the character of the axial and dorsal furrows delimiting the pygidial axis. The two sides of the dorsal furrow in *X. goniocercum* do not turn outward before ceasing in *X. belemnurum,* and the axis is carried further backward by a carinate ridge.

Formation and locality.—Canadian ? near Malad, Idaho. The exact locality is unknown.

XENOSTEGIUM KIRKI, new species

Plate 24, figs. 18-21

Observations.—This species is closely allied to *Xenostegium goniocercum.* The glabella is expanded to a slightly greater degree and its better preservation permits a more complete illustration of the characters of the genus. The pygidium is also quite similar.

Specific name given in recognition of the work of Dr. Edwin Kirk of the U. S. Geological Survey in the Beaverfoot-Brisco-Stanford Range area during the field season of 1923.

Formation and locality.—Ozarkian: (17a) Mons formation. .5 mile (.8 km.) north of Stoddart Creek, 5.5 miles (8.8 km.) south of Sinclair Canyon, British Columbia.

(67q) Douglas Lake Canyon Valley, Sawback Range, Alberta, Canada.

XENOSTEGIUM SCHOFIELDI, new species

Plate 24, fig. 15

Observations.—This species differs from *Xenostegium kirki* in the greater distance from the margin, where the axis terminates, and its longer triangular outline. Otherwise it is quite similar.

Specific name given in recognition of Dr. S. J. Schofield of the Geological Survey of Canada, in the southeastern portion of British Columbia.

Formation and locality.—Ozarkian: (19n) Mons formation. Swansea Mountain, northeast of Windermere, British Columbia, Canada.

XENOSTEGIUM SHEPHARDI (Raymond)

Plate 24, figs. 16, 17

Megalaspis shephardi Raymond, 1922, Amer. Journ. Sci., Vol. 3, p. 204 footnote.

Observations.—A better preserved specimen than the one available to Raymond is illustrated by figure 16. This species differs from known species of the genus in the length of the portion between the terminus of the axis and base of the longer posterior spine.

Formation and locality.—Ozarkian: Mons formation. Sinclair Canyon (Raymond's locality).

(21h) Sinclair Mountain on Wonah Ridge, one mile (1.6 km.) north of Sinclair Pass.

(65y) North side of Clearwater Canyon, two miles (3.2 km.) from divide at head of canyon and about 21 miles (33.8 km.) in an air line, 2° west of Lake Louise Station.

All in British Columbia, Canada.

XENOSTEGIUM ? SULCATUM, new species

Plate 24, fig. 9

Observations.—This cranidium is referred to *Xenostegium* with reservation because of the more convex, rounded frontal limb. The glabella expands slightly and is defined all around by a dorsal furrow, that makes a very peculiar indentation into the front of the glabella. Glabellar furrows indicated by shallow depressions. A small, rounded boss occurs back of the palpebral lobes. Fixed cheeks very narrow. Free cheek unknown. Surface covered with strong, transverse, irregular lines.

Formation and locality.—Ozarkian: (55z) St. Charles formation ? Blacksmith Fork Canyon, 10 miles (16 km.) east of Hyrum, Cache County, Utah.

XENOSTEGIUM TAURUS, new species

Plate 24, figs. 1, 2

Observations.—This species differs from *X. goniocercum* mainly in the deeper dorsal furrow in front of the glabella and the shorter, wider pygidium. The central portion of the glabella is fairly well preserved and shows several depressions, indicating the position of the glabellar and occipital furrows. Eyes situated far back, and the manner in which the palpebral lobes are broken away indicates that they were somewhat erect.

The associated pygidium is shorter and wider than that of *X. goniocercum*.

Formation and locality.—Ozarkian: (61q) Chushina formation. Billings Butte (Extinguisher), above Hunga Glacier, Robson Peak District, British Columbia, Canada.

DESCRIPTION OF PLATE 15

FIG. 1. (Natural size.) A large dorsal shield, somewhat crushed. U. S. Nat. Mus., Cat. No. 15439a.

2. (× 2.) A smaller, less distorted specimen with right free cheek displaced. U. S. Nat. Mus., Cat. No. 15439b.

3. (× 2.) A fine specimen without the free cheeks. U. S. Nat. Mus., Cat. No. 15439c.

4. (× 2.) A small individual. U. S. Nat. Mus., Cat. No. 15439d.

Matrix, argillaceous shale. Specimens thickened by development of fibrous calcite or aragonite.

Middle Cambrian, Wheeler formation. (Loc. 4): Antelope Springs, House Range, Utah.

FIG. 5. (× 2.) A small specimen without free cheeks and the pleura on the right side. U. S. Nat. Mus., Cat. No. 70232.

6. (× 2.) Large individual preserving the left free cheek. Tail bent under the body. U. S. Nat. Mus., Cat. No. 70233.

7. (× 2.) Cranidium showing the up-turned front and general proportions. Glabella slightly flattened. U. S. Nat. Mus., Cat. No. 70234.

Matrix, soft olive shale.

Middle Cambrian, Wolsey shale. (Loc. 4g): 5 miles (8 km.) northeast of Logan, Montana.

FIG. 8. (Natural size.) Large cranidium. U. S. Nat. Mus., Cat. No. 15434a.

9. (Natural size.) Entire individual. U. S. Nat. Mus., Cat. No. 15434b.

10. (Natural size.) Smaller but less distorted cranidium. U. S. Nat. Mus., Cat. No. 15434c.

Matrix, pink or buff calcareous shale. Fossils not completely flattened.

Middle Cambrian, Chisholm formation. (Loc. 31): Pioche, Nevada.

FIGS. 11, 12. (× 2.) Dorsal view and side outline of a cranidium, illustrating the steep front, wide fixed cheeks with their peculiar grooves and the other characters of this species. U. S. Nat. Mus., Cat. No. 70235.

13. (× 2.) Another cranidium. U. S. Nat. Mus., Cat. No. 70236.

14. (× 2.) Cranidium with portion of thorax attached. U. S. Nat. Mus., Cat. No. 70237.

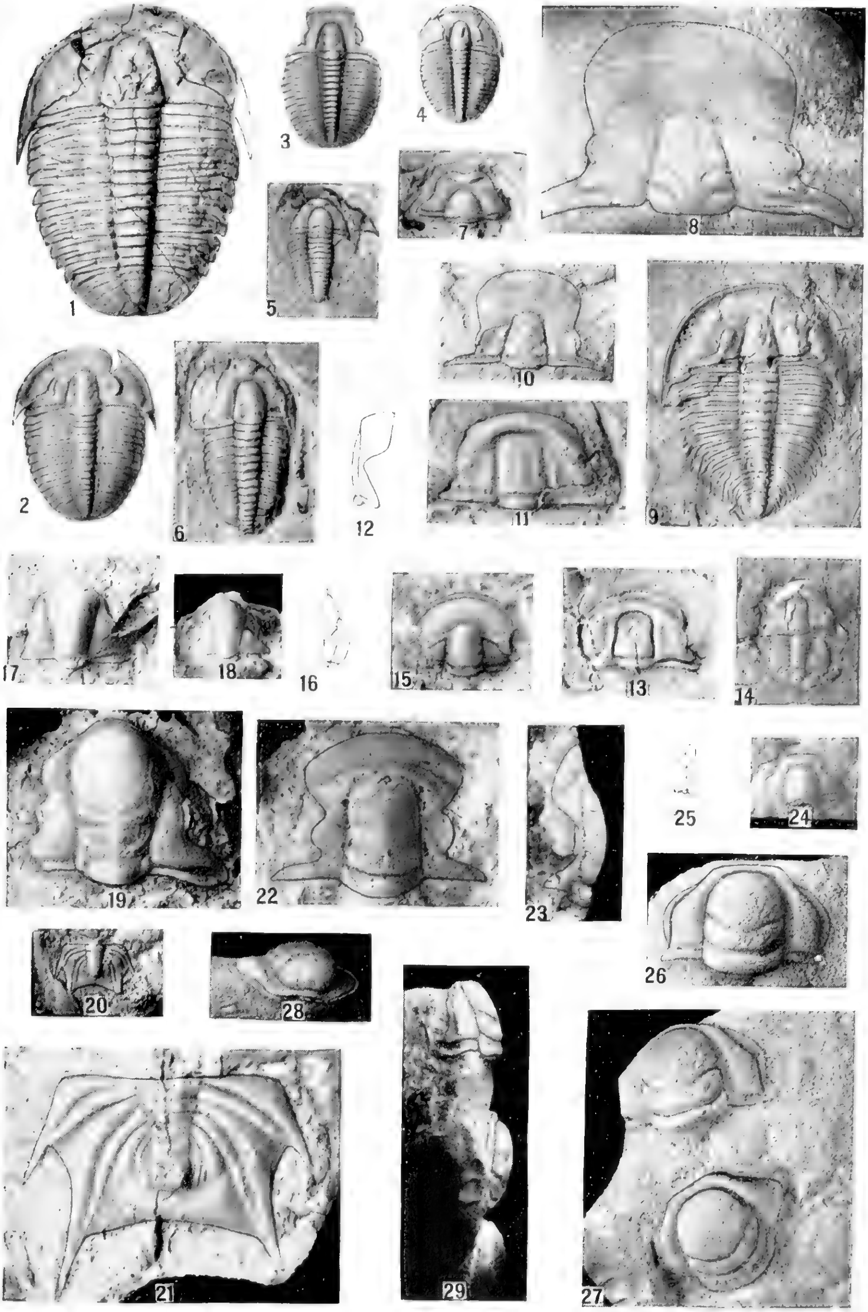
Matrix, soft brown shale. Fossils not flattened.

Middle Cambrian, Spence shale member of Ute formation. (Loc. 55c): Spence Gulch, 15 miles (24 km.) west of Montpelier, Idaho.

FIGS. 15, 16. (× 2.) Dorsal view and side outline of the type cranidium. U. S. Nat. Mus., Cat. No. 24560.

Matrix, gray limestone.

Upper Cambrian, Hamburg limestone? (Loc. 66): Eureka District, Nevada.



CAMBRIAN TRILOBITES

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Holteria problematica (Walcott) 93
FIG. 17. (× 4.) Dorsal view of a very small cranidium. U. S. Nat. Mus., Cat. No. 24606a. (See text figure 13.)
18. (× 1.) A larger cranidium. U. S. Nat. Mus., Cat. No. 24606b.
19. (× 1.) A large, almost complete cranidium. U. S. Nat. Mus., Cat. No. 24606c.
20. (× 1.) A small pygidium. U. S. Nat. Mus., Cat. No. 24606d.
21. (× 1.) Largest pygidium in the collections. U. S. Nat. Mus., Cat. No. 24606e.

Matrix, gray limestone.
Upper Cambrian. (Loc. 58): Eureka District, Nevada.

Wilbernia pero (Walcott) 124
FIGS. 22, 23. (Natural size.) Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 23859.

Matrix, limestone
Upper Cambrian, Wilberns formation. (Loc. 70): Morgans Creek, Burnet County, Texas.

Desmetia annectans (Walcott) 83
FIGS. 24, 25. (× 2.) Dorsal view and side outline of the type cranidium. U. S. Nat. Mus., Cat. No. 24571.

Matrix, thin-bedded limestone.
? Ozarkian, Goodwin formation. (Loc. 201): Eureka District, Nevada.

Irvingella major Ulrich and Resser MSS 98
FIG. 26. (Natural size.) Restoration based on the photograph of the upper specimen in fig. 27.
27. (Natural size.) Several somewhat abraded cranidia.
28. (Natural size.) Front view of cranidium illustrated in fig. 26.
29. (Natural size.) Side view of group of cranidia. Figs. 26-29 on one slab, U. S. Nat. Mus., Cat. No. 70238.

Matrix, micaceous sandstone.
Upper Cambrian, Franconia (Micaceous shale member) formation. (Loc. 80n): Ableman, Wisconsin.

DESCRIPTION OF PLATE 16

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Modocia oweni (Meek and Hayden) 106

FIGS. 1, 2. Dorsal and side views of a cranidium in coarse sandstone. U. S. Nat. Mus., Cat. No. 24581.

Matrix, sandstone.

Upper Cambrian, Deadwood formation. Castle Creek, Black Hills, South Dakota.

3. Dorsal view of the type cranidium of the species. U. S. Nat. Mus., Cat. No. 1180.

Matrix, fine-grained sandstone.

Upper Cambrian, Deadwood formation. Head of Powder River, Big Horn Mountains, Wyoming.

Dunderbergia nitida (Hall and Whitfield) 85

FIG. 4. Dorsal view of a fairly complete cranidium. U. S. Nat. Mus., Cat. No. 24572a.

5. Side view of original type specimen. U. S. Nat. Mus., Cat. No. 24572b.

6, 7. Dorsal and side views of pygidium assigned to this species. U. S. Nat. Mus., Cat. No. 24572c.

Matrix, limestone lenses in shale.

Upper Cambrian, Secret Canyon shale. (Loc. 61): Eureka District, Nevada.

Iddingsia similis (Walcott) 97

FIGS. 8, 9. Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 24641.

Matrix, limestone.

Upper Cambrian, Secret Canyon shale. (Loc. 60): Eureka District, Nevada.

Iddingsia robusta (Walcott) 97

FIGS. 10, 11. Dorsal and side views of an imperfect cranidium. U. S. Nat. Mus., Cat. No. 24609.

Matrix, limestone.

Upper Cambrian, Secret Canyon shale. (Loc. 61): Eureka District, Nevada.

Eurekia dissimilis (Walcott) 90

FIG. 12. Dorsal view of a fragmentary cranidium which is the original type of the species. U. S. Nat. Mus., Cat. No. 24615.

Matrix, limestone.

Upper Cambrian, Secret Canyon shale. (Loc. 54): Prospect Mountain, New York Canyon, Eureka District, Nevada.

Eurekia granulosa Walcott 90

FIG. 13. A cranidium on which the missing parts have been restored. U. S. Nat. Mus., Cat. No. 70239.

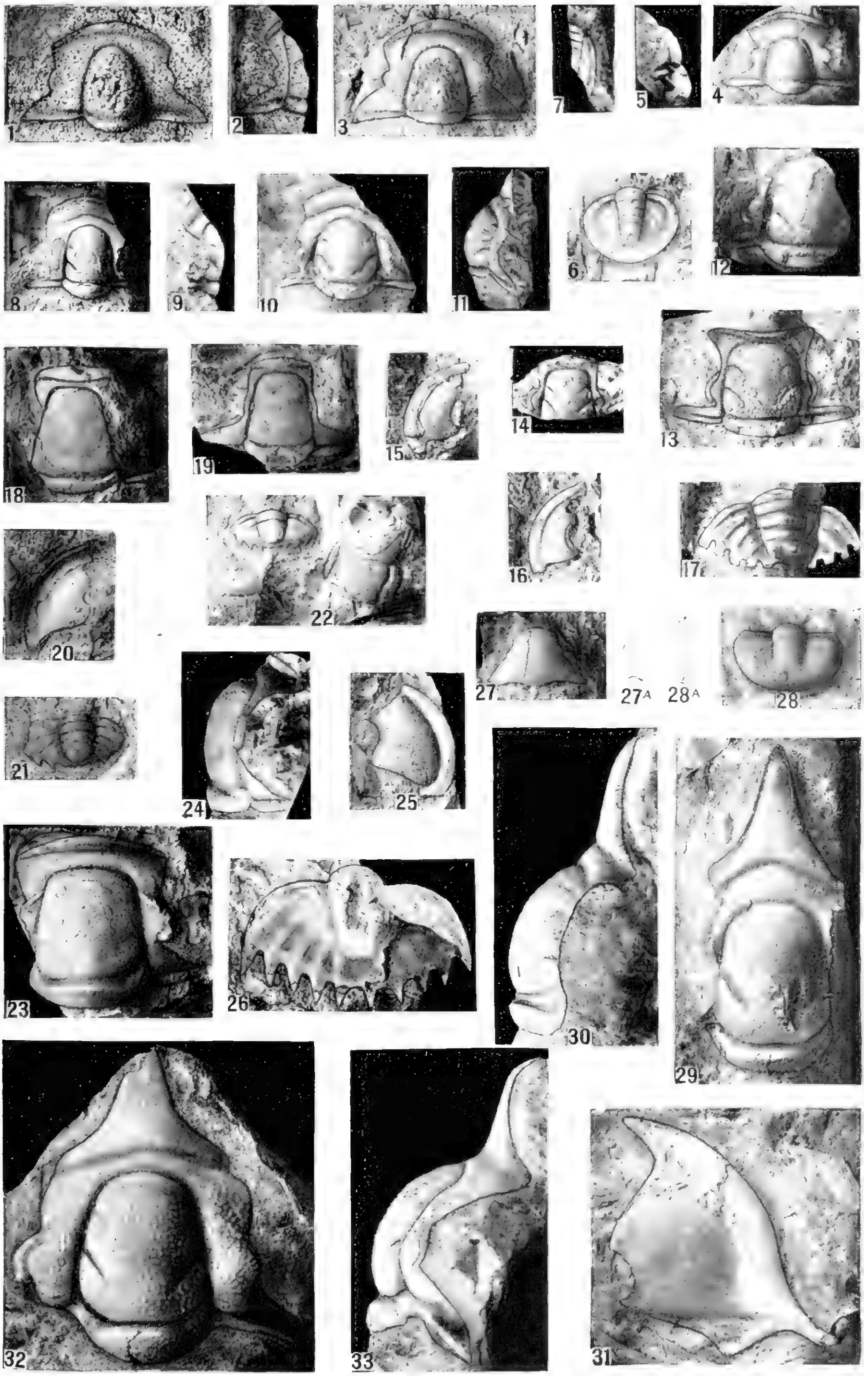
14. Small cranidium with the front fairly complete, used in the restoration of fig. 13. U. S. Nat. Mus., Cat. No. 70240.

15, 16. Free cheeks. U. S. Nat. Mus., Cat. Nos. 70241, 70242.

17. Pygidium assigned to this species. Restored in outline on right side. U. S. Nat. Mus., Cat. No. 70243.

Matrix, granular limestone.

Upper Cambrian, Hamburg ? formation. (Loc. 88): West side of Highland Range, 17 miles (27.3 km.) southwest of Pioche, Nevada.



CAMBRIAN TRILOBITES

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Corbinia valida Walcott 82

FIG. 18. Dorsal view of the single cranidium in the collections. U. S. Nat. Mus., Cat. No. 70244.

Matrix, limestone.
Ozarkian, Mons. formation. (Loc. 65x): Clearwater Canyon, Alberta.

Corbinia horatio Walcott 81

FIG. 19. Dorsal view of the type cranidium. U. S. Nat. Mus., Cat. No. 70245.
20. Associated free cheek. U. S. Nat. Mus., Cat. No. 70246.
21. A small imperfect associated pygidium. U. S. Nat. Mus., Cat. No. 70247.
22. Associated cranidium and pygidium. U. S. Nat. Mus., Cat. No. 70248.

Matrix, limestone.
Ozarkian, Mons formation. (Loc. 65x): Clearwater Canyon, Alberta.

Maladia americana Walcott 105

FIGS. 23, 24. Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 70249.
25. Associated free cheek assigned to this species. U. S. Nat. Mus., Cat. No. 70250.
26. An incomplete associated pygidium with outlines restored. U. S. Nat. Mus., Cat. No. 70251.

Matrix, coarse limestone.
Upper Cambrian, Ovid formation. (Loc. 54x): Two Mile Canyon, 2 miles (3.2 km.) southeast of Malad, Idaho.

Kingstonia apion Walcott 103

FIGS. 27, 27a. (× 2.) Dorsal view and side outline of the type cranidium. U. S. Nat. Mus., Cat. No. 70252.
28, 28a. (× 2.) Dorsal view and side outline of the associated pygidium assigned to this species. U. S. Nat. Mus., Cat. No. 70253.

Matrix, limestone.
Upper Cambrian, Maryville formation. (Loc. 127): 5 miles (8 km.) west of Cleveland, Tennessee.

Dokimocephalus pernasutus (Walcott) 84

FIGS. 29, 30. Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 24608a.
31. A nearly complete associated free cheek. U. S. Nat. Mus., Cat. No. 24608b.

Matrix, limestone.
Upper Cambrian, Secret Canyon shale. (Loc. 61): Eureka District, Nevada.

Dokimocephalus gregori Walcott 84

FIGS. 32, 33. Dorsal and side views of this remarkable cranidium. U. S. Nat. Mus., Cat. No. 70254.

Matrix, limestone.
Upper Cambrian. (Loc. 11e): Southwest of Potosi, Missouri.
(All figures natural size except 27 and 28.)

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Burnetia urania (Walcott) 77

FIGS. 1, 2. (Natural size.) Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 23861a.

3. (Natural size.) Associated free cheek. U. S. Nat. Mus., Cat. No. 23861b.

Matrix, granular limestone.

Upper Cambrian, Cap Mountain formation. (Loc. 68): Packsaddle Mountain, Llano County, Texas.

Bynumia eumus (Walcott) 78

FIG. 4. (Natural size.) Dorsal view of a typical cranidium. U. S. Nat. Mus., Cat. No. 70255.

5, 6. (Natural size.) Dorsal view and side outline of an exfoliated cranidium. U. S. Nat. Mus., Cat. No. 70256.

Matrix, limestone.

Upper Cambrian, Lyell formation. (Locs. 66m, 64b): Sawback Range northwest of Lake Louise, Alberta, Canada.

Ucebia ara Walcott 118

FIG. 7. (× 2.) Dorsal view of type cranidium. U. S. Nat. Mus., Cat. No. 70257.

8. (× 2.) A second cranidium. U. S. Nat. Mus., Cat. No. 70258.

Matrix, limestone.

Upper Cambrian, Warrior limestone. (Loc. 107k): Center County, Pennsylvania.

Elvinia roemeri (Shumard) 88

FIGS. 9, 10. (Natural size.) Dorsal and side views of the cranidium chosen as representing Shumard's conception of this species. U. S. Nat. Mus., Cat. No. 70259.

11. (Natural size.) Associated free cheek. U. S. Nat. Mus., Cat. No. 70260.

12, 13. (Natural size.) Dorsal and side views of associated pygidium assigned to this species. U. S. Nat. Mus., Cat. No. 70261.

Matrix, granular limestone.

Upper Cambrian, Cap Mountain formation. (Loc. 68): Packsaddle Mountain; (Loc. 70): Morgans Creek, Texas.

Vistoia prisca Walcott 122

FIG. 14. (× 2.) Dorsal view of an entire dorsal shield slightly compressed laterally. U. S. Nat. Mus., Cat. No. 70262.

Matrix, fine-grained siliceous shale.

Middle Cambrian, Chetang formation. (Loc. 62f): Southwest base of Robson Peak, British Columbia, Canada.

Taenicephalus shumardi (Hall) Ulrich and Resser 117

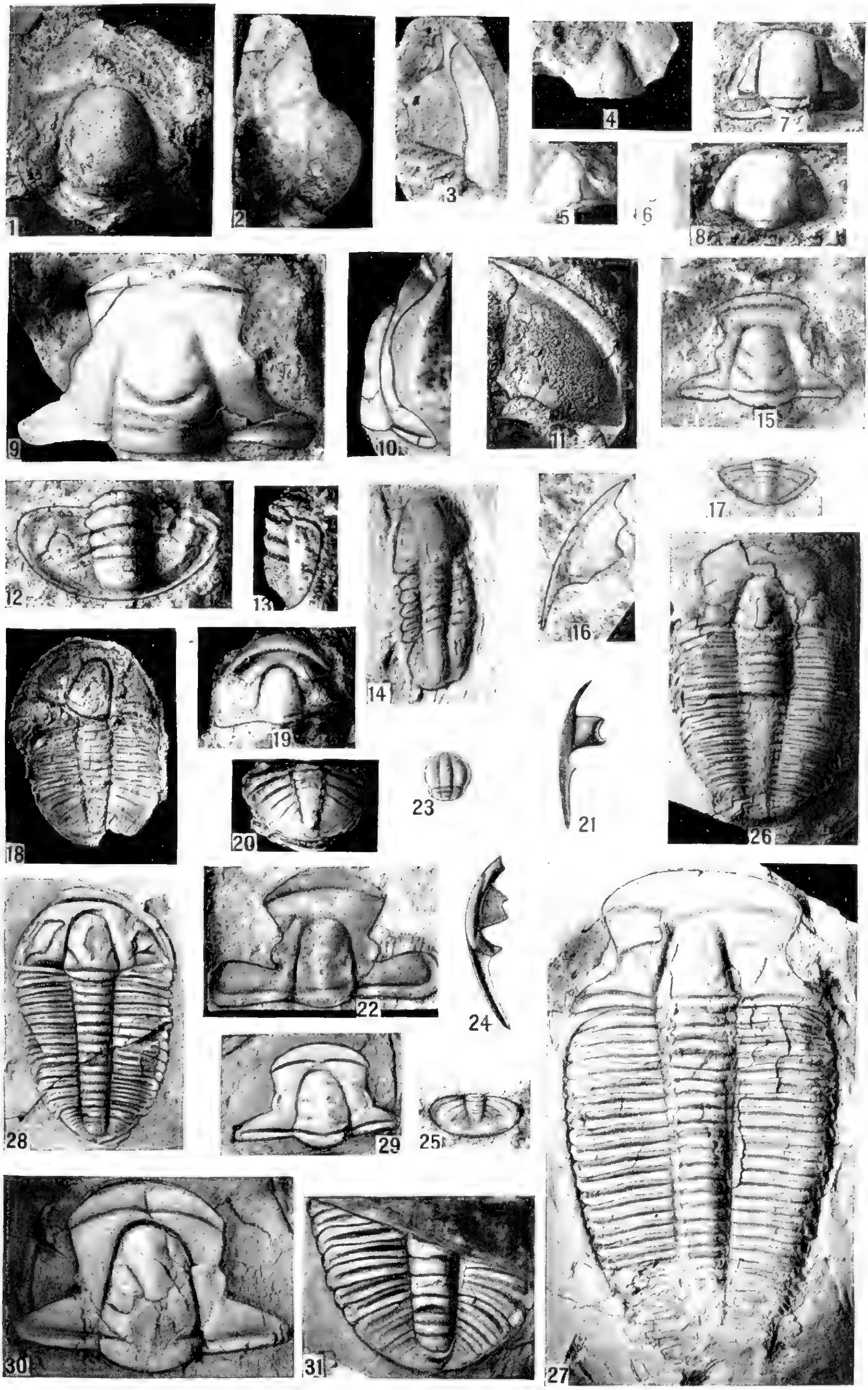
FIG. 15. (× 2.) Cranidium with outlines restored. U. S. Nat. Mus., Cat. No. 70263.

16. (× 2.) Free cheek. U. S. Nat. Mus., Cat. No. 70264.

17. (× 2.) Pygidium assigned to the species. U. S. Nat. Mus., Cat. No. 70265.

Matrix, sandstone.

Upper Cambrian, Franconia formation. (Loc. 83): Trempealeau, Wisconsin.



CAMBRIAN TRILOBITES

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Cedaria prolifica Walcott.................................... 79

FIG. 18. (Natural size.) Dorsal view of a nearly entire individual. U. S. Nat. Mus., Cat. No. 70266.
19. (Natural size.) Cranidium in limestone. U. S. Nat. Mus., Cat. No. 70267.
20. (Natural size.) Pygidium. U. S. Nat. Mus., Cat. No. 70268.
21. (Natural size.) Drawing of a free cheek. U. S. Nat. Mus., Cat. No. 70269.

Matrix, limestone nodules in shale or fossils, thickened by growth of fibrous calcite.

Upper Cambrian, Conasauga formation. (Loc. 91): Cedar Bluff, Alabama.

Cedaria tennesseensis Walcott.................................... 79

FIG. 22. (× 2.) An entire cranidium. U. S. Nat. Mus., Cat. No. 70270.
23. (× 8.) Drawing of protaspis stage. U. S. Nat. Mus., Cat. No. 70271.
24. (Natural size.) Associated free cheek. U. S. Nat. Mus., Cat. No. 70272.
25. (Natural size.) Associated pygidium. U. S. Nat. Mus., Cat. No. 70273.

Matrix, soft purple shale.

Upper Cambrian, Nolichucky shale. (Loc. 107a): Northwest of Knoxville, Tennessee.

Chancia ebdome Walcott.................................... 80

FIG. 26. (Natural size.) Dorsal shield with 20 thoracic segments. U. S. Nat. Mus., Cat. No. 70274.

Matrix, shale. Specimens not entirely flat.

Middle Cambrian, Spence shale. (Loc. 55c): Bear Lake County, Idaho.

Chancia evax Walcott.................................... 81

FIG. 27. (Natural size.) A large dorsal shield with about 24 thoracic segments. Pygidium and free cheeks broken away. U. S. Nat. Mus., Cat. No. 70275.

Matrix, shale.

Middle Cambrian, Spence shale. (Loc. 55c): Bear Lake County, Idaho.

Armonia pelops Walcott.................................... 69

FIG. 28. (Natural size.) Slightly crushed entire dorsal shield. U. S. Nat. Mus., Cat. No. 70276.
29. (Natural size.) Cranidium preserving convexity and form. U. S. Nat. Mus., Cat. No. 70277.
30. (Natural size.) A large slightly crushed cranidium. U. S. Nat. Mus., Cat. No. 70278.
31. (Natural size.) Posterior part of thorax with pygidium attached. U. S. Nat. Mus., Cat. No. 70279.

Matrix, shale. Specimens not completely flat.

Upper Cambrian, Conasauga formation.. (Loc. 95): Cowan Creek, Alabama.

DESCRIPTION OF PLATE 18

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Elkia nasuta (Walcott) 85

FIG. 1. (Natural size.) Dorsal view of the type cranidium. U. S. Nat. Mus., Cat. No. 24607.

2. (Natural size.) Dorsal view of a slightly smaller cranidium. U. S. Nat. Mus., Cat. No. 70280.

3. (Natural size.) Smaller cranidium preserving the posterior portion of the palpebral lobe. U. S. Nat. Mus., Cat. No. 70281.

Matrix, limestone.

Upper Cambrian, Secret Canyon shale ? Eureka District, Nevada.

Housia varro (Walcott) 95

FIG. 4. (Natural size.) Dorsal view of the type cranidium. U. S. Nat. Mus., Cat. No. 62831.

5, 6. (Natural size.) Free cheeks assigned to this species. U. S. Nat. Mus., Cat. Nos. 62833, 62832.

7. (Natural size.) Associated pygidium slightly distorted. U. S. Nat. Mus., Cat. No. 62836.

8. (Natural size.) Associated thoracic segment. U. S. Nat. Mus., Cat. No. 62834.

Matrix, siliceous shale.

Upper Cambrian, Orr formation. (Loc. 30y): Orr Ridge, House Range, Utah.

Hardyia metion Walcott 91

FIG. 9. (× 3.) Dorsal view of the type cranidium. U. S. Nat. Mus., Cat. No. 70282.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 66k): Ranger Canyon, Sawback Range, Alberta, Canada.

Tostonia iole (Walcott) 117

FIGS. 10, 11. (× 2.) Dorsal and side views of the type cranidium. U. S. Nat. Mus., Cat. No. 24566a.

12. (× 2.) A somewhat larger head. U. S. Nat. Mus., Cat. No. 24566b.

13. (× 2.) Small pygidium. U. S. Nat. Mus., Cat. No. 70283.

14. (× 2.) A larger and more complete pygidium. U. S. Nat. Mus., Cat. No. 70284.

Matrix, limestone.

Upper Cambrian, Secret Canyon shale. (Loc. 64): Adams Hill, Eureka District, Nevada.

Anoria tontoensis (Walcott) 68

FIG. 15. (Natural size.) A small broken specimen illustrating the main characters. U. S. Nat. Mus., Cat. No. 62686.

16. (Natural size.) View of the mould of a larger crushed specimen, which retains the free cheeks. U. S. Nat. Mus., Cat. No. 62685.

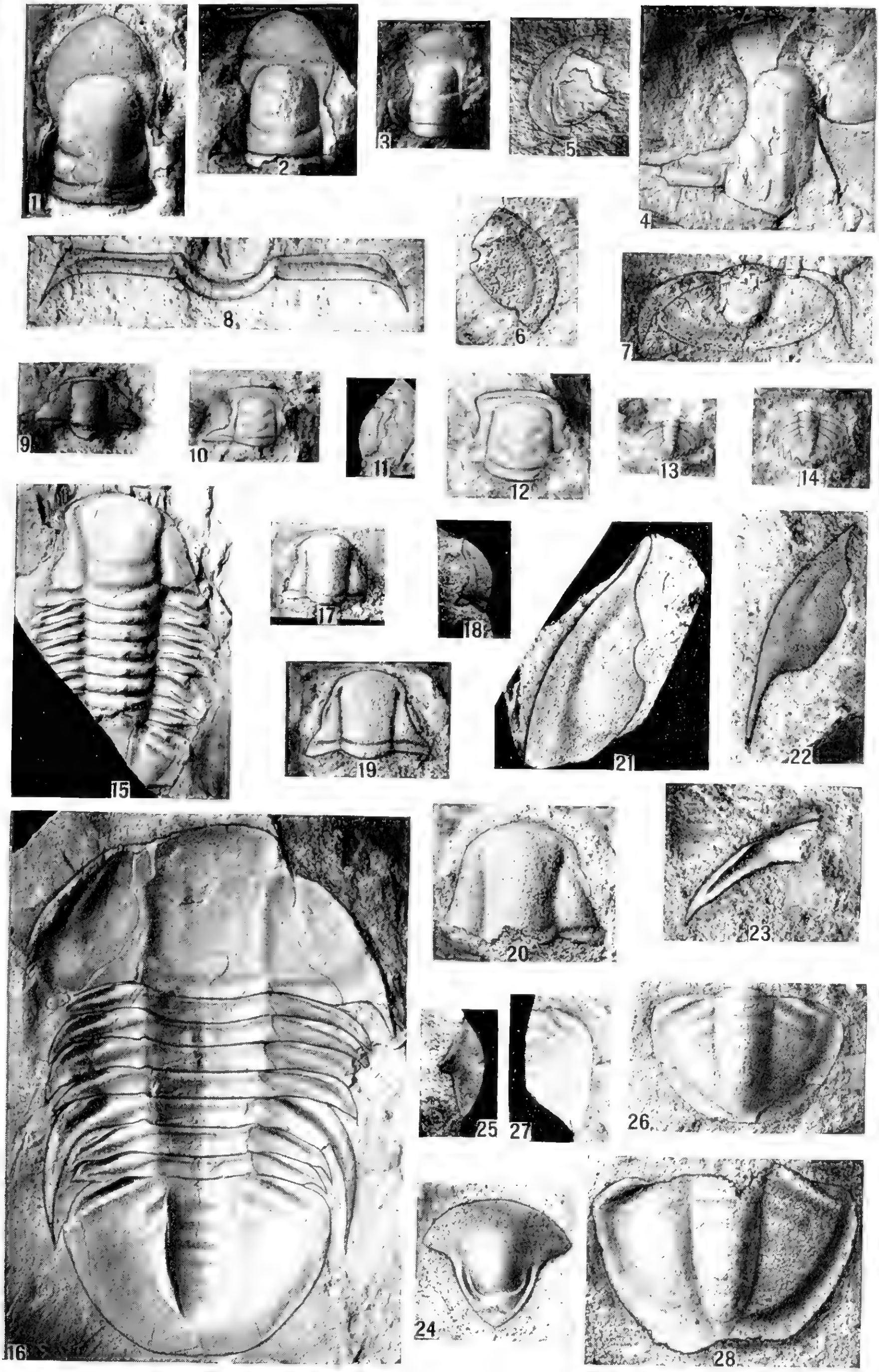
17, 18. (Natural size.) Dorsal and side views of a small cranidium. U. S. Nat. Mus., Cat. No. 62688.

19. (Natural size.) A slightly larger cranidium. U. S. Nat. Mus., Cat. No. 70285.

20. (Natural size.) Large head partly broken away along posterior edge. U. S. Nat. Mus., Cat. No. 70286.

21. (Natural size.) Free cheek posed to show the thickened frontal extension of the doublure. U. S. Nat. Mus., Cat. No. 70287.

22. (Natural size.) A second free cheek, preserving the genal spine and showing to what extent the suture is intramarginal. U. S. Nat. Mus., Cat. No. 70288.



UPPER CAMBRIAN TRILOBITES

Anoria tontoensis (Walcott)—Continued

FIG. 23. (Natural size.) Portion of a thoracic segment. U. S. Nat. Mus., Cat. No. 62692.

24, 25. (Natural size.) Ventral and side views of the associated hypostoma. U. S. Nat. Mus., Cat. No. 62689.

26, 27. (Natural size.) Dorsal and side views of a typical pygidium. U. S. Nat. Mus., Cat. No. 62694.

28. (Natural size.) A larger, but somewhat broken tail. U. S. Nat. Mus., Cat. No. 62693.

Matrix, sandstone and olive micaceous shale.

Upper Cambrian, Bright Angel shale. (Locs. 74 and 74e): Grand Canyon, Arizona. Specimens represented by figs. 15 and 16 compressed in shale, others in sandstone, with natural convexity preserved.

DESCRIPTION OF PLATE 19

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Idahoia serapio Walcott.. 96

FIGS. 1, 2. (Natural size.) Dorsal and side views of an almost complete cranidium. Outlines restored. U. S. Nat. Mus., Cat. No. 70289.

3. (Natural size.) Broken and distorted cranidium but with the occipital spine well preserved. U. S. Nat. Mus., Cat. No. 70290.

4, 5. (Natural size.) Associated free cheek and cast from mould of same, preserving the general characters. U. S. Nat. Mus., Cat. Nos. 70291, 70292.

6. (Natural size.) Portion of large, free cheek with genal spines. U. S. Nat. Mus., Cat. No. 70293.

7. (Natural size.) Cast of the outer portion of a free cheek preserving several small patches of test. Note the striations on the rim. U. S. Nat. Mus., Cat. No. 70294.

8. (Natural size.) Smaller free cheek showing outer surface. U. S. Nat. Mus., Cat. No. 70295.

9, 10. (Natural size.) Associated hypostoma referred to the species. U. S. Nat. Mus., Cat. No. 70296.

11. (Natural size.) Pygidium somewhat doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 70297.

12. (Natural size.) Cast of an associated broken pygidium. U. S. Nat. Mus., Cat. No. 70298.

Matrix, limestone.

Upper Cambrian, Ovid formation. (Locs. 54w, 4y): Near Malad, Idaho.

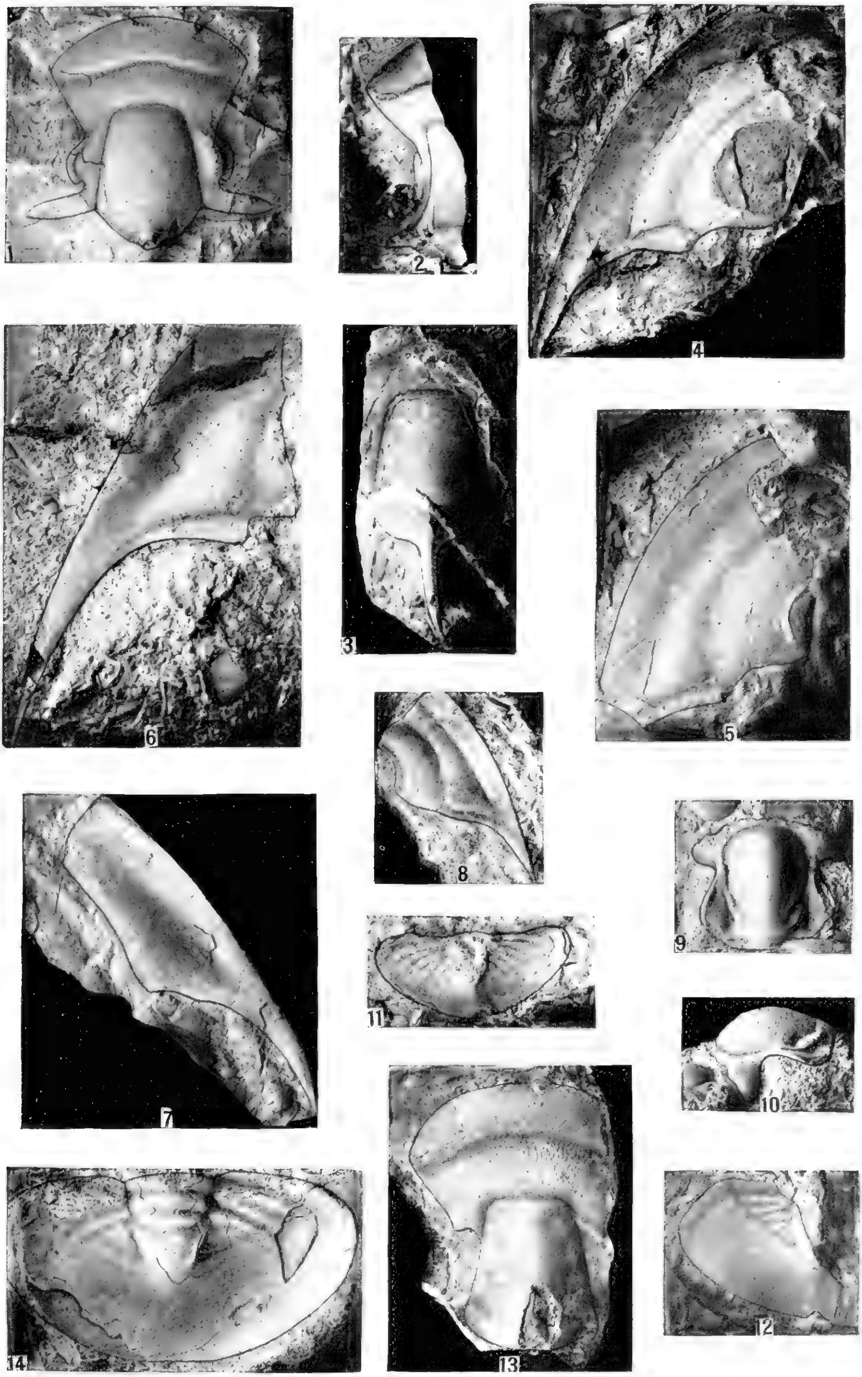
Idahoia maladensis Walcott.. 99

FIG. 13. (Natural size.) Large incomplete cranidium. U. S. Nat. Mus., Cat. No. 70299.

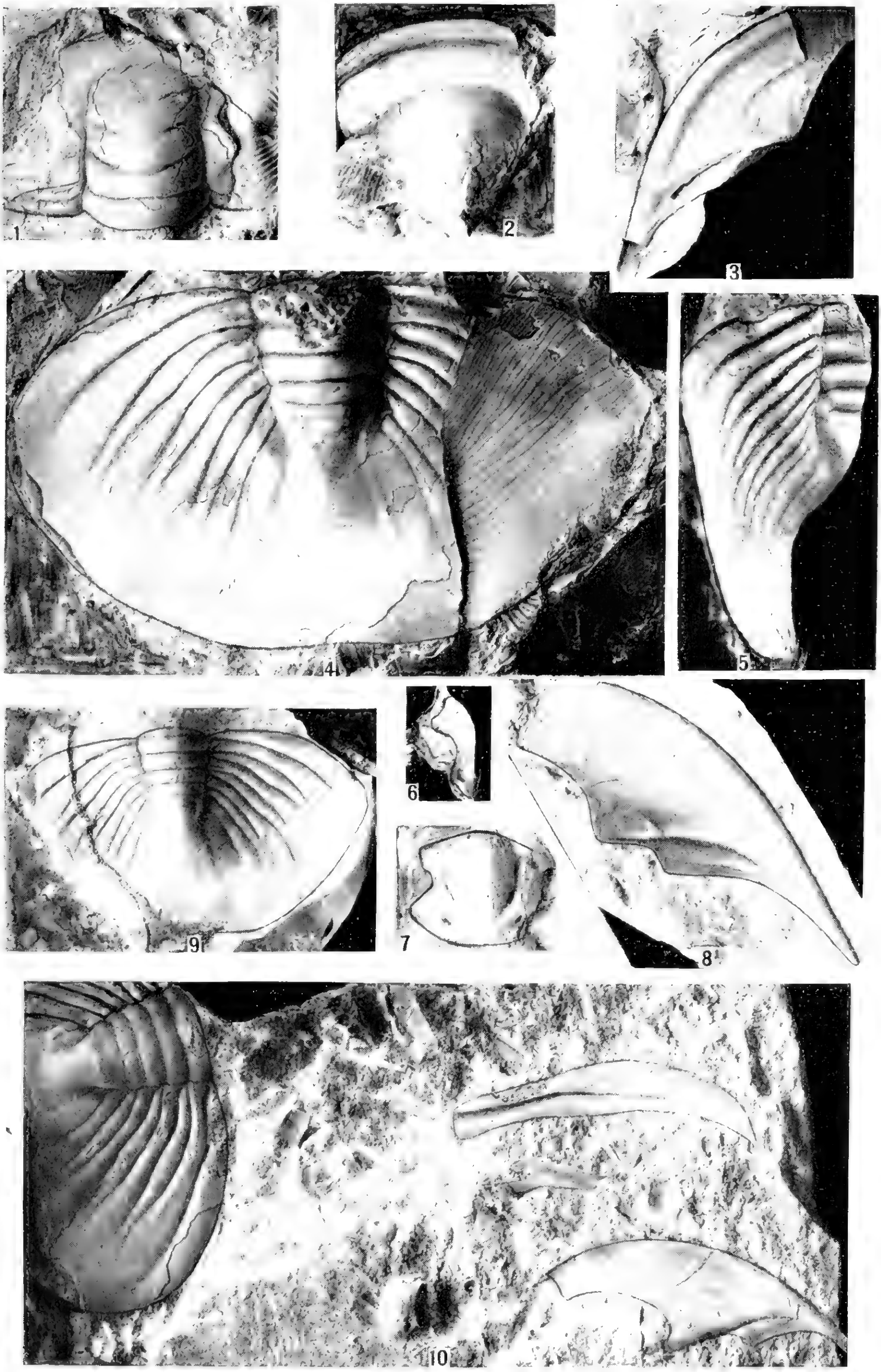
14. (Natural size.) Well preserved pygidium referred to the species. U. S. Nat. Mus., Cat. No. 70300.

Matrix, limestone.

Upper Cambrian, Ovid formation. (Loc. 5e): 2 miles (3.2 km.) southeast of Malad, Idaho.



IDAHOIA



BRISCOIA

DESCRIPTION OF PLATE 20

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Briscoia sinclairensis Walcott 75

FIG. 1. (Natural size.) Dorsal view of a fairly complete cranidium. U. S. Nat. Mus., Cat. No. 70301.

2. (Natural size.) Front portion of a large cranidium. U. S. Nat. Mus., Cat. No. 70302.

3. (Natural size.) Associated free cheek assigned to the species. U. S. Nat. Mus., Cat. No. 70303.

4, 5. (Natural size.) Dorsal and side views of a large pygidium, illustrating the course of the pleural furrows. U. S. Nat. Mus., Cat. No. 70304.

6, 7. (Natural size.) Side and dorsal views of an associated hypostoma referred to the species. U. S. Nat. Mus., Cat. No. 70305.

8. (Natural size.) An associated free cheek preserving most of the genal spine. U. S. Nat. Mus., Cat. No. 70306.

9. (Natural size.) Cast of a fairly complete pygidium. U. S. Nat. Mus., Cat. No. 70307.

10. (Natural size.) Slab with free cheek, thoracic segment and portion of a pygidium. Note surface ornamentation. U. S. Nat. Mus., Cat. No. 70308.

Matrix, limestone.

The specimens represented by figs. 1 to 7 are from Lower Ozarkian, Mons formation. (Loc. 16t'): Sinclair Canyon, British Columbia, and figs. 8 to 10 are from Lower Ozarkian, Mons formation. (Loc. 64n): Near base of 1e of field section. Glacier Lake Section, Alberta, Canada.

DESCRIPTION OF PLATE 21

PAGE

Symphysurina woosteri Ulrich (MSS.) 115

FIGS. 1, 2. (× 2.) Dorsal and side views of a fairly complete cranidium, showing shape, position and size of eyes and median tubercle. U. S. Nat. Mus., Cat. No. 70309.

3. (× 2.) Dorsal view of associated free cheek, border broken away at genal spine. U. S. Nat. Mus., Cat. No. 70310.
4. (× 2.) Front view of cheek showing extension of rim and doublure under front of cranidium. U. S. Nat. Mus., Cat. No. 70311.
5. (×2.) Broken free cheek, with border removed, exposing the peculiar depressions in the under side of the doublure. U. S. Nat. Mus., Cat. No. 70312.
6. (Natural size.) Free cheek, giving general aspect. U. S. Nat. Mus., Cat. No. 70313.
7. (Natural size.) Another small free cheek, with rim removed, more complete than fig. 5. U. S. Nat. Mus., Cat. No. 70314.
8. (× 2.) Associated thoracic segment. U. S. Nat. Mus., Cat. No. 70315.
9. (× 2.) Pygidium, general aspect with test preserved. U. S. Nat. Mus., Cat. No. 70316.

10, 11. (Natural size.) Dorsal and side views of the interior cast of an associated pygidium. U. S. Nat. Mus., Cat. No. 70317.

Matrix, white chert.

Upper Ozarkian, Oneota dolomite. (Loc. 193): Rudolph's Quarry, Trempealeau, Wisconsin.

Symphysurina spicata Ulrich (MSS.) 113

FIGS. 12, 12a. (× 2.) Dorsal view of a cranidium showing general aspect. U. S. Nat. Mus., Cat. No. 70318.

13. (× 2.) Small broken cranidium. U. S. Nat. Mus., Cat. No. 70319.
14. (× 2.) Another small cranidium, poorly preserved. U. S. Nat. Mus., Cat. No. 70320.
15. (× 2.) Nearly complete free cheek. U. S. Nat. Mus., Cat. No. 70321.

16, 17. (× 2.) Dorsal and side views of an associated pygidium, partly exfoliated. U. S. Nat. Mus., Cat. No. 24647.

18. (× 2.) Small pygidium. U. S. Nat. Mus., Cat. No. 70322.

Matrix, thin-bedded limestone.

Ozarkian, Goodwin formation. (Loc. 201a): Eureka District, Nevada.

Symphysurina ? entella Walcott 112

FIGS. 19, 19a. (Natural size.) Cranidium showing course of facial suture. U. S. Nat. Mus., Cat. No. 70323.

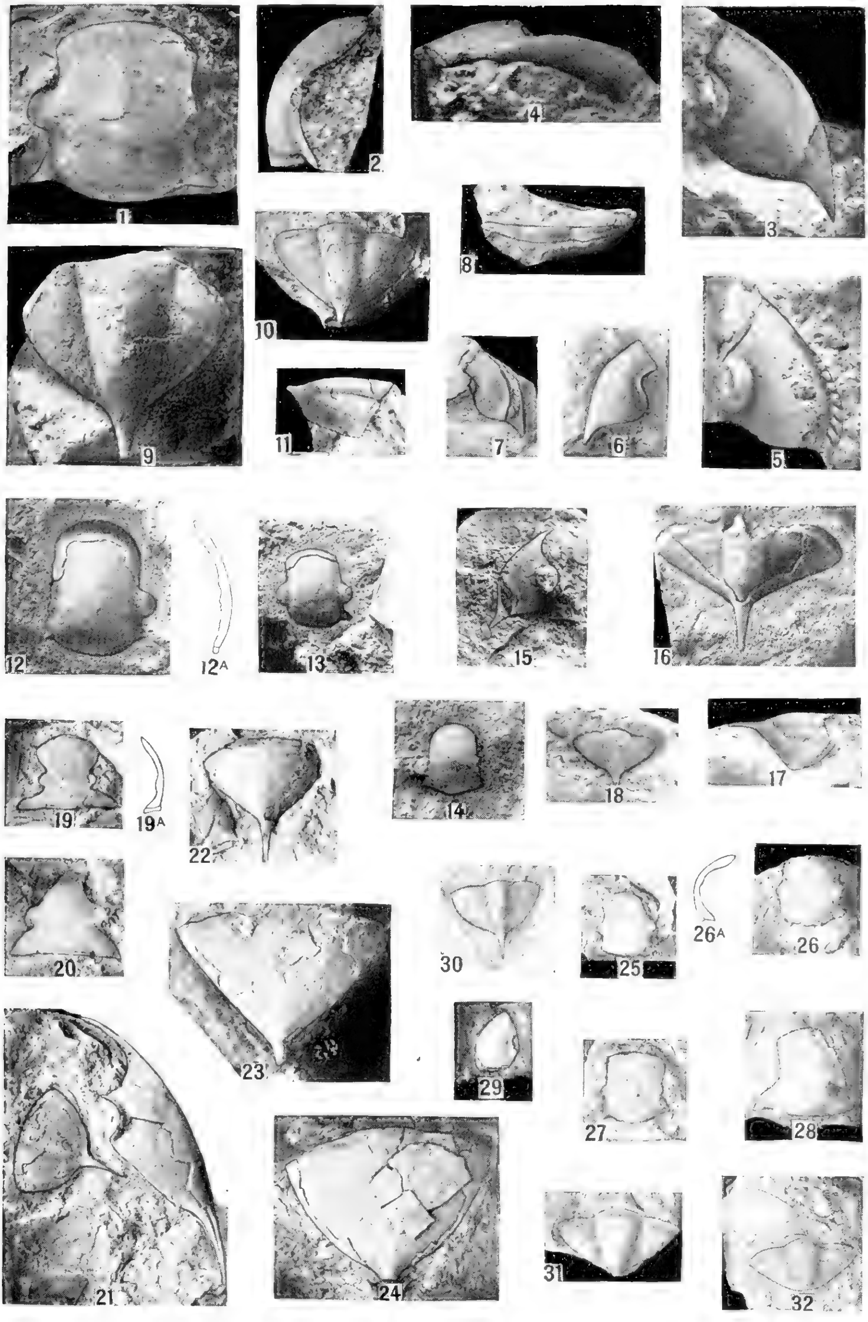
20. (Natural size.) Broken cranidium showing posterior portion and palpebral lobes. U. S. Nat. Mus., Cat. No. 70324.
21. (Natural size.) Free cheek and pygidium referred to this species. U. S. Nat. Mus., Cat. No. 70325.

22-24. (Natural size.) Associated pygidia with test more or less exfoliated. U. S. Nat. Mus., Cat. Nos. 70326, 70327, 70328.

30. (× 2.) Small pygidium. U. S. Nat. Mus., Cat. No. 70329.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 65w): Clearwater Canyon, Alberta, Canada.



SYMPHYSURINA

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Symphysurina eugenia Walcott.................................... 113

FIGS. 25-28. (Natural size.) More or less broken cranidia preserving general shape. U. S. Nat. Mus., Cat. No. 70330.

29. (Natural size.) A small free cheek. U. S. Nat. Mus., Cat. No. 70331.

31. (Natural size.) Small associated pygidia. U. S. Nat. Mus., Cat. No. 70332.

32. (Natural size.) An associated broken free cheek and pygidium. U. S. Nat. Mus., Cat. No. 70333.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 65v): Clearwater Canyon, Alberta, Canada.

DESCRIPTION OF PLATE 22

PAGE

Kainella billingsi (Walcott) 102

FIG. 1. (Natural size.) Large cranidium, the outlines of which have been restored, illustrating the main characters of the species and genus. U. S. Nat. Mus., Cat. No. 70334.

2. (Natural size.) Side view fig. 1.

3. (Natural size.) Associated free cheek, supposed to belong to this species. Border broken away all around, exposing the doublure. General direction of facial suture indicated. U. S. Nat. Mus., Cat. No. 70335.

4, 5. (Natural size.) Dorsal and posterior views of an associated pygidium referred to this species. Outline restored. U. S. Nat. Mus., Cat. No. 70336.

6. (Natural size.) Associated thoracic segment from near the posterior end of the thorax. U. S. Nat. Mus., Cat. No. 70337.

7. (Natural size.) Associated segment from the anterior end of the thorax. U. S. Nat. Mus., Cat. No. 70338.

Matrix, limestone.

Ozarkian, Chushina formation. (Loc. 61q): Robson Peak District, British Columbia.

Moxomia angulata (Hall and Whitfield) 107

FIGS. 8, 9. (Natural size.) Dorsal and side views of the cranidium, the only portion of this trilobite known. U. S. Nat. Mus., Cat. No. 70339.

Matrix, limestone.

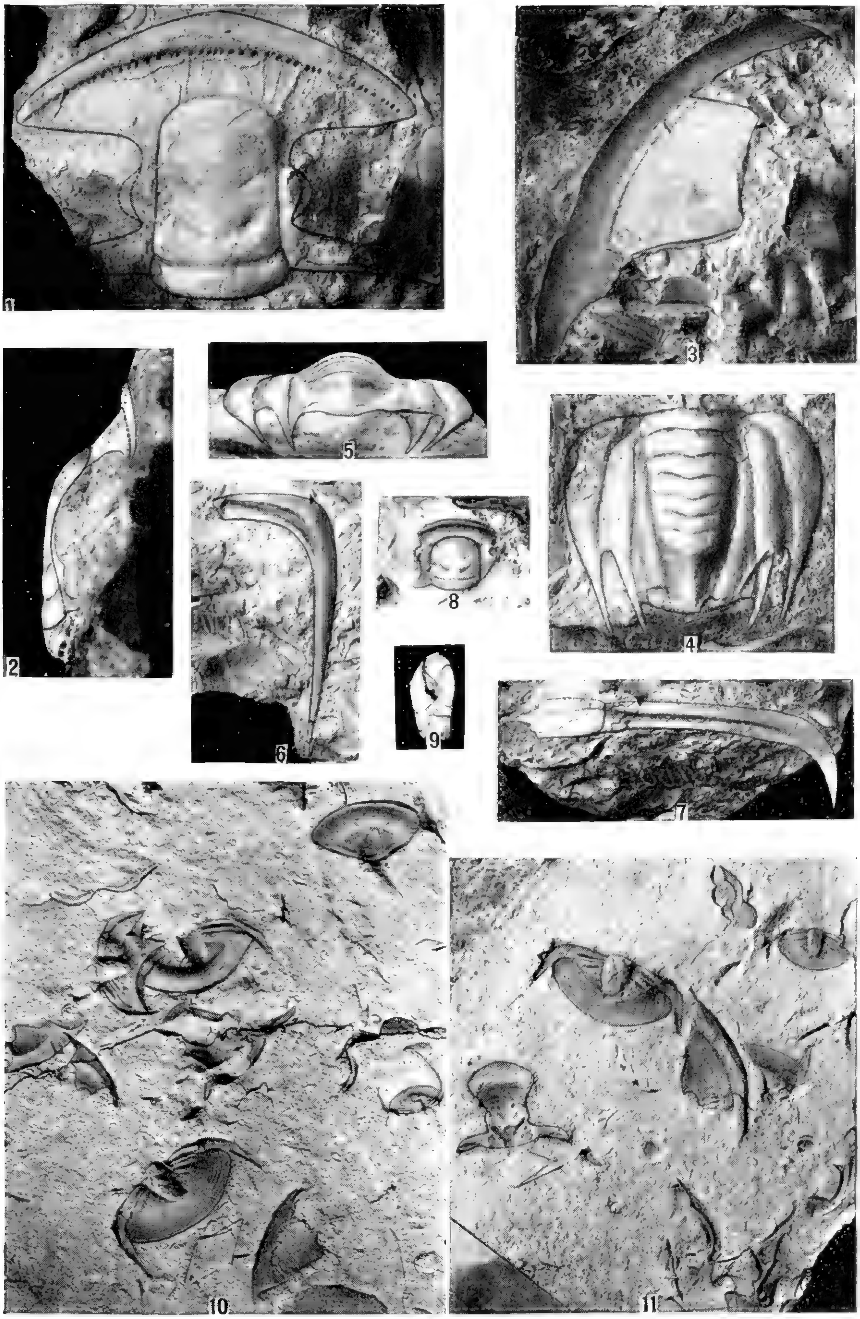
Ozarkian, Chushina formation. (Loc. 61q): Robson Peak District, British Columbia.

Housia canadensis Walcott (see pl. 7, figs. 4, 8) 94

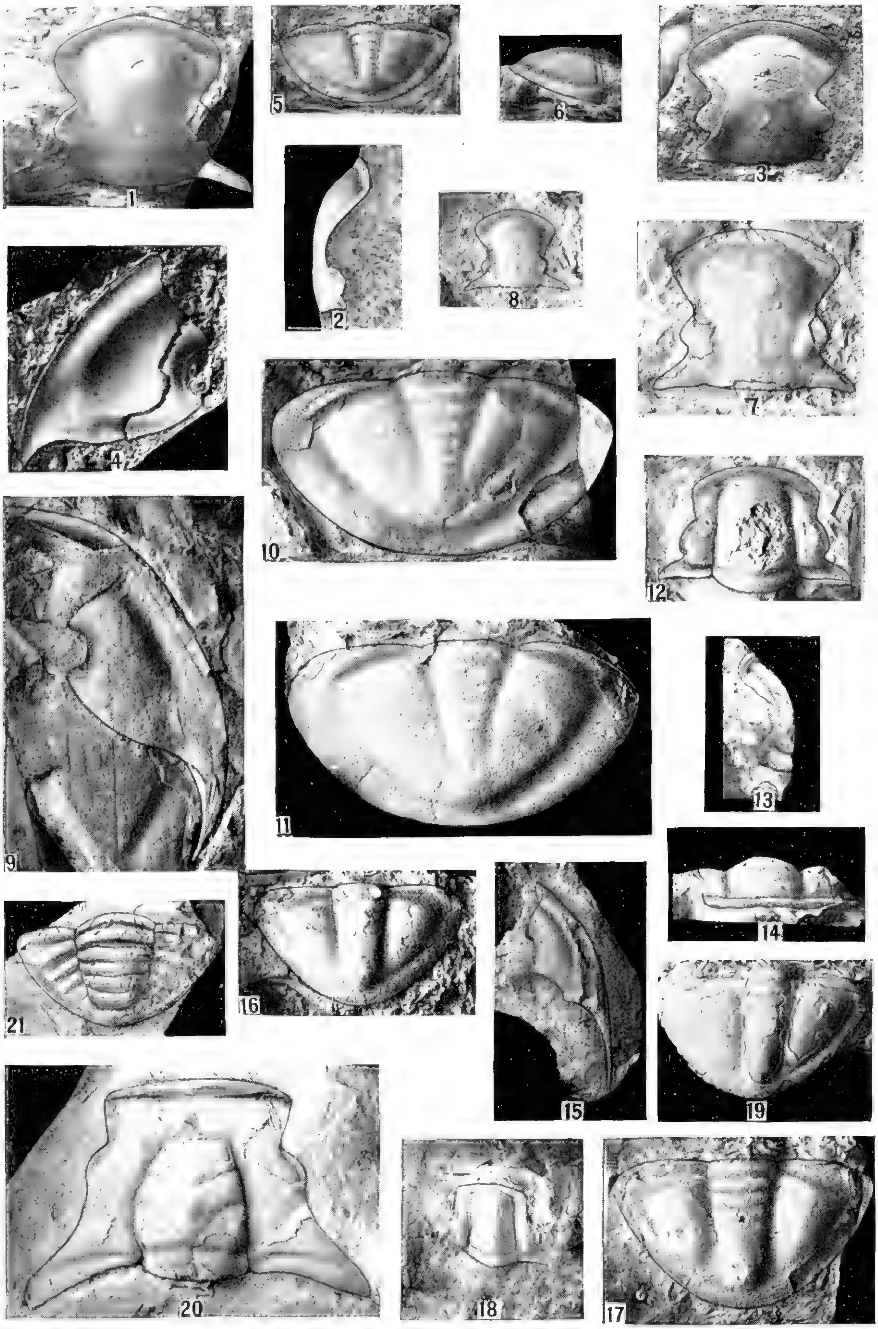
FIGS. 10, 11. (Natural size.) Shaly limestone with various parts of this species. These are better preserved than the previously illustrated specimen. U. S. Nat. Mus., Cat. No. 70340.

Matrix, siliceous shale.

Upper Cambrian, Goodsir formation. Mount Goodsir, British Columbia.



KAINELLA—MOXOMIA—HOUSIA



BELLEFONTIA—LEIOSTEGIUM—MOOSIA

DESCRIPTION OF PLATE 23

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Bellefontia collieana (Raymond) Ulrich 72

FIGS. 1, 2. (× 2.) Dorsal and side views of a small but fairly complete cranidium. U. S. Nat. Mus., Cat. No. 70341.

3. (× 2.) Dorsal view of a less complete head. U. S. Nat. Mus., Cat. No. 70342.

4. (× 2.) A small, partly exfoliated free cheek. U. S. Nat. Mus., Cat. No. 70343.

5, 6. (Natural size.) Dorsal and side views of an associated pygidium, from which the test has been exfoliated. U. S. Nat. Mus., Cat. No. 70344.

Matrix, limestone.

Canadian, Lower Stonehenge. (Loc. 271r): Bellefonte, Pennsylvania.

Bellefontia nonius Walcott 72

FIG. 7. (Natural size.) Cranidium with outlines restored. U. S. Nat. Mus., Cat. No. 70345.

8. (Natural size.) Small head. U. S. Nat. Mus., Cat. No. 70346.

9. (Natural size.) Free cheek found in association with this form. U. S. Nat. Mus., Cat. No. 70347.

10, 11. (Natural size.) Pygidia showing the characters of the species. U. S. Nat. Mus., Cat. Nos. 70348, 70349.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 65y): North side of Clearwater Canyon, 2 miles (3.2 km.) from divide at head of canyon and about 21 miles (33.8 km.) in an air line north, 2° west, of Lake Louise Station, on the Canadian Pacific Railway, Alberta, Canada.

Leiostegium manitouensis Walcott 104

FIGS. 12-14. (Natural size.) Dorsal, side, and front views of a fairly complete cranidium illustrating the generic and specific characters. U. S. Nat. Mus., Cat. No. 70350.

15. (Natural size.) Free cheek. Rim broken away, exposing the doublure for most of the distance. U. S. Nat. Mus., Cat. No. 70351.

16. (Natural size.) Dorsal view of an associated pygidium. U. S. Nat. Mus., Cat. No. 70352.

17. (Natural size.) Dorsal view of a well preserved associated pygidium. U. S. Nat. Mus., Cat. No. 70353.

18. (Natural size.) Small, slightly distorted cranidium. U. S. Nat. Mus., Cat. No. 70818.

19. (Natural size.) Pygidium preserving most of the test. U. S. Nat. Mus., Cat. No. 70817.

Matrix, red siliceous limestone.

Ozarkian (Manitou limestone). (Loc. 187): Manitou Park, Colorado. Ozarkian (Chushina formation). (Loc. 61q): Billings Butte, east, near base of Robson Peak, British Columbia.

Moosia grandis Walcott 107

FIG. 20. (Natural size.) A large cranidium somewhat distorted, illustrating the characters of the species. U. S. Nat. Mus., Cat. No. 70355.

21. (Natural size.) Pygidium associated and referred to this species. U. S. Nat. Mus., Cat. No. 70356.

Matrix, siliceous shale.

Upper Cambrian, Goodsir formation. Moose Creek, British Columbia.

DESCRIPTION OF PLATE 24

PAGE

Xenostegium taurus Walcott 128

FIG. 1. (Natural size.) Dorsal view of the pygidium and an oblique view of the cranidium. U. S. Nat. Mus., Cat. No. 70357.

2. (× 2.) Dorsal view of the type cranidium.

Matrix, limestone.

Ozarkian, Chushina formation. (Loc. 61q): Billings Butte (Extinguisher), above Hunga Glacier, Robson Peak District, British Columbia, Canada.

Xenostegium belemnurum (White) 125

FIG. 3. (× 2.) Cranidium with test badly eroded on same rock with fig. 4, the original type. U. S. Nat. Mus., Cat. No. 70358.

4. (Natural size.) Dorsal view of White's original type specimen. Hologenotype, U. S. Nat. Mus., Cat. No. 8562.

Matrix, limestone.

Canadian ? (Loc. 67i): Queen Spring Hill, southeast of Schellbourne, Nevada.

Xenostegium goniocercum (Meek) 127

FIGS. 5, 6. (Natural size.) Dorsal views of the original type pygidia of the species. U. S. Nat. Mus., Cat. No. 11600.

7. (Natural size.) Cast of another pygidium. U. S. Nat. Mus., Cat. No. 70361.

8. (Natural size.) Small pygidium doubtfully referred to the species. U. S. Nat. Mus., Cat. No. 70360.

Matrix, limestone.

Canadian ? Near Malad, Idaho.

Xenostegium ? sulcatum Walcott 128

FIG. 9. (× 2.) Dorsal view of only cranidium discovered. U. S. Nat. Mus., Cat. No. 70359.

Matrix, limestone.

Ozarkian, St. Charles formation ?. (Loc. 55z): Blacksmith Fork Canyon, Utah.

Xenostegium albertensis Walcott 125

FIGS. 10, 11. (Natural size.) Dorsal and side views of the type pygidium. U. S. Nat. Mus., Cat. No. 70362.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 66v): Upper Johnson Creek Canyon, Sawback Range, Alberta, Canada.

Xenostegium ? eudocia Walcott 126

FIG. 12. (Natural size.) Central portion of the cranidium. U. S. Nat. Mus., Cat. No. 70363.

Matrix, limestone.

Ozarkian, St. Charles formation. (Loc. 55z): Blacksmith Fork Canyon, Utah.

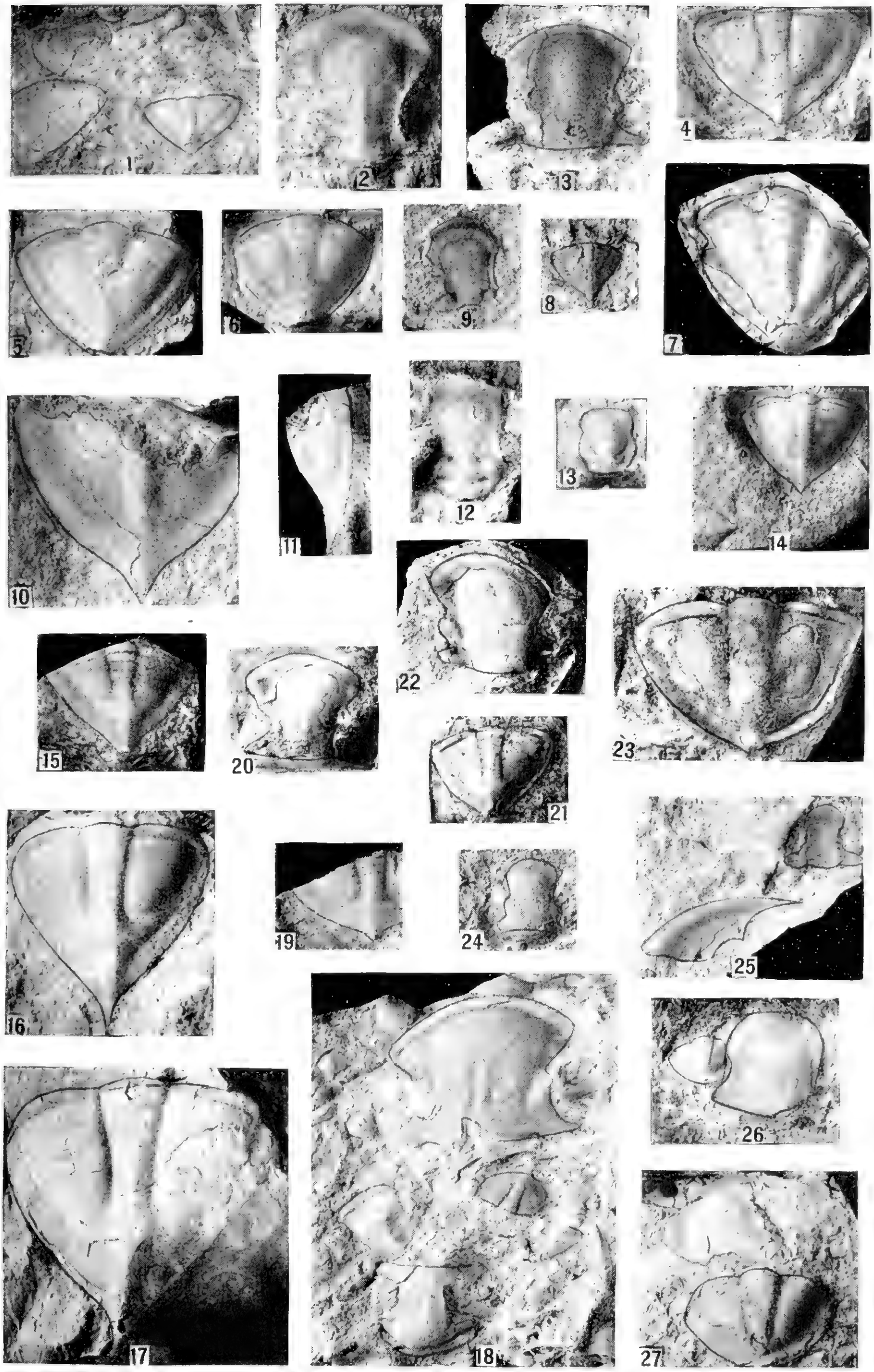
Xenostegium euclides Walcott 126

FIG. 13. (× 2.) Associated hypostoma which may belong to this species. U. S. Nat. Mus., Cat. No. 70364.

14. (× 2.) Large and small pygidium. U. S. Nat. Mus., Cat. No. 70365.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 66v): Upper Johnson Creek Canyon, Sawback Range, Alberta, Canada.



CAMBRIAN TRILOBITES

PAGE

Xenostegium schofieldi Walcott 127

FIG. 15. (Natural size.) Type pygidium. U. S. Nat. Mus., Cat. No. 70366.

Matrix, limestone.

Ozarkian, Mons formation. North end of Swansea Mountain, north-northeast of Lake Windermere, British Columbia, Canada.

Xenostegium shepardi (Raymond) 128

FIG. 16. (Natural size.) Dorsal view of an excellent pygidium. U. S. Nat. Mus., Cat. No. 70367.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 66u): Above Mons Glacier, Glacier Creek District, Alberta, Canada.

FIG. 17. (Natural size.) Cast of Raymond's type. U. S. Nat. Mus., Cat. No. 70368.

Matrix, limestone.

Ozarkian. Mons formation, Sinclair Canyon, British Columbia, Canada.

Xenostegium kirki Walcott 127

FIG. 18. (Natural size.) Several cranidia and pygidia. U. S. Nat. Mus., Cat. No. 71369.

19. (Natural size.) Posterior portion of a pygidium. U. S. Nat. Mus., Cat. No. 71370.

Matrix, limestone.

Ozarkian, Mons formation. (Loc 170): North of Stoddart Creek Canyon, Stanford Range, British Columbia, Canada.

FIG. 20. (Natural size.) Partially exfoliated cranidium doubtfully referred to this species. U. S. Nat. Mus., Cat. No. 70371.

21. (Natural size.) Pygidium associated with fig. 20. U. S. Nat. Mus., Cat. No. 70372.

Matrix, limestone.

Ozarkian, Mons formation: (Loc. 67q): Douglas Lake, Canyon Valley, Sawback Range, Alberta, Canada.

Xenostegium douglasensis Walcott 125

FIG. 22. (Natural size.) An imperfect cranidium. U. S. Nat. Mus., Cat. No. 70373.

23. (Natural size.) Associated pygidium. U. S. Nat. Mus., Cat. No. 70374.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 67q): Douglas Lake, Canyon Valley, Sawback Range, Alberta, Canada.

Isoteloides ? sp. undt 100

FIG. 24. (Natural size.) Fragment of a cranidium. U. S. Nat. Mus., Cat. No. 70375.

Matrix, limestone.

Ozarkian, Mons formation. (Loc. 67h): 3 miles (4.8 km.) south of Wilcox Pass, Alberta, Canada.

Isoteloides ? lautus Walcott 99

FIG. 25. (Natural size.) Cranidium and associated free cheek. U. S. Nat. Mus., Cat. No. 70376.

Matrix, limestone.

Ozarkian, Mons formation. (66v): Upper Johnson Creek Canyon, Sawback Range, Alberta, Canada.

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Isoteloides occidentalis Walcott.. 99

FIG. 26. (Natural size.) Cranidium and associated pygidium. U. S. Nat. Mus., Cat. No. 70377.

Matrix, limestone.

Ozarkian, ? Mons formation. (Loc. 67h): 3 miles (4.8 km.) south of Wilcox Pass, Alberta, Canada.

Isoteloides ? maladensis Walcott.. 99

FIG. 27. (Natural size.) Cranidium and associated pygidium. U. S. Nat. Mus., Cat. No. 70378.

Matrix, limestone.

Upper Ozarkian ? Near Malad, Idaho.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 75, NUMBER 4

CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

No. 4.—PRE-DEVONIAN SEDIMENTATION IN SOUTHERN CANADIAN ROCKY MOUNTAINS

(WITH PLATE 25)

BY
CHARLES D. WALCOTT

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

No. 4.—PRE-DEVONIAN SEDIMENTATION IN SOUTHERN CANADIAN ROCKY MOUNTAINS[1]

By CHARLES D. WALCOTT

(With Plate 25)

CONTENTS

ILLUSTRATIONS

[1] Published posthumously. Dr. Walcott completed the manuscript only ten days before his death on February 9, 1927. The proofs have been corrected by Dr. Charles E. Resser.

EXPLANATION

Area of the Bow Trough. Includes deposits of Lower, Middle and Upper Cambrian, Devonian and Carboniferous time. In direct communication at the north with Glacier Lake Trough.

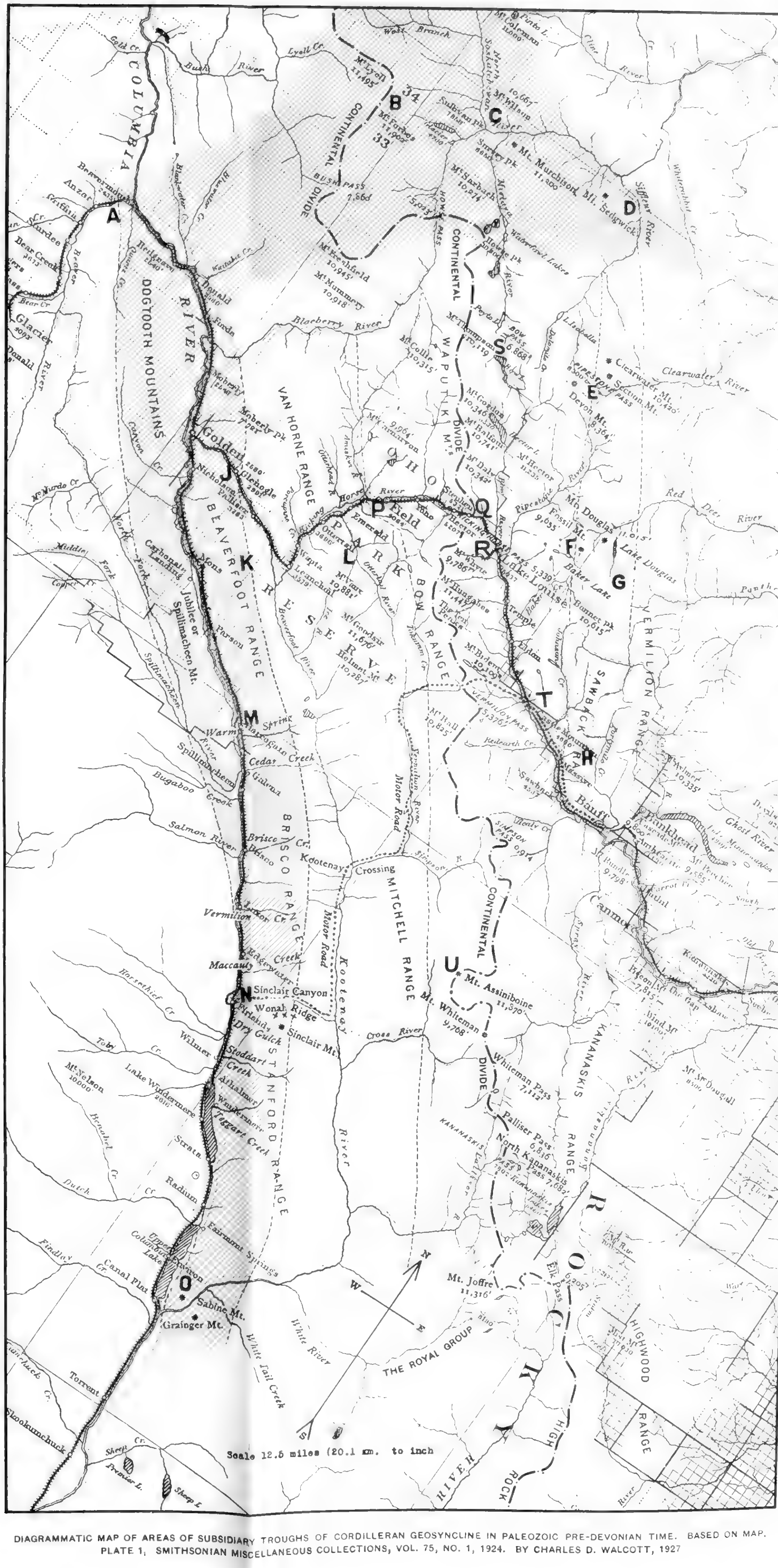
Southern portion of area of Glacier Lake Trough. Includes deposits of Lower, Middle, and Upper Cambrian, Ozarkian, Devonian, and Carboniferous time.

Area of Sawback Trough, which is superjacent to deposits of Bow Trough. Includes deposits of Upper Cambrian, Ozarkian, Ordovician, and Devonian time. In direct communication at the north with Glacier Lake Trough.

Area of Goodsir Trough. Includes deposits of Upper Cambrian and possibly of later time. A barrier separates it from Glacier Lake Trough at the north.

Area of Beaverfoot Trough. Includes deposits of Lower and Upper Cambrian, Ozarkian, Ordovician, Silurian, and Devonian time. In direct communication at the north with Glacier Lake Trough.

West of the Beaverfoot Trough the terraine is formed of pre-Cambrian rocks of the Purcell and Selkirk Mountains, and an occasional remnant of Devonian and Carboniferous limestone. In the eastern section of the Bow Trough area the Cretaceous rocks are folded and faulted in with the Paleozoic limestones, but east of the eastern margin of the trough the Cretaceous is subjacent by the eastward overthrust of the Paleozoic. This overthrust extends for hundreds of miles along the "Rocky Mountain Front," occasionally bringing up the pre-Cambrian with the Paleozoic above it.



DIAGRAMMATIC MAP OF AREAS OF SUBSIDIARY TROUGHS OF CORDILLERAN GEOSYNCLINE IN PALEOZOIC PRE-DEVONIAN TIME. BASED ON MAP, PLATE 1, SMITHSONIAN MISCELLANEOUS COLLECTIONS, VOL. 75, NO. 1, 1924. BY CHARLES D. WALCOTT, 1927

INTRODUCTION

In the progress of my reconnaissance in western Alberta and eastern British Columbia of the pre-Devonian formations of the Rocky Mountains from the Saskatchewan River drainage south to the line of Crows Nest Pass, many interesting problems appeared, for the detailed study of which there was but little time in the field. One of the most insistent of these was the problem of the location and extent of the original areas of deposition of the sediments now forming the series of stratigraphic formations between the pre-Cambrian and the Devonian. Much time and effort were devoted to collecting fossils from the Cambrian and Ozarkian rocks in order to obtain data that could be relied on regarding an area where irregularities of sedimentation, and subsequent displacement of strata by faulting and folding, had greatly complicated the normal stratigraphic succession of the formations. At first, with the great section of McConnell on the line of the Canadian Pacific Railway[1] as a guide (fig. 18), I considered that the entire series of sediments had been deposited in a broad seaway that filled the Cordilleran Geosyncline in upper Lower Cambrian time and that this seaway gradually narrowed as it received sediments from the great hinterland to the west and east until Devonian time. This impression was strengthened in studying the Glacier Lake-Saskatchewan River section, and in 1924 I published a transverse theoretical section of the Cordilleran Trough, based on conclusions reached at that date.[2] The section may possibly be a fairly correct one for the Glacier Lake-Saskatchewan area, but it does not now afford a satisfactory explanation for the Bow-Kicking Horse River section, 60 to 70 miles (96.5 to 112.6 km.) to the south-southeast.

The object of this paper is to call attention to conclusions based on further field studies and the working over since 1924 of a considerable amount of unpublished geological and paleontological data on the formation of the Cordilleran Geosyncline, located in the drainage areas of the Bow, Kicking Horse, and Saskatchewan Rivers.

The boundary between the Bow and Goodsir Troughs should be drawn about one-fourth of an inch to the west (left) where it crosses the Kicking Horse River, near Field (*P* on map) and con-

[1] Geol. and Nat. Hist. Surv. of Canada, Ann. Rep. for 1886, 1887, Pt. D, pp. 15D-31D, and accompanying colored section.

[2] Soc. Géol. de Belgique. Livre Jubilaire 1924. La Discordance de Stratification et la Lacune Stratigraphique Pré-Dévonienne dans les provinces Cordillères d'Alberta et de Colombie Britannique, Canada.

tinues northwest to the Blaeberry River. Southeast of Field it passes eastward to the boundary line represented on the map.

CORDILLERAN GEOSYNCLINE

The Cordilleran Geosyncline has been characterized by Schuchert as the oldest, longest, and widest continuous seaway known. During the Palaeozoic it extended from the Arctic Ocean southward through what is now the mountainous region of western North America into northwestern Mexico, a distance of 3,000 miles (4,827 km.). In Canada the width of this seaway was in most places a few hundred miles, while in the United States it was many hundreds of miles wide. The eastern shore of this vast geosyncline (seaway) and its marine extensions was the Canadian shield and its southern prolongation, Siouia. On the west it was bounded by Cascadia.[1]

In this paper we are chiefly concerned with the portion of the geosyncline that is now embraced in the area between the 49th and 54th parallels, a distance of about 350 miles (563.2 km.). The width of the geosyncline in pre-Cambrian time is unknown, but judging from the presence of Proterozoic deposits of Beltian time far to the west of the Cambrian outcrops, it was probably 300 or 400 miles (482.7 or 643.6 km.). In early Paleozoic time it may have been in places 200 miles (321.8 km.) or more, but as yet we do not know conclusively what pre-Devonian formations are present in the area west of the "Rocky Mountain Trench"; of the later Paleozoic, limestones of Devonian and Carboniferous age have been recognized which were presumably deposited in bays and along the shores of the old Selkirkian land area. On a line (from *I* through *M* on map, pl. 25) extending from the Rocky Mountain front at Devils Gap, northeast of Banff, Alberta, west-southwest through Banff and over the Continental Divide to the pre-Cambrian Proterozoic terraine on the west side of the Columbia River valley, the geosyncline may have been 200 to 250 miles (321.8 to 402.3 km.) broad; at present, after narrowing of the area by compression, folding, and thrusting of the pre-Devonian Paleozoic formations, the width occupied by them is about 160 miles (257.4 km.). On a parallel line that crosses the strike of the Continental Divide and the Cordilleran Trough 100 miles (160.9 km.) north, the area over which the pre-Devonian formations now occur is about 180 miles (289.6 km.) in width.

To what extent during pre-Devonian time the bottom of the Cordilleran Geosyncline was wrinkled and thus made into a complex geosyncline with minor troughs has not been fully determined, but

[1] Bull. Geol. Soc. America, Vol. 34, 1923, p. 184.

we find evidence of the former existence of several troughs in which distinct series of sediments were deposited with the marine life of their time embedded in them.

There is also evidence of longitudinal undulations of the bottom of the troughs that influenced the depth and character of the sediments to such an extent as to now cause a most disconcerting disappearance and reappearance of formations with their characteristic faunas.

It is clear that at the beginning of Proterozoic time the Cordilleran Geosyncline was broad, and relatively shallow, with extended land areas on both its eastern and western sides. This is indicated by the immense amount of fine sand and silts that were brought into the trough and distributed by gentle currents and wave action. There are neither great conglomerates indicating lands of high relief, nor coarse, cross-bedded sandstones suggesting a sea with strong tidal currents and waves attacking the coast line. The Beltian limestones, of which great thicknesses occur in Montana [1] and possibly in Alberta, are relatively shallow water deposits similar to those of the great inland lakes of Tertiary time, east of the Rocky Mountains.

Many thousand feet of arenaceous, calcareous and siliceous deposits accumulated as the geosyncline gradually deepened because of the downward pressure of the load of sediments it was receiving. There may have been longitudinal troughs within the geosyncline as in Paleozoic time, but at present the study of the areal geology is not sufficiently advanced to outline more than one of them.

PROTEROZOIC DEPOSITS IN THE CORDILLERAN GEOSYNCLINE

At the close of Proterozoic time the greatest thickness of deposits was in the area that is now the Purcell and Selkirk Mountains of British Columbia. Daly gives the following sections of the formations: [2]

	Feet	Meters
Ross quartzite (in part)	2,500	762
Nakimu limestone	350 +	107 +
Cougar formation	10,800 +	3,292 +
Laurie formation	15,000 +	4,572 +
Illecillewaet quartzite	1,500 +	457 +
Moose metargillite	2,150	655
Limestone (marble)	170	52
Basal quartzite	280 +	85 +
	32,750	9,982

[1] Bull. Geol. Soc. America, Vol. 17, 1906, p. 7. Bull. U. S. Geol. Surv., No. 384, 1909, p. 41.

[2] Geol. Surv. Canada, Transcontinental Excursion No. C 1, Guide Book No. 8, pt. II, 1913, p. 183.

This enormous mass of sediments accumulated in a trough (Selkirk), the western margin of which was formed by a pre-Beltian land area west of the present Alberta Canyon on the Canadian Pacific Railway, or it may have been as far west as Revelstoke in the Columbia River valley. This distance is now only 40 to 60 miles (64 to 97 km.), as it has been shortened by compression, folding, and more or less faulting of the strata.

To the eastward of the Purcell Range, the pre-Cambrian (Beltian) is concealed by Cambrian and later formations all the way to the Bow Valley[1] where a series of fine, impure sandstones and shales of pre-Cambrian age are exposed that indicate the approach to an eastern shore line of relatively low relief. On this eastern side of the geosyncline there are only about 3,470 feet (1,057.6 m.) of Beltian sediments exposed. These accumulated in a broad, shallow sea that preceded the Bow Trough.

To the south in Montana, Beltian sediments similar to those of the Bow Valley area accumulated to a depth of 36,000 feet (10,972.8 m.)[2] or more prior to the advent of the Cambrian sea.

The close of the period of deposition of Beltian sediments was followed by a slight diastrophic movement that in the Canadian area resulted in low undulations and minor faulting of the strata and the formation of the Bow Trough, so that when the Lower Cambrian sea advanced from the south it had an unobstructed seaway. This trough deepened as sediments were deposited until over 2,000 feet (609.6 m.) in depth of sands and siliceous muds accumulated in it. On the western side of the geosyncline the Purcell Trough deepened and a great thickness of sands referred by Daly to the Lower Cambrian were deposited. These include:

	Feet	Meters
Sir Donald Quartzite	5,000 +	1,524.0 +
Ross Quartzite	2,750	838.2
	7,750 +	2,362.2 +

The upper part of the Ross Quartzite is referred by Daly to the Lower Cambrian and the lower 2,500 feet (762 m.) to the Beltian. He states that " The lower part of this formation is of pre-Cambrian age; the upper part is probably to be assigned to the Lower Cam-

[1] Smithsonian Misc. Coll., Vol. 53, No. 7, 1910, pp. 423-431.

[2] Bull. Geol. Soc. America, Vol. 17, 1906, pp. 7, 15. Bull. U. S. Geol. Surv., No. 384, 1909, p. 41.

brian."[1] A detailed study of the Ross Quartzite and the Sir Donald Quartzite may result in the discovery of a fauna or of an unconformity that will serve as a boundary between the Beltian and the Cambrian, if the latter is actually present in the Selkirk Mountains.

It is my present opinion that the troughs and embayments of the Cordilleran Geosyncline in Proterozoic Beltian time were filled with fresh or brackish waters that had for long periods very slight connection, if any, with either the Pacific or Arctic Oceans. The land surface of the continent then extended out to the margins of the continental platform, and the epicontinental bodies of water discharged their overflow into shallow streams that finally reached the oceans through deep and narrow channels. As far as known there is little if any evidence of the existence of open seaways connecting the inland seas and the oceans during Proterozoic time. Any sediments brought by streams were carried out to the margin of the continental shelf and deposited on the steep slopes descending to the abyssal depths of the oceans. This almost complete separation of the epicontinental waters from the oceans serves to explain the nearly entire absence of marine faunas in the sandstones, shales, and limestones of the Beltian series of formations, and the presence of great algal deposits and of a few species of invertebrates of marine derivation that became adapted to a fresh water habitat after working their way up a favorable stream to the inland bodies of water. In no other way can I explain the presence of a few fossil forms in narrow bands of shale and sandstone in the Beltian formations of the Cordilleran Geosyncline in Montana[2] and the absence of the marine faunas of Lipalian time[3] that preceded the marine faunas accompanying the flooding of the Cordilleran and Appalachian Geosynclines at the beginning of Lower Cambrian time.

TROUGHS OF PALEOZOIC TIME

Plate 25 and fig. 14

In the latitude of the Bow-Kicking Horse Rivers the earliest of these troughs was the Bow Trough on the eastern side of the geosyn-

[1] Geol. Surv. Canada, Transcontinental Excursion No. C 1. Guide Book No. 8, pt. II, 1913, p. 137.

[2] Bull. Geol. Soc. America, Vol. 17, 1906, pp. 1-28.

[3] Smithsonian Misc. Coll., Vol. 57, No. 1, 1910, p. 14, Footnote: "Lipalian (λειπω) 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." See also Vol. 64, No. 2, 1914, p. 82.

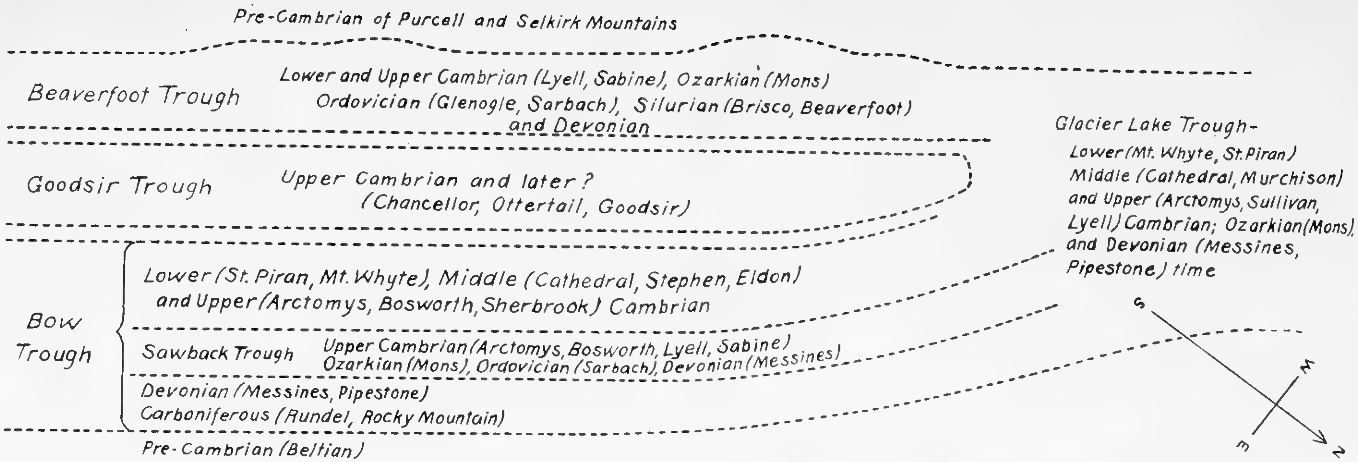


FIG. 14.—Diagrammatic outlines of subsidiary troughs of Cordilleran Geosyncline in pre-Middle Devonian time, based on map, pl. 25. The theoretical barrier boundaries between the Bow, Goodsir, and Beaverfoot Troughs are indicated by dotted lines, as are the margins of the Sawback Trough. All of the troughs except the Goodsir were connected by an open seaway at the north with the broad Glacier Lake Trough.

The troughs as here outlined represent only that portion of their original areas that remain after narrowing by compression, folding, faulting, and thrusting of the formations deposited in the troughs: this narrowing was probably from 10 to 30 per cent and in some instances much more.

cline. This was followed to the west by the Goodsir and finally the Beaverfoot Trough. The Bow Trough had open connection with the Glacier Lake Trough on the north (*B, C, D* on map and fig. 14) and with troughs or broad seaways to the south more or less intermittently all through Paleozoic time. The Goodsir Trough, as we now recognize it, did not have a direct connection with either the Bow or Beaverfoot Troughs, and except during a relatively short period in late Lower Cambrian time there was no connection between the areas of the Bow and Beaverfoot Troughs by which the fauna in one could have access to the other. The Goodsir Trough had no known connection with the Glacier Lake Trough and only very slight and short connections in Upper Cambrian time with the seaways to the south. The Beaverfoot Trough was in open connection with the Glacier Lake Trough on the north and at intervals with the seaways to the south. Deposition in the Sawback Trough appears to have been active at about the same time as in the Beaverfoot Trough, and there was an open seaway connection on the north into the broad Glacier Lake Trough that permitted the Sabine and Mons faunas to pass freely between the south end of the Beaverfoot Trough at Sabine Mountain (*O* on map) to Ranger Canyon (*H* on map) in the Sawback Trough, a distance of approximately 225 miles (362.0 km.). The probability is that the faunas mentioned passed from the Glacier Lake Trough south into the Sawback Trough, but they may have come in from the south through a seaway of which as yet we have no information. There was nowhere a regular uninterrupted sequence of deposits in any of these troughs from the beginning to the end of Paleozoic time. This was prevented by diastrophic movements of greater or less extent that occurred in the Cordilleran Geosyncline, from its inception until the "high Ancestral Rocky Mountain geanticline" blotted out its eastern side and later its median portion.[1]

Usually the boundaries of the troughs were low and afforded little mechanical sediment for deposition and, as determined by the faunas that lived in the seaways, we learn that they were not all of the same age and that the diastrophic movements affecting the geosyncline were subject to long periods of quiescence, in which accumulation of sediments may have caused deepening, and local tilting caused both deepening and shallowing of the troughs.

At present it is very difficult to form a clear conception of the original condition of the troughs in pre-Devonian time. On the eastern

[1] Schuchert, *loc. cit.*, pp. 186, 187.

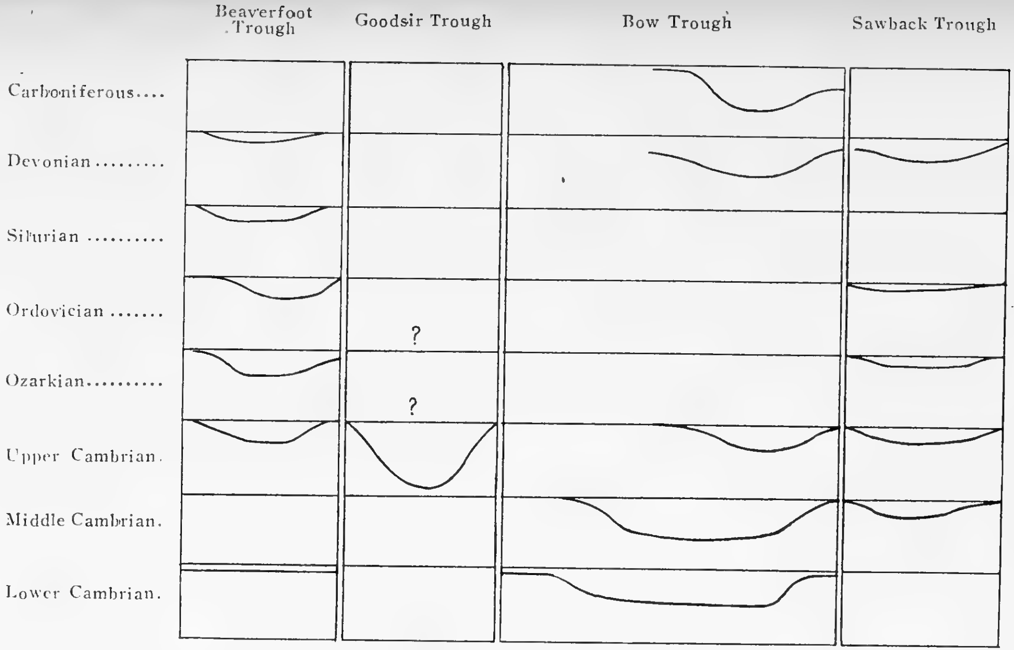


FIG. 15.—Diagrammatic sketch to show extent of maximum deposition of sediments as now known in the Bow, Goodsir, Beaverfoot and Sawback Troughs in each geologic period of Paleozoic time. This is intended to illustrate: (1) the relative amount of sedimentation in each trough; (2) the relationship in time of the Beaverfoot and Sawback Troughs; (3) the independent character of the Goodsir Trough; and (4) the great development of the Lower and Middle Cambrian in the Bow Trough.

How much, *if any*, of the later sediments of the Goodsir Trough are of Ozarkian or Ordovician age is undetermined.

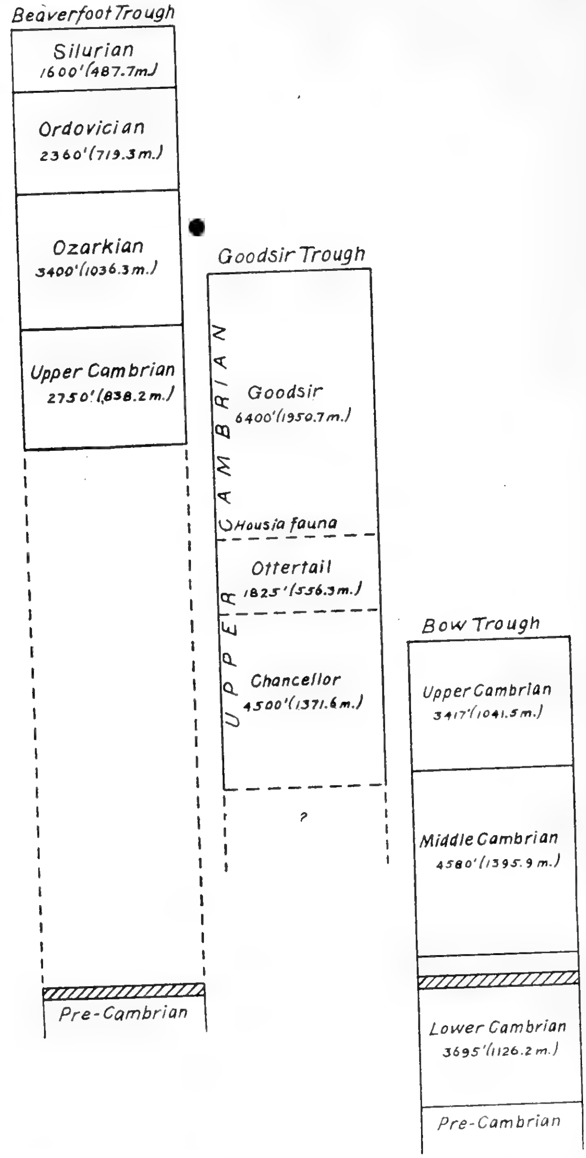


FIG. 16.—Stratigraphic sections of the Bow, Goodsir, and Beaverfoot Troughs. Each section is placed with reference to the time at which the various formations were deposited. Thus the sediments of the upper portion of the Lower Cambrian (Mesonacis zones) were deposited in the Bow and Beaverfoot Troughs about the same time, but there is no record of the deposition of sediments of this time in the Goodsir Trough. These sections serve to further explain the diagrammatic outlines of fig. 15.

side[1] the faulting and eastward thrusting of the sedimentary formations has forced the rocks, representing deposits in originally distinct troughs, eastward over each other until all evidences of land or shallow sea barriers between the troughs have been destroyed or deeply buried. On the western side the strata of the Beaverfoot Trough have been forced into overturned folds at the north end of the Beaverfoot Range west of the Kootenay fault, also faulted and possibly folded at the south in the Brisco and Stanford Range. The strata of the Goodsir Trough were also deeply affected, as shown by Allan's fine sections accompanying Map 142A of the Kootenay District.[2] These movements were usually, if not always, accompanied by displacements that are now recorded by profound faults and the juxtaposition of unlike formations containing faunas that are not in their normal stratigraphic order. The more or less irregular thrusting with concurrent and later erosion are accountable for the present position and exposures of the buried sections of the original troughs and the disappearance of their intervening barriers.

Examples of the overthrust of the sedimentary contents of a former trough are the thrust of the Cambrian and later limestones of the Bow Trough of the Rocky Mountain Front over on the Cretaceous formations, and the thrust of the Ozarkian, Ordovician, and Silurian rocks of the Beaverfoot Trough against, and probably on, the Upper Cambrian rocks of the Goodsir Trough. The great Lewis fault now marks the eastern limit of the Bow Trough, and the Kootenay fault the eastern limit of the Beaverfoot Trough.

A number of fine sections accompanying the report of Dr. D. B. Dowling of the Geological Survey of Canada[3] illustrate the effect of the eastward pressure that displaced and compressed the strata of the Bow Trough and the superjacent Cretaceous and Jurassic strata. A section a little south of Panther River is outlined by text figure 17.

The section on the line of the Bow-Kicking Horse Rivers illustrates the geological structure, as determined by McConnell and Allan, from the Rocky Mountain Front to the Columbia River, a distance of 72 miles (115.8 km.). The broad features of this section are shown by figure 18.

A typical section displaying the overthrust of the strata of the Bow Trough on the Devonian of the Sawback Trough is shown by figure

[1] See sections accompanying McConnell's Report D. Rept. Geol. Surv. Canada, Vol. 11, for 1886 (1887). Also sections of Dowling on maps of Cascade Coal Basin, Sheets 1-10, Geol. Surv. Canada, No. 26b, 1907, No. 949.

[2] Geol. Surv. Canada, 1915. Accompanying memoir No. 55 by J. A. Allan

[3] Cascade Coal Basin of Alberta, 1907.

19, where the pre-Cambrian with the superjacent Lower and Middle Cambrian is thrust over the Devonian of Fossil Mountain. Tilted up at a steep angle beneath the Devonian (fig. 20) are the Ordovician (Sarbach), Ozarkian (Mons), Upper Cambrian (Sabine, Lyell, Bosworth and Arctomys), and Middle Cambrian (Eldon), and finally the Eldon is thrust over on the upturned strata of Devonian age.

Ulrich, in discussing the overthrust troughs within the Appalachian Geosyncline, says, "The evidence on which this belief in distinct troughs is based is threefold in character, faunal, lithologic, and structural. The first is shown by differences in fossil contents. * * * The second is expressed, first by peculiarities in the succession of the various types of sediments, and second, the degree of metamorphism to which the deposits have been subjected. The third component of the evidence is the physical proof of excessive folding and overthrusting shown by the structure of the various rock masses."[1]

The following descriptions of the Cordilleran troughs include the criteria on which they have been distinguished and named.

BOW TROUGH

Plate 25

The area considered to have been included in the Bow Trough now has a width, on a line from the Devils Gap at Ghost River to Mt. Stephen (*I* to *P* on map, pl. 25), of about 40 miles (64.4 km.). The trough was narrow and confined to the eastern portion of the Cordilleran Geosyncline when the waters of Lower Cambrian time first flooded it and began to deposit siliceous silts and fine sands derived from the pre-Cambrian Beltian rocks on the gently sloping eastern shores of the seaway and brought into it by tributary streams. As this early trough deepened, more than 2,000 feet (609.6 m.) of sands and silts accumulated before the waters overlapped the margins of the trough on the east and west and deposited sand and arenaceous and calcareous muds during the closing period of Lower Cambrian time. This widening of the trough extended westward as far as Mt. Stephen (*P* on map) and eastward to the line of the Ghost River (*I* on map) at Devils Gap. At this time the Cambrian sea penetrated into the Beaverfoot Trough (*J, K, M, N* on map) and brought with it a late Lower Cambrian (Mesonacidae) fauna similar to that in the Bow Trough (see figs. 15, 16).

The broad Bow Trough gradually deepened, the sands and siliceous silts being succeeded by calcareous sediment with interbedded sili-

[1] Bull. Geol. Soc. America, Vol. 22, 1911, pp. 442, 443.

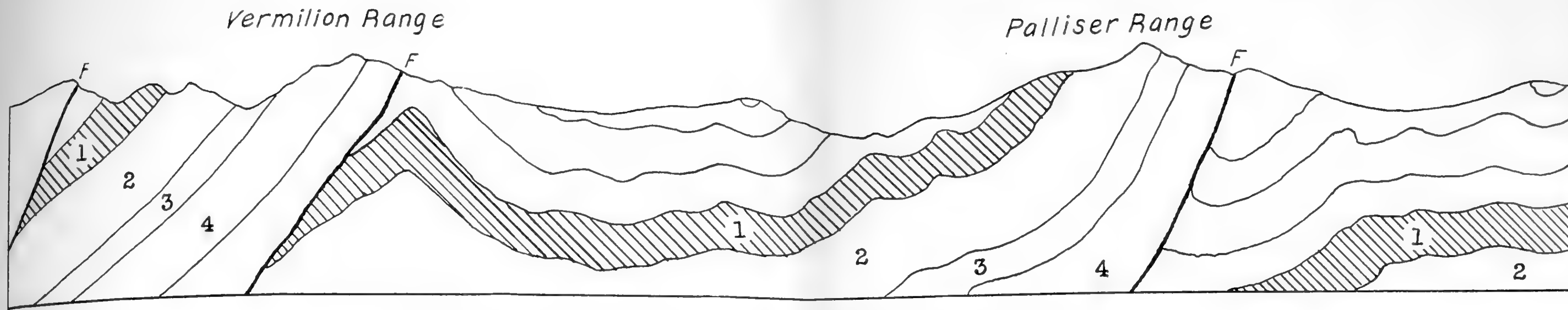


FIG. 17.—Geological section crossing Vermilion and Palliser Ranges. After Dowling.

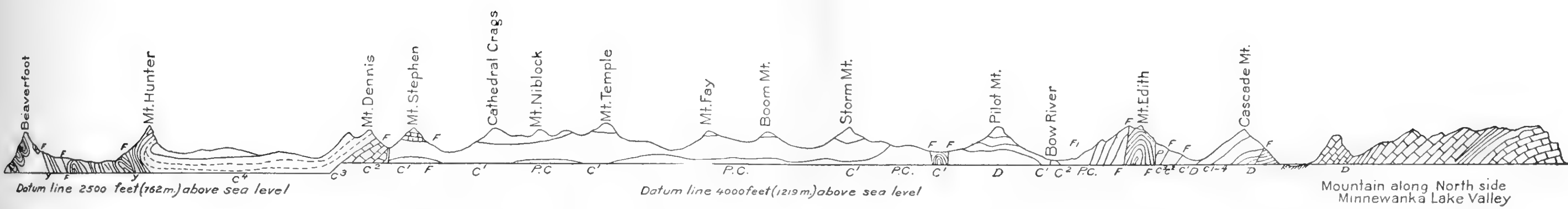


FIG. 18.—Diagrammatic section along the Bow-Kicking Horse Rivers illustrating the geologic structure as determined by McConnell and Allan. Vertical scale twice the horizontal Length of section 72 miles (115.8 km.). The section is on the strike of the formations from Storm Mountain to Cathedral Crags. See map (pl. 25) on line of letters, *J*, *P*, *Q*, *T*, *H*, *I*.

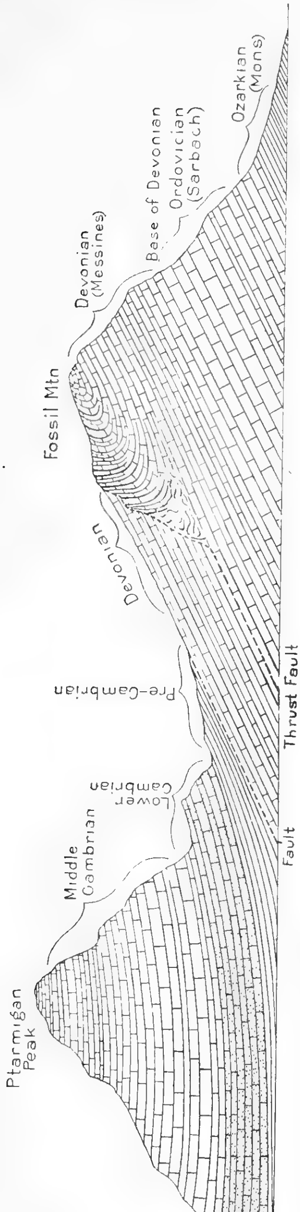


FIG. 19.—Diagrammatic section of the geological formations occurring in Ptarmigan Peak and Fossil Mountain (*F* on map. pl. 25) on the north side of Ptarmigan and Baker Lakes, showing the position of the strata and the overthrusting of the Ptarmigan Peak pre-Cambrian Hector sandy shales on the Devonian limestones.

Locality.—Baker Lake is 7.25 miles (11.7 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta.

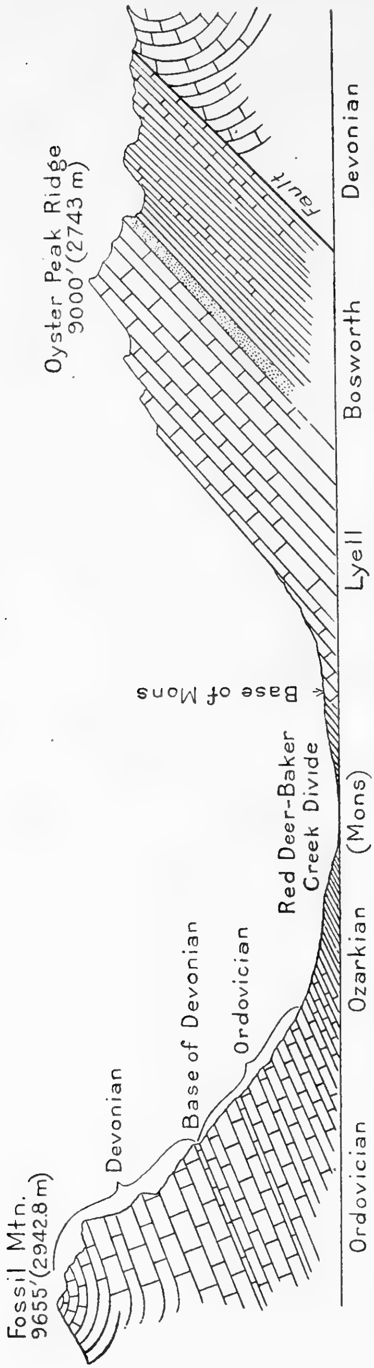


FIG. 20.—Diagrammatic outline of section northeast of Baker Lake from summit of Fossil Mountain eastward across the Red Deer-Baker Creek Divide to Oyster Peak Ridge at Cotton Grass Cirque in Sawback Range. This is a continuation eastward of the section illustrated by fig. 19.

Locality.—Same as fig. 19.

ceous muds which now form the Mt. Whyte limestones and shales as they occur at the base of Castle Mountain in the Bow Valley, at Mt. Assiniboine and Mt. Bosworth on the Continental Divide, and their western outcrop at Mt. Stephen. The trough, now 20 to 30 miles (32.2 to 48.3 km.) or more in width, continued to deepen during the time of the deposition of the limestone of the Middle Cambrian Cathedral formation, 1,212 feet (369.4 m.); the Stephen, 640 feet (195.1 m.); and the Eldon, 2,728 feet (831.5 m.); a total of 4,580 feet (1,395.9 m.) of limestones before a shallowing of the seaway resulted in the deposition of the Arctomys siliceous silts that marked the close of Middle Cambrian time and the beginning of the deposition of the Upper Cambrian formations. After the deposition of the Arctomys silts and fine sands, 268 feet (81.7 m.) thick,[1] the seaway again deepened and the deposits now forming the Upper Cambrian limestones of the Bosworth formation 1,587 feet (483.7 m.), the Paget and Sherbrook 1,735 feet (528.8 m.) were laid down, a total thickness, with the Lower and Middle Cambrian sandstones and limestones, of 10,170 feet (3,099.8 m.). As far as we now know, the Chancellor shales of the Goodsir Trough do not follow the Sherbrook limestones and they were not deposited within the Bow Trough.

About the time sedimentation in the Bow Trough ceased, or just before, calcareous sediments were being deposited in the then forming Goodsir Trough in an area now occupied in part by the Van Horn Range. These calcareous deposits were later buried beneath a great thickness of argillaceous and siliceous muds that now form the Chancellor shales. The latter may have been deposited and subsequently removed by erosion from part of the area east of their present surface outcrop, but my impression is that when the floor of the Bow Trough was elevated and the long period of limestone forming deposits abruptly ceased with the close of the Sherbrook, it was only within the limits of the Goodsir Trough that the fine argillaceous and siliceous material, now forming the Chancellor shales, was deposited in the Goodsir seaway. The limestones beneath the base of the Chancellor formation in the Van Horn Range are probably of Upper Cambrian age, but until diagnostic fossils are found, it will not be practicable to correlate them with any of the known formations of the Bow Trough.

Near the eastern side of the Bow Trough at Ghost River (*I* on map), about 500 feet (152.4 m.) of late Lower Cambrian sand-

[1] At Glacier Lake the Arctomys formation has a thickness of 1,386 feet (422.5 m.).

stones and shales and 1,122 feet (341.9 m.) of Middle Cambrian limestones represent the eastern extension of the Middle Cambrian limestones of the Mt. Bosworth and Mt. Stephen area, where they are 5,244 feet (1,598.4 m.) thick. No sediments of Upper Cambrian or Ozarkian age appear to have been deposited in this eastern area.

Extent of Bow Trough.—The seaway of the Trough was probably from 50 to 60 miles (80.5 to 96.5 km.) in width, at the time of its greatest development. Its extension to the south-southwest appears to have been limited by the pre-Cambrian Kintla Island uplift,[1] but it was undoubtedly connected on the south with an open seaway, as yet unrecognized, of the Cordilleran Geosyncline, for the Lower and Middle Cambrian faunas of Utah and Nevada are closely related to those of the Bow Trough Lower and Middle Cambrian formations. To the north-northwest of the Bow Valley, similar characteristic faunas of Lower and Middle Cambrian age have been found 42 miles (67.6 km.) distant in the Glacier Lake, Saskatchewan area, also in the Robson Peak District 167 miles (268.7 km.) from the Bow Valley. It is probable that the Bow Trough was an open seaway from the Bow Valley to the Saskatchewan area in Lower and early Middle Cambrian time, for the Lower Cambrian St. Piran and Mt. Whyte formations, the Middle Cambrian Cathedral limestones, and a representative of the Stephen formation (Murchison) occur in Mt. Sedgwick (*D* on map, see figs. 20, 21, p. p. ?), but the great Eldon limestone is absent. The Arctomys shales which followed the close of the Middle Cambrian have a large development at Glacier Lake, gradually thinning out to the southeast in the Sawback Range (*F* and *H* on map) and on Mt. Bosworth (*R* on map) in the Bow Trough. With the Arctomys, the formations common to the Bow Trough and the Saskatchewan area terminate, unless the fauna of the Upper Cambrian Sullivan formation be found later to be similar to that of the Bosworth of the Bow Trough sections, in which case the Bosworth will be the last of the Bow Trough formations deposited in the Saskatchewan area.

A band of limestone 165 feet (50.3 m.) thick beneath the Lyell formation in the Sawback Range (*H* on map) may represent the Bosworth, but a thickening of this band, 18 miles (28.9 km.) farther to the north-northwest in the Range, to 500 feet (152.4 m.) leads to the inference, in the absence of fossils, that it is a thinning out of an extension of the Sullivan from the northwest rather than the extension of the Bosworth to the northwest.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, p. 191.

The development of a narrow trough at the close of Middle Cambrian time within the area of the northern extension of the Bow Trough is mentioned in the description of the Sawback Trough.

A comparison of the three sections is given in figure 16, p. 156.

Longitudinal undulation.—The extent of a longitudinal undulation, or a tipping of the bottom, of the Bow Trough during the deposition of the Lower and Middle Cambrian formations is shown by the thinning out of the Middle Cambrian Eldon formation from a thickness of 2,728 feet (831.5 m.) at Mt. Stephen (*P* on map) to zero in the section on the Saskatchewan River about 50 miles (80.5 km.) to the north (*D* on map). The subjacent Stephen formation persists; also the superjacent Arctomys formation which is conformable with the Stephen (see fig. 22, p. 168). The Arctomys is nearly five times as thick in the Glacier Lake section (*B* on map, pl. 25) as at Mt. Bosworth (*R* on map).

GOODSIR TROUGH

Plate 25 and fig. 14

West of the Bow Trough and east of the Beaverfoot Trough (*K*, pl. 25) and subparallel to it a deep narrow trough was developed and gradually silted up in Upper Cambrian time by fine, argillaceous and siliceous muds that ultimately formed the laminated Chancellor shales 4,500 feet (1,371.6 m.) thick; calcareous-siliceous sediments that formed the Ottertail limestones 1,825 feet (556.3 m.) thick and the Goodsir shales and limestones 6,400 feet (1,950.7 m.) thick, a total of over 12,700 feet (3,870.9 m.) of Upper Cambrian and possibly some later sediments, and there may have been earlier Cambrian deposits of which there is no known record.

In the absence of fossils from the upper 5,500 feet (1.676.4 m.) of strata of the Goodsir formation we are unable to determine the age of that part of the section. I have searched in vain on the flanks of Mt. Goodsir for traces of fossils in the abundant talus from the Goodsir formation above the lower fossiliferous 500 feet (152.4 m.) and Dr. Allan met with no better success. These limestones and shales are even more barren of indications of life than the 4,500 feet (1,371.6 m.) of Chancellor shales which have an occasional faint outline of a fragment of an *Agnostus* or the cranidium of a small trilobite. None of the above mentioned formations has been recognized either east or west of the area assigned to formations of the Goodsir Trough, and they do not appear to have been deposited in the trough for a greater distance than 120 miles (193.1 km.) and a width of about 20 miles (32.2 km.) but they may be found in the future west of the Continental Divide in the drainage areas of the Blaeberry, Bush and other rivers to the north-northwest, but my present impression is that they were limited to about where we now know them. The greatest thickness of sedimentation was on the line of the broad syncline of the Ottertail Range, where the strata referred to the Goodsir formation form a high mountain ridge that rests in a synclinal trough of the Ottertail limestone, which is superjacent to the Chancellor shales. The area of the formations of the Goodsir Trough is outlined by faults, both on the east and west, that serve to delimit roughly the compressed lateral boundaries of the trough. The northern extension of this trough has not been traced beyond the Van Horn Range, and nothing was seen of its included formations or their contained faunules about the headwaters of the Saskatchewan River (*B*, pl. 25), 50 miles (80.5 km.) north of the Kicking Horse Canyon at Ottertail. To the south-southeast of the Ottertail Range, in the Vermilion and Mitchell Ranges, a great thickness of thin-bedded limestones with shaly partings appears to represent the Goodsir and Ottertail formations; the Chancellor shales extend along the southwestern side of the Ottertail, Vermilion, and Mitchell Ranges; and the broad canyon valleys of the Beaverfoot and Kootenay Rivers were largely eroded in the shales of the Chancellor and the readily broken down Ottertail formation.

In places these Goodsir Trough shales and limestones rise nearly to the summit of the northeastern side of the Beaverfoot-Brisco-Stanford Range, and are in contact with the Silurian, Brisco and Beaverfoot limestones of the Beaverfoot Trough along the line of the great Kootenay fault which now outlines the contact between the formations deposited in the two Troughs.

No fossils have been reported from the Goodsir, Ottertail, or Chancellor formations of the Beaverfoot-Kootenay River area that are upturned against the east-northeast side of the Beaverfoot-Brisco-Stanford Range, but as soon as the great Kootenay fault is crossed to the strata on the southwest side of the fault, fossils are abundant in the Silurian, Brisco and Beaverfoot; Ordovician (Canadian), Glenogle and Sarbach; Ozarkian, Mons; and Upper Cambrian, Sabine formations. Almost in a step one passes from a singularly barren series of shales and limestones to a record of abundant and varied marine life. This indicates that the seaway of the Goodsir Trough had little direct connection with the great Cordilleran seaways and their faunas, while the Beaverfoot Trough, in its time, was in open connection with the seaways to the north and the connecting seaways on the south.

BEAVERFOOT TROUGH

Plate 25 and fig. 21

On the western side of the Cordilleran Geosyncline there was a narrow trough that connected on the north with the Glacier Lake Trough (*B* on map), and terminated on the south, as far as we now know, at about what is now the southern end of the Stanford Range. That this trough connected with seaways extending north to the Arctic Ocean and far to the south, is indicated by the presence of similar genera in the faunules of Cambrian, Ozarkian and Silurian formations in Alaska, British Columbia, Idaho, Utah, and Nevada. In this trough, south of the Kicking Horse Canyon, there were deposited in Upper Cambrian time the following formations: Lyell limestones, 860 feet (262.1 m.),[1] and the Sabine shales, 750 feet (228.6 m.); in Ozarkian time, the Mons limestones and shales, 3,400 feet (1,036.3 m.); in Ordovician (Canadian) time, the Sarbach limestone, 200+ feet (60.9+ m.), and the Glenogle shales, 2,160 feet (658.4 m.); and in Silurian time, the Beaverfoot and Brisco formations, 1,600 feet (487.7 m.); making a total thickness of over 8,700 feet (2,651.7 m.) of sediments deposited prior to the incursion of the Devonian sea. There was also a considerable thickness of arenaceous and siliceous material deposited in Lower Cambrian time that now forms the Lower Cambrian sandstones and shales on the eastern slopes of the pre-Cambrian on the western side of the Columbia River Valley. These Lower Cambrian sands and muds were deposited in the Bow, Glacier Lake, and Beaverfoot Troughs, and in the depressed areas of the Purcell and Selkirk Mountains. This is evidenced by the presence of the same character of sandstone, containing a similar late Lower Cambrian fauna, wherever the outcrops now occur from Ghost River on the eastern side across the area of the Bow Trough and on the western side of the Columbia River Valley.

The extension of the Beaverfoot Trough has not been traced north of the Kicking Horse River, but at Glacier Lake, about 50 miles (80.5 km.) north of the Kicking Horse River, the thick-bedded Upper Cambrian Lyell limestones are overlain by calcareous shales and thin layers of interbedded limestone of the Sabine formation, and

[1] Walker reports a maximum thickness of about 2,000 feet (609.6 m.) south of Fairmount Springs, where he confuses it with the Ottertail formation. Geol. Surv. Canada, Memoir 148, 1926, p. 21.

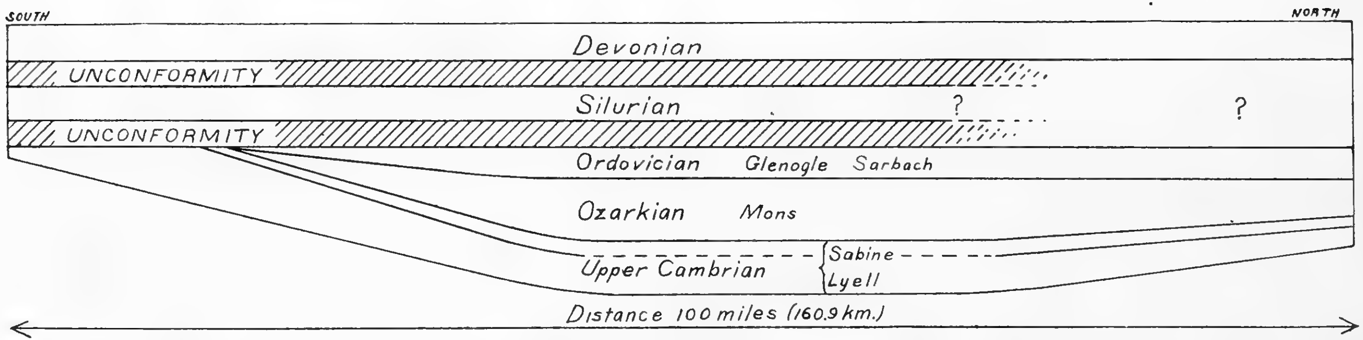


FIG. 21.—Diagrammatic northwest-southeast section of formations deposited in Beaverfoot Trough between the pre-Cambrian of Grainger Mountain (southeast of *O* on map, pl. 25), and Glacier Lake (*B* on map). The Silurian not having been reported from the Glacier Lake area is not extended north of the position of the lower Kicking Horse River drainage area.

the latter are subjacent to the limestones of the Ozarkian, Mons formation, and they, in turn to the limestones of the Ordovician (Canadian) Sarbach formation, indicating strongly that they were deposited under similar conditions. The presence of diagnostic faunules in the Sarbach, Mons, and Sabine formations proves that there was an open seaway from Sabine Mountain to Glacier Lake, a distance of 130 miles (209.2 km.). None of these faunules or a similar succession of formations has been recorded east or northeast of the Beaverfoot Trough for a distance of 38 miles (61.1 km.) or until the southwestern side of the Sawback Trough east of the great Castle Mountain fault is reached.

The Silurian, Brisco and Beaverfoot formations and Ordovician (Canadian) Glenogle graptolite shales extend from the southern end of the Stanford Range (*O* on map) north-northwest to the Kicking Horse Canyon (*J* on map), but they have not been reported from beyond the Kicking Horse drainage area. They should be looked for in the Blaeberry River and Bush River drainage areas, along the western slopes of the Continental Divide.

The character of the folding and faulting to which the strata of the Beaverfoot Trough have been subjected is shown by the sections of McConnell[1] and Allan[2] of the northern portion of the Beaverfoot Range and the Walcott section of the Brisco-Stanford Range at Sinclair Canyon, 55 miles (88.5 km.) southeast.[3]

SAWBACK TROUGH

Plate 25

The Bow Trough appears to have shallowed towards the close of Middle Cambrian time, so that the shallow water Arctomys formation and the calcareous sediments of the Sullivan were almost excluded from it except in the depression we are now designating as the Sawback Trough. This trough extended from the Glacier Lake Trough (*D* on map), with which it was connected by an open seaway, southeast as far at least as the Bow Valley (*H* on map).

The Sawback Trough was at first a narrow depression or downwarp in the bottom of the Bow Trough that accompanied the slight

[1] Rept. Geol. Surv. Canada, Rept. D., Vol. II for 1886 (1887). Section p. 42 D.

[2] Geol. Surv. Canada, Guide Book No. 8, Pt. II. Transcontinental Excursion C, 1, 1913. Structure section.

[3] Smithsonian Misc. Coll., Vol. 75, No. 1, p. 10, fig. 2.

The anticline of the eastern end of this section is probably broken by faults or possibly by a synclinal fold, or both faults and fold. Such a structure is suggested at the head of Dry Gulch a little south of Sinclair Canyon.

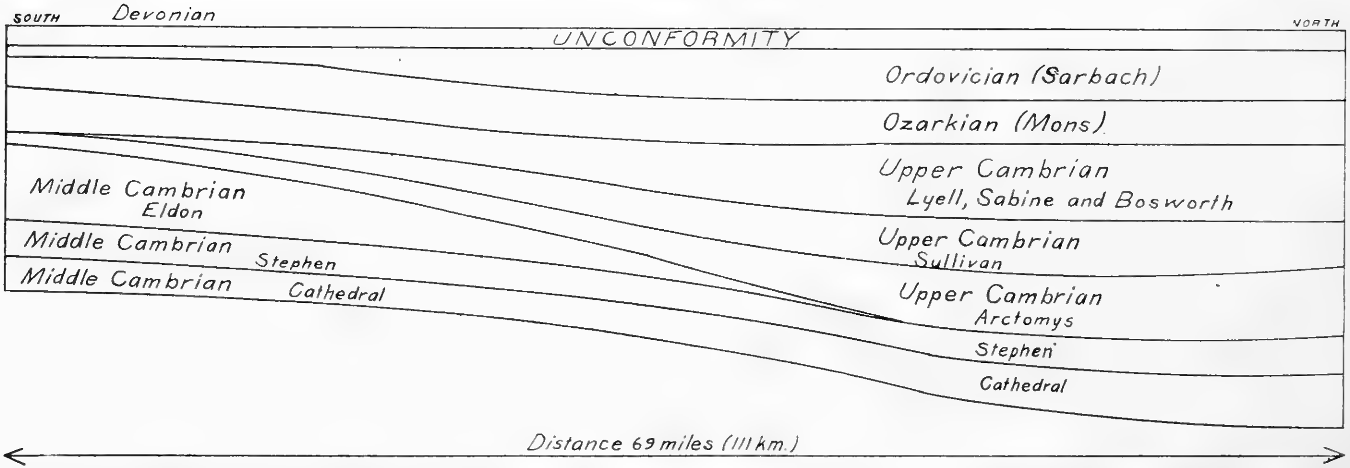


FIG. 22.—Diagrammatic northwest-southeast section of formations deposited in the Sawback Trough between Bow Valley (*H* on map) and Glacier Lake Trough, *B*, *C*, *D*, on map, pl. 25, and fig. 19.

diastrophic movement marking the close of Middle Cambrian time. We might consider it a continuation of the Bow Trough, but as a series of sediments were deposited in it that are not found elsewhere in the Bow Trough, and which are limited, as now known, to the Sawback, Glacier Lake, and Beaverfoot Troughs, it is more convenient to give it a distinct name and thereby more closely record the history of sedimentation in this area of the Cordilleran Geōsyncline. Judging from the thickness of sediments deposited (see fig. 22), this depression gradually deepened from the Bow Valley on the south to the north-northwest as far as Glacier Lake and beyond, except in late Middle Cambrian time.

As now known, the area of outcrops of Upper Cambrian, Ozarkian, and Ordovician sediments in this Trough is between the great Castle Mountain fault at Johnston Creek and the faults of the Sawback Range southwest of Forty Mile Creek, and thence north-northwest to the head of the Saskatchewan River drainage. (On the map from *H* to *F* and *G*, to *E* to *C*).

On the line of the headwaters of Red Deer River (*F* and *G* on map) the pre-Devonian formations include the Skoki; Ordovician, Sarbach; Ordovician (Canadian), Mons; Ozarkian, Lyell, Bosworth and Arctomys; Upper Cambrian, and Eldon; Middle Cambrian in the Sawback Range. The Upper Cambrian Sherbrook, Paget, and most, if not all, of the Bosworth formation were not deposited, and the Eldon limestone is thin and confined to the eastern side of the Trough.

At the head of Clearwater River (*E* on map) about 42 miles (67.6 km.) north-northwest of Bow Valley, there is a fine development of the Sarbach, Mons, and Lyell formations, and these are all present in the Glacier Lake Trough as well as in the Beaverfoot Trough.

With the close of the period of deposition of the Ordovician, Sarback and Skoki formations, the Sawback Trough ceased to function so that the succeeding Devonian sea occupied nearly all of the original Bow Trough area, the Glacier Lake Trough, and much of the area of the Beaverfoot Trough.

GLACIER LAKE TROUGH

The formations deposited in this Trough were studied in the Glacier Lake area (*B*, *C*, and *D* on map) about the headwaters of the Saskatchewan River, 54 miles (86.9 km.) north-northwest of the Bow Trough section and 120 miles (193.1 km.) south-southeast of the Robson Peak District section. The typical section of the formations

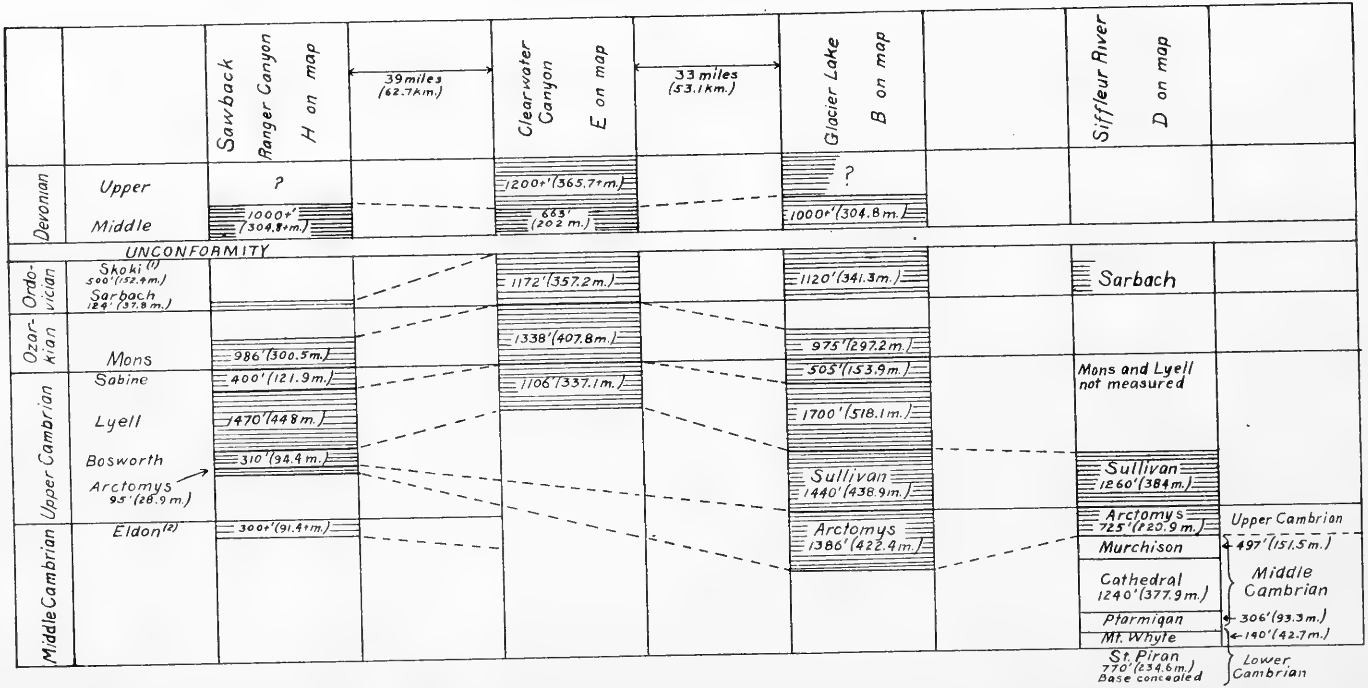


FIG. 23.—A diagrammatic sketch of four sections crossing the formations deposited in the Sawback Trough, and, as far as known, of the subjacent Middle Cambrian formations of the Glacier Lake and Bow Troughs, as exposed in the Siffleur Saskatchewan River section.

[1] The Skoki formation occurs at Fossil Mountain (*F* on map), 23 miles (37 km.) north-northwest of Ranger Canyon section (*H* on map), where it has a thickness of 500 feet (152.4 m.). It has not been identified at Ranger Canyon as elsewhere in the Sawback Trough.

[2] Six miles (9.7 km.) west of Ranger Canyon section, at Castle Mountain, the Eldon has a thickness of 1,905 feet (580.6 m.) and at Mt. Bosworth, 28 miles (45.1 km.) northwest, 2,728 feet (831.5 m.).

deposited in the Trough as they now occur, after being faulted, upturned, and undulated by compression, extends from the western side of Whiterabbit Creek at 52° north latitude, west-southwest, over the ridge east of Siffleur River (*D* on map) and along the north side of Mt. Sedgwick, Mt. Murchison, Mt. Sarbach, and Mt. Forbes to Mons Peak on the Continental Divide west of Glacier Lake (*B* on map), a distance of about 35 miles (56.3 km.). It is quite probable that it should be continued still farther to the west to the pre-Cambrian in the area at the head of Bush River on the western side of the Continental Divide. Unfortunately we have no knowledge of the formations there; they may be displaced by faults with possibly one or more troughs indicated, as in the Bow-Kicking Horse section, where the formations of the Goodsir and Beaverfoot Troughs occur between the Continental Divide and the Proterozoic Beltian formations.

Glacier Lake Trough was of long duration. It was in existence in middle Lower Cambrian time, and continued to receive deposits until the close of the Sarbach Ordovician (Canadian) formation, and possibly in Silurian and Devonian time.

The continuïty of deposition seems to have been largely uninterrupted except in Middle Cambrian time, when the calcareous sediments that formed the Eldon limestone, 2,728 feet (831.5 m.) thick in the Bow Trough, 40 miles (64.4 km.) to the south-southeast, were not deposited; at least they have not been observed at any of the outcrops where the Arctomys and Stephen are in contact. There were also some minor interruptions, and certainly one great one (Mons), occasioned presumably by a diminution of the supply of sediment or a temporary raising of the level of the bottom of the trough.

The sediments deposited may be summarized as follows:

Calcareous shales and limestones	6,668 feet (2,032.4 m.)
Arenaceous and siliceous sandstones and shales......	2,911 feet (887.3 m.)

On the eastern side the northwesterly extensions of the Bow and Sawback Troughs were in open communication with the sea of the Glacier Lake Trough except during Middle Cambrian Eldon time, with possibly a few minor interruptions.

On the western side, the Beaverfoot Trough presumably had an open seaway to the Glacier Lake Trough, for the faunas of the Upper Cambrian Sabine formation and the large faunas of the Ozarkian Mons formation are essentially of the same type in the Stanford Range (*N* on map) and the Glacier Lake section (*B* on map). The fauna of the Ordovician (Canadian) Sarbach formation is of the same type in the Beaverfoot, Glacier Lake, and Sawback Troughs, but the Glenogle graptolite fauna of the Beaverfoot Trough has not been found in the Glacier Lake Trough, although there is a strong probability that it may be present in the region west of Mons Peak in the area of the upper Bush River drainage basin.

We know little of the Glacier Lake Trough northwest of Glacier Lake, except that it extended 24 miles (38.6 km.) as far as Wilcox Pass at the head of the North Saskatchewan River, and had open communication to Robson Peak District more than 96 miles (154.5 km.) northwest of Wilcox Pass.

ROBSON TROUGH

The typical section of this trough in the Robson District is 174 miles (279.9 km.) north-northwest of the Bow Valley, where the great formations of the Bow Trough are so finely exposed to view, and 120 miles (193.1 km.) north-northwest of the section of the Glacier Lake Trough. It is now bounded on the southwest by Proterozoic Beltian sandstones and shales of the ridges of Little Grizzly and Whitehorn Peaks of the Selwyn Range, and on the northeast by the great Moose Pass fault between the Lower and Upper Cambrian formations that extends from Moose Pass south-southeast down the canyon of Moose River and north-northwest towards and into the high broken ridge northeast of the Smoky River Canyon. At Moose Pass the Lower Cambrian is thrust over the Upper Cambrian limestones, and from their character I am inclined to think that these Upper Cambrian and presumably later formations were deposited in a trough that began to form in early Upper Cambrian time east of the Robson Trough after deposition of sediments in the Robson Trough seaway had ceased.

The Robson Trough as now interpreted, after being narrowed by compression and faulting, has a width of 14 miles (22.5 km.) on a line extending from Moose Pass southwest to Little Grizzly Peak above Lake Kinney. If the Upper Cambrian and other pre-Devonian formations north-northeast of Moose River were included in the Robson Trough and not in a trough adjoining it on the northeast, the width of the Robson Trough as now outlined would be correspondingly increased to 22 miles (35.4 km.) or perhaps 24 miles (38.6 km.).

The known Paleozoic deposits of the Robson Trough have a thickness of 13,300 feet (4,053.8 m.) exclusive of any that may have been deposited east of the Moose Pass fault. These include Ordovician ?, Ozarkian, Upper and Middle Cambrian limestones and Lower Cambrian sandstones, arenaceous and siliceous shales.

Limestones	9,400 feet (2,865.1 m.)
Sandstones and shales	3,900 feet (1,188.7 m.)

The formations of the Robson Trough are of the general character of those of the Glacier Lake and Bow Troughs. They differ in details and contained faunas, but there is sufficient similarity to lead to the conclusion that they were deposited in connecting troughs of the Cordilleran Geosyncline and possibly in a more or less continuous trough that extended from north of the Robson District to south of the Bow Valley.

It is to be regretted that we do not have a section of the pre-Devonian formations east of the Moose Pass fault, as it is possible that not only a great thickness of Upper Cambrian strata is present, but also Ozarkian, Ordovician, and possibly Silurian. The Silurian occurs to the north in Alaska and to the south in the Beaverfoot-Brisco-Stanford Range of British Columbia, and the Devonian in the ridges east of the Upper Cambrian and northeast of Henry House.

It is to be noted that in the Robson and Glacier Lake Districts the known Upper Cambrian rocks are east of the Continental Divide and in the Bow-Kicking Horse area they are west of the divide.

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CAMBRIAN GEOLOGY AND PALEONTOLOGY

V

No. 5.—PRE-DEVONIAN PALEOZOIC FORMATIONS OF THE CORDILLERAN PROVINCES OF CANADA

(With Plates 26 to 108)

BY
CHARLES D. WALCOTT

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PREFACE

The manuscript of this paper was left by the late Dr. Charles Doolittle Walcott in such shape that it could be satisfactorily completed. Having been associated with the author in his Cambrian work for almost 13 years, and having conducted some of the investigations to obtain the necessary data used in this summary of his stratigraphic studies in the Canadian Rockies, I have undertaken the task of completing and publishing the paper.

Only such alterations have been made as were contemplated by Dr. Walcott, or that have resulted from plans of procedure we had previously agreed upon.

From notes and fragments, it appears that Dr. Walcott intended to add a discussion of the structure and of the paleogeography, but neither of these subjects was sufficiently developed to permit me to include the chapters. He had also planned to publish certain correlation charts that I was making, but under the circumstances it is thought best to omit them.

The present report, which I feel sure will take its place among the outstanding stratigraphic papers, has had a remarkable history. It existed in partly finished form for a number of years, always about completed in Dr. Walcott's mind, but since each year's work in the field and laboratory added so much new information, and new problems arose so persistently, the date for sending it to press was repeatedly advanced, a procedure which, considering the present status of the Cambrian studies, is in no wise out of the ordinary. The remarkable thing was that Dr. Walcott, when well past the age at which many men cease work altogether, put aside this manuscript, took the time to study the newer principles of stratigraphy, and then rewrote the entire work on the new basis; truly the mark of a great mind.

Chas. E. Resser.

March 19, 1928.

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PART I

INTRODUCTION

When examining Dr. R. G. McConnell's stratigraphic section of the Bow Valley, Alberta, and westward into the Kicking Horse Canyon to Field, British Columbia, in 1907, I found so much of interest and promise in the Middle and Lower Cambrian [1] and the pre-Cambrian [2] of the Bow Valley that I gave little attention to the study of the Upper Cambrian of the Mount Bosworth section,[3] and did nothing with the Upper Cambrian of Mount Dennis and west, which was subsequently so admirably worked out by Allan in 1910-1911.[4] During the field season of 1918 I examined the Upper Cambrian formations of Wolverine Pass and vicinity south of Mount Dennis, and 21 miles (33.8 km.) south of the Mount Bosworth section, and in 1919 measured a very complete section of the Ozarkian and Upper Cambrian at Glacier Lake,[5] 40 miles (64.4 km.) north, 30° W. of Allan's Mount Dennis section. This section was found to differ materially from the Mount Dennis-Ottertail-Goodsir section of Allan and could be compared only in part with the Upper Cambrian formations of the Mount Bosworth section. In the season of 1920 a partial section was examined on the Siffleur River south of the Saskatchewan River, which includes the Lyell, Sullivan, and Arctomys formations of the Upper Cambrian of the Glacier Lake section, also the Middle Cambrian Murchison and Cathedral formations. This section indicated that the Murchison formation of the Glacier Lake section should be referred to the Middle Cambrian and correlated with the Stephen formation of the Mount Bosworth section, which is about 37 miles (59.5 km.) to the south.

The next section studied was that near the head of the Clearwater River, which is 20 miles (32.1 km.) south, 19° east of the Siffleur section. The Clearwater section includes the formations of the upper

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 208-216.

[2] Idem, No. 7, pp. 423-431.

[3] Idem, No. 5, pp. 204-208.

[4] Geol. Surv. Canada, Report for 1911 (1912), pp. 178-181. Also Mem. No. 55, 1914, pp. 60-102.

[5] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.

portion of the Glacier Lake section from the Ghost River pre-Devonian disconformity down through the Sarbach, Mons, and Lyell formations.

The Upper Cambrian and Ozarkian formations of the Sawback Range, collectively named Sawback formation by Allan,[1] were hastily examined in Ranger Canyon, 12 miles (19.3 km.) northwest of Banff in 1920, and found to contain fossils of the Mons and Lyell formations of the Glacier Lake section, and in 1921 a section that is finely exposed in the amphitheater at the head of Ranger Brook Canyon was measured from the unconformity at the base of the Devonian down through the Mons, Lyell, Bosworth, and Arctomys formations and into the subjacent middle Cambrian Eldon formation.

During the field season of 1922, a section of the Mons formation was examined near the head of Douglas Lake Creek in the northern part of the Sawback Range, 23.5 miles (37.8 km.) southeast of the Clearwater section and about 14 miles (22.5 km.) northwest of the Ranger Brook section; also an incomplete section at the southern end of the Brisco-Stanford Range in Sinclair Canyon, British Columbia, 41 miles (66 km.) south-southwest of the Ranger Brook section and on the western slope of the main range of the Rocky Mountains. The Sinclair Canyon section indicated a great development of the Mons formation, which caused me to return in 1923 to study it and the pre-Devonian formations of the Beaverfoot-Brisco-Stanford Range between Kicking Horse Canyon on the north and Kootenay River at Canal Flats on the south. The results were published in 1924.[2]

In considering the relations of the great lower Paleozoic sections of the Cordilleran ranges in Utah, Nevada, and the Canadian Cordillera in 1893 (Bull. U. S. Geol. Surv., No. 81), I realized that there was strong evidence for correlating certain Upper Cambrian and pre-Devonian formations throughout the Cordilleran region from the Bow Valley-Kicking Horse district of Alberta and British Columbia to the Basin ranges of Utah and Nevada, but before discussing this correlation I preferred to wait and study the northern sections and make collections of fossils from well-determined formations on which to base conclusions. In this paper the more or less imperfect reconnaissance sections of Nevada and Utah are referred to for the purpose of comparison with those of the Canadian Cordillera, but it should be understood that a thorough, critical study must be made

[1] Geol. Surv. Canada, Report for 1912 (1914), p. 168. Also Guide-Book No. 8, Pt. 2, Transcontinental Excursions, 1913, p. 182.

[2] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924.

of all of these sections and many others before stratigraphic and paleontologic correlations of more than a general character can be made for the Cordilleran area.

Geologists may, perhaps, wonder why I did not acquire many more geological data and larger collections in the Canadian Rockies during the period 1907 to 1925. The answer will be found in the many physical obstacles encountered in the field, such as unfavorable weather (often from one-third to one-half of the short field season would be lost because of rain, snow, or cold); long distances to be traveled with pack train; and last, but not least, the inability of a man of three score years and more to utilize fully the trails of mountain goat and sheep above timber line, where the finest exposures of the strata usually occur. More than three full seasons were devoted to collecting a large and unique fauna from the celebrated Burgess shale quarry. In Washington, administrative and public duties demanded so much time and energy that field notes and collections were often inadequately studied and prepared for publication.

One of the fascinating features of the geology of the Canadian Cordillera is the delightful uncertainty of the results of structural and stratigraphic work. The sections are complicated by irregularities of sedimentation, both longitudinal and transverse, in the secondary troughs of the original Cordilleran Geosyncline, and by both normal and thrust faulting. Great shale deposits thousands of feet in thickness like those of the Chancellor formation may be absent in a section a few miles distant or a great calcareous series of shales and limestones like the Goodsir may be apparently represented in the section by limestones of varying character and thickness or be altogether absent. Were it not for a few formations like the Lyell of the Cambrian, the Mons of the Ozarkian, and the Messines of the Devonian, even an approximate idea of the geologic history of this wonderland could only be given by a detailed areal geologic map with structural sections, based on thorough study of the formations, their sedimentation, and contained fossil remains. My study of it has been of the nature of a reconnaissance, made with the view of furnishing to the future areal and structural geologist some additional data on the succession of the pre-Devonian fossil faunas and faunules in the various sedimentary formations that collectively form one of the great pre-Devonian sections of the world.

Acknowledgments.—In a previous paper[1] I have acknowledged my indebtedness to Dr. Rudolf Ruedemann of the New York State Mu-

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 7.

seum, Dr. Edwin Kirk and Dr. Charles E. Resser of the United States National Museum, and Dr. E. M. Kindle, the Director of the Geological Survey of Canada—also to the officials and employees of the Canadian Pacific Railway and the Canadian National Parks, all of whom have given unfailing courtesy and assistance, and to Mrs. Walcott, my enthusiastic assistant and comrade. I also wish to acknowledge the receipt of grants for several years from the Joseph Henry Fund and Othneil C. Marsh Fund of the National Academy of Sciences. These grants have made it possible for Dr. Charles E. Resser to do more field, laboratory, and office work, and for Mr. J. A. Mirguet to work the fossils from their matrix. In the preparation of illustrations, Mr. DeLancey Gill of the Bureau of American Ethnology has given valuable service, and some of the diagrammatic sections have been skillfully drawn from my rough sketches by Miss Frances Wieser. I am greatly indebted to Mr. W. P. True, editor of the Smithsonian Institution, for his careful editorial work on the text and the makeup of the paper.

GEOGRAPHIC NOMENCLATURE

My experience in the use of new geographic names has been varied. At times I was compelled to propose names for certain topographic features in order to tie in the geological sections and localities mentioned with the topography so that they could be recognized by future workers. A few of the names proposed have been accepted by the Canadian Board of Geographic Names when located in the Province of Alberta, but there has been a persistent opposition to recognition of those suggested for localities in British Columbia. The names that have been used and later applied to geological formations will presumably be recognized in the future.

COTTON GRASS AND TILTED MOUNTAIN CIRQUES

These names were proposed for two large glacial cirques (see pls. 52-55) on the western side of the high limestone ridge between Oyster Peak and Tilted Mountain of the western side of the Sawback Range.[1] They open to the west towards Baker Lake. The stream from Cotton Grass Cirque flows into a branch of the headwaters of Red Deer River, and that from Tilted Mountain Cirque into upper Baker Creek.

A small glacial lake occurs in the bottom of each cirque, and strongly marked mountain sheep trails lead from the head of the cirques eastward into the canyons of the range that open to the north.

[1] Smithsonian Misc. Coll., Vol. 77, No. 2, 1925. Legend of fig. 1, p. 1. Also fig. 7. Idem, Vol. 78, No. 1, figs. 2 and 4.

ROBSON PEAK DISTRICT

I selected and used several Indian names to designate unnamed topographic features in the Robson District, as all the good old English, Scotch, and Irish names had been used again and again in the Cordillera. I did not care to use, for instance, the name Robson for six different objects within a limited area, and so ventured to call the great glacier Hunga (Indian for chief). The names Extinguisher and Rearguard seem to be so inappropriate and trivial that I ventured to suggest a change to Billings Butte and Iyatunga (black) in the hope that a future generation might see fit to do the same.

The name Phillips Mountain was applied to the point above Snowbird Pass which, on Wheeler's map of 1911, is called Lynx Center Station, and its elevation given as 9,542 feet (2,908.4 m.). The name Phillips having been used by Wheeler in 1911 for a mountain north of Whitehorn, and approved later by the Geographic Board, the name Chushina[1] (small) Ridge replaces Phillips Mountain of Walcott. Lynx Mountain (see pls. 105, 107) (10,471 feet, 3,191.6 m.) is nearly a mile (1.6 km.) south of the high point of Chushina Ridge, and Mount Resplendent (11,173 feet, 3,405.5 m.) is more than three miles (4.8 km.) south-southwest of Lynx.

In my published photographs[2] the summits of Lynx and Resplendent are concealed by clouds and only the high limestone cliffs north of Resplendent and south of Billings Butte (Extinguisher) are in sight. The sharp summit of Resplendent is fully 2 miles (3.2 km.) south of Billings Butte and a mile south of the high cliffs seen to the left and above Billings Butte.

GEOLOGICAL NOMENCLATURE

Geological nomenclature as applied to rock formations is of service only if it enables the student to refer the named formation to its position in an established stratigraphic system. If it encumbers maps and texts with terms that lead only to confusion and error, the sooner it is correctly redefined or goes to the scrap heap the better.

With the increase of information by field study and accurate surveys, reinforced in the case of the sedimentary rocks by thorough paleontological research and in the case of the crystalline and eruptive rocks by petrographic studies, it is inevitable that there will be a breaking up of former units and groupings that will necessitate new

[1] Approved by Geographic Board of Canada.

[2] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pl. 57, fig. 2; pl. 58, fig. 2.

names for newly defined units and groupings of units. This will mean the dropping of old names, the meaning of which has been the subject of controversy, and those whose authors have included under one term, through lack of information or because of preconceived ideas, units that may belong to one or more systems. Without doubt we should endeavor to preserve names given by pioneer workers, but not at the sacrifice of clarity or the advancement of knowledge. The long and bitter controversy of Murchison and Sedgwick over the terms Silurian and Cambrian was largely the result of the lack of information and was injurious to the progress of geological science.

The rules for geological nomenclature formulated and promulgated by the International Geological Congress are most helpful and if followed by geologists will be of great assistance not only to the professional geologist but to all instructors, students, engineers, and laymen who have occasion to refer to geological literature.

SAWBACK FORMATION

The name "Sawback" formation was proposed by Dr. John A. Allan in 1913 for the formations lying beneath the known Devonian of the Sawback Range.[1] Not finding any fossils, he tentatively referred the entire series of limestones and shales, estimated to have a thickness of 3,700 feet (1,127.8 m.), to the Devonian. This was repeated without reservations in 1915,[2] but in 1916 Allan reported[3] that in oolitic beds west from Mount Edith numerous fragments of Cambrian trilobites occur; that the beds containing them may be correlated with the Paget formation, and the shales beneath with the Bosworth formation; and that the gray arenaceous limestones at the base of the section correspond to the Middle Cambrian Eldon formation. He mentions having found salt crystals in a shale series beneath the oolitic limestones and that this indicates a continental origin for the shales. These shales are now referred to the basal Upper Cambrian Arctomys formation. Allan thus includes in his Sawback formation, as we now know it, one Ozarkian, three Upper Cambrian, and one Middle Cambrian formation.

L. D. Burling states in his report of field-work for 1915[4] that Dr. E. M. Kindle had found in 1915 Cambrian fossils in the upper part of the Sawback formation, and that he (Burling) had collected

[1] Summary Rep. Geol. Surv. Canada for 1912 (1914), p. 172. Twelfth Int. Geol. Cong. Guide Book, No. 8, pt. 2, p. 182.

[2] Summary Rep. Geol. Surv. Canada for 1914 (1915), p. 43.

[3] Summary Rep. Geol. Surv. Canada for 1915 (1916), p. 102.

[4] Idem, p. 99.

fossils from a dozen or more faunal horizons in the section, but nothing further is published by him in this or subsequent reports about the collections or the section.

During the season of 1921 a trail was completed under my direction to the head of Ranger Brook into the heart of the Sawback Range, and a carefully measured section made from the base of the Devonian down through the Sarbach, Mons, Lyell, and Arctomys formations to the Eldon. Fossils were collected and subsequently identified.

In 1924, Dr. Kindle published a paper entitled " Standard Palaeozoic section of the Rocky Mountains near Banff, Alberta "[1] in which he follows Allan and includes in the estimated 3,700 feet (1,127.8 m.) of the " Sawback limestone " the following geologic formations: One Ordovician (Canadian), Sarbach;[2] three Upper Cambrian, Sabine, Lyell, and Arctomys; and one Middle Cambrian formation, the Eldon, which was identified by Allan through lithologic resemblance.

I should prefer to use the term Sawback, but if we were to give only one formational name to every great limestone series as a matter of convenience in mapping the areal geology, or for a sentimental reason, I fear the history of the deposition of sedimentary formations in the Cordilleran Geosyncline would be a most imperfect and misleading one. It must be remembered that what appears on superficial examination to be the record of continuous deposition, may in reality be a record imperfect and broken by great gaps caused by non-deposition of one or more formations. Such unconformities occur in the pre-Devonian limestone series of the Sawback Trough and must be taken into account in identifying and naming the formations both of the Sawback Trough and those that were deposited elsewhere during the periods of non-deposition. In addition to the character of the strata and their order of conformable or unconformable superposition, the paleontological record should always be given careful consideration. If that record shows in an apparently continuous series of beds that there are faunas missing which occur in different formations or systems elsewhere in well-established sections, then the geologist should recognize that there are breaks in the stratigraphic record that necessitate his searching for and finding the interruptions resulting from non-deposition or erosion. When these are found he must divide the apparently continuous series of strata into units or forma-

[1] Pan-Amer. Geologist, Vol. XLII, No. 2, 1924, p. 15.

[2] Kindle refers to the Sarbach as Walcott's Sarback formation, evidently overlooking the fact that the name was derived from Mount Sarbach (10,700 feet, 3,261.4 m.) in the Glacier Lake District, where the formation has a thickness of 1,120 feet (341.4 m.).

tions and designate them by appropriate names if they have not been named elsewhere in the same geological province.

The break in the record may be found in an apparently solid layer of rock, as shown by a block to which I called attention in 1912.[1] The lower part of the layer carries typical Upper Cambrian, the upper part typical Upper Chazyan fossils, and the strata and faunas of the intervening Canadian formations are absent. Elsewhere the missing strata and faunas appear, and the two faunas of the solid layer of rock are found to be separated by several geological formations, which proves that a long time interval elapsed between the deposition of the lower and upper portions of the layer. A critical examination of the block also showed a marked difference in the composition or structure of its lower and upper portions, which is not apparent on a hasty inspection. This illustration is given here in order to show how futile are lithological characters and broad generalizations, based on imperfect knowledge, in determining the limits of geological formations and even systems.

Every field geologist working in sedimentary formations should have sufficient knowledge of the faunas that he may encounter to identify the horizon in which they occur, or else have a trained paleontologist with him to collect the fossils and post him from day to day on the stratigraphic position of the various strata he is studying. Less than this means inaccurate maps, structure sections, and historical records.

I insert the above observations here as the Sawback formation is a good illustration of the difficulties a geologist will meet with in the great Cordilleran and Appalachian Mountain ranges, and the broad intercontinental areas. Thanks to Ulrich, Schuchert, and their associates, much has been done to elucidate the history of the continent from the beginning of Paleozoic time to the present. Much remains to be done especially in the western United States, Canada, and Alaska.

DEVONIAN

The first to recognize and name the Devonian formations of the Bow Valley section of Alberta was R. G. McConnell of the Canadian Geological Survey, who in 1887 published, under the heading of Banff limestone, the "Banff series." He says:

"The Banff limestone series has a total thickness of about 5,100 feet [1,554.5 m.], and is divisible into a lower and upper limestone, and into lower and upper shales:"[2]

[1] Smithsonian Misc. Coll., Vol. 57, No. 9, 1912, pp. 253-254.

[2] Geol. Surv. Canada, Report for 1886 (1887), Pt. D, p. 17 D.

The series is divided as follows (p. 15 D):

Carboniferous passing down into Devonian	Upper Banff shales Upper Banff limestone Lower Banff shales Lower Banff limestone
Devonian	Intermediate limestone

" The fossils of the Banff limestone show both Devonian and Carboniferous forms " (p. 19 D.)

" The fossils of the Intermediate limestone are usually badly preserved and consist mainly of almost structureless corals." (P. 21 D.)

Dr. D. B. Dowling in 1907[1] refers the Upper Banff shale to the Permo Triassic and proposes the name Rocky Mountain quartzite for the " fine grained sandstones " of the lower portions of McConnell's Upper Banff shale. This formation and the Upper Banff limestone, Lower Banff shale, and Lower Banff limestone, are referred to the Carboniferous.

The " Intermediate series " is referred to the Devonian.

In 1913 Dr. H. W. Shimer published the results of his study of the Banff series and tabulated the formations as follows:[2]

Permian		Upper Banff shale
	Miss. Penn.	Rocky Mountain quartzite Upper Banff limestone Lower Banff shale
Devonian		Lower Banff limestone Intermediate limestone

Shimer's reference of the Lower Banff limestone and Intermediate limestone to the Devonian was based on the fossils found in them.

In 1914 Dr. J. A. Allan followed Shimer, except that he added a lower limestone series, the Sawback limestone, to the base of the Devonian.[3]

Messrs. Kindle and Burling, in 1916, referred the " Intermediate limestone " to the Devonian, and Allan's Sawback limestone to the Cambrian.[4]

[1] Geol. Surv. Canada, Pub. No. 949, 1907, p. 9.

[2] Bull. Geol. Soc. Amer., Vol. 24, pp. 234, 235.

[3] Summary Rep. Geol. Surv. Canada for 1912 (1914), pp. 172, 173.

[4] Idem for 1915 (1916), p. 99.

In 1919 I studied the formations of the Glacier Lake District at the headwaters of the Saskatchewan River, and during the field season of 1920 the Devonian and pre-Devonian formations at the head of Clearwater River and Pipestone Pass, about 33 miles (53.1 km.) east-southeast of Glacier Lake section. In 1924 I proposed the name Messines for the Middle Devonian limestone at Glacier Lake, where it is superjacent to the Ordovician (Canadian) Sarbach formation.[1] The Messines appear to be the equivalent of the Intermediate limestone of McConnell. The name Pipestone was proposed for the Upper Devonian limestone at Pipestone Pass, which is about 33 miles

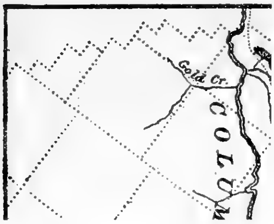
<table>
<tr><th></th><th>McConnell 1887</th><th></th><th>Walcott (Present paper)</th></tr>
<tr><td rowspan="5">BANFF SERIES
Carboniferous passing downward into Devonian.</td><td>Upper Banff shales</td><td>Triassic</td><td>Spray River (Kindle)</td></tr>
<tr><td rowspan="2">Upper Banff limestone</td><td rowspan="2">Pennsylvanian</td><td>Rocky Mountain quartzite (Dowling)</td></tr>
<tr><td>Rundle limestone (Kindle)</td></tr>
<tr><td>Lower Banff shales</td><td>Miss.</td><td>Banff shale (McConnell)</td></tr>
<tr><td>Lower Banff limestone</td><td rowspan="2">Devonian</td><td>Pipestone limestone (Walcott)</td></tr>
<tr><td>Devonian</td><td>Intermediate limestone</td><td>Messines limestone (Walcott)</td></tr>
</table>

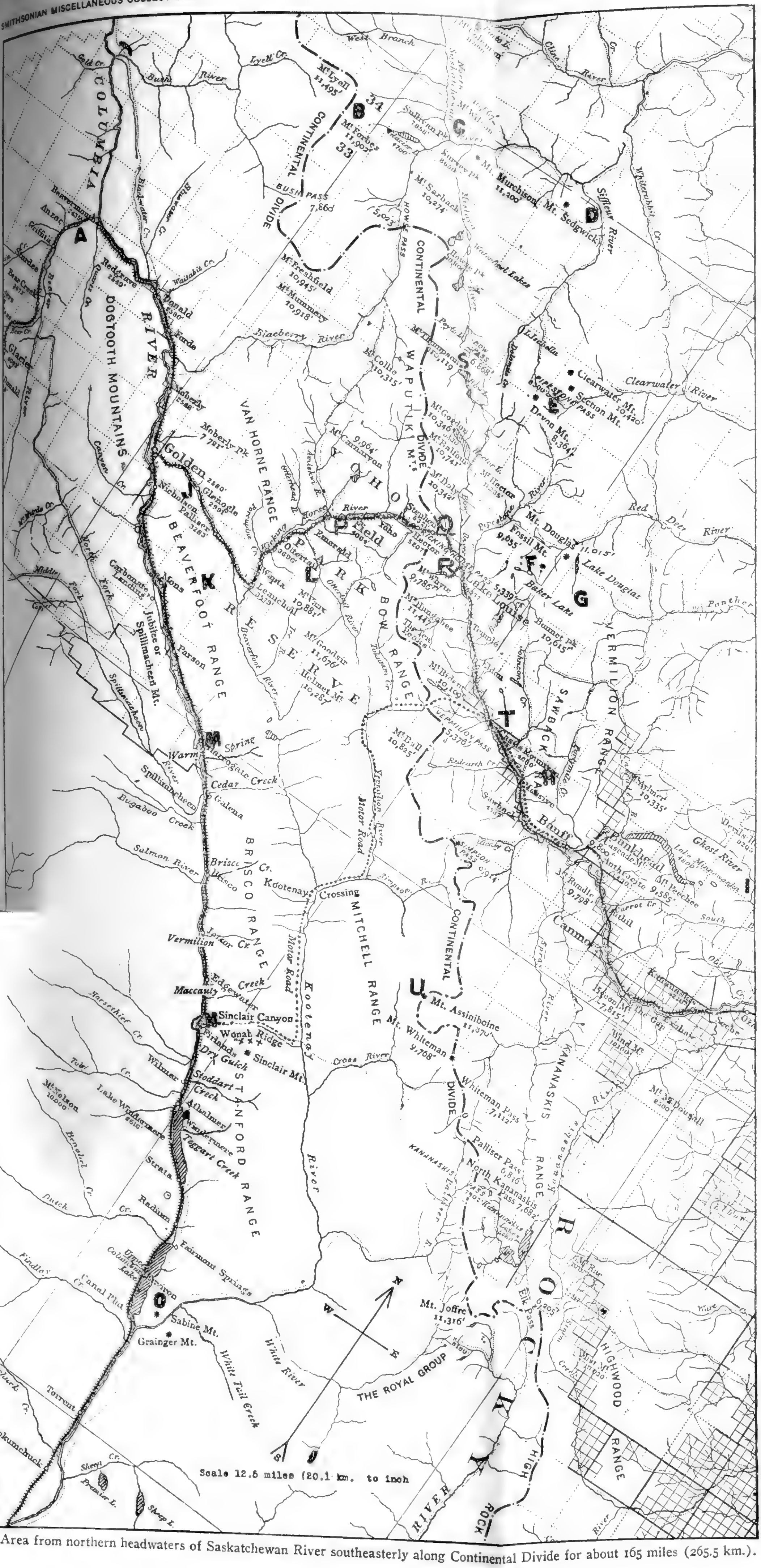
(53.1 km.) east-southeast of Glacier Lake, and 42 miles (67.6 km.) north of the south end of the Sawback Range, where McConnell studied his Banff limestone series. The Pipestone limestone is presumably the stratigraphic equivalent of the Lower Banff limestone of McConnell.

Dr. E. M. Kindle published the results of his study of the Devonian section of the south end of the Sawback Range in 1924.[2] He found that the Upper Banff shale of McConnell contained a Triassic fauna and proposed the name Spray River formation for it. For the Upper Banff limestone the name Rundle Mountain was proposed, and the Lower Banff shale was shortened to Banff shale. The Lower

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, June 28, 1924, pp. 50, 51.

[2] Pan-Amer. Geologist, Vol. 42, No. 2, September, 1924, pp. 113-124.


Gold Cr.
COLUM



Area from northern headwaters of Saskatchewan River southeasterly along Continental Divide for about 165 miles (265.5 km.).

Banff limestone and Intermediate limestone were bracketed under "Devonic" and called Banff limestone and dolomite. "Lower half probably Mid-Devonic."

With our present information the Banff series and Intermediate limestone of McConnell are classified as shown on opposite page.

McConnell correlated the great limestone series beneath his Intermediate limestone in the Sawback Range with his Castle Mountain group. Later, Allan included these limestones under the name Sawback formation, which I have in this paper assigned to five formations (see Sawback formation, p. 190).

DESCRIPTION OF PLATE 26

This map is based on a general land survey map of southern Alberta issued by the Department of the Interior, Ottawa, Canada. Scale 1:79200 or 12.5 miles (20.1 km.) to the inch. The true north and south is shown by the land survey lines.

The heavy faced letters A to U indicate the approximate position of the following localities:

A. Present known limit of western outcrops of Cambrian rocks of Cordilleran Geosyncline.

B. Area about the head of Glacier Lake, Alberta. The geologic section (p. 338) is located a little to the right and east of B.

C. Area about Mount Wilson, Alberta, the typical locality of the Mount Wilson quartzite (p. 208). Mount Sarbach is about 10 miles (16.1 km.) south of Mount Wilson.

D. Locality of the Siffleur River section, Alberta (p. 333). Mount Sedgwick is about 3 miles (4.8 km.) west of D. Siffleur River flows to the northwest just above the top of the letter D.

E. Section Mountain, Alberta (pl. 80), is just above the right upper end of E, at the head of Clearwater River, Alberta. The Clearwater section (p. 327) is near the upper part of the letter E.

F. Location of Fossil Mountain section, Alberta (p. 281). Baker Lake is at the lower end of the F.

G. Bonnet Peak section, Alberta (p. 272), is near the upper side of G at the northwest end of the Sawback Range.

H. Location of Ranger Canyon section, Alberta (p. 264), in Sawback Range. The town of Banff is about 10 miles (16.1 km.) to the southwest.

I. Area of Ghost River section (p. 259), on the west side of Ghost River near where it turns south after passing out from its canyon, Alberta.

J. The location of the Glenogle graptolite beds (p. 218), is a little east of Glenogle Station, on the Canadian Pacific Railway, British Columbia.

K. Type locality of the Beaverfoot formation on the Beaverfoot Range, British Columbia.

L. Ottertail escarpment where the Upper Cambrian Ottertail limestone is well exposed, also to the southeast of L along the Ottertail River, British Columbia.

M. Harrowgate, and Warm Spring Creek, British Columbia. An outcrop of Devonian limestones occurs near the head of Warm Spring Creek.

N. Location of Sinclair Canyon, British Columbia, between the Brisco and Stanford ranges. It is the most important canyon between Golden and Canal Flats. It cuts through the various geologic formations at nearly a right angle to the strike of the strata.

O. Sabine Mountain at south end of Stanford Range, British Columbia, where a pre-Devonian stratigraphic section was examined.

P. Location of Mount Stephen section; also, on the northwest side of the Kicking Horse River, Mount Burgess, Mount Field, and the Burgess shale section (p. 315), British Columbia.

Q. Mount Bosworth on the Continental Divide, where the geologic section (p. 308) extends from the Alberta slope over the Divide into British Columbia.

R. The Lake Louise and Agnes section, Alberta (p. 302), is located about 3 miles (4.8 km.) southwest of Lake Louise Station on the Canadian Pacific Railway.

S. Bow Lake section, Alberta (p. 324), is located near the head of Bow Lake, on the eastern slope of the Continental Divide.

T. The Castle Mountain section, Alberta (p. 274), is located near the lower side of the T opposite Castle Mountain Station on the Canadian Pacific Railway.

U. Mount Assiniboine section (p. 296) about 22 miles (35.4 km.) in an air line south of Banff, in British Columbia.

DISTANCES IN DIRECT LINE BETWEEN TYPICAL SECTIONS REFERRED TO IN THIS PAPER

Glacier Lake section at B on map, plate 26, is taken as a base for reference at the north; Mount Stephen at P and Mount Bosworth at Q in the Kicking Horse-Bow River area.

From Glacier Lake section to:			
Siffleur section (D)	25 miles	(40.2 km.)	east-northeast
Clearwater section (E)	33 miles	(53.1 km.)	east-southeast
Fossil Mountain-Oyster Peak section (F)	52 miles	(83.7 km.)	east-southeast
Mount Bosworth section (Q)	42 miles	(67.5 km.)	southeast
Ranger Canyon section in Sawback Range (H)	69 miles	(111.0 km.)	southeast
Ghost River section (I)	87 miles	(139.9 km.)	east-southeast
Mount Dennis section (P)	43 miles	(69.1 km.)	south-southeast
Sinclair Canyon section	100 miles	(160.9 km.)	south-southeast
Sabine Mountain section (N)	132 miles	(212.4 km.)	south-southeast
Mount Robson section	125 miles	(201.1 km.)	north-northwest
Ranger Canyon section (H) to:			
Ghost River section (I)	24 miles	(38.6 km.)	east-northeast
Mount Stephen section (P) to:			
Clearwater section (E)	26 miles	(41.8 km.)	north-northeast
Ranger Canyon section (H)	32 miles	(51.4 km.)	east-southeast
Ghost River section (I)	55 miles	(88.5 km.)	east
Mount Bosworth section (Q)	7 miles	(11.3 km.)	northeast
Mount Bosworth section (Q) to:			
Clearwater section (E)	19 miles	(30.6 km.)	north
Glacier Lake section (B)	42 miles	(67.6 km.)	north-northwest
Ranger Canyon section (H)	29 miles	(46.7 km.)	southeast
Clearwater section (E) to:			
Sinclair Canyon section (N)	72 miles	(115.8 km.)	south
Ranger Canyon section (H) to:			
Sinclair Canyon section (N)	40 miles	(64.3 km.)	south-10° west

CORDILLERAN GEOSYNCLINE

The extent, importance, and general contents of the Cordilleran Geosyncline have been outlined in the preceding paper.[1] In the following pages a more detailed account is given of the sequence of events, thickness and character of the formations, and their stratigraphic values.

In a paper published in 1924,[2] I considered that the formations constituting the great section extending from Ghost River on the Rocky Mountain front (I on map, pl. 26) to the pre-Cambrian on the west side of Columbia River Valley (N on map) had been deposited in regular sequence in a single Cordilleran trough, and the accompanying diagrammatic sketch of the section showed the formations so arranged from the Lower Cambrian to the Silurian. This view was strongly sustained by the Glacier Lake-Saskatchewan River

[1] Pre-Devonian Sedimentation in Southern Canadian Rocky Mountains. Smithsonian Misc. Coll., Vol. 75, No. 4, 1927.

[2] Smithsonian Misc. Coll., Vol. 75, No. 1.

section (B, C, D on map), as the Devonian limestones were present not only on the eastern and western sides of the trough, but also for a long distance in Mounts Murchison and Sedgwick of the central portion.

During the field season of 1924 I had the opportunity of studying the formations of the Beaverfoot-Brisco-Stanford Range and of passing in rapid review the entire Kicking Horse River section. This caused me to question my view of 1923 but it was not until the summer of 1926 that I concluded that while the 1923 view might be generally correct for the Glacier Lake-Saskatchewan section, it did not correctly record the history of the deposition of the Bow-Kicking Horse section.

PRE-DEVONIAN UNCONFORMITY AND INTERVAL IN THE CORDILLERAN PROVINCES

Many sections in the Cordilleran Provinces clearly prove that there was a great stratigraphic break at the base of the Devonian limestones which are so strongly developed over the eastern section of the Rocky Mountains and less so in the area east and west of the "Rocky Mountain Trench." This unconformity in western Canada extends from the Forty-ninth Parallel on the south to Yellowhead Pass and far beyond to the north. That the Devonian limestones were deposited entirely across the Cordilleran Geosyncline by the transgressing Devonian sea on the line of the Bow-Kicking Horse Rivers is not probable, but in my paper of 1923 (published in 1924),[1] I assumed that they were, being largely influenced by the Glacier Lake-Saskatchewan River section (B, C, D on map, pl. 26), where the Devonian limestones are present on the eastern and western sides of the geosyncline and also in the central portion in Mounts Murchison and Sedgwick. Near the shore line on the eastern and western sides of the geosyncline, the deposition of pre-Devonian sediment was usually irregular and thinner than in the central parts, and often the beds disappeared entirely. This great unconformity I first recognized on the Rocky Mountain front, west of and above Ghost River and named it the Ghost River Interval. In most instances I have used this as the upper limit of the study of the stratigraphic sections, the Clearwater River Canyon, where the Devonian is included, being an exception.

[1] Walcott, La Discordance de Stratification et la Lacune Stratigraphique Pré-Dévonienne dans les provinces Cordillères d'Alberta et de Colombie Britannique, Canada. Libre Jubilaire, Soc. Géol. de Belgique, 1924, pp. 119-123, pls. I-III. Section on p. 121.

In several localities stratified, nonfossiliferous deposits occur between the base of the Middle Devonian and the subjacent fossiliferous rocks of the lower Paleozoic. For two of these deposits, the exact ages of which are unknown, I have proposed the names Ghost River and Mount Wilson formations. Deposits at other localities have not been named as they consist of only a few feet of shale and their distribution has not been traced for any considerable distance. For discussions of these formations see pages 210, and 208.

The extent of the time interval and magnitude of the stratigraphic break in the Ghost River section are indicated by the presence of about 25,000 feet (7,620 m.) of strata in the Bow-Kicking Horse Pass and River sections, between the lower part of the Middle Cambrian and the Middle Devonian Messines limestones, that are not present at Ghost River. These formations include:

	Feet	Meters	Feet	Meters
Silurian:				
Brisco formation			1,200	365.8
Beaverfoot formation			400	121.9
Canadian:				
Glenogle shales			1,700 +	518.2 +[1]
Ozarkian (Lower and Upper only):				
Mons and unnamed formations			3,800	1,158.2
Upper Cambrian (Lower and middle portions only):				
Goodsir formation[2]	6,040	1,841.0		
Ottertail limestone	1,825	556.3		
Chancellor formation	4,500	1,371.6		
Sherbrook formation	1,375	419.1		
Paget formation	360	109.7		
Bosworth formation	1,587	483.7		
Arctomys formation	268	81.6		
Total Upper Cambrian			15,955	4,863.0
Middle Cambrian:				
Eldon formation	2,728	831.5		
Stephen formation	640	195.1		
Cathedral formation	1,212	369.4		
Total Middle Cambrian			4,580	1,396.0
Total			25,635	8,423.1

Of the above formations the Brisco, Beaverfoot, Glenogle, and Mons were deposited in the Beaverfoot Trough; the Goodsir, Otter-

[1] In Walker's section at the head of Windermere Canyon the Glenogle is given a thickness of 2,152 feet (655.9 m.).

[2] See footnote p. 200.

tail, and Chancellor in the Goodsir Trough; the Sherbrook, Paget, Bosworth, Arctomys, Eldon, Stephen, and Cathedral in the Bow Trough.

To what extent, if any, contemporaneous deposition went on in the Goodsir and Beaverfoot Troughs is unknown. At present we have no evidence that any of the formations of the area assigned to the Goodsir Trough are represented in the areas of the Beaverfoot or Bow Troughs, so I have inserted them all at their maximum thickness.[1]

Near Elko, B. C., on the Crowsnest branch of the Canadian Pacific Railway and 132 miles (212.4 km.) south-southwest of the Ghost River section, the Devonian limestone is superjacent to the Elko formation, which consists of a massive-bedded siliceous dolomite and a massive gray siliceous limestone containing indistinct coral-like forms.[2] Beneath the Elko there is a formation with a Middle Cambrian fauna,[3] but the exact contact of the Elko and Burton formations was not seen by Schofield. In 1914 he referred the Elko (p. 81) to the " Silurian Ordovician, or Cambrian " and assigns to it a thickness of 90 feet (27.4 m.), but in 1922 the Elko is bracketed with the Burton as Middle Cambrian.[4] From my studies in the Canal Flat area of British Columbia it seems not unlikely that the Elko limestone will be found to be the equivalent of one or more of the great Upper Cambrian limestones or possibly the Middle Cambrian Eldon limestone[5] of the Mount Bosworth section.[6] The known relations of the pre-Devonian formations to the pre-Cambrian of the Selkirk and Dogtooth Mountains on the western side of the Columbia River Valley from Canal Flats to Golden, B. C., are described in the paper on the Beaverfoot-Brisco-Stanford Range.[7]

[1] Since this was written a restudy of the few fossils found in the formations of the Ottertail Range indicates the possibility that the lower portion of the Goodsir and hence also the underlying Ottertail and Chancellor are not younger than the lower half of the Upper Cambrian. If this possibility should be proved to be a fact, then these formations will have to be correlated with the Bosworth and adjacent formations, or perhaps, since the contained faunas are not the same, will interfinger with them.—C. E. R.

[2] Schofield, S. J., Geol. Surv. Canada, Museum Bull. No. 2, 1914, p. 83.

[3] Idem, p. 125.

[4] Geol. Surv. Canada, Museum Bull. No. 35, 1922, p. 15.

[5] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, pp. 204-209.

[6] This interpretation has been considerably altered by recent discoveries of new faunas by members of the Geological Survey of Canada.—C. E. R.

[7] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 39.

The presence of this great stratigraphic break at the base of the Devonian near Elko and the upper Columbia River Valley proves that conditions existed on the western side of this portion of the Cordilleran Trough in Silurian, Ordovician, and part of Cambrian time, similar to those that prevailed on the eastern side in the Ghost River area at the same period. It was a time of irregular and slight sedimentation on the gently sloping pre-Cambrian strata forming the southwestern and western shore and adjoining shallow sea of the Cordilleran Geosyncline, while in the Bow, Goodsir and Beaverfoot Troughs a great thickness of sediments was accumulating.

Devonian transgression.—The Devonian transgression recorded so clearly in the Rocky Mountains of Alberta and British Columbia has been reported from the Ozark uplift in Missouri [1] where the Devonian rests unconformably on the Canadian Jefferson City dolomite (Beekmantown). More recently the following statement occurs in a report on the Devonian of Missouri [2] " In central Missouri the oldest Devonian rocks are Middle Devonian in age, and the youngest underlying rocks are older than the Niagaran of the Middle Silurian. The time interval between the youngest underlying rocks and the oldest Devonian probably ranges between three million and ten million years in different sections. During this time some 5,000 feet [1,524 m.] of sediments were deposited in places in New York and Pennsylvania."

The Devonian transgression is also beautifully shown by Dr. L. F. Noble in a series of sections in the Grand Canyon of Northern Arizona, where the Devonian rests unconformably on the Upper Cambrian.[3] Within the Cordilleran area south of the Forty-ninth Parallel, the base of the Devonian is superjacent to various formations in different areas and sections. At this time the great Middle Devonian submergence extended over more than one-third of the North American continent.

FOLDING OF PRE-DEVONIAN SEDIMENTARY FORMATIONS OF THE CORDILLERAN GEOSYNCLINE OF THE CANADIAN ROCKY MOUNTAINS

The area selected for consideration includes the drainage basin of Bow River from the Rocky Mountain front westward to the Continental Divide, and on the west of the Divide the drainage basin of the Kicking Horse River and the streams to the north and south that flow west into the Columbia River. This area is about 72 miles (115.8 km.)

[1] Journ. Geol., Vol. XXX, No. 6, 1922, pp. 450-458.
[2] Missouri Bureau of Geology and Mines, Vol. 17, 2d ser., 1922, pp. 4, 5.
[3] U. S. Geol. Surv., Prof. Paper 131-B, 1922, pl. XX.

across on a northeast-southwest line passing through Kicking Horse Pass, and about 65 miles (104.6 km.) on a line passing through Banff in the Bow Valley. The north and south axis extends from Crowsnest Pass to the headwaters of the Saskatchewan River, about 225 miles (362 km.).

There has been little compression of the strata and shortening of the northwest-southeast axis but the pressure from the southwest has flexed, faulted, and upturned the strata to such an extent as to materially shorten the northeast-southwest axis and narrow the area originally occupied by the pre-Devonian sediments in this region. This is illustrated by the sections of McConnell[1] and Allan[2] which cross the Rocky Mountains on the line of the Bow Valley and Kicking Horse Pass and River, also by the sections of the Cascade Coal Basin by Dowling[3] and photographs of the upturned strata of the Sawback Range in this paper (pls. 30, 31). The shortening of the transverse axis and consequent narrowing of the area on this line is estimated to be about 25 per cent, which leads to the conclusion that its original width was about 96 miles (154.5 km.). On the south the sea narrowed to where, near Kootenay Pass, the pre-Cambrian land area of Kintla Island appears to have cut it off on the east and south as far as Marias Pass in Montana. It is probable that the connection between the Cambrian sea north and south of this island[4] was to the west.

The area of Cambrian sedimentation in the province outlined between Kootenay Pass and Thompson Pass is approximately 18,000 square miles (46,620 sq. km.). In this there is a northwest-southeast belt within which the sediments accumulated to a great thickness and from which they diminished toward the northeast and southwest shore lines of the sea. The greatest known depth of pre-Devonian Paleozoic sedimentation was along what is now the line of the Bow and Kicking Horse Pass and Rivers, where, in the Bow, Goodsir, and Beaverfoot Troughs of the geosyncline, it was over 28,000 feet (8,534.4 m.).[5] The thinning out to the eastward is shown by the pre-Devonian formations in the Ghost River section on the Rocky Mountains front (I on map), which have 1,122 feet (342 m.) of strata that are referred to the Middle Cambrian and 500 feet (152.4 m.) to the Lower Cambrian; also a deposit of unknown age (Ghost River forma-

[1] Geol. Surv. Canada, Report for 1886 (1887), Pt. D, p. 42 D.

[2] Geol. Surv. Canada, Transcontinental Excursion, Guide Book No. 8, Pt. II, 1913. Section in pocket.

[3] Geol. Surv. Canada, Rep. Cascade Coal Basin and maps, 1907.

[4] Problems of American Geology, Yale Univ. Press, 1915, p. 197.

[5] See footnote p. 200.

tion) 285 feet (86.9 m.) thick that is subjacent to the Devonian limestone. To the southwest near Elko, British Columbia, there are a few feet in thickness of Lower and Middle Cambrian strata superjacent to the pre-Cambrian and a thin deposit of magnesium limestone (Elko) of undetermined age beneath the Devonian.[1]

The character of the displacement of the strata on the western side of the Sawback Range is illustrated by plates 30, 33. The strata of plate 33 are inclined 60° to 75° to the west-southwest, whereas the beds a few miles north, plates 43, 49, are inclined 40° to 60°.

CHARACTER OF THE ROCKS

The predominant rock of the pre-Devonian formations is calcareous. In the combined Kicking Horse Canyon and Bow River sections of the Bow, Goodsir, and Beaverfoot Troughs, the total thickness from the pre-Cambrian to the top of the Silurian is approximately 28,000 feet (8,534.4 m.), distributed as follows:

	Feet	Meters
Limestones of varying character and purity	16,180	4,931.7
Calcareous and argillaceous shales	6,740	2,054.4
Argillaceous and arenaceous shales	1,700	518.2
Arenaceous shales and sandstones	3,078	938.2
Quartzitic sandstones	600	182.9

The limestones may be almost pure, as in the Ozarkian Mons formation; siliceous, as in the Silurian Brisco formation; dolomitic as in the Upper Cambrian Bosworth formation; more or less arenaceous as in the Middle Cambrian Cathedral formation; quartzitic as in the Lower Cambrian Fort Mountain formation; argillaceous as in the Upper Cambrian Chancellor formation; or a combination of calcareous, siliceous, arenaceous and argillaceous material. The shales vary from the calcareous of the Mons to the siliceous of the Burgess shale member of the Middle Cambrian Stephen formation, and the argillaceous of the Chancellor to the arenaceous of the Lower Cambrian St. Piran formation. The quartzitic sandstones of the Fort Mountain are underlain by a fine siliceous conglomerate of varying thickness and character.

Thoroughly washed beach sands, with a varying amount of small quartz pebbles, composed the greater part of the lower beds of the Fort Mountain formation. Such quartzitic sands are not known to have occurred again, except as small lenses, until the transgressing

[1] Schofield, S. J., Geol. Surv. Canada, Museum Bull. No. 2, 1914, p. 81.

Silurian sea deposited them over the impure sandstones and shales of the Ordovician in the western side of the Cordilleran sea, where they now form the Wonah quartzite of the Beaverfoot-Brisco-Stanford Range, and later when the Devonian transgressing sea deposited the sands now forming the Mount Wilson quartzite of the Clearwater and Saskatchewan areas.

The Beltian pre-Cambrian rocks are mainly arenaceous and siliceous shales, with some fine conglomerate and more or less friable sandstone. They are unlike the superjacent Cambrian rocks except where they may have furnished the material that was distributed over the bottom of the Cambrian sea and incorporated in the shales and sandstones in the lower part of the Lower Cambrian.

The limestones are persistent in character over relatively large areas but they vary in amount of included arenaceous and argillaceous material, in the extent of dolomitization, and in the thickness of layers, which range from a thin shale to a layer several feet thick. Such variations may be noted by comparing the Bow-Kicking Horse section with that of Glacier Lake and even better with the Robson Peak section.

Sedimentation.—When the advancing Cambrian sea penetrated the area of the Cordilleran Geosyncline, the adjoining land surfaces were of low relief with only minor elevations and depressions. An exception appears to have existed in Kintla Island,[1] which was not, as far as now known, covered by a post-Beltian pre-Devonian sea. The impure sandstones and shales of the Beltian series of the Algonkian had not been greatly disturbed or eroded since the withdrawal of the great inland non-marine seas in which they were deposited, although they were undoubtedly more or less decayed and disintegrated.

That the advancing waters encountered only slight elevations in and along the shores of the Cordilleran Geosyncline is evidenced by the almost entire absence of coarse conglomerates, and the presence, above the coarse basal sandstones and fine conglomerates, of deposits of very fine-grained sandstones and mud rocks.

As the sands and mud were gathering in the shallow Lower Cambrian sea, the Bow Trough of the Cordilleran Geosyncline was slowly deepening until 4,000 feet (1,219.2 m.) or more of shallow water sediments accumulated before the calcareous sediments now forming the Mount Whyte limestones began to be deposited. This period appears to have been sufficiently long to permit of the thorough work-

[1] Problems of American Geology, Yale Univ. Press, 1915, p. 167.

ing over of the disintegrated surface material in the path of the advancing sea and that brought into it by tributary streams. There is almost no coarse material present in the Middle and Upper Cambrian, Ozarkian and Ordovician, the prevailing deposits being calcareous except in the Goodsir Trough of the geosyncline, where an immense amount of argillaceous, finely arenaceous, and siliceous matter greatly increased the thickness of the deposits of Upper Cambrian in the Beaverfoot Trough in Ordovician time. In the central area of the geosyncline, where limestones predominate, the same general character of sediments continues from about the Fiftieth Parallel 200 miles (321.8 km.) or more to the north. This includes the Bow Trough and its extensions north and south. The conditions mentioned indicate that the lands on the east were of low relief while those of the western or Selkirk side of the geosyncline were moderately elevated. From the west, where the drainage was favorable great quantities of fine siliceous and argillaceous muds and slimes were carried to the Goodsir seaway. These conditions changed at the close of Upper Cambrian Chancellor time, and 2,000 feet (609.6 m.) of calcareous deposits gathered, which now form the Ottertail limestones. Another shifting of the western lands resulted in the resumption of the influx of siliceous muds which, with calcareous matter, formed the 6,400 feet (1,950.7 m.) of shales and siliceous limestones of the Goodsir formation. This shift of the source of sediments in Upper Cambrian time is most marked in the Goodsir Trough, but it also occurs on the eastern side of the geosyncline in Alberta, as is shown by the abrupt change from the thick-bedded magnesian limestones of the Upper Cambrian Lyell formation to the calcareous shale and interbedded interformational conglomerate limestone of the superjacent Sabine formation.

The prevailing rock of the Ordovician (Canadian) [1] Sarbach formation is calcareous on the eastern (Sawback Trough) and in the central portion of the Cordilleran area in the Glacier Lake Trough, but

[1] The Sarbach formation is referred to both the Ordovician and Canadian systems at various places in the text. This lack of uniformity of treatment results from two things: first, the fact that the different parts of the text were written at different times, and second, the desire to avoid writing two words each time the term is used. It must be noted that the true Ordovician is much more sparingly represented throughout the Canadian Rockies than the lower beds now referred to the newer Canadian system. Dr. Walcott was willing to follow Dr. Ulrich in regarding the Canadian beds as probably constituting a separate system.—C. E. R.

in the western area, in the Beaverfoot Trough, the Ordovician (Canadian) Glenogle formation is made up of argillaceous and arenaceous shales formed of muds and fine sands derived from a western land area that was probably more elevated than during Upper Cambrian and Ozarkian time.

The Silurian and Devonian rocks are nearly all calcareous, with some very fine argillaceous and arenaceous matter intermingled and an occasional siliceous, cherty band of limestone. A few bands of fine quartzitic sandstones indicate local changes of land conditions and drainage with a temporary supply of fine sand that was usually thoroughly washed prior to its final deposition.

The origin and character of the sediments deposited in the Cordilleran Geosyncline in Paleozoic time form a most interesting subject for study; a study worthy of a well-trained young geologist who wishes to make a contribution to the geological history of the western side of the North American continent.

PART II

PRE-DEVONIAN PALEOZOIC FORMATIONS

The pre-Devonian Cordilleran seas, as far as known, were persistent for long periods, during which large accumulations of sediment were deposited in the troughs that were formed from time to time in the Cordilleran Geosyncline. Sometimes deposition was going on in two or more of these minor troughs at the same time, and at other times possibly only in one, as in the case of the Goodsir Trough in Upper Cambrian time. In the closing period of Lower Cambrian time, the sands and arenaceous and siliceous silts were embedding the Mesonacidae fauna in the Beaverfoot Trough on the west and along the eastern shore of the Bow Trough on the east, and again later the Lyell, Sabine, and Mons limestones were being deposited in the Beaverfoot and Sawback Troughs, the intervening stretches of the geosyncline being separated by barriers or else elevated above the water and not receiving deposits. To the north, however, the Beaverfoot and Sawback Troughs extended as open seaways into the Glacier Lake Trough, permitting the Cambrian and Ozarkian faunas to pass freely between them for a long period.

Fluctuations in the depth and extent of the seaways in the troughs resulted in more or less abrupt changes in the extent, character, and thickness of the deposits, and in the consequent succession of faunas, the latter receiving at varying intervals new accessions from the Pacific Ocean on the south and west and from the Arctic Ocean on the north.

In some areas, changes in extent and depth resulted in accumulations of sediments, and in others diastrophic movements caused a tilting of the bottom of the seaways, so that very little deposition, if any, took place for considerable periods, while in not far distant areas or troughs one or more geological formations or parts of formations were deposited. The shallowing of the seaways towards the eastern and western shores and at times within the minor troughs resulted in irregular and overlapping deposition, and often in non-deposition of sediments, that gave rise to unconformities of varying degrees of magnitude, without evident disconformity at the contacts between the newer and older formations. This occurred in Cambrian, Ozarkian, and later Paleozoic time. One of the most marked unconformities is at the base of the Silurian at the time of the Wonah transgression,[1] and another at the base of the Devonian (pp. 201, 192), at the time of the Messines transgression.[2]

An example of great variation in deposition within the area of the geosyncline is afforded by the Middle Cambrian Eldon limestone, which is 2,728 feet (831.5 m.) thick in the Bow-Kicking Horse section at Mount Stephen and absent in the Siffleur section (p. 333) of the Saskatchewan River area 39 miles (62.7 km.) to the north. The Beaverfoot, Brisco, Wonah, and Glenogle formations of the Beaverfoot Trough in the Stanford-Brisco Range, and the Goodsir formation of the Goodsir Trough, are not known to occur north of the Kicking Horse River drainage, and at Glacier Lake the pre-Devonian section is very dissimilar to that of the Bow-Kicking Horse section.

In the following pages will be found a discussion of the formations under the names now in use, giving their history, content, and general characters.

DEVONIAN

It has not been my purpose to study the Devonian formations further than to identify those that occur immediately above the great Ghost River interval. In this connection I have had occasion to name the Messines formation of the Middle Devonian in the Glacier Lake section and the Pipestone formation of the Upper Devonian. These formations are discussed on page 194.

Two formations, Ghost River formation and Mount Wilson quartzite, occur beneath the Middle Devonian and above the remaining lower Paleozoic rocks.

MOUNT WILSON QUARTZITE. WALCOTT, 1923

Type locality.—Mount Wilson, on the north side of the Saskatchewan River (C on map, pl. 26) in the Glacier Lake Trough.

Derivation.—From Mount Wilson.

Character.—Compact, white quartzite or quartzitic sandstone in layers varying from 2 inches (5.1 cm.) to 6 feet (1.8 m.) in thickness. It breaks up into angular blocks and fragments, and shows very little erosion except where rounded and polished by glaciation.

Thickness.—At Mount Wilson (C on map) 250 feet (76.2 m.). At Clearwater Canyon (E on map) 32 miles (51.5 km.) southeast of

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[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 50.

[2] Named after the Messines formation at the base of the Devonian in the area between the Saskatchewan and Bow Rivers in the Rocky Mountains of Alberta.

Mount Wilson, 24 feet (7.3 m.) maximum thickness and thinning out on the strike to zero. Ten miles (16.1 km.) north of Mount Wilson it has a thickness of 100 feet (30.5 m.) and 2 miles (3.2 km.) farther north it is represented by but a thin band of quartzite.

Fauna.—None known.

Geographic distribution.—From Mount Wilson on the north (C on map) to the head of Clearwater Canyon (E on map), 32 miles (51.5 km.) to the southeast. It extends up the north fork of the Saskatchewan River 10 miles (16.1 km.) to opposite the mouth of Alexandra River, where it is 100 feet (30.5 m.) thick, but 2 miles (3.2 km.) farther north it has thinned down to a few feet.

Stratigraphic Relations.—At all the outcrops seen, the quartzite was subjacent to the Middle Devonian Messines limestone and overlies the Canadian Sarbach limestone.

Observations.—The Mount Wilson quartzite is one of the formations occurring in the Ghost River Interval (see p. 198) of which we have no faunal data to determine its age. It is presumably a deposit of the transgressing Devonian sea, and if this is correct there were no other deposits between the time of the close of the deposition of the Canadian Sarbach limestones and the incoming of the Devonian sea. Nō indications of erosion were observed at the summit of the quartzite, or of the Sarbach limestones in the absence of the quartzite. The Devonian rests on both, without evidence of unconformity, just as it does on the Ghost River formation at Ghost River (p. 210), although a great unconformity exists, as evidenced by the absence of several formations occurring elsewhere. We have similar conditions in connection with the Wonah quartzite, which occurs 50 miles (80.5 km.) to the south[1] in the Sinclair Canyon section. Here a quartzite of similar character to the Mount Wilson quartzite is subjacent to a limestone carrying a well-marked Richmond fauna, proving that a basal quartzite and superjacent Silurian formations were deposited in the Sinclair Canyon area of the Beaverfoot Trough between the Canadian Glenogle shales and the Middle Devonian. The Wonah quartzite and superjacent Silurian formations are unknown in the Goodsir, Bow, Sawback, and Glacier Lake Troughs, which indicates that the transgression of the Richmond sea with deposition of sediments did not extend over these areas. Both quartzites are superjacent to Canadian formations; the Wonah is above the Glenogle graptolite shales and the Mount Wilson above the Sarbach limestones, but the Wonah quartzite is overlain by a Silurian limestone and the

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, pp. 14, 49.

Mount Wilson quartzite by a Middle Devonian limestone. With our present information I think the Wonah quartzite represents the sands of the transgressing Silurian sea and the Mount Wilson quartzite the sands of the transgressing Devonian sea, and that the Wonah should be referred to the Silurian, and the Mount Wilson to the Devonian.

This problem must be worked out in detail by geologists of the future, who should study the Paleozoic formations of the Cordilleran area from Nevada through to the Yukon River in Alaska, in hopes that somewhere an unbroken succession of deposits may be found containing the faunas that existed from early Cambrian time through to Middle Devonian time.

Ghost River Formation. Walcott, 1921 [1]

On the Rocky Mountain front, west of Calgary, a non-fossiliferous formation occurs beneath the Devonian, to which the name Ghost River was applied in the field notes of 1920. This formation is formed of thin-bedded and shaly, buff-colored magnesian limestones, 285 feet (86.9 m.) in thickness, which are superjacent to the Middle Cambrian limestones of the Ptarmigan formation, and subjacent to massive Middle Devonian limestones (Intermediate limestone of McConnell, Messines formation of Walcott,[2] or Banff limestone and dolomite of Kindle).[3] The lower layers are conformable with the beds beneath for a long distance and the upper beds appear to be conformable with the Devonian above, but at this upper contact there is an abrupt change to the dark massive-bedded, fossiliferous Middle Devonian limestone. No fossils of any kind were seen in or on the Ghost River magnesian limestones and shales.

The Ghost River formation was traced from the south fork of Ghost River north to the Panther River, but it may extend farther along the Rocky Mountain front.

In the Ranger Brook section (H on map), 24 miles (38.6 km.) west-southwest of the Ghost River section (I on map), there is a band of black arenaceo-argillaceous shale about 6 feet (1.8 m.) in thickness beneath the dark massive-bedded Devonian (Messines) limestones and above the light gray, more or less cherty Sarbach limestones. This band of shale occupies the stratigraphic position of the magnesian limestones of the Ghost River formation, and appears to be

[1] Smithsonian Misc. Coll., Vol. 72, No. 6, 1921, p. 5; also Vol. 67, No. 8, 1923, p. 463.

[2] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, pp. 50, 51.

[3] Pan-Amer. Geologist, Vol. 42, No. 2, 1924, pp. 120, 121.

conformable to both the superjacent Devonian and the subjacent Sarbach, but it is to be noted that a great thickness of strata is present at Ranger Canyon, beneath the shale band, that is not present to the eastward at Ghost River, and that presumably was not deposited there. Again, 15 miles (24.1 km.) northwest of Ranger Brook in the Douglas Lake Canyon section (G on map) and on the general northwest strike of the Cordilleran geosyncline, a band of buff-colored arenaceous shale 10 feet (3 m.) in thickness occurs between the Devonian and the subjacent Sarbach, but in a section on the eastern slope of Fossil Mountain (F on map) 38 miles (61 km.) northwest of the Ghost River section and 4 miles (6.4 km.) west of the Douglas Lake Canyon section, a series of thin layers of magnesian limestone with interbedded thin layers of chert 35 feet (10.7 m.) thick, that stratigraphically occupies the position of the Ghost River formation, occurs beneath the Middle Devonian Messines limestones and above the Skoki formation.

SILURIAN

The Silurian is represented on the western side of the Beaverfoot-Brisco-Stanford Range by the limestones of the Brisco and Beaverfoot formations and the Wonah quartzite, all of which were deposited in the Beaverfoot Trough and as far as known not elsewhere in the area of the Cordilleran Geosyncline now under consideration. The base of the Silurian is definitely marked by the Wonah quartzite which records the advance of the Silurian sea into the Beaverfoot Trough.

I have given my opinion on including the Beaverfoot formation, with its "Richmond" fauna, in the Silurian rather than in the Ordovician [1] and have nothing more to add to it here as all the evidence from the Cordilleran area appears to be strongly, and to me conclusively, in favor of referring the Beaverfoot to the Silurian.

Mr. J. F. Walker [2] studied the Brisco and Beaverfoot formations in the Stanford Range of the Windermere map area and concluded that the two formations are transitional into each other, and refers to them as the "Beaverfoot-Brisco formations (Richmond and Silurian)," [3] adding that "the Richmond is transitional into the Silurian." [4]

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 41.

[2] Geol. Surv. Canada, Mem. No. 148, Geology and Mineral Deposits of Windermere Map Area, 1926, pp. 31-34.

[3] Idem, p. 31.

[4] Idem, p. 32.

Mr. Walker's measured section[4] near the head of Windermere Creek is as follows:

Beaverfoot-Brisco Formations	Feet
Several hundred feet of light grey limestone disturbed and poorly exposed.	
1. Light grey limestone weathering light grey. A 4-foot bed weathering dark grey at 16 feet from top. Fauna from top beds. *Virginia* sp. (Silurian)	64
2. Grey limestone weathering a dark slate grey	10
3. Light grey limestone weathering light grey. Stringers and nodules of black chert at 97 feet from top	127
4. Grey limestone weathering a dark slate grey	55
5. Chiefly grey limestone weathering a dark slate grey with light weathering bands in upper part. White chert nodules in a dark grey horizon 50 feet from top. Crinoid stems observed beneath chert horizon	65
6. Light grey limestone weathering light grey. Crinoid stems observed 25 feet from top	70
7. Limestone weathering light and dark grey. Crinoid stems, corals, and brachiopod fragments observed at top. A collection from an horizon 100 feet from top contains: *Halysites* n. sp. (a) *Diphyphyllum* n. sp. *Favosites* sp. *Streptelasma* sp. *Rhynchotrema* n. sp. nr. *R. capax* *Rhynchotrema* sp. Brachiopod undt. *Actinoceras* sp. "This fauna shows the beginning of those forms which give a Silurian aspect to beds which still retain an undoubted Richmond fauna."	130
8. Dark grey limestone weathering dark slate grey with a few light weathering beds. *Fauna:* from the top *Rhynchotrema increbescens* n. var. 75 feet from top *Streptelasma* n. sp. *Halysites* n. sp. Coral undt. Crinoid stems *Rhynchotrema increbescens* n. var. 143 feet from top, lots A (upper) and B (lower) separated by about 2 feet Lot A. *Dinorthis* sp. *Rhynchotrema* sp. (a) nr. *R. capax* *Byssonychia radiata* var.	

[4] Loc. cit., p. 32-33.

	Feet
Lot B. a Stromatoporoid	
Cyrtodonta ? sp.	
Spyroceras sp.	
Actinoceras ? siphuncle	
Trilobite fragments	
"These two lots, though but a couple of feet apart, have an entirely different matrix as well as a different fauna. Lot A is a typical Upper Ordovician Beaverfoot fauna. Lot B represents a Richmond horizon, but both matrix and fauna differ from any other Richmond section submitted."	
188 feet from top	
Halysites n. sp. (a)	
Streptelasma n. sp.	
Rhynchotrema n. sp. (a) nr. *R. capax*	
Plectambonites cf. *saxeus* (Sardeson)	
Protokionoceras ? n. sp.	213
9. Calcareous sandstone, Crinoid stems observed at top	25
Part of section measured	759

Mr. Walker adds: "The calcareous sandstone at the base rests on the Wonah quartzite."

It is evident from this section that Nos. 7 to 9 inclusive [368 feet (112.2 m.)] represent the Beaverfoot formation, and that No. 5 is at the base of the Brisco formation. The *Virginia* sp. in No. 1 belongs in the Brisco fauna, while the faunules of 7 and 8 belong in the Beaverfoot.

Dr. Edwin Kirk and I had no difficulty in finding a line of demarcation between the two formations in the Stanford Range north of Sinclair Canyon and between Sinclair and Stoddart Canyons and on Sabine Mountain. Dr. Kirk spent several weeks studying and collecting from the Silurian and did not note the presence of passage beds or intermingling of the faunas of the Beaverfoot and Brisco formations. Even where there appear to be transition beds such as Mr. Walker noted, it is highly probable that a critical study at such localities will reveal differences not noticeable in a brief field inspection.

Brisco Formation. Walcott, 1924[1]

Type locality.—Westward-facing cliffs of the Brisco Range above the Columbia River Valley between Harrowgate and Sinclair Canyons, British Columbia.

Derivation.—From Brisco Range.

Character.—Dark gray, rough-weathering, more or less siliceous magnesian limestones, with a belt of black argillaceous and calcareous shales 300 feet (91.4 m.) above the base of the formation.

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 47.

Thickness.—Allan gives a thickness of 1,850 feet (563.8 m.) for the Silurian of the Beaverfoot Range, which includes both the Brisco and Beaverfoot formations. I estimated a thickness of 1,200 feet (365.8 m.) for the Brisco formation as it occurs in the Brisco Range.[1] Walker measured 759 feet (231.3 m.) in the Windermere map area.[2]

Geographic distribution.—The Brisco limestones extend the entire length of the Beaverfoot-Brisco-Stanford Range from the Kicking Horse Canyon to Sabine Mountain. Mr. J. F. Walker reports them from the north and south sides of Horsethief Creek in the Purcell Range[3] west of the Columbia River, and they occur in the high cliffs of the ridge between the Columbia and Spillimacheen rivers 10 to 20 miles (16 to 32 km.) south of Golden, British Columbia. It is probable that the Brisco extends north of the Kicking Horse Canyon but it has not been reported as far as known to me.

Fauna.—Dr. Edwin Kirk reported that within 50 feet (15.2 m.) of the base of the Brisco in the Windermere Creek section he found *Pentamerus* sp., and a little higher stratigraphically *Virginia* sp. occurred in abundance in the Sinclair Canyon section. In the upper portion a more abundant fauna was collected near the head of Windermere Creek which included:

Halysites sp.
Syringopora sp.
Favosites sp.
Atrypina sp.
Spirifer sp.
Stropheodonta sp.

In the argillaceous shale about 300 feet (91.4 m.) above the base of the Brisco a graptolitic faunule occurs in which Dr. Rudolf Ruedemann identified:

Monograptus cf. *spiralis* Geinitz
Monograptus marri Perner
Retiolites (*Gladiograptus*) *geinitzianus* Barrande

Observations.—The Brisco is the most recent of the pre-Devonian formations deposited in the Beaverfoot Trough and, as far as known, in the Cordilleran Geosyncline. From its character, uniform bedding, and thick layers, it was presumably deposited in clear water, with the exception of a brief period when black argillaceous muds gave a favorable habitat for a characteristic Silurian graptolite fauna.

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[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 11.

[2] Geol. Surv. Canada, Mem. No. 148, 1926, pp. 32, 33.

[3] Loc. cit., p. 31.

The deposition of dark gray siliceous and calcareous sediments was interrupted, after 300 feet (91.4 m.) had been laid down, by an influx of fine, dark argillaceo-calcareous muds and occasional deposits of purer argillaceous silts upon which the graptolites flourished. About 100 feet (30.5 m.) of these mixed beds accumulated before the order of sedimentation was reversed, 50 feet (15.2 m.) of bluish-black calcareous muds were next deposited, and deposition of the dark gray siliceous and calcareous sediments then continued without further interruption to the close of the deposit, more than 800 feet (243.8 m.) above the graptolite zone.

Beaverfoot Formation. Burling, 1922[1]

Type locality.—Southwestern side of the crest of Beaverfoot Range south of Kicking Horse Canyon from 6 to 20 miles (9.6 to 32 km.)

Derivation.—From Beaverfoot Range.

Character.—Compact, hard, gray, dolomitic, rough-weathering limestones with considerable gray chert in the form of small nodules, stringers, and thin irregular layers. Usually in layers 6 inches (15 cm.) to 2 feet (.6 m.) in thickness. Some of the layers are less dolomitic and more friable after prolonged weathering, and the silicified fossils and cherts weather out in strong relief; the silicified corals are often entirely free from the matrix.

Thickness.—The limestones of this formation usually form a sheer cliff or a series of small cliffs that average a total thickness of 400 feet (121.9 m.) in the Brisco Range.

Geographic distribution.—The Beaverfoot has, as far as known, the same distribution as the Brisco, with which it is closely associated in nearly all sections of the Beaverfoot-Brisco-Stanford Range.

Organic remains.—From the collections made by Dr. Edwin Kirk of the U. S. Geological Survey, in the Beaverfoot-Brisco-Stanford Range, he has identified the following:

Beatricea sp.
Receptaculites sp.
Paleofavosites sp.
Streptelasma trilobatum Whiteaves
Columnaria alveolata Goldfuss
Columnaria (*Paleophyllum*) cf. *stokesi* (E. and H.)
Halysites sp.
Rhynchotrema cf. *capax* (Conrad)
Rhynchotrema argenturbica (White)
Zygospira cf. *recurvirostris* Hall
Plectambonites cf. *saxeus* (Sardeson)

[1] Geol Mag., Vol. 59, p. 459.

Hebertella occidentalis (Hall)
Dinorthis subquadrata (Hall)
Maclurina sp.
Endoceras sp.

Dr. Kirk, in submitting the report on the fossils, wrote:[1]

The Beaverfoot (Richmond) is composed in the main of heavy bedded dolomitic limestones, weathering brownish to lead colored. It seems to vary in thickness in different sections. In the Upper Columbia Lake and Windermere Creek sections it apparently does not exceed 200 feet in thickness. In the Sinclair Canyon sections higher beds are present, consisting of thinner-bedded, purer limestones, and here it attains a thickness of about 400 feet. The fauna is identical with that of the upper Bighorn of Wyoming, of the upper portion of the Fremont of Cañon City, Colorado, and of the Richmond of Stony Mountain, Manitoba.

Mrs. Walcott and I collected, from the lower 20 feet (6.1 m.) of the limestone above the Wonah quartzite in Sinclair Canyon, the following as identified by Dr. Kirk:

Columnaria alveolata Goldfuss
Columnaria (*Paleophyllum*) cf. *stokesi* (Edwards and Haime)
Favosites sp.
Streptelasma rusticum Billings
Rhynchotrema argenturbica (White)
Zygospira cf. *recurvirostris* Hall
Plectambonites cf. *saxeus* (Sardeson)
Hebertella cf. *occidentalis* (Hall)
Dinorthis cf. *subquadrata* (Hall)

The known Richmond fauna has such a wide distribution in the Mississippi drainage area, the Cordilleran region, and Alaska, and it is so distinctive, that its value as a horizon marker is unquestioned, and it is especially valuable in the Beaverfoot-Brisco-Stanford Range area as it occurs above a strongly marked disconformity between the Ordovician and Silurian. It characterizes the Beaverfoot formation so clearly that it is not possible to unite the Beaverfoot with the Brisco formation, which has a very different fauna. A superficial knowledge of the faunas of the Beaverfoot and the Brisco might lead to erroneous identification, and cause the unwary geologist to attempt to establish transitional faunas and to include two formations in one, but a thorough study and comparison of all the elements entering into the problem—lithologic, stratigraphic, and faunal—will usually lead to the discovery of unsuspected evidence of disconformity and faunal changes of such magnitude as to warrant the demarcation of distinct formations in an apparently continuous stratigraphic and faunal series of strata. This has occurred many times in the past and will occur in the future.

[1] Smithsonian Misc. Coll., Vol, 75, No. 1, 1924, p. 13.

Wonah Quartzite. Walcott, 1924[1]

Type locality.—Southwest slope of Wonah Ridge on Sinclair Mountain above Sinclair Canyon at the northern end of Stanford Range, eastern British Columbia.

Derivation.—Named from Wonah Ridge.

Character.—Thick-bedded, white to grayish-white quartzite, the lower layers of which are occasionally slightly cross-bedded.

Geographic distribution.—This quartzite has been traced from Sabine Mountain at the south end of the Stanford Range, north to Sinclair Canyon and into the Brisco Range. The quartzite described by Allan[2] at the north end of the Beaverfoot Range as occurring at the base of the Silurian limestones (Beaverfoot) and above the graptolite shales (Glenogle) is undoubtedly the same formation.

Thickness.—Variable. It ranges from 42 feet (12.8 m.) to over 100 feet (30.4 m.) in a distance of 2 miles (3.2 km.) in Sinclair Canyon. Near the head of Windermere Canyon, Walker reports 167 feet (50.9 m.), and that "east of Tegart Mountain it is a coarse-bedded sandstone 40 feet (12.1 m.) thick." Its representative in the Beaverfoot Range, 15 miles (24.1 km.) southeast of Kicking Horse Canyon, has a measured thickness of 800 feet (243.8 m.).

ORDOVICIAN

Skoki Formation. New Formation

Type locality.—Light gray limestones, forming broken cliffs beneath the Middle Devonian Messines limestone cliff on the eastern side of Skoki Mountain and on the northeast shoulder of Fossil Mountain (F on map) which is directly south across the canyon between Skoki and Fossil Mountains. Skoki Mountain is 9 miles (14.5 km.) northeast of Lake Louise Station, Alberta. (See pls. 47-49.)

Derivation.—From Skoki Mountain (8,750 feet, 2,667 m.).

Character.—Light gray, siliceous and magnesian limestones in layers 15 to 24 inches (38.1 to 60.9 cm.) thick. In the lower half of the formation the limestones are finer and contain thin interbedded layers and nodules of bluish-gray chert that weathers to a buff and reddish-brown color.

Thickness.—On the northeast shoulder of Fossil Mountain, 500 feet (152.4 m.).

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[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 49.

[2] Geol. Surv. Canada, Mem. No. 55, 1914, pp. 101, 102.

Organic remains.—The most abundant fossils are undetermined forms of cephalopods and gastropods. A study of the fauna indicates a Chazyan age for the Skoki formation.[1]

Observations.—The Skoki formation has not been identified in the Clearwater section (E on map), although it may possibly be present there in the upper part of the limestones that are now included in the Sarbach, immediately beneath the Mount Wilson quartzite.

It was not recognized in the Glacier Lake area (B on map), but it should be looked for there beneath the Devonian and above the Sarbach.

Robson Formation. Walcott, 1913[2]

Type locality.—Robson Peak District, Robson Peak and probably east of Moose Pass.

Derivation.—From Robson Peak.

Character.—Bands of thin layers of bluish-gray limestones, with interbedded siliceous, arenaceous, and dolomitic limestones.

Thickness.—Estimated 500+ feet (152.4+ m.) on Robson Peak.

Geographic distribution.—Robson Peak and east of Moose Pass, and presumably on the strike of the latter to the north and south.

Fauna.—None known to a certainty.

Observations.—This formation is of doubtful value. All the strata included in it may belong to the subjacent Chushina. No Canadian fossils have been found in the débris brought down on the glacier. It was referred by me to the Ordovician in 1913 because of the presence of a fauna at Billings Butte which was then regarded as of Ordovician age but which is now referred to the Ozarkian. Only the upper 500 feet (152.4 m.) of the Robson formation of 1913 are now being even tentatively referred to the Ordovician.

CANADIAN

Glenogle Formation. Burling, 1922[3]

Type locality.—Kicking Horse Canyon, in vicinity of Glenogle Station on the Canadian Pacific Railway, and north end of Beaverfoot Range.

[1] In 1926 Dr. Charles S. Evans of the Canadian Geological Survey secured a collection on the north side of Sinclair Canyon, 11 feet below the Wonah quartzite, that contains a species of *Ampyx*. This discovery indicates that the uppermost beds assigned to the Glenogle formation, at some places at least, must be separated and placed into a formation of Chazyan age, perhaps into the Skoki.—C. E. R.

[2] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, p. 336.

[3] Geol. Mag., Vol. 59, 1922, p. 456.

Derivation.—From Glenogle Creek Station.

Character.—Allan describes the formation as follows:

In Glenogle creek and in the small creek to the west, this formation was found to be about 1,700 feet [518.2 m.] thick. The beds are steeply dipping to the northeast, and form part of an overturned fold, so that they appear to be overlain conformably by the uppermost beds of the Goodsir formation. The Graptolite shales consist of black, carbonaceous, and brown, fissile shale at the top, underlain by grey shales with another band of black shales near the base. Underlying these shales are more massive, calcareous beds which are lithologically similar to some of those in the Goodsir formation, and which for this reason have been placed in the Goodsir formation.[1]

Some of the uppermost beds are highly fossiliferous. The best exposure of this fossiliferous, black, thinly laminated shale is in a small creek a few hundred meters west of Glenogle station. Some of the graptolites obtained were almost a foot long.[2]

Thickness.—Estimated by Allan at 1,700 feet (518.2 m.).[3] In Sinclair Canyon, I measured a series of shales and sandstones beneath the Wonah quartzite that is 1,655 feet (504.4 m.) in thickness, and Walker measured 2,152 feet (655.9 m.) of shales at the head of Windermere Canyon in which the Glenogle graptolite fauna is finely preserved.[4]

Geographic distribution.—In the Kicking Horse Canyon below and at Glenogle and up Glenogle Creek, northern end of Beaverfoot Range and south along the range to Sinclair Canyon and Windermere Canyon in the Brisco-Stanford Range.

Fauna.—A large and varied series of graptolites of Ordovician Canadian age collected by Walker were identified by Dr. Rudolf Ruedemann, and a list of them is published by Walker in a table showing the stratigraphic range of each species.[5] This is a most important contribution to the stratigraphy and paleontology of the Beaverfoot Trough and aids greatly in establishing the independent origin of its sediments and faunas. They have not been reported as occurring in the Goodsir Trough.

Observations.—I proposed to call the arenaceous shales and quartzitic sandstones beneath the Wonah quartzite in the Sinclair Canyon section, the Sinclair formation,[6] stating that the section " should include an extension of the Glenogle shale " and if so the name Sinclair

[1] These calcareous beds have since been found to contain fossils of the Ozarkian fauna.

[2] Geol. Surv. Canada, Mem. No. 55, 1914, p. 100.

[3] Idem, p. 100.

[4] Idem, pp. 26-31.

[5] Idem, pp. 26, 27.

[6] Idem, pp. 15, 34, 50.

might become a synonym of Glenogle, unless there should be two distinct faunas in the Sinclair division of the Sinclair Canyon section, in which event both the names Glenogle and Sinclair would be retained.

The more recent studies (1925) of Mr. J. F. Walker in the Windermere map area prove conclusively that the Glenogle graptolite fauna extends throughout the upper arenaceous beds and the lower black shales and argillaceous layers at the head of Windermere Creek[1] that correspond to the Sinclair formation of Walcott. This makes the term Sinclair a synonym of Glenogle.

Sarbach Formation. Walcott, 1923[2]

Type locality.—Glacier Lake and Mount Sarbach area at the head of the Saskatchewan River. Mount Sarbach, 10,700 feet (3,261.3 m.), rises between the south (Mistaya) and middle (Howse) forks of the Saskatchewan, and Glacier Lake is west of the middle fork at the north base of Mount Forbes, 11,902 feet (3,627.7 m.). The Sarbach formation occurs in the cliffs of Mount Sarbach and continues west into Mount Forbes.

Derivation of name.—From Mount Sarbach.[3]

Character and thickness.—Glacier Lake (B on map). 1. Thick-bedded, siliceous gray limestones, 700 feet (213.4 m.). 2. Argillaceous shales and limestones, 420 feet (128 m.). Total, 1,120 feet (341.4 m.).

Clearwater Canyon (E on map) 33 miles (53.1 km.) southeast of Glacier Lake. 1. Compact, hard, thick-bedded siliceous limestones, 762 feet (232.3 m.). 2. Gray siliceous limestones in thick layers above and thinner layers in lower part, 410 feet (125 m.). Total, 1,172 feet (357.2 m.).

On northeast shoulder of Fossil Mountain (F on map) 18.5 miles (29.8 km.) south-southeast of Clearwater Canyon section. 1. Thick-bedded, hard, more or less dolomitic limestone and interbedded belts of gray limestone, 900 feet (274.3 m.). 2. Light gray magnesian limestone with a little chert, 415 feet (126.5 m.).

In Ranger Canyon (H on map) in the Sawback Range, 36 miles (57.9 km.) southeast of the Clearwater section, the Sarbach is represented by 124 feet (37.8 m.) of lead-gray and dark gray cherty

[1] Loc. cit., pp. 24-31.

[2] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15; Vol. 67, No. 8, 1923, p. 459.

[3] Kindle misquoted Sarbach as Sarback and called attention to its similarity to Sawback of Allan. Pan-Amer. Geol., Vol. 42, No. 2, 1924, p. 117. Walker falls into the same error. Geol. Surv. Canada, Mem. No. 148, 1926, p. 22.

magnesian limestones. At the head of Douglas Creek, 7 miles (11.3 km.) east of Fossil Mountain, it has a thickness of 520 feet (158.5 m.) of cherty magnesian limestones similar to those in Ranger Canyon.

In character and thickness the Sarbach is quite uniform from Glacier Lake to Fossil Mountain, a distance of over 50 miles (80.5 km).

Geographic distribution.—The Sarbach has not been noted north of the Saskatchewan drainage area (B, C, D on map) or south of the Baker Lake area (F on map) except as represented by the trilobite *Megalaspis,* in the Sinclair Canyon section (N on map) at the head of Windermere Creek. It appears to have a north and south range of about 80 miles (128.7 km.) and to occur in the Glacier Lake, Sawback, and Beaverfoot Troughs. The Sinclair Canyon occurrence indicates that the formation may be looked for in the interval between Sinclair Canyon and Glacier Lake.

Stratigraphic relations.—The Sarbach[1] at its typical locality on Mount Sarbach is beneath the dark Middle Devonian limestones without apparent unconformity between them, but at Mount Wilson, 8 miles (12.8 km.) north, a white quartzite over 250 feet (76.2 m.) thick made up of massive layers forms a cliff beneath the Devonian and above the Sarbach (see pl. 79). In the Clearwater Canyon section (E on map) 33 miles (53.1 km.) to the east-southeast, the same conditions occur except that the quartzite is only 24 feet (7.3 m.) thick, and a short distance to the eastward it thins out and disappears (see pl. 82), so that the Devonian rests on the Sarbach.

On the northeast shoulder of Fossil Mountain (F on map) the Ordovician Skoki formation occurs between the Devonian and the Sarbach, but at Ranger Canyon (H on map) and the head of Lake Douglas Creek (G on map) there is only a thin band of arenaceous shale between them.

The lower boundary of the Sarbach in the Sarbach-Glacier Lake area is at the base of a strongly-defined cliff on the south side of Mons glacier (pl. 91). In the Clearwater section the thick-bedded siliceous and magnesian limestones of the Sarbach rest on a band of thinner layers, carrying a fauna of Canadian facies, which in turn are superjacent to the bluish-gray limestones that are referred to the Ozarkian Mons formation. The lower boundary is also distinctly exposed on the east side and northeast shoulder of Fossil Mountain, near Baker Lake (F on map).

[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15; Vol. 67, No. 8, 1923, p. 459.

The presence in the Sinclair section (N on map) in the Stanford Range[1] of a limestone identical in appearance with the gray limestones of the Clearwater and Fossil Mountain sections and carrying similar fossils clearly indicates a thin deposit of the Sarbach beneath the Glenogle and above the Mons formation, and from the presence of a variety of *Phyllograptus illicifolius* Hall and a species of *Didymograptus* in the lower Sarbach of Fossil Mountain, (see p. 283) it is highly probable that the Glenogle shales are the stratigraphic equivalent of a portion of the Sarbach formation.

Observations.—The Sarbach limestones in the lower Sinclair Canyon are undoubtedly a portion of a thin deposit or lentil beneath the lower Glenogle.

Mr. J. F. Walker, of the Geological Survey of Canada, when mapping the geology of the Windermere topographic sheet east of the Columbia River Valley in 1924, found at the head of Windermere Creek near the summit of the Stanford Range a band of compact, dark, bluish-gray limestone beneath the Glenogle shales and above the Mons limestones; among the fossils he collected from this limestone are numerous specimens of a species of *Megalaspis* that is similar to one from the lower part of the Sarbach formation on the northeast shoulder of Fossil Mountain (see p. 287). Dr. E. O. Ulrich also recognized the genus *Shumardia* in the Walker collection, but I did not find it at Fossil Mountain. Dr. Ulrich considered the species of *Megalaspis* as closely allied to the *M. limbatus* of Sweden. This fauna had not before been recognized in America and marks a horizon that must be searched for elsewhere in the Cordilleran area. It may be that it will be found in the limestones above the Mons formation in the Stoddard-Dry Creek or Sinclair sections.[2] It should also be looked for in the Clearwater Canyon and Glacier Lake sections of the Lower Sarbach.

Fauna.—The fauna of the Sarbach is best known in the Clearwater and Fossil Mountain sections (p. 283), where the presence of "Canadian" graptolites and *Lecanospira* proves the fauna to be of Canadian age. The genera and species as far as determined are listed in the stratigraphic sections.

OZARKIAN

The Upper Ozarkian, as defined by the recent work of Ulrich, is represented throughout much of the Canadian Rocky Mountain region where the lower Paleozoic beds are present. Lower Ozarkian fossils

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 15.
[2] Idem, pp. 16, 22.

have been collected from only two localities, most of the Lower and apparently all of the Middle Ozarkian being lacking. Our present knowledge of the faunas permits a determination of boundaries for the Ozarkian system in the region under discussion even though the position of several formations is not yet fixed.

Upper Boundary of Ozarkian

Northern Cordilleran area.—A great disconformity is indicated at the summit of the Ozarkian Mons formation in Alberta and British Columbia. In the Glacier Lake (p. 338) and Clearwater Canyon (p. 327) sections, the Sarbach formation overlies the Ozarkian, and in the Ranger Canyon (p. 264) section the Sarbach, a thin bed of shale, separates the Mons from the superjacent Devonian. At other places various formations overlie the Mons, thus indicating tectonic movements following the close of the Ozarkian.

Southern Cordilleran area.—No sections have been clearly determined with a view to locating the upper boundary of the Ozarkian in the Rocky Mountains south of Canada. In practically every case, however, where Ozarkian is known there is no difficulty in recognizing where it terminates, as the succeeding formations are usually much younger and hence are readily distinguished. Everywhere throughout the Cordilleran area, further field-work must be done in order to permit a proper solution of this as well as many other stratigraphic problems.

Lower Boundary of Ozarkian

Briefly stated, the lower boundary of the Mons is marked by a widespread and abrupt change in the character of the strata, and the upper boundary by a change in the character of the limestones and by disconformities produced by extensive changes in the sea bed that resulted locally in non-deposition of sediments above the Mons.

The outstanding feature of all of the sections where the contact of the Upper Cambrian and Ozarkian is seen, is that the sediments of the Upper Cambrian deposits were unlike those of the basal beds of the Ozarkian and that, with the exception of the Tilted Mountain locality, very few fossils have been found in the upper layers of the Cambrian, while the basal layers of the Ozarkian usually contain an abundant fauna.

Northern Cordilleran area.—The Ozarkian Mons formation in the Saskatchewan and Sawback areas usually has at the base more or less argillaceous shale with layers of gray limestone and interformational conglomerate made up of small fragments of shaly limestone in a calcareous matrix. The sea was shallow in early Ozarkian time and a different fauna came in after the change in conditions following the close of the Cambrian.

Southern Cordilleran area.—In the Blacksmith Fork section and other places on the western front of the Rocky Mountains, well-defined Ozarkian beds of Mons age are known but in no case has a definite boundary been drawn, because all the collections in hand were made before the significance of the faunas was grasped.

No definite decision can yet be made regarding the position of this boundary in the Eureka District, Nevada. Whether to draw it at the top of the Secret Canyon shale or include the overlying Hamburg limestone in the Cambrian cannot be decided until the stratigraphic meaning of the Hamburg fossils has been learned. It is certain that the lower portion of the Pogonip formation, now designated as the Goodwin formation, is to be correlated with the Mons. No good contact of the Goodwin on the underlying beds has yet been found, and the problem is further complicated by the mistaken conception of the main Eureka District section as a simple anticlinal structure when in reality it consists of a repetition of the formations by thrust faulting.

In the House Range of Utah, the Notch Peak formation was tentatively referred to the Ozarkian owing to the inexact information as to the stratigraphic meaning of its fauna. Now however it has been proved that the underlying Orr formation is to be tentatively correlated with the lower Upper Cambrian Eau Claire formation of Wisconsin and that the Notch Peak belongs closely above it. This reassignment eliminates all Ozarkian from the House Range.

Mons Formation. Walcott, 1920[1]

Type locality.—Southeast side of Mons glacier, near base of northwest ridge extending down from Mount Forbes at the head of Glacier Lake Canyon Valley, about 48 miles (77.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta.

Derivation.—From Mons Peak, 10,114 feet (3,082.7 m.), and Mons glacier, which extends eastward from below the peak. (See pl. 91.)

Character.—An upper section of massive beds of calcareous shale with thin, intercalated layers of hard, gray limestone. A middle section of thick-bedded, dull gray limestone with a little included arenaceous

[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15; also Vol. 67, No. 8, 1923, p. 459.

matter, and a lower section of calcareous shales with interbedded limestone in thick and thin layers. The sections vary in detail but this general character of shales and limestone is found at nearly all outcrops of the Mons over a wide area.

Thickness.—In the Glacier Lake section, 1,480 feet (451.1 m.), made up of calcareous shale, 235 feet (71.6 m.), massive gray limestone, 740 feet (225.5 m.), and calcareous shale below, 505 feet (153.9 m.) thick. Thirty-three miles (53.1 km.) to the southeast, at the head of the Clearwater River, the Mons has a thickness of 1,394 feet (424.8 m.), and at Ranger Canyon, 72 miles (115.8 km.) southeast from Glacier Lake, it is 986 feet (300.5 m.) thick. It is absent in the section of the Rocky Mountain front at Ghost River 24 miles (38.6 km.) east of Ranger Canyon. South of the Kicking Horse Canyon in the Beaverfoot-Brisco-Stanford Range the Mons thickens until at Sinclair Canyon it is about 3,826 feet (1,166.2 m.). At the southern end of the Stanford Range it thins out and does not appear in the Sabine Mountain section.

In my paper on the geological formations of the Beaverfoot-Brisco-Stanford Range,[1] I included the shales and interbedded limestone beneath the Silurian of Sabine Mountain in the Mons formation, but with the inclusion of their fauna in the Upper Cambrian, the original formation name Sabine is returned to and the Mons eliminated from the Sabine Mountain section.

Geographic distribution.—The typical Mons extends north from the Glacier Lake area to the headwaters of the north Saskatchewan drainage area, and presumably still farther north to where it disappears or merges into the Chushina formation towards the Robson Peak District. East of Glacier Lake it occurs in Mount Murchison and Mount Sedgwick and in the cliffs above the east side of the Siffleur River, and thence southeast for about 60 miles (96.5 km.) to Bow River Valley. South of Glacier Lake it is found in the lower Kicking Horse Canyon east of Golden, and from there southeast nearly to the south end of the Stanford Range.

Stratigraphic relations.—The upper boundary of the Mons in the Glacier Lake and Sawback Troughs as it occurs in the Glacier Lake (B on map), Clearwater Canyon (E on map), and Fossil Mountain (F on map) sections is clearly defined by the superjacent Sarbach limestone, and in the Douglas Lake Canyon (G on map) and Ranger Canyon (H on map) sections, by the Ghost River shale that is immediately subjacent to the fossiliferous Middle Devonian Messines

[1] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, pp. 25-28.

limestone. The lower boundary in the Glacier Lake section is at the base of a massive band of gray limestone 740 feet (225.6 m.) thick, beneath which the fossiliferous shales and thin layers of interbedded limestones of the Sabine formation occur. At Section Mountain on the north side of the Upper Clearwater Canyon (E on map), the Mons is superjacent to a dolomitic limestone, that is referred to the Lyell formation, the Sabine formation with its characteristic fossils being absent. The base of the Mons is more or less concealed in the Fossil Mountain-Oyster Peak section, but a mile to the south at Tilted Mountain Brook, there is a band of magnesian limestone 130 feet (39.6 m.) thick below the base of the Mons shales that is referred to the Sabine formation, which here has a thickness of 415 feet (125.6 m.) and contains several Upper Cambrian faunules.

Chushina Formation. Walcott, 1923[1]

Type locality.—Northwest slope of Chushina Ridge, above Snowbird Pass, and north base of Lynx Mountain above Hunga glacier, and at Billings Butte (Extinguisher).

Derivation.—From Chushina glacier and Ridge (see pls. 94, 105).

Character.—Hard, dark gray limestones in thick layers that break down into thin layers on weathering. Interbedded bands of calcareous shale occur at several horizons.

Thickness.—Estimated at 1,500 feet (457.2 m.), but this is probably too small.

Geographic distribution.—Robson Peak massif and probably east of Moose Pass. Ice and snow make it difficult of access, and not until the section is studied east of Moose Pass is there much hope of knowing the exact limits or characters of the formation.

Fauna.—The *Kainella* fauna occurs in the limestone of Billings Butte and on the summit of Iyatunga Mountain (Rearguard), hence this formation is equivalent to a portion of the Mons.

Observations.—The base of the Chushina is clearly defined on Iyatunga Mountain but the upper boundary is arbitrarily assumed to be 1,500+ feet (457.2+ m.) above, although it has not been worked out either stratigraphically or by paleontological evidence.

UPPER CAMBRIAN

The Upper Cambrian formations may be grouped by their geographic distribution and character in two rather distinct regions—

[1] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 458.

first, those west of the position of the present Continental Divide[1] which include the Goodsir, Ottertail, and Chancellor formations that were deposited in the Goodsir Trough of the Cordilleran Geosyncline; second, those deposited in the Bow and Sawback Troughs mainly east of the Continental Divide; these include the Sherbrook, Paget, Lyell, Bosworth, and Arctomys formations in areas adjoining the Bow Valley. Allan mentions the occurrence of limestones beneath the Chancellor formation northwest of Mount Hunter in the Van Horn Range[2] which he referred to the Sherbrook, and I found a limestone similar in character and stratigraphic position to that of the Lyell formation in the Stanford Range,[3] which was deposited in the Beaverfoot Trough west of the Goodsir Trough in which the Goodsir, Ottertail, and Chancellor formations were deposited. The Arctomys formation is beneath the Lyell in the Sawback Range section in Ranger Canyon, also to the northwest in the Tilted Mountain and Oyster Mountain section (pp. 291, 285). The Sabine and Lyell are the two Upper Cambrian formations that are now known to occur east of the Continental Divide in the Glacier Lake and Sawback Troughs and west of it in the Beaverfoot Trough; otherwise the Upper Cambrian formations of the eastern and western areas of the Cordilleran Geosyncline have little, if anything in common.

Sabine Formation. Schofield, 1920[4]

I was greatly puzzled, when examining the section at the south end of Sabine Mountain in 1923, to find a fauna of apparently Upper Cambrian age in a formation occupying the stratigraphic position of the Ozarkian Mons formation as the latter occurs in the Sinclair Canyon section, 34 miles (54.7 km.) to the north. I had previously identified this fauna as of Upper Cambrian age from a collection sent me by Professor S. J. Schofield, but in the lower portion of the Mons formation in Stoddart and Sinclair Canyons there was a somewhat similar fauna that might be referred either to the Mons or the Upper Cambrian, depending on the genera and species present in the particular bed and locality. This led me, when publishing a prelimi-

[1] It is not assumed that the present Continental Divide was in existence, or had any influence on the distribution or characters of the various formations in pre-Devonian time. It is merely a convenient topographic feature by which to locate the present position of the outcrops of the various pre-Devonian formations of the Cordilleran Trough.

[2] Geol. Surv. Canada, Mem. No. 55, 1914, p. 84.

[3] Smithsonian Misc. Coll., Vol. 75, No. 1, 1924, p. 20.

[4] Trans. Roy. Soc. Canada, 3d ser., Vol. 14, Sec. IV, 1920, p. 76.

nary report on the Sabine Mountain section in 1924, to include the shales and interbedded limestones of the section in the lower Mons, and to compare the subjacent thick-bedded magnesian limestones with the Upper Cambrian Lyell formation of the Glacier Lake section. During the following field season of 1924, a fortunate discovery of a strongly defined Upper Cambrian fauna in interbedded gray limestones and shales near the top of the Lyell formation and beneath the Mons in the northern Sawback Range at Tilted Mountain proved that a fauna similar to the one at Sabine Mountain was of undoubted Upper Cambrian age, and also that the genus *Briscoia* of the lower Mons occurred in association with it. This makes it possible to apply the name Sabine, as used by Schofield, to at least the lower portion of the formation on Sabine Mountain, and strengthens the view that the magnesian limestone beneath the Sabine should be correlated with the Lyell formation of the Sawback Mountains and the upper Saskatchewan River areas.

Type locality.—Sabine Mountain, at the south end of the Stanford-Brisco Range, near Canal Flats, British Columbia.

Character.—Usually rather light colored, granular limestones, filled with fossils.

Geographic distribution.—This formation occurs to the south of the type locality, at Ram Creek, and to the north in Sinclair Canyon. These three localities are all situated on the eastern margin of the Rocky Mountain Trench.

It is interesting to note that the Sabine formation occurs also far to the northeast in the Tilted Mountain and Glacier Lake sections.

Fauna.—The Sabine formation contains a typical Upper Greensand fauna of the Franconia formation as developed in Wisconsin. It contains *Ptychaspis,* and particularly a close ally of *Ellipsocephalus curtus.*

Lyell Formation. Walcott, 1919, 1923[1]

Type locality.—Head of Glacier Lake Canyon at foot of southeast branch of Lyell glacier, and extending along the northern cliffs of Mount Forbes (see pl. 88).

Derivation of name.—From Lyell Mountain and glacier.

Character.—Dark and light gray, thick-bedded, hard, more or less siliceous and magnesian rough-weathering limestones of a somewhat uniform character in the Glacier Lake, Sawback Range, and Beaverfoot Troughs.

[1] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 460.

Thickness.—In the Glacier Lake section, 1,700 feet (518.2 m.).

Clearwater Canyon section, 33 miles (53.1 km) east-southeast of Glacier Lake section, 1,050 feet (320 m.).

Oyster Peak Ridge section, 18 miles (29 km.) south of Clearwater Canyon section, 1,555 feet (474 m.).

Ranger Canyon section, 21 miles (33.8 km.) south-southeast of Oyster Peak Ridge section and 69 miles (111 km.) southeast of Glacier Lake section, 1,470 feet (448.1 m.).

Sinclair Canyon section, 100 miles (160.9 km.) south-southeast of Glacier Lake section, 860 feet (262 m.) in thickness between the Mons and a fault that cuts off the limestones referred to the Lyell.

The thickness of the Lyell in the Sawback and Glacier Lake Troughs is unusually uniform on the northwest-southeast axis of the deposit, for a pre-Devonian formation deposited in the Cordilleran Trough. In the Ghost River section, 25 miles (40.2 km.) to the eastward (I on map), the Lyell is absent by non-deposition and it is unknown to the southwest in the Bow and Goodsir Troughs, but it is well developed in the Beaverfoot Trough.

The Glacier Lake section is in the Glacier Lake Trough; the Clearwater Canyon, Fossil Mountain-Oyster Peak Ridge, and Ranger Canyon sections are in the Sawback Trough, and the Sinclair section is in the Beaverfoot Trough.

Geographic distribution.—The Lyell limestones were seen as far north as the head of Castleguard River 18 miles (28.9 km.) north of Glacier Lake (B on map, pl. 26), and from there were traced by several intermediate sections to the Ranger Canyon section (H on map), a distance of nearly 85 miles (136.8 km.). It is not present 25 miles (40.2 km.) east of Ranger Canyon in the Ghost River section (I on map) on the Rocky Mountain front, and I have not identified it to the south of the Sawback Range in the Assiniboine area, but this may be due to my rapid reconnaissance over the area where it may possibly occur. To the west of the Continental Divide in British Columbia it has not been recognized in the lower Kicking Horse Canyon, but about 60 miles (96.5 km.) to the southeast in Sinclair Canyon section, a similar limestone occurs beneath the Sabine formation that is referred to the Lyell. It also occurs along the Stanford Range as far as Sabine Mountain 39 miles (62.8 km.) southeast of Sinclair Canyon, where it is subjacent to the Sabine formation.

Stratigraphic relations.—The Lyell is conformably beneath the Upper Cambrian Sabine formation in the Glacier Lake section, and this relation is known to continue 69 miles (111 km.) to the southeast to the Ranger Canyon section of the Sawback Range; and also in the Sinclair section 100 miles (160.9 km.) south-southeast of Glacier Lake on the west side of the Continental Divide, where the general character and the fauna of the Sabine are the same as at Glacier Lake.

The lower boundary of the Lyell in the Sawback Range is placed at the base of a band of reddish-brown, arenaceous shales and limestones that occur beneath a series of thick-bedded, more or less magnesian limestones. In the Glacier Lake section there are 430 feet (131.1 m.) of gray limestone beneath 1,270 feet (387.1 m.) of massive-bedded, partly magnesian limestones.

The fossils from the Lyell indicate that the formation is: (1) younger than the Sherbrook of the Bow Trough and the Ottertail of the Goodsir Trough; and (2) possibly older than the Sabine of the Beaverfoot, Glacier Lake and Sawback Troughs.

Fauna.—Very few fossils have been found in the Lyell limestones. In the Glacier Lake section none was seen in the upper 1,320 feet (402.3 m.) except an occasional annelid trail or boring. A bed of hard, slabby limestone here broke the series of thick-bedded, rough-weathering limestones, and on the surface of some of the thinner slabs, valves of a small *Lingulella* sp. and a few graptolites were found. The latter included a well-preserved new species of *Dendrograptus, D. ramosissimus* Rued., and a new genus and species, *Mastigograptus macrotheca* Rued. The genus *Dendrograptus* is of late Upper Cambrian age in the upper Mississippi Valley. Six feet (1.8 m.) above the base of the Lyell at Glacier Lake, fragments of two species that suggest *Anamocarella*[1] occur, but they are of little value in determining the stratigraphic position of the Lyell formation. No fossils were seen in the Clearwater Canyon section of the Lyell (E on map, pl. 26), but about 19 miles (30.6 km.) southeast of Clearwater Canyon, in the Tilted Mountain Cirque section (see p. 291) many fragments of small trilobites were found and the genera *Conaspis* and *Kingstonia* were identified.

At about the same horizon in the Ranger Canyon section (H on map), beneath the great limestone 1,325 feet (403.9 m.) thick, species of the following genera were collected: *Agnostus, Irvingella,* and *Saratogia.*

No fossils were seen in the Lyell of the Beaverfoot Trough in the Brisco-Stanford Range.

Observations.—The Lyell limestones were deposited under nearly uniform conditions in the Glacier Lake, Sawback, and Beaverfoot

[1] Research in China. Carnegie Inst. of Washington, Vol. III, 1913, pp. 195-210, pls. 19-21.

Troughs. They are compact, hard, and, on weathered surfaces, rough and often dark, although on a fresh break they are light and medium light gray in color. They do not have the smooth, weathered surface of the Ottertail, Mons, and Stephen limestones, but are more like the Middle Cambrian Eldon, and Silurian Beaverfoot limestones.

The absence of fossils in the upper 1,000 feet (304.8 m.) or more of the Lyell limestones favors the view that during the period of its deposition, conditions were unfavorable for their preservation. The deposition of the calcareous deposits forming the Lyell limestones abruptly ceased, except at Tilted Mountain, where the argillaceous and calcareous muds accumulated in the shallow seaways and contain the fauna of the Upper Cambrian Sabine formation. This same order of events occurred in the Glacier Lake, Sawback, and Beaverfoot Troughs.

Mr. J. F. Walker, in his instructive and valuable memoir on the Windermere map area,[1] correlates the Lyell limestones of the Beaverfoot Trough as they occur in the Stanford Range with the Ottertail limestones of the Goodsir Trough. I think that this correlation is not sound for the following reasons:

1. The Lyell limestone is a rather coarse, rough-weathering, hard, more or less magnesian limestone with a very meager marine fauna below, and none, as far as known, in the upper 1,000 feet (304.8 m.) or more of its thickness.

2. The Ottertail limestone is described by Allan as follows:[2]

> This formation is, in general, a lithological unit, being composed essentially of limestone, massive and thin-bedded, with intercalated layers of calcareous shale. The shaly character of the beds is more evident towards the base of the formation. On a fresh surface the rock composing the whole band is characterized by its grey or bluish colour, while on weathered faces it is light grey to black. The shale bands are so distributed between the more massive beds that they do not greatly affect the steepness of the slope on the exposed face.

Fragmentary remains of brachiopods and trilobites occur throughout the Ottertail, and entire specimens are not uncommon.

In weathering, the hard Lyell limestones break down into angular blocks and fragments and the Ottertail limestones into a débris slope of slabby limestone and large blocks mixed with calcareous shale. The Ottertail formation is underlain by the readily disintegrated Chancellor shale, which, by undermining, causes the Ottertail to form high, clean-cut cliffs (see pl. 75).

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[1] Geol. Surv. Canada, Mem. No. 148, 1926, pp. 21, 22.

[2] Geol. Surv. Canada, Mem. No. 55, 1914, p. 87.

Goodsir Formation. Allan, 1914

The Goodsir formation presents a number of problems of unusual stratigraphic, structural, and faunal interest.

Dr. R. G. McConnell, in a brief report on his classical reconnaissance section near the 51st parallel,[1] grouped the limestones and shales west of Field into the Castle Mountain group, stating that in the west along the Columbia (Beaverfoot Range) it was overlain by the graptolite shales.

Later, Dr. John A. Allan studied the formations west of Field and proposed the name of Goodsir for a portion of the shales and siliceous limestones of McConnell's Castle Mountain group that occur in the Ottertail Range. In his account of the formation, published in 1914,[2] it is described as lying conformably on the Upper Cambrian limestones of the Ottertail formation, with a basal band of soft calcareous red-weathering shales overlain by a band of greenish, dense siliceous shale. These two bands are together about 150 feet (45.7 m.) thick, and from them, most, but not all, of the fossils found in the typical Goodsir have been collected. He continues:

Character.—In general the lower half of the Goodsir formation consists at the base of alternating bands of (1) soft argillaceous and calcareous slate, grey and buff coloured, and forming gentle slopes; and (2) harder bands of siliceous and dolomitic, siliceous slate weathering fawn and light yellow, and forming steep ledges. This character only holds true in Striped mountain and Beaverfoot valley where the measures though more highly cleaved are less affected by contact metamorphism. In the section on Mt. Goodsir this distinction of alternating hard and soft bands can not be made and the formation consists of cherts, cherty limestone, banded cherts, shales, thin-bedded limestones siliceous and dolomitic, interbedded with siliceous shale. The dense compact nature of all the beds and their thin-bedded character are features especially characteristic of the formation in this locality. The colour on weathered surfaces is dark brown, chocolate brown, reddish, purplish, olive, buff, drab, and grey. The general colour of the whole when viewed from a distance is dark brown. On account of their dense, hard character, most of the beds break up into sharp, rectangular fragments, which on further decomposition form sharp edged, rock débris. The uppermost 500 feet [152.4 m.] of the formation in Striped mountain consists of alternating beds like those at the base, but the strata do not tend to outcrop in ledges since the beds in the different bands are of nearly equal hardness. The highest bed is a greenish purple, hard, dense, siliceous limestone that contains numerous lenticular concretions of pyrrhotite with some chalcopyrite.[3]

Distribution and thickness.—This formation caps the Ottertail mountains. There are a few square yards exposed on the extreme top of Mt. Hurd; it

[1] Geol. Surv. Canada, Report for 1886 (1887), Pt. D, pp. 24-26 D.

[2] Geol. Surv. Canada, Mem. No. 55, 1914, pp. 94-100.

[3] Loc. cit., pp. 95, 96.

caps Mt. Vaux and underlies Hanbury glacier at the head of Ice River valley. The valley of the northeast fork of Ice river has been cut through this formation into the underlying Cambrian. It continues in Mt. Goodsir where it has the greatest development, but is again cut off at the divide between Moose Creek and Goodsir Creek valleys. On the east side of Moose creek this formation is again exposed on Helmet mountain on the tops of the interstream ridges and over the greater part of the ridge terminating in Striped mountain. On account of the southward dip of the beds away from the igneous rock of Ice river, the formation forms the top of Mt. Mollison and its southward slope; it continues northwest on the slope overlooking the Beaverfoot valley until it pinches out in a synclinal fold on the south slope of Chancellor peak. It presumably floors the upper part of Beaverfoot valley and is developed on the east slopes of the Beaverfoot range. The area of this formation exposed in the Beaverfoot range is bounded on the southeast by a fault, and towards the north another fault defines the northeastern limit of the same area, the fault passing between Leanchoil station and the ridge of Mt. Hunter.

The greatest thickness is exposed in the south tower of Mt. Goodsir, but even there the highest beds do not represent the top of the formation as developed elsewhere outside of this district. Plate XI, B, shows the total thickness of the Goodsir formation in Mt. Goodsir and also the underlying Ottertail formation. An attempt was made to accurately measure the thickness of these beds, but on account of the long talus slopes and the inaccessible cliffs, especially in the upper 2,000 feet [609.6 m.], the attempt was unsuccessful. Since at this locality the average dip of the beds is 20 degrees and the upper and lower limits are observable, it was possible to estimate the thickness of the formation in Mt. Goodsir and this was found to be 6,040 feet [1,840.9 m.] [1]

Age and correlation.—This formation, as determined by faunal evidence, belongs to the lower Ordovician. It is conformable with the Upper Cambrian beds and on account of the lack of fossils in the upper part of the Ottertail limestone, the lower limit of the Ordovician cannot be clearly defined. Fossil horizons were found at four localities, but in each case near the base of the formation. In Ice River valley fossils were found on the west side of the amphitheatre at the head of the east fork; also on the north side of Mollison Creek valley about ½ mile [.8 km.] above its junction with Ice river. At both of these localities, the fossil-bearing beds are in the same horizon and consist of a greenish, calcareous and siliceous shale. The beds occur about 30 feet [9.1 m.] from the base of the formation as there developed. The other two localities in which fossils were found occur in Moose Creek valley on the northeast slope of Mt. Mollison, about 1,000 feet [304.8 m.] above the bottom of the valley. The beds there consist of a dense, greenish, siliceous shale, weathering light grey and buff, and occur within 300 feet [91.4 m.] of the base of the formation.

The fossils collected have been determined by Dr. Walcott. He found four new species; of these the trilobite *Ceratopyge* has not been described before from this country. This genus has been described as occurring at the base of the Ordovician in Sweden. The presence of this fauna in these beds is the chief evidence for placing the beds of the Goodsir formation at the base of the Ordovician.[2]

[1] Loc. cit., pp. 94, 95.

[2] Loc. cit., p. 99.

Since the above was published in 1914, L. D. Burling collected more and better specimens of fossils in the lower portion of the formation that clearly prove that my reference of one of the species of trilobite to *Ceratopyge* was incorrect and that the lower part of the Goodsir shales should be correlated with the Upper Cambrian Orr formation of the House Range section, Utah.[1] My restudy of the collection of Allan and that of Burling fully sustains the Upper Cambrian age of the fauna and that the lower portion of the Goodsir in its type section and area should undoubtedly be referred to the Upper Cambrian. To what extent the 6,040 feet (1,840.9 m.) of limestones of the section on Mount Goodsir should be included in the Goodsir formation is undecided, as no fossils have been found in the middle and upper parts of the section and no upper boundary of the Goodsir is known either on Mount Goodsir or in any of the typical areas of the formation in the Ottertail Range.

Goodsir formation and the Beaverfoot Range.—In describing the distribution of the Goodsir formation, Allan says:

> The formation forms the top of Mt. Mollison and its southward slope; it continues northwest on the slope overlooking the Beaverfoot valley until it pinches out in a synclinal fold on the south slope of Chancellor Peak. *It presumably floors the upper part of Beaverfoot valley* and is developed on the east slopes of the Beaverfoot range. The area of the formation exposed in the Beaverfoot range is bounded on the southeast by a fault and towards the north another fault defines the northeastern limit of the same area.

Allan apparently did not follow up the eastern slopes of the Beaverfoot-Brisco Range to near the top of the ridge, for if he had, he would have found a profound fault with a northwest-southeast trend and a southwest hade between the "Goodsir" limestones and shales and the Silurian limestones, a fault that extends from the Kicking Horse River south-southeast the entire length of the Beaverfoot-Brisco-Stanford Range. This Kootenay fault marks the boundary of the outcrops between the "Goodsir" of Allan and the Silurian, Ordovician, and Ozarkian formations of the Beaverfoot-Brisco-Stanford Range. On the northeast slope of the Beaverfoot Range, opposite Glenogle, the Kootenay fault brings the limestones of the Goodsir and the Mons in close proximity and it was perfectly natural for Allan to assume the identity of the two limestone formations, and to so map and represent them in his sections and text. At that time there were no fossils known from the limestones west of the Kootenay fault and none from the limestones of the adjacent Beaverfoot Valley.

[1] Summary Rep. Geol. Surv. Canada for 1915 (1916), pp. 98, 99. Geol. Mag. London, Vol. 59, No. 700, 1922, p. 458.

With the discovery of typical Mons fossils west of the Kootenay fault and typical Upper Cambrian fossils at Wapta Falls in the limestones east of the fault, the distinction between the Goodsir and Mons is conclusive.

Organic remains.—Through the courtesy of the Director of the Geological Survey of Canada, I had the opportunity of studying the first collection of fossils made by Dr. Allan, and reported on them in 1912.[1] The material was not well preserved, but one species of trilobite appeared to belong to the genus *Ceratopyge,* and I correlated the fauna with that of the *Ceratopyge* zone of northwestern Europe, saying:

> 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 Brachiopods (Monogr. U. S. Geol. Surv., Vol. 51, 1912), 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 (Ulrich, Bull. Geol. Soc. America, 1911, Vol. 22, pl. 27) of the Mississippi region placed in a terrane between the Cambrian and Ordovician.[2]

This led Dr. Allan to refer the Goodsir to the Ordovician in his final report of 1914.[3]

L. D. Burling, collecting for the Geological Survey of Canada, found a number of fossils in the lower 300 feet (91.4 m.) of the Goodsir, among which are several species not in the Allan collection that, taken with those first found by Allan, fully establish the fauna as of Upper Cambrian age.

The fauna is designated as the *Housia* fauna and includes species of *Obolus, Lingulella* and *Pseudagnostus.*[4]

Observations.—Since Allan's work appeared in 1914, three discoveries related to it have been made:

1. The Goodsir fauna has proved to be of Upper Cambrian and not Ordovician age.

2. I have identified an Ozarkian formation (Mons) 3,300 feet (1,005.84 m.) in thickness in the Beaverfoot-Brisco-Stanford Range, as of post-Cambrian and pre-Ordovician age. This formation has

[1] Smithsonian Misc. Coll., Vol. 57, No. 7, 1912, pp. 229-234, pl. 35.

[2] Idem, p. 231.

[3] Geol. Surv. Canada, Mem. No. 55, 1914, p. 99.

[4] As stated in the note on p. 200, subsequent study of this fauna and comparisons with others collected in the Black Hills and elsewhere, indicates the possibility that these fossils belong well down in the Upper Cambrian.—C. E. R.

been identified by its contained fossils in the Beaverfoot Range, both adjoining the Kicking Horse Canyon and to the south in the continuing Brisco and Stanford Ranges.

3. The limestones west of the Kootenay fault identified by Allan as Goodsir on the northeast slope of the Beaverfoot Range and beneath the Glenogle graptolite shales prove to be of Ozarkian (Mons) age and their contained fossils belong far above the Goodsir formation fauna as now known. In fact, two or more geological formations occur elsewhere between the horizon of the Goodsir *Housia* fauna and the Mons fauna.

These three discoveries render the correlation of the lower Goodsir and Mons formations of doubtful value in either the Ottertail Range or the Beaverfoot-Brisco-Stanford Range. The typical Goodsir was a relatively local deposit of siliceous, argillaceous, and calcareous muds that had a limited east and west distribution with an unknown north and south range in the Goodsir Trough of the Cordilleran Geosyncline. The formation is now known only in Mount Goodsir and adjoining areas of the Ottertail Range south of the Kicking Horse Canyon, and possibly on the eastern side of the Beaverfoot Range east of the Kootenay fault. Its upper boundary is unknown, but it may be somewhere in the 6,000+ feet (1,828.8+ m.) of shales and siliceous limestone on Mount Goodsir. The lower 500 feet (152.4 m.) of the formation is of known Upper Cambrian age, but without the evidence of fossils, or a lithologic break or unconformity between its Upper Cambrian *Housia* fauna and the summit of the limestone series on Mount Goodsir, it is not practicable to draw a definite boundary between the Goodsir and a next superjacent formation, if one is present. It may represent the Mons formation, although there is no paleontological or stratigraphic evidence in favor of that supposition. In the Beaverfoot Trough, the massive Upper Cambrian Lyell limestone is overlain by shaly beds with a *Briscoia-Saukia* fauna holding a stratigraphic position in the Ozarkian lower than any of the faunas in the typical Mons, but clearly above the Sabine middle Upper Cambrian fauna. There is no trace of this *Briscoia-Saukia* or the Sabine faunas in the Goodsir formation, or of the Goodsir *Housia* fauna in the Beaverfoot Trough section.

The name Goodsir should be restricted to a typical Goodsir formation on Mount Goodsir or else used as a series name for the entire 6,000+ feet (1,828.8+ m.) referred to the Goodsir by Allan. If this latter course is followed, then as faunas and boundaries are discovered in the Goodsir series, formations will be defined and named, as has been done in the case of the Knox limestone of the Appalachian Trough and McConnell's Castle Mountain limestones of the Bow Trough. It would be going back to the practice of the period from 1860 to 1890 to incorporate in one formation faunas of Cambrian, Canadian, and Ozarkian time, as has been done recently by Walker when he included in his section, as the Goodsir formation, the pre-Silurian limestones of the Stanford Range of the Windermere map area above the massive Upper Cambrian Lyell limestones. He absorbs in the Goodsir formation, the Ozarkian Mons formation with its several subfaunas, the Canadian Sarbach formation with its very typical fauna, and the Upper Cambrian Sabine formation and its fauna. This is done in spite of his objection to my correlating the Lyell limestone of the Glacier Lake and Sawback Troughs with a similar limestone in the same stratigraphic place in the Beaverfoot Trough. He says: "Walcott has used the name Lyell? in describing this formation in the Stanford Range. The correlation with the Lyell is made over a gap of 100 to 132 miles (160.9 to 212.3 km.) and across the summit of the Rocky Mountains."

Walker does not appear to realize that the type locality of the Mons formation and its faunules is the same as that of the Lyell formation, and that all of the faunas he has incorporated in the Goodsir are typical of the Mons both in the Glacier Lake section and 100 miles (160.9 km.) or more distant in the Stanford Range of the Beaverfoot Trough.

The question arises as to where, if at all, the Goodsir formation occurs in the Beaverfoot-Brisco-Stanford Range. It may possibly be present on its eastern slope, east of the great Kootenay fault, but the limestones occurring there may belong to the upper Ottertail formation. If of Goodsir age, it is evident that the formation thinned out rapidly to the west and south and was not deposited in the Beaverfoot Trough or over the area now occupied by the central and western portions of the Beaverfoot-Brisco-Stanford Range. It is not present in the Sinclair Canyon, Stoddart Creek, or Sabine Mountain sections, and has not been identified west of the Kootenay fault.

Ottertail Formation. Allan, 1914

Type locality.—In the high escarpments of the northeast side of Ottertail Range from Mount Hurd southward.

Derivation of name.—From Ottertail Range.

Character.—Allan describes the formation as follows:[1]

[1] Geol. Surv. Canada, Mem. No. 55, 1914, p. 91.

This formation is, in general, a lithological unit, being composed essentially of limestone, massive and thin-bedded, with intercalated layers of calcareous shale. The shaly character of the beds is more evident towards the base of the formation. On a fresh surface the rock composing the whole band is characterized by its grey or bluish colour, while on weathered faces it is light grey to black. The shale bands are so distributed between the more massive beds that they do not greatly affect the steepness of the slope on the exposed face.

At various horizons in the formation, the beds consist of alternating bands from ¼ inch to 2 inches thick, of varying hardness, so that on the weathered surface the rock has a distinctly furrowed appearance. Although in such cases the fresh surface of the rock may appear to be uniform in composition, yet in reality the harder bands are dolomitic or siliceous, while the softer bands are calcareous. Cherty layers are very common in this formation; they usually are less than 1 inch thick, but their greater hardness causes them to form ridges on the weathered surfaces. This banded or furrowed character is well exposed in the limestone on the east slope of Garnet mountain.

At Wolverine Pass (see pls. 75, 76), high cliffs of thin layers of bluish-gray limestones are finely exposed and readily accessible. It was here that Mrs. Walcott and I collected a few characteristic Upper Cambrian fossils.

Thickness.—Allan measured a partial section on the east side of Ice River Valley that has a thickness of 1,550 feet (472.4 m.) and a more complete section on the south slope of Ottertail Valley, where the total thickness of the formation is 1,640 feet (499.9 m.). There is an apparent rapid thickening of the Ottertail to the southeast, where, on Limestone Peak Allan estimated a thickness of 2,450 feet (746.8 m.) of limestone.[1] It is possible, however, that the upper portion of this inaccessible section may be formed of the siliceous limestone and shale of the superjacent Goodsir formation.

Geographic distribution.—The Ottertail, like the overlying Goodsir and subjacent Chancellor formation, is, as far as known, narrowly limited in its east and west distribution to the Ottertail and Vermilion Ranges southeast of the Kicking Horse River, although it probably continues southeast into the Mitchell Range between the Kootenay River and the Continental Divide. I noted, a little north of Cross River, a series of thin-bedded, bluish-gray limestones with shaly partings that closely resemble the Ottertail limestones, and similar strata occur on the northeastern slope of the Beaverfoot-Brisco-Stanford Range; presumably the greater part of the Beaverfoot River Valley, as well as the Kootenay River Valley nearly to Palliser River, is underlain by the Ottertail and Goodsir formations. How far north-

[1] Loc. cit., p. 86.

west of the Kicking Horse River the Ottertail formation may extend is unknown.

Stratigraphic relations.—These have been described by Allan as follows:

> The upper and lower contacts of the formation are everywhere sharply marked and can be located, especially when viewed from a short distance, within a few feet. At the lower contact are the red weathering beds of the Chancellor formation, while at the upper contact is another thin-bedded slaty series very distinct in character from the more resistant blue limestone of the Ottertail formation. This formation is, therefore, a unit, and can almost always be readily distinguished from the overlying and underlying formations and forms a good horizon marker.

Organic remains.—Allan found many fragments of fossils among which only two genera could be provisionally identified—*Lingulella,* and cranidia of a small trilobite that belongs to some one of the genera to which are now being referred American forms heretofore referred to *Ptychoparia.*

In a band of gray limestone, made up of layers from 3 inches (7.6 cm.) to 30 inches (76.2 cm.) in thickness, that occurs about 200 feet (60.9 m.) from the base of the Ottertail formation at Wolverine Pass, Mrs. Walcott and I found many fragments and a number of nearly entire trilobites. The fauna (Loc. 63x) contains *Obolus myron* Walcott, *Lingulella siliqua* Walcott, and a trilobite belonging to an undescribed genus that appears to be related to *Kainella.*

Observations.—The Ottertail formation is clearly defined by its lithologic characters and fauna and by an easily recognized line of demarcation at both base and summit. Its fauna as far as known is quite distinctive, and as it is overlain by Upper Cambrian, it may also be placed in that division.

The limestones and calcareous shales composing the formation are more of the type of those of the superjacent Goodsir formation than of any other formation either in the Goodsir or Beaverfoot Troughs. Mr. J. F. Walker has correlated the thick-bedded, rough-weathering arenaceous and magnesian limestones beneath the Sabine formation in the Stanford Range in Sinclair Canyon, at the mouth of Stoddart Canyon, and along the range to the south as far as Sabine Mountain, with the Ottertail formation, but in my judgment, this correlation is not supported by lithologic, stratigraphic, or paleontological evidence. I will speak of this more fully under the Lyell formation (p. 228).

Chancellor Formation. Allan, 1914

Type locality.—East and north slopes of Chancellor Peak, on the southwest side of the Ottertail Range.

Derivation of name.—From Chancellor Peak.

Character.—(After Allan.)

The formation is characterized throughout its thickness by its remarkable lithological uniformity and by the reddish colour of the weathered outcrops of its upper portion. In general the unaltered portion of the series of beds is thin-bedded with a slaty cleavage parallel with the stratification plane.

The lower members of the formation are greyish, calcareous shales, meta-argillites and argillites, sometimes even phyllitic in character towards the bottom of the section, weathering greenish, greyish, reddish, yellowish, and buff.[1]

A characteristic feature of these rocks is their banded character as developed on weathered surfaces. A rock may be dark grey on the fresh surface, but where weathered it appears to be composed of bands of grey, alternating with others of red, yellow, or brown colour. In other examples the fresh rock may be a blue limestone or calcareous slate, and yet where weathered it shows a distinct banding due to alternating bluish and buff coloured layers, or bluish and yellowish layers. Again, as it frequently happens, certain bands resist the action of the atmosphere and stand out as ridges on the weathered surface. It was found that in some cases these harder layers were siliceous, while the softer ones were calcareous. In other instances the harder layers were dolomitic, and the softer, calcareous, or the harder might be calcareous and the softer argillaceous. At different localities several hundred feet of sediments were found displaying the results of such differential weathering.

It is somewhat difficult to realize under what conditions these sediments were laid down in order to produce their banded structures. It seems to the writer that these alternating bands, with their different qualities so prominently developed under the influence of weathering, indicate seasonal variations of atmospheric conditions during the period of deposition. That is to say, the harder and more siliceous layers may each represent the amount of sedimentation during the annual season of heavy rainfall, when relatively coarse material would be washed down into the inland sea, while the softer layers may represent the product of the dry season when only the finer material would be washed out from the shore.[2]

Thickness.—Allan gives 1,162 feet (354.2 m.) as the total thickness in the Ice River Valley on the east side of Chancellor Peak, and states that there are thicker and better exposed sections on the southwest slope of the Ottertail Valley, and that northwest of Mount Hunter in the Van Horn Range, the Chancellor formation is about 4,500 feet (1,371.6 m.) thick.[3] I examined the Chancellor on the slopes east

[1] Loc. cit., p. 77.

[2] Idem, pp. 83, 84.

[3] Idem, p. 84.

and northeast of Wolverine Pass in the Ottertail Range, but did not find a satisfactory section for measurement. The contact with the superjacent Ottertail limestones is plainly shown a little north of the Pass.

Geographic distribution.—The Chancellor formation appears to be a local deposit in the same sense as the Ottertail, as both are limited to the Ottertail and Vermilion Ranges and adjoining valleys to the northeast drained by the Ottertail and Vermilion rivers. It may continue to the southeast into the Mitchell Range, where the topography, as seen from the Kootenay Valley, strongly suggests that it was eroded from the shaly strata of the Chancellor formation. Allan states that the sheared zone is limited on the northeast by the Stephen-Dennis fault; also that the formation forms the base of the Van Horn Range northeast of the Ottertail Range and Kicking Horse River.[1]

Stratigraphic relations..—The relations of the upper boundary of the Chancellor to the superjacent Ottertail limestones are clearly shown in numerous sections in the Ottertail Range. The limestones form cliffs and steep ledges in strong contrast with the slopes and rounded ridges and knolls of the Chancellor shales (see pl. 75). Allan found a massive limestone to the northwest of Mount Hunter in the Van Horn Range, subjacent to the shales of the Chancellor[2] which he assumed to be the representative of the Sherbrook formation (see p. 242).

Fauna.—The only fossils reported by Allan were from the Van Horn Range. They include some poor specimens of *Lingulella, L. isse* Walcott? and *Agnostus* sp.?[3] I found a number of poor specimens of *Agnostus* east of Wolverine Pass.

I noted in Hoodoo Canyon, between Chancellor and Vaux Mountains, large boulders of a light gray quartzitic sandstone 3 to 5 feet (.9 to 1.5 m.) in diameter. One boulder, 5 feet (1.5 m.) through, had many vertical *Scolithus* (Annelid) borings from 5 to 10 millimeters in diameter and filled with white quartz. The borings were more irregular than *Scolithus linearis* of the *Olenellus* zone of the Appalachian region. The boulders were probably derived from a lentil of sandstone in the Upper Cambrian, possibly in the Chancellor formation. I also noted other boulders with filled annelid borings penetrating them in a very irregular manner.

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[1] Loc. cit., p. 81.

[2] Idem, p. 84.

[3] Idem, p. 80.

Sherbrook Formation. Walcott, 1908[1]

Type locality.—West spur of Mount Bosworth, east and above Sherbrook Lake, northwest of Hector Station on the Canadian Pacific Railway.

Derivation of name.—From Sherbrook Lake.

Character and thickness.—Massive-bedded, gray and bluish-gray limestone with more or less chert in the upper 285 feet (86.9 m.), superjacent to 190 feet (57.9 m.) of oolitic gray limestone, beneath which greenish-drab and gray siliceous shales, with interbedded, oolitic layers, extend for 335 feet (102.1 m.). Below this, a belt of gray oolitic limestone 65 feet (19.8 m.) thick is superjacent to 610 feet (185.9 m.) of arenaceous, dolomitic, steel-gray limestone. The total thickness is 1,485 feet (452.6 m.).

Geographic distribution.—The Sherbrook as a distinct formation is known only in the western part of Mount Bosworth. It has not been traced to the east, northwest, or north, unless the Sullivan formation of the Glacier Lake section represents it.

Stratigraphic relations.—On Mount Bosworth the gray limestones of the Sherbrook are usually clearly separated from the subjacent dark bluish-gray limestones of the Paget, but in some sections it is difficult to recognize a distinct line. The Chancellor shales are reported by Allan as superjacent to thick-bedded limestones in the Van Horn Range which he correlated with the limestones of the Sherbrook formation of the Mount Bosworth section. As far as known to me this correlation was a theoretical one, based on the occurrence of a "massive limestone" beneath the Chancellor shales 2 miles (3.2 km.) east of Leanchoil Station on the Canadian Pacific Railway.

Fauna.—The known fauna is limited to a few species from the middle and upper parts of the section. It includes *Lingulella isse* Walcott from the shales, and fragments of trilobites, including *Crepicephalus,* from the limestone.

The Sherbrook fauna is closely related to the *Crepicephalus* fauna that occurs in the lower portion of the Upper Cambrian of Missouri and in Patterson Canyon, Snake Range, Nevada. It is to be correlated with the upper portion of the Eau Claire formation of Wisconsin.

Paget Formation. Walcott, 1908[2]

Type locality.—Paget Peak, and western slope of Mount Bosworth on the Continental Divide.

Derivation of name.—From Paget Peak.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 204.

[2] Idem, p. 205.

Character.—Massive-bedded, dark bluish-gray limestones 60 feet (18.3 m.) at the top, with thick layers of gray oolitic limestone with interbedded bands of green siliceous shale below.

Thickness.—At Mount Bosworth, 360 feet (109.7 m.).

Geographic distribution.—Known only at Mount Bosworth, Paget Peak, and northwest along the Continental Divide to Mount Daly.

Stratigraphic relations.—This formation might be included with the Sherbrook, as its upper 60 feet (18.3 m.) of heavy, blue limestone is underlain by 300 feet (91.4 m.) of gray oolitic beds much like the oolitic limestone of the Sherbrook. There are no diagnostic forms that serve to distinguish it from the Sherbrook fauna. My reason for separating it as a distinct formation was because it forms a marked topographic feature on Mount Bosworth and on Paget Peak.

Bosworth Formation. Walcott, 1908[1]

Type locality.—South side of Mount Bosworth on the Continental Divide above Kicking Horse Pass.

Derivation of name.—From Mount Bosworth.

Character and thickness.—Alternating bands of thick, shaly layers, and thin layers of dolomitic limestone, with 48 feet (14.6 m.) of intercalated siliceous shale, forming a series 1,587 feet (483.7 m.) thick on Mount Bosworth.

At Castle Mountain, 20 miles (32.2 km.) southeast of Mount Bosworth, the formation has a thickness of 423 feet (128.9 m.). In the Ranger Canyon section of the Sawback Range, 10 miles (16.1 km.) south-southeast of the Castle Mountain section, 165 feet (50.3 m.) of gray oolitic limestone is referred to it, and at Cotton Grass Cirque, 11 miles (17.7 km.) north of Castle Mountain section, the Bosworth is represented by 500 feet (152.4 m.) of limestone, arenaceous limestone, and shale. On Ghost River, 32 miles (51.5 km.) east of Castle Mountain, it is entirely absent through non-deposition. The upper strata of the Bosworth in the Sawback Range sections vary from thin layers of gray oolitic limestones interbedded in arenaceous shales to alternating beds of shale and thin layers of compact sandstone. No evidence of an unconformity was observed at the summit of the Bosworth, but a disconformity exists by non-deposition of the Paget, Sherbrook, and more or less of the upper part of the Bosworth in the Sawback Range area.

Geographic distribution.—The Bosworth is a formation that was largely deposited in the central area of the Cordilleran Geosyncline;

[1] Loc. cit., pp. 205, 208.

it thins rapidly eastward and changes in character to the northwest, and has not been recognized in the Glacier Lake section. How far it extends to the southeast is unknown.

Stratigraphic relations.—The upper limit of the Bosworth at Mount Bosworth is clearly defined by the abrupt change from its thick layers of gray magnesian limestone to the oolitic limestones of the Paget formation. The base is readily distinguished from the shallow water, estuarian-like deposits of the Arctomys formation.

Fauna.—I have seen only a few fragments of trilobites and an *Obolus* from the Bosworth formation.

Sullivan Formation. Walcott, 1919, 1923[1]

Type locality.—In the cliffs on the north side of Glacier Lake Canyon, east of southeast branch of Lyell glacier and south of Mount Sullivan.

Derivation of name.—From Mount Sullivan.

Character.—This is largely an arenaceous and siliceous shale with much interbedded, compact, hard, gray, and in the lower half, oolitic limestones.

Thickness.—The only section measured gave a total thickness of 1,440 feet (438.9 m.).

Geographic distribution.—Known only at Glacier Lake and the headwaters of the Saskatchewan River drainage, but it may be that when an areal geologic map is made the Sullivan may be traced into some Upper Cambrian formation of the Sawback Range and the Kicking Horse section. To the northeast of the Castleguard River and to the south of Mount Castleguard the characteristic erosion of the Sullivan shales and interbedded limestones is finely shown in the sharp ridges and points rising above the alplands. The formation has not been recognized in the Robson Peak District.

Stratigraphic relations.—The top of the series of arenaceous shales was taken as the summit of the formation. This line is clearly outlined beneath the cliff formed by the compact, hard limestone at the base of the Lyell. The lower boundary is even more distinctly seen where the shales rest on the light gray laminated limestones of the Arctomys formation.

Fauna.—This formation contains a *Crepicephalus* fauna and hence is to be correlated with the Sherbrook and Paget formations.

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[1] Smithsonian Misc. Coll., Vol. 67, No. 8, p. 461.

Lynx Formation. Walcott, 1913[1]

Type locality.—Chushina Ridge from Snowbird Pass to Lynx Mountain; also on Iyatunga, Robson Peak District.

Derivation.—From Lynx Mountain.

Character.—Thin-bedded, bluish-gray limestones with alternating bands of calcareous light gray shale.

Thickness.—Measured on Iyatunga Mountain (Burling), 2,765 feet (842.8 m.).

Geographic distribution.—Not known outside of the Robson massif, but it probably extends to the north and south and also east and southeast of Moose Pass in the Tokana Mountains.

Fauna.—Upper Cambrian apparently to be correlated with the Lyell formation.

At the base a thick band (200 feet, 60.9 m.) of gray, greenish, and reddish-brown siliceous and arenaceous shales, containing mud cracks and ripple marks, would appear to represent the Arctomys.

Arctomys Formation. Walcott, 1919[2]

Type locality.—South slopes of Sullivan and Survey Peaks on the north side of Glacier Lake (pl. 26 at B).

Derivation of name.—From Arctomys Peak situated a short distance northwest of the type locality.

Character.—Finely laminated, smooth-surfaced limestones overlying siliceous, arenaceous, and calcareous shales and interbedded laminated limestones; the entire formation at Glacier Lake conveys the impression that it was a deposit of fine silts, sands, and calcareous muds or slimes in a shallow sea that marked the beginning of the Upper Cambrian in the Cordilleran Geosyncline in this area. At Mount Bosworth, Ranger Brook Canyon, and Cotton Grass Cirque, ripple marks, mud cracks, and casts of salt crystals occur on the hard, finely arenaceous, shaly layers.

The formation appears to represent the period of deposition of a series of shallow fresh-water deposits, alternating with brackish water and marine sediments such as would occur in a shallow sea near the mouth of a large river, bringing fine sand, mud, and slimes derived from low, old land surfaces. These fine shales and sandstones alternate with more or less thin, calcareous and arenaceous layers and have on their surfaces ripple marks, mud cracks, and casts of salt crystals. They represent, in the Bow Valley area, the period of transition from

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, p. 334.

[2] Idem, Vol. 67, No. 8, p. 461.

the massive Middle Cambrian Eldon limestone beneath to the quite different magnesian limestones of the Upper Cambrian Bosworth formation above.

Thickness.—At the type locality near Glacier Lake, 1,386 feet (422.4 m.) (pl. 26 at B). At Cotton Grass Cirque, 48.5 miles (78 km.) southeast of Glacier Lake section, 725 feet (220.9 m.), and in the Ranger Canyon section, 69 miles (110 km.) southeast of Glacier Lake, 95 feet (28.9 m.) (pl. 26 at H). The formation appears to be represented by the lower 268 feet (81.7 m.) of the Bosworth formation included in the Mount Bosworth section of 1908,[1] which is 42 miles (67.6 km.) south-southeast of Glacier Lake (pl. 26 at Q). In the Robson Peak District, about 125 miles (201.1 km.) north-northwest of Glacier Lake, the Lynx formation of the Upper Cambrian has at its base 200 feet (60.9 m.) of shallow water arenaceous shales that represent the Arctomys formation. The shales are superjacent to the Titkana limestones of the Middle Cambrian and at the base of the Upper Cambrian.

Geographic distribution.—Glacier Lake Canyon and headwaters of Saskatchewan River. It occurs to the southwest in the Ranger Brook Canyon section of the Sawback Range, and is represented at Mount Bosworth on the north side of the Bow River Valley. The particolored arenaceous shales at the base of the Lynx formation of the Robson massif at Snow Bird Pass represent the Arctomys formation in the Robson Peak District.

Stratigraphic relations.—The Arctomys formation is definitely bounded by the Upper Cambrian Sullivan formation above, and the Middle Cambrian Murchison formation below, in the Glacier Lake section, and its representative in the Sawback Range sections at Cotton Grass Cirque, Ranger Brook Canyon, and Mount Bosworth has the Upper Cambrian Bosworth above and the Middle Cambrian Eldon formation below. In the Kicking Horse Pass section on Mount Bosworth the Arctomys is clearly defined at its base where it rests on the Middle Cambrian Eldon limestone, which does not appear to be represented in the Glacier Lake section.

MIDDLE CAMBRIAN

Eldon Formation. Walcott, 1908[2]

Type locality.—Southeast slope of Castle Mountain opposite Eldon on the Canadian Pacific Railway.

Derivation.—From Eldon station.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 208.

[2] Idem, No. 1, p. 3.

Character.—Light gray with some dark gray siliceous and arenaceous limestones, mainly in thick layers grouped in massive bands that form great cliffs on Castle Mountain, Mount Bosworth and Mount Stephen (see pls. 38, 39, 67, 70). A band of bluish-gray, thin-bedded limestone occurs towards the top, one about midway, and another about 700 feet (213.4 m.) from the base on Mount Stephen.

Thickness.—At Castle Mountain, 1,905 feet (580.6 m.); in the Mount Bosworth section, 22 miles (35.4 km.) northwest of Castle Mountain, 2,728 feet (831.5 m.); and on Mount Stephen, about 8 miles (12.9 km.) southwest of Mount Bosworth, 2,840 feet (865.6 m.).

Geographic distribution.—Castle Mountain and northwest, at Mount Bosworth, and at Mount Stephen. It may extend to the southwest in the "Main Range" southwest of the Continental Divide. I have not seen it north of the Bow Valley, and it is absent in the Siffleur River section.

Fauna.—Middle Cambrian and related to the fauna of the subjacent Stephen formation. Very few of the species are yet described.

Observations.—The Eldon was deposited in the central portion of the Cordilleran Geosyncline, where the greatest thickness of Cambrian sediment accumulated. Like the Goodsir of the Upper Cambrian, it was a relatively local deposit.

Stephen Formation. Walcott, 1908[1]

Type locality.—Northwest side of Mount Stephen, above Field.

Character.—On Mount Stephen, calcareous, siliceous, and finely arenaceous shales with more or less argillaceous matter, superjacent to a thick band of bluish-black limestones in thin layers, which in turn is underlain by a series of oolitic and gray limestones alternating with bands of dolomitic limestone and a few bands of siliceous shale.

Thickness.—At Mount Stephen, 712 feet (217 m.), at Mount Bosworth, 640 feet (195.1 m.), and at Castle Mountain, 366 feet (111.6 m.). In the Siffleur River section, 36 miles (57.9 km.) north of Mount Bosworth, the Murchison formation that occupies the stratigraphic position of the Stephen is 497 feet (151.5 m.) in thickness.

Geographic distribution.—Mount Stephen, Mount Bosworth to Castle Mountain, a distance of about 31 miles (49.9 km.). It extends southeast of the Bow Valley in the "Main Range," but how far is unknown. To the north about 40 miles (64.4 km.) it is represented

[1] Loc. cit.

in the Saskatchewan Valley by the Murchison formation, and 125 miles (201.1 km.) to the north, in the Robson Peak section, by the Titkana formation.

Fauna.—The large and abundant fauna is of Middle Cambrian age. Some of the genera and species are listed in the section.

Murchison Formation. Walcott, 1919, 1923[1]

Type locality.—Cliffs south and above Siffleur River, about 12 miles (19.3 km.) east-northeast of Mount Murchison.

Derivation of name.—From Mount Murchison.

Character.—Bluish-black compact limestones above and below, 120 feet (36.6 m.) of dove-colored and gray limestones.

Thickness.—497 feet (151.5 m.) in the Siffleur section.

Geographic distribution.—Known only about the headwaters of the Saskatchewan River at Glacier Lake, Mount Murchison, and above the Siffleur River in the northeastern spurs of Mount Sedgwick. The Murchison may prove to be the same formation as the Stephen of Mount Stephen above Field, British Columbia, but in the absence of the Eldon above it, a close correlation cannot be made.

Stratigraphic relations.—A massive-bedded, dolomitic limestone occurs beneath the Murchison that is of the same type as the Cathedral limestone of the Mount Bosworth and Mount Stephen sections of the upper Kicking Horse Canyon area, but the upper limit is defined by the presence of thin, parti-colored layers of dolomitic limestones of the Arctomys formation.

Fauna.—The Murchison formation appears to contain a typical Stephen fauna.

Titkana Formation. Walcott, 1913[2]

Type locality.—Titkana Peak, Robson Peak District.

Derivation.—From Titkana Peak.

Character.—Massive-bedded, bluish gray limestones composed of thin layers that break down on weathered slopes. Bands of hard, gray, siliceous and dolomitic buff-weathering limestones, 50 to 100 feet (15.2 to 30.5 m.), are interbedded at irregular intervals.

Thickness.—As hastily measured and estimated, 2,200 feet (670.6 m.).

Geographic distribution.—As far as known, the Titkana occurs only in the Robson Peak District. It may be compared with the

[1] Smithsonian Misc. Coll., Vol. 67, No. 8, p. 462.

[2] Idem, Vol. 57, No. 12, p. 334.

Murchison of the Saskatchewan River area and the Stephen of the Bow River Valley-Kicking Horse River sections, and as surveys are extended along the main range to the north and south of Robson Peak District, the formation will presumably be found to have a wide distribution.

Fauna.—Middle Cambrian, resembling the Stephen fauna.

Observations.—In the future the Titkana as a formation may be found to change its lithological character and volume from place to place, and it will then receive distinctive names.

CATHEDRAL FORMATION. WALCOTT, 1908[1]

Type locality.—South face of Mount Bosworth between Hector and Stephen on the Canadian Pacific Railway, also finely exposed in Cathedral Crags east of Mount Stephen.

Derivation of name.—From Cathedral Crags.

Character.—More or less arenaceous, thick and thin layers of hard, gray limestone forming fine cliffs where not broken down.

Thickness.—At Mount Bosworth, 1,212 feet (369.4 m.), at Castle Mountain in the Bow Valley, 705 feet (214.9 m.), and in the Siffleur River section 34 miles (54.7 km.) north, 1,240 feet (377.9 m.). It may be that the Ptarmigan formation is included in the lower portion of the Siffleur section, but in the cliff exposures there was no evidence of this obtainable.

Geographic distribution.—Mount Bosworth, Cathedral Crags, Mount Stephen in Kicking Horse Canyon area. Cliffs of Mount Sedgwick on south side of Siffleur River.

Stratigraphic relations.—Upper limit defined by the thin-bedded, dark, bluish-gray limestones of the Stephen formation in the Kicking Horse Canyon area and by similar limestones in the Siffleur River section. The lower boundary is clearly marked in the northern cliffs of Popes Peak at Ross Lake on the south side of Kicking Horse Pass opposite Mount Bosworth.[2] The Cathedral terminates below in a massive-bedded, rough, arenaceous limestone that rests conformably on a thin-bedded, arenaceous, mottled limestone of the Ptarmigan formation. This same relation also occurs in the eastern cliffs of Mount Bosworth overlooking the Bow River Valley.

Fauna.—Annelid trails and borings only.

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[1] Smithsonian Misc. Coll., Vol. 53, No. 1, p. 4.

[2] Idem, Vol. 67, No. 2, 1917, pp. 13, 14, pl. 2.

TATEI FORMATION. WALCOTT, 1913[1]

Type locality.—Tatei Ridge northeast of Titkana Peak, Robson Peak District.

Derivation.—From Tatei[2] Ridge.

Character.—Thick-bedded, siliceous and arenaceous, gray, cliff-forming limestones.

Thickness.—800 feet (243.8 m.).

Fauna.—Unknown.

Observations.—The Tatei, on account of its hard, thick-bedded limestones, resists erosion to a greater extent than the limestones of the Titkana and subjacent Chetang, and despite long-continued glaciation forms a marked cliff on the ridge northeast of Titkana Peak. It is probably a relatively local deposit and may not be recognized outside of the Robson District.

PTARMIGAN FORMATION. WALCOTT, 1917[3]

Type locality.—South base of Ptarmigan Peak, 4.75 miles (7.7 km.) northeast of Lake Louise Station on the Canadian Pacific Railway.

Derivation of name.—From Ptarmigan Peak.

Character.—More or less arenaceous gray limestone, with interbedded bands of thinner-bedded, dark bluish-black limestones and some interbedded beds of shale.

Thickness.—At Ptarmigan Peak, 516 feet (157.3 m.); at Bow Lake 20 miles (32.2 km.) northwest of Ptarmigan Peak, 534 feet (162.8 m.); at Ross Lake, 8.5 miles (13.7 km.) west-southwest of Ptarmigan Peak, 664 feet (202.4 m.); at Castle Mountain in Bow Valley, 272 feet (82.9 m.); at Ghost River on Rocky Mountain front, 1,122 feet (341.9 m.).

Geographic distribution.—Ptarmigan Peak, Mount Bosworth, Mount Pope, Rocky Mountain front between Devils Gap and Ghost River, and presumably far to the north up the Bow Valley and to the north of the Saskatchewan River. Its characteristic *Albertella* fauna occurs in the Robson District section above Coleman Brook, and far to the south of the Bow Valley near the North Kootenay Pass.

Fauna.—A large and varied lower Middle Cambrian fauna, that was described and illustrated in 1917,[4] occurs in the section at Ross Lake.

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[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 334.

[2] Name first spelled Tatay, but was afterward changed to Tatei by Geographic Board of Canada.

[3] Smithsonian Misc. Coll., Vol. 67, No. 1, 1917, pp. 1-4.

[4] Idem, No. 2.

This fauna is known from its characteristic trilobite as the *Albertella* fauna.

Chetang Formation. Walcott, 1913[1]

Type locality.—Cliffs west of and above Coleman glacier, Robson Peak District.

Derivation.—From Chetang Cliffs.

Character.—Bluish-gray, evenly-bedded limestones in thin layers, with very little shale in the partings between the layers.

Thickness.—Above Coleman glacier and Brook, 900 feet (274.3 m.).

Geographic distribution.—Chetang cliffs and probably to the northwest and southeast.

Fauna.—Middle Cambrian *Albertella* fauna, which occurs in the Ptarmigan formation north and south of Kicking Horse Pass.

Observations.—The sedimentation of the Chetang formation is not unlike portions of the Titkana, from which it is separated by the hard Tatei limestones 800 feet (243.8 m.) in thickness.

LOWER CAMBRIAN

Mount Whyte Formation. Walcott, 1908[2]

Type locality.—North slope of Mount Whyte and southwest of Lake Louise.

Derivation of name.—From Mount Whyte.

Character.—Alternating bands of gray and bluish-black limestone. Siliceous and calcareous shales, with some interbedded sandstones near the lower part.

Thickness.—At Mount Whyte, 386 feet (117.6 m.), south slope of Mount Bosworth, 390 feet (118.9 m.); north side Mount Stephen above railroad tunnel, 315 feet (96 m.); at Bow lake, 21 miles (33.8 km.) north-northwest of Mount Whyte, 762 feet (232.3 m.); at Ptarmigan Peak, 9 miles (14.5 km.) northeast of Mount Whyte, 252 feet (76.8 m.); southeast slope of Castle Mountain, 248 feet (75.6 m.); in cliffs at south side of Siffleur River, 446 feet (136 m.).

Geographic distribution.—The formation is widely distributed both to the north and south of the Bow River Valley. It appears to be represented by the Hota formation in the Robson Peak District and it occurs in the Saskatchewan River Valley area on Mount Sedgwick south of the Siffleur River. To the south it may be represented by

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 335.

[2] Idem, Vol. 53, No. 1, 1908, p. 4.

the arenaceous shales near Cranbrook, and it is finely developed at Mount Schaffer and other localities along the main range of the Rocky Mountains.

Fauna.—The known fauna includes 28 genera and 60 species, and a restudy of the material now in progress will undoubtedly add a large number of species and probably genera. The fauna includes representatives of both Lower and Middle Cambrian genera.[1] In fact at the present time, until more diastrophic evidence has been obtained, the exact boundary between the Middle and Lower Cambrian cannot be drawn with any degree of certainty.

Observations.—The formation name Mount Whyte was proposed in 1908[2] for a series of alternating bands of limestone and siliceous and calcareous shale some 386 feet (117.7 m.) in thickness as found on the north slope of Mount Whyte above Lake Agnes and about 2 miles (3.2 km.) west of the outlet of Lake Louise, Alberta. Later[3] a detailed section was published, accompanied by preliminary lists of the genera and species of fossils that had been found at several horizons, and a list of species found in drift blocks on the south slope of Mount Bosworth that were supposed to have been derived from the Mount Whyte formation, but which later work has proved to have come from a higher horizon.

St. Piran Formation. Walcott, 1908[4]

Type locality.—Slopes of Mount St. Piran a little northwest of Lake Louise.

Derivation of name.—From Mount St. Piran.

Character.—This is essentially a sandstone formation, with some greenish, siliceous and arenaceous shales in its upper portion. The sandstones are more or less quartzitic in the middle and lower parts of the section, and vary in color from light gray to dirty gray. brownish, purplish, and pink.

Thickness.—At Mount St. Piran, 2,705 feet (824.5 m.). In the Mount Bosworth section, about 5 miles (8 km.) northwest of Mount St. Piran, 503 feet (153.3 m.) is exposed, followed below by the Lake Louise shale, 105 feet (32 m.), and the Fort Mountain quartzitic sandstone, 600+ feet (182.9+ m.) in thickness, all of which may be included but have not been recognized in the Mount St. Piran section. At Castle Mountain, 24 miles (38.7 km.) southeast of Mount St.

[1] Smithsonian Misc. Coll., Vol. 67, No. 3, 1917, pp. 62-67.

[2] Idem, Vol. 53, No. 1, 1908, p. 4.

[3] Idem., No. 5, pp. 212-215.

[4] Idem, Vol. 53, No. 1, p. 4.

Piran, the formation has a thickness of 55+ feet (16.8+ m.), with the base concealed by débris. In the cliffs on the south side of the Siffleur River, it is 770 feet (234.7 m.) thick, with base concealed beneath the talus.

Geographic distribution.—Upper Kicking Horse Canyon at Mount Stephen. North and south sides of Bow River Valley from Mount Bosworth on Continental Divide to Castle Mountain. In the upper Saskatchewan Valley in the cliffs on the south side of Siffleur River It may be represented by the Mahto sandstones in the Robson Peak District. To the south it presumably occurs in the Mount Assiniboine massif above Gog Lake, and in the north ridge of Wedgewood Peak.

Fauna.—Annelid trails and borings, *Hyolithes* sp., fragments of *Olenellus* cf. *O. canadensis* Walcott, and small trilobites.

Hota Formation. Walcott, 1913[1]

Type locality.—Southwest spur of Mahto Mountain, Robson Peak District.

Derivation.—From Hota cliffs on the north side of Coleman Brook and the southwest side of Mahto Mountain.

Character.—Massive-bedded, arenaceous limestones in great bands of light and dark gray color and a pinkish-weathering band in the upper portion.

Thickness—On Mahto Mountain, 800 feet (243.8 m.).

Geographic distribution.—Southwest side of Mahto Mountain and probably to the southeast to Moose River and to the northwest in the high ridge southeast of Smoky River below Calumet Creek.

Fauna.—Lower Cambrian.[2]

Observations.—The Hota occupies the stratigraphic position of the Mount Whyte formation of the Bow River Valley and Saskatchewan sections but it differs in its more uniform series of thick-bedded, arenaceous limestones. The same sort of *Mesonacidae* occurs in each, which makes it probable that the two formations were being deposited about the same time but from different sources of sediment.

Lake Louise Shale. Walcott, 1908[3]

Type locality.—In cliffs on the Beehive and Fairview Mountain above upper end of Lake Louise.

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 335.

[2] Idem, No. 11, 1913, p. 309. By error all the fossils from the Robson Peak region described in this paper were referred to the Mahto formation which however is unfossiliferous.

[3] Idem, Vol. 53, No. 1, p. 4.

Derivation.—From Lake Louise, Alberta.

Character.—Compact, gray siliceous shale.

Thickness.—At Lake Louise on the northeast side of the Beehive, 105 feet (32 m.).

Geographic distribution.—This shale is limited as far as known to the vicinity of Lake Louise and along the front of the Bow Range to Vermilion Pass.

Fauna.—Annelid and trilobite trails, a small brachiopod, *Micrometra* (*Iphidella*) *louise* Walcott, a *Hyolithes,* and a fragment of a trilobite.

Observations.—The Lake Louise shale is a good horizon marker and locally serves to separate the St. Piran and Fort Mountain formations. It may extend across Bow River Valley into Mount Bosworth, but it was not seen there or at Redoubt Mountain.

Fort Mountain Formation. Walcott, 1912[1]

Type locality.—Redoubt Mountain, about 5 miles (8 km.) north of Lake Louise Station on the Canadian Pacific Railway.

Derivation.—From Redoubt[2] Mountain.

Character.—Massive-bedded, cliff-forming, purplish, hard, fine-grained quartzitic sandstones, with bands of siliceous and finely arenaceous shale in lower portion. An arenaceous, quartzitic basal conglomerate occurs in some localities.

Thickness.—At Redoubt Mountain the formation is finely exposed, but it was not measured in detail. The basal conglomerate is 360 feet (109.7 m.) in thickness with a band of shale 44 feet (13.4 m.) thick above it, and superjacent to the shale, several hundred feet of quartzitic sandstones. At Fairview Mountain (see p. 302), 940 feet (286.5 m.) in thickness is exposed, and on the north slope of Mount Temple, the lower sandstone outcrops down to its contact with the pre-Cambrian. In its greatest development the formation has a thickness of 1,324 feet (403.5 m.) on the south side of the Bow River Valley.

Geographic distribution.—The formation is known from Mount Stephen eastward to Kicking Horse Pass and southeast down the Bow River Valley to Castle and Copper Mountains. It forms a great

[1] Monogr. U. S. Geol. Surv., 51, p. 131.

[2] The name Fort Mountain occurs on a topographic map of the Rocky Mountains, Department of the Interior, Canada, 1903-1907, Arthur O. Wheeler, Topographer. On a map issued in 1914 of the Selkirk and Rocky Mountains, Department of the Interior, it is changed to Redoubt Mountain, and this is continued on subsequent maps, having been approved by the Geographic Board.

cliff on Wedgewood Peak of the Mount Assiniboine massif, and it occurs in the cliffs of Mount Sedgwick above the Siffleur River, 80 miles (128.7 km.) northwest of Assiniboine. The McNaughton sandstones of the Robson Peak section, 125 miles (201.1 km.) north of Mount Sedgwick, may represent the Fort Mountain in that area.

Fauna.—A few annelid trails and borings.

Observations.—The Fort Mountain formation represents the beach sands of the transgressing early Cambrian sea and probably occurs at the base of sections whenever the waters of the Lower Cambrian covered the irregular surface of the pre-Cambrian rocks that formed the bottom of the sea. At Redoubt Mountain and on Little Vermilion Creek northeast of Vermilion Pass, fine arenaceous conglomerates are superjacent to the pre-Cambrian, but in other localities where the pre-Cambrian surface was finely disintegrated the basal beds may be shales or fine sandstone.

MAHTO FORMATION. WALCOTT, 1913[1]

Type locality.—Mahto Mountain, between Calumet Creek and Coleman Brook in the northern part of the Robson Peak District.

Derivation.—From Mahto Mountain.

Character.—Massive-bedded quartzitic sandstones, with some thin layers of hard, compact sandstones and a few thin bands of dirty grayish-brown arenaceous shale.

Thickness.—On Tah and Mahto Mountains, southwest of Moose Pass, 1,800 feet (548.6 m.).

Geographic distribution.—Northeastern face of Mahto Mountain, and northwestern, north, and northeasterly slopes of Tah Mountain. A survey of the Moose and Smoky River area will undoubtedly extend the area of the formation to the northwest and southeast.

TAH FORMATION. WALCOTT, 1913[2]

Type locality.—Tah Mountain at Moose Pass, Robson Peak District.

Derivation.—From Tah Mountain.

Character.—Hard, siliceous, green and purple colored shales, with irregularly intercalated beds of compact, purple and gray limestone in central portion.

Thickness.—At Tah Mountain, 800 feet (243.8 m.).

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[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 335.

[2] Idem.

Geographic distribution.—Northeastern slope of Tah Mountain and southeast down Moose River Valley. It is probable that the high ridge northwest of Calumet Creek and northeast of Smoky River is formed of the Tah, Mahto, and higher formations.

McNaughton Formation. Walcott, 1913[1]

Type locality.—Moose Pass and McNaughton Mountain, northeast of Moose River and northwest of Grant Brook.

Derivation.—From McNaughton Mountain.

Character.—Light gray, massive-bedded quartzitic sandstones.

Thickness.—Estimated on McNaughton Mountain, 500+ feet (152.4+ m.).

Geographic distribution.—McNaughton Mountain and northwest to Moose Pass west of the Moose Pass fault.

Fauna.—None found.

ALGONKIAN

BELT SERIES

Hector Formation. Walcott, 1910[2]

Type locality.—Redoubt Mountain (referred to as Fort Mountain in 1910) (see pl. 46).

Derivation.—From Mount Hector, where Lower Cambrian strata are superjacent to the Hector formation.

Character.—Finely arenaceous and siliceous greenish, reddish, and purple shales. A thin intraformational conglomerate, composed of thin layers of compact, pinkish limestone in a fine arenaceous matrix, occurs 110 feet (33.5 m.) below the top of the shales, and 820 feet (249.9 m.) from the top there is a massive-bedded conglomerate of quartz pebbles and fragments of pinkish gray limestone in a coarse and fine-grained sandstone matrix. In the Mount Temple section a few layers of hard, dove-colored to pinkish limestone occur about 700 feet (213.4 m.) below the top of the Hector, and 855 feet (260.6 m.) below that a massive conglomerate, 365 feet thick (111.3 m.), formed of pebbles of quartz, sandstone, siliceous shale and fragments of a reddish-purple jaspery rock, all in a coarse sandstone matrix.

Thickness.—At Redoubt Mountain, 1,300 feet (396.2 m.), and on opposite side of Bow River Valley, on the northeast ridge of Mount Temple and northwest of the Valley of the Ten Peaks, 2,150+ feet (655.3+ m.).

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 335.

[2] Idem, Vol. 53, No. 7, 1910, p. 428.

Geographic distribution.—The Bow River Valley from west of Hector Lake nearly to Banff Station, a distance in direct line of about 45 miles (72.4 km.) is underlain by the Hector and Corral Creek formations. Northwest of Laggan (now Lake Louise Station) they extend up the Pipestone River nearly to the Little Pipestone and eastward entirely around the group of mountains of which Ptarmigan Peak is the highest point. Opposite Castle Mountain the exposures continue up Little Vermilion Creek, over 5 miles (8 km.).

Fauna.—None known.

Observations.—The upper part of the Hector is essentially the same at the east base of Ptarmigan Peak as at the south end of Redoubt Mountain, except that the dark gray shales are thinner, which brings the purple shales nearer to the Lower Cambrian. A little north of the head of Baker Lake, the shales of the Hector have been thrust eastward over the westward sloping Upper Devonian limestones (see pl. 45). There is a large exposure of the shales, and the contact of the basal bed of the Lower Cambrian with the Hector is finely shown.

Corral Creek Formation. Walcott, 1910[1]

Type locality.—Corral Creek northeast of Laggan (now Lake Louise Station).

Derivation.—From Corral Creek.

Character.—Coarse-grained, light-gray sandstones, with a few thick layers of fine quartz conglomerate; 120 feet (36.6 m.). Hard quartzitic sandstones that usually break up on exposure to weather. They are impure, and the quartz grains are a dead milky white, or glassy and stained.

Thickness.—Estimated on the hills adjoining Corral Creek 1,320+ feet (402.3+ m.) down to an anticline and greatly disturbed strata.

Geographic distribution.—Approximately the same as the Hector shales but more within the limits of the Bow River Valley.

Fauna.—None known.

Observations.—In northern Montana and a little north of the International Boundary a distance of from 140 to 175 miles (225.3 to 281.6 km.) south-southeast from the Bow River Valley, the Algonkian Camp Creek and Kintla-Shephard series of arenaceous shales and sandstones appear to have about the same stratigraphic position as the Hector-Corral Creek strata. They overlie the great Siyeh limestone which is not exposed in the Bow River Valley area but may underlie the valley as fragments of limestone occur in the Hector conglomerate. The Siyeh should be below the Corral Creek sandstones, if the two sections are at all similar.

[1] Loc. cit.

Miette Formation. Walcott, 1913[1]

Type locality.—Yellowhead Pass, Robson District.

Derivation.—From Miette River, which cuts through the Miette sandstones and shales east of Yellowhead Pass.

Character.—Massive-bedded, more or less dirty gray sandstones, with thick bands of gray and greenish siliceous shales.

Thickness.—Estimated at over 2,000+ feet (609.6+ m.) in Yellowhead Pass.

Geographic distribution.—Vicinity of Yellowhead Pass and northwest down the Frazer River as far as Grand Fork and north to Lake Kinney. To the east and north of the Pass its extension has not been traced.

Fauna.—No traces of life have been reported.

Observations.—The Miette is comparable in position with the Hector and Corral Creek formations of the Bow River Valley.

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, p. 335.

PART III

STRATIGRAPHIC SECTIONS

In this third part, detailed sections are given for all the more important localities where lower Paleozoic beds outcrop in the Rocky Mountains of Alberta and British Columbia, as far as they are available. The sections are usually in natural order, *i. e.,* the highest beds present or studied are described first, followed by the other beds in descending order. The localities represented are arranged in a geographic order, based as far as possible on mountain chains or groups. Without some such arrangement, one not familiar with the geography of the Canadian Rocky Mountains would find it very difficult to locate many of the places here discussed. This difficulty is further increased by the inadequate maps available.

These sections have not all been worked out in equal detail or accuracy, but they present what is now known concerning the character and thickness of the beds and the nature and relationships of the contained faunas. Much further and more detailed work is urgently needed throughout all of the region.

The faunal lists accompanying the sections contain but a small fraction of the species that have been collected, but as the rest are undescribed, the inclusion of their names in the lists would be useless.

DEVILS GAP AND GHOST RIVER AREA

In the cliffs of the Rocky Mountain front between the south fork of Ghost River and Red Deer River, the Devonian forms the upper cliffs, and Cambrian formations form the lower. Between the Devonian and the Cambrian, the thin Ghost River formation breaks down to form a terraced slope. No traces of the Ozarkian (Mons) were observed and there is no evidence of it having been removed by erosion. It is barely possible that the magnesian limestones of the Ghost River formation were deposited in Upper Cambrian time, but as stated previously, there is no proof for this view. The outstanding stratigraphic feature of this area is the absence of Silurian, Ordovician, Ozarkian, and some Upper and Middle Cambrian formations that are so well developed in the Sawback Range and the western side of the Rocky Mountains generally.

The section that follows is located 2 miles (3.2 km.) east-northeast of head of Lake Minnewanka on the north side of a broad canyon called Devils Gap, which is about 51 miles (82.1 km.) west of Calgary, Alberta, Canada. The Gap extends back from the east face of the cliffs 6 miles (9.6 km.) to Lake Minnewanka at right angles to the strike of the westward dipping strata so as to expose the Carboniferous, Devonian, and pre-Devonian formations in the lower portion

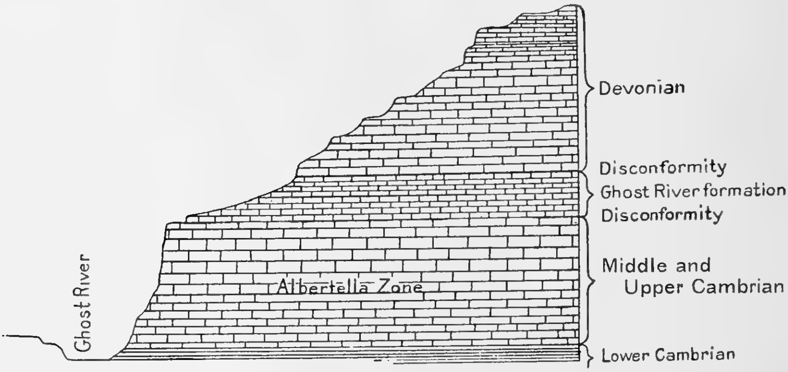


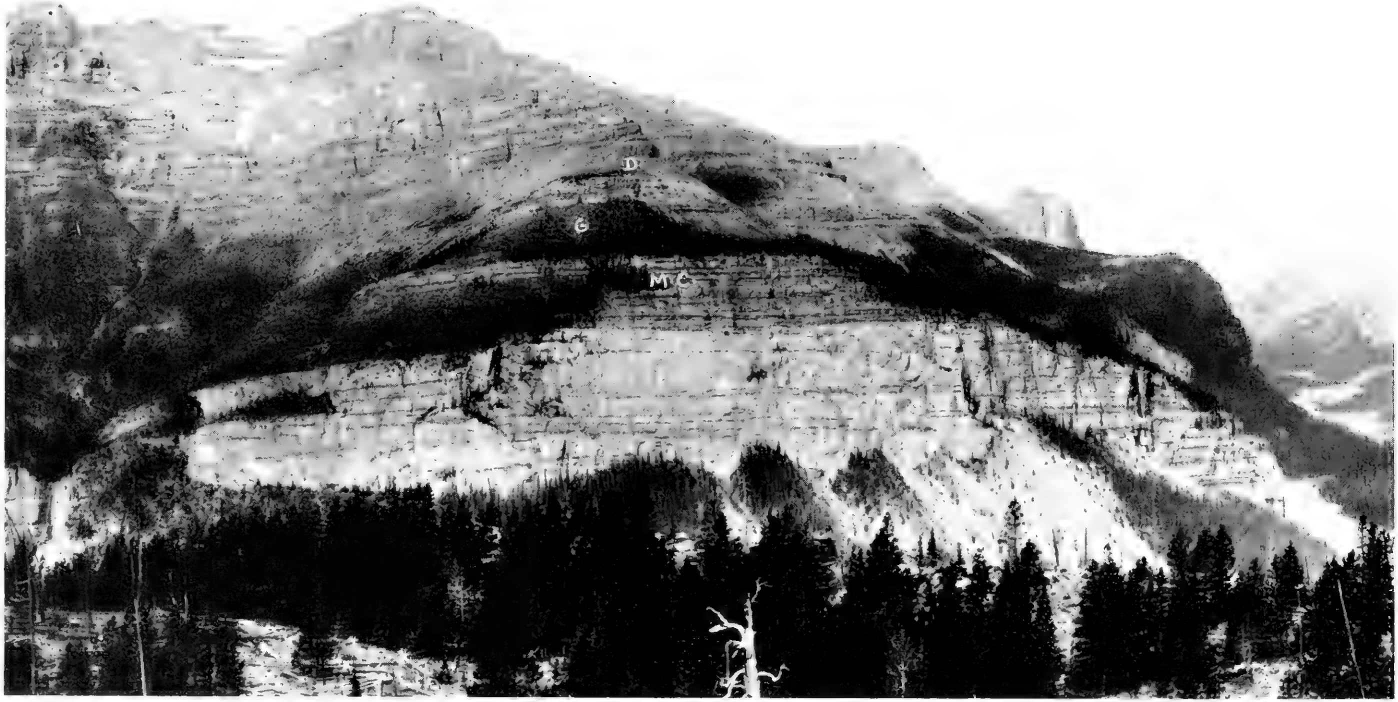
FIG. 24. Diagrammatic sketch of the section of the ridge that faces eastward above the Ghost River. This is based on the measured section up to the Devonian, illustrated in photograph reproduced on plate 27.
Locality.—Same as plate 27. (At I on map, plate 26.)

of the eastward facing cliffs. The Carboniferous and Devonian formations were studied by Dr. H. W. Shimer, who published the following section.[1] Allan's figures are also given.

	Shimer		Allan	
PERMIAN	Feet	Meters	Feet	Meters
Upper Banff shales and sandstones....	1200	365.8	1400 +	426.7 +
CARBONIFEROUS				
PENNSYLVANIAN				
Rocky Mountain quartzite.............	600	182.9	800	243.8
Upper Banff limestone................	2200	670.6	2300	701.0
MISSISSIPPIAN				
Lower Banff shale....................	1300	396.2	1200	365.8
DEVONIAN				
Lower Banff limestone................	1000	304.8	1500 +	457.2 +
Intermediate limestone	1600	487.7	1800 +	548.6 +

Shimer's section did not extend below the "Intermediate" limestone, and it is probable that the thicknesses given for the formations are based on estimates rather than accurate measurement.

[1] Bull. Geol. Soc. Amer., Vol. 24, 1913, pp. 233, 234.

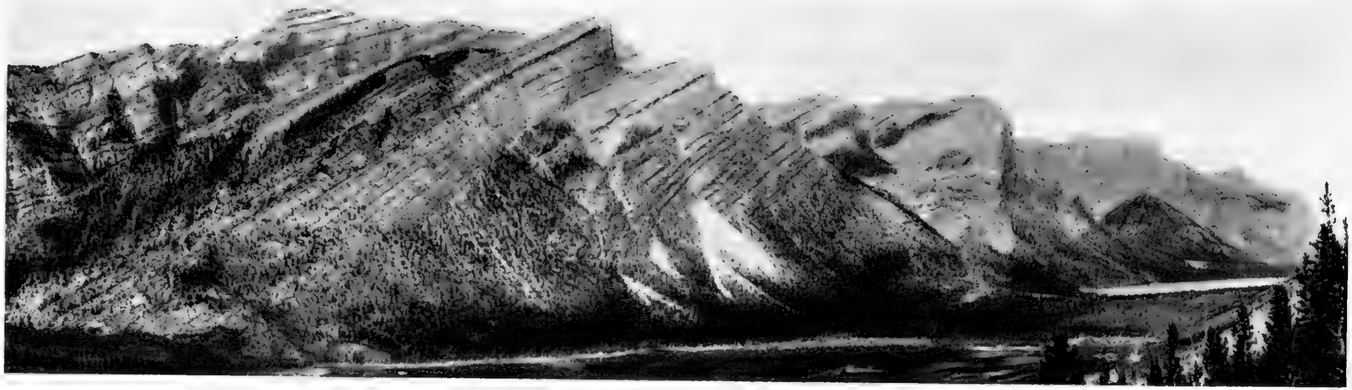


The Devonian (*D*) limestones extend from the Ghost River beds up to the Carboniferous limestones, as seen in the high summits of the right side of the view. The Ghost River formation (*G*) forms a slope at the summit of the lower limestone cliffs of the Cambrian (*MC*). The Albertella fauna occurs in the limestones at about the horizon of *A* on the lower cliff.

Locality.—At *I* on map, plate 26. Eastward facing cliffs rising above Ghost River a little south of the canyon through which the river flows from the mountains. The cliffs are about 20 miles (32.2 km.) east-northeast of Banff, Alberta, Canada.

The Ghost River formation occurs on the slope at the summit of the bold lower cliffs, with the Cambrian limestones below and the Devonian limestones above. The high points include limestones of Carboniferous age. The stratigraphic section was measured on the right side of the small stream flowing into the river from the west.

Locality.—At *I* on map, plate 26. Eastward facing cliffs between the South Fork of Ghost River and the area south of the canyon through which Ghost River flows, about 20 miles (32.2 km.) east-northeast of Banff, Alberta, Canada.



Cliffs on the north side of Devils Gap, east of Lake Minnewanka, showing at right Cambrian rocks in eastward facing cliff, and above these the thin Ghost River formation, and west to the left a succession of superjacent Devonian limestones.

Locality.—At *l* on map, plate 26. Between Ghost River and a point about one mile (1.6 km.) east of Lake Minnewanka, 14 to 19 miles (22.5 to 30.6 km.) east-northeast of Banff, Alberta, Canada.

Dr. John A. Allan gives a somewhat greater thickness to the formations[1] (second column), which is probably more accurate, but these are possibly merely more careful estimates. I did not measure the formations above the base of the Devonian as I began the section at that horizon.

The lower member of the Devonian caps the eastward-facing points between the south fork of Ghost River and the cliffs a few miles north of the Canyon of Ghost River. This member is about 400 feet (121.9 m.) thick and formed of a coarse, dark, lead-colored, massive-bedded limestone in which occur many corals and Stromatoporoid forms.

The basal bed of Devonian limestone is about 8 feet (2.4 m.) thick and rests on the slightly undulating surface of the buff-colored, slabby, magnesian limestone beneath; it is filled with irregularly globular masses of a Stromatopora-like organism varying in size from 1 cm. to 10 cm. Four feet (1.2 m.) above this bed, there is a second *Stromatopora* bed about 5 feet (1.5 m.) thick; in places the two beds merge, forming a bed 10 to 16 feet (3 to 4.9 m.) thick.

Similar beds are repeated higher up in the section several times, and there are also layers of finer limestone filled with slender stems of corals, a few gastropods, and often many specimens of *Atrypa reticularis*. These dark basal beds of the Devonian retain the same general character 54 miles (86.9 km.) to the northwest at the head of the Clearwater River (p. 326), and at Glacier Lake Canyon, 87 miles (140. km.) distant in an air line; they usually cap the outlying cliffs of most of the ridges and spurs, as the softer gray limestones and shales immediately above have broken down to form a terrace at the foot of cliffs formed of the upper portion of the Devonian.

For the formation beneath the Messines on Ghost River the name of the locality, Ghost River, has been proposed[2] (see p. 210).

DEVONIAN

GHOST RIVER FORMATION

	Feet	Meters
1. Steel-gray, fine-grained, thin-bedded, buff-weathering, finely arenaceous magnesian limestone, with a few layers of siliceous purple-colored shale 110-125 feet (33.5 to 38.1 m.) from the top; bands of somewhat thicker layers of the limestone occur in the central portions, some of which break down in thin slabs which cover the talus slopes in places. The thinner shaly and		

[1] Geol. Surv. Canada, Guide Book No. 8, pl. II, Transcontinental Excursion, 1913, p. 169.

[2] Smithsonian Misc. Coll., Vol. 67, No. 6, 1923, p. 463.

	Feet	Meters
slabby layers suggest that they were deposited as slightly arenaceous slimy muds in a shallow body of water	285	86.9

Fauna.—No traces of trails or any form of life were observed on the line of the section or at other localities along the outcrop on Ghost River.

CAMBRIAN

Upper and Middle Cambrian Formations

	Feet	Meters
1. Thin-bedded gray limestone with abundant annelid trails on weathered surfaces	252	76.8
2. Gray and bluish-gray, thin-bedded limestones that break down and usually form a shelf or terrace between the cliffs above and below	40	12.2
3. Massive-bedded, cliff-forming gray limestone, breaking down into thinner layers on weathered slopes	830	253.0
Total	1,122	342.0

This series of beds cannot now be subdivided into formations, as the laboratory study of the fossils has revealed the presence of several faunas not noted in the field. The Ptarmigan *Albertella,* the Stephen *Glossopleura boccar,* and the Upper Cambrian *Ptychaspis* faunas are represented in the collections. Whether the intervening Cathedral or Eldon formations are represented by some of the unfossiliferous beds cannot be determined from the information now in hand.

Lower Cambrian

Directly across from the mouth of Ghost River Canyon, and a little south of it, the river has cut into the western base of Marsh Mountain[1] so as to expose a series of thin-bedded gray sandstones, and greenish and purplish shales. The surfaces of the thin layers of sandstone are almost covered with trails of small and large annelids, and bits

[1] Marsh Mountain (8,000 feet, 2,438.4 m.) is a name that I have given to a mountain outlier that rises in front of the main line of cliffs a little to the northeast of the mouth of Ghost River Canyon; its summit is about 5 miles (8 km.) east of the bold cliff of Devils Head (9,204 feet, 2,805 m.) and about 51 miles (82.1 km.) west of Calgary, from where both summits can be seen against the western sky line.

Marsh Mountain is formed of a mass of Middle Cambrian limestone that has been pushed eastward over onto the Cretaceous shales and limestones on the line of a great thrust fault extending all along this portion of the Rocky Mountain front; as the limestones are of the same age as those of the lower portion of the eastward facing cliffs to the westward, it is probable that a north and south fault occurs along the western side of the mountain.

The name Marsh is derived from the large marsh at the southeastern base of the mountain.

of the tests of trilobites were seen on freshly broken surfaces. The cliff is about 100 feet (30.5 m.) high, and is formed of contorted and broken layers, dipping roughly toward the river, where, broken down, they form a steep slope to the river.

The slope above the cliff is covered with soil for 100 feet (30.5 m.) or more to ledges of darkish gray, coarse-weathering limestones, evidently a part of the Middle Cambrian limestones that form the eastward-facing cliffs at the summit of Marsh Mountain. From the position and character of the lower sandstones and shales it is highly probable that they represent the arenaceous beds of the upper portion of the Lower Cambrian beneath the Mount Whyte series of the Mount Bosworth section. If this interpretation is correct, the Cambrian section of the Front Range between the south fork of Ghost River and the south fork of Panther River, and probably still farther northwest, includes the St. Piran and Mount Whyte formations of the Lower Cambrian, and the Ptarmigan formation of the Middle Cambrian, with which the section terminates above at a plane of disconformity resulting from the non-deposition in this region of the missing Middle and Upper Cambrian and later formations up to the Devonian.

SAWBACK RANGE AREA

The Ordovician, Ozarkian, and Cambrian strata examined by me in the Sawback Range continue on the same strike from the northeast side of the Bow Valley 6 miles (9.7 km.) northwest of Banff, to the north side of the head of Clearwater Canyon, a distance of about 50 miles (80.5 km.). The strata are upturned to the northeast and dip to the southwest from 65° to 75° along the Bow Valley and from 25° to 75° southwesterly at various points along the line of their outcrop to the northwest. The Canadian Sarbach formation is usually directly subjacent to Middle Devonian limestones from the Bow Valley northwest as far as Saskatchewan River. An exception occurs on the northeast shoulder of Fossil Mountain, where the Ordovician Skoki formation occurs between the Sarbach and Devonian (F on map, pl. 26). Below the Sarbach the section extends down through the Ozarkian Mons formation and the Upper Cambrian into the Middle Cambrian Eldon limestone. In the Ranger Canyon section (H on map) an over-thrust fault has carried this belt of strata up against the outcrop of a second block of Devonian limestone on the northeast side of Upper Ranger Canyon. The section extends down into the Eldon limestone from Ranger Canyon to the Red Deer River and probably still farther to the north-northwest. The Eldon limestone is best exposed southwest of the Sawback Range in Castle Mountain and in the high ridges on the southwest side of Little Pipestone Creek and the upper Pipestone River.

The structure of the Sawback Range, so well worked out by McConnell,[1] has greatly facilitated erosion of the highly inclined strata and thus given many miles of clear exposure of the various formations involved in the uplift and faulting. These are often difficult of access because of high points and ridges and steep slopes, but once the section is determined, any given bed may usually be followed for a long distance. These uplifts and ridges are well illustrated by plates 30, 31.

Ranger Canyon Section

At the mouth of Ranger Canyon the quartzites and limestones of the Carboniferous dip at a high angle to the southwest, and as the canyon cuts back into the range, lower and lower beds are exposed down to the Devonian, and below that the Sarbach and Mons formations. The section of the latter was measured near the head of the northeast branch of Ranger Brook Canyon 10 miles (16 km.) north-northwest in an air line from Banff, Alberta.

Ranger Brook heads high up in the Sawback Range near the divide separating it and the branches of Fortymile Creek on the northeast side of the range. It flows southeast for nearly two miles (3.2 km.) and then southwest through a canyon between Mount Sawback on the north and Mount Allan on the south, and passes out at the southwest foot of the range, flowing past the Massive Park and Game Warden lodge, on the Banff-Windermere motor road, to the Bow River.

The contact between the thin bed of shale at the base of the dark Middle Devonian limestones of the Messines formation carrying *Stromatopora* and numerous corals, with the subjacent light gray, siliceous and cherty limestones representing the Sarbach formation, is well shown in the cliffs at the northeast head of the canyon; also along its northwest side and southeast rim where the canyon turns to the southwest and cuts through the Devonian and superjacent Carboniferous limestones.

The contact on the south side of the canyon is best seen at a point about 3 miles (4.8 km.) above the mouth of Ranger Canyon, and a mile (1.6 km.) south of the brook. It occurs in a steep, narrow ravine that extends from a notch on the top of the ridge 1,500 feet

[1] Geological Structure of the Rocky Mountains, by R. G. McConnell. Geol. & Nat. Hist. Surv. Canada, Report for 1886 (1887), Pt. D.

Upturned layers of limestone, quartzite, shale, and sandstones of the Carboniferous, and on the crest of the ridge to the right the Devonian limestones. The dip of the layers is from 60° to 80° to the southwest.

Locality.—At *H* on map, plate 26. Southwestern face of the Sawback Range, 2 miles (3.2 km.) north of Massive Switch on the Canadian Pacific Railway, and 10 miles (16.1 km.) west-northwest of Banff, Alberta, Canada.

FIG. 1.—Looking up Ranger Brook Canyon to the amphitheater in the heart of the Sawback Range. The Carboniferous limestones in the foreground overlie the Pipestone and Messines formations that form the light colored cliff on the right side of the canyon. The Mons formation forms the eastern slope of the ridge east of these cliffs, beneath a thin band of Sarbach siliceous limestones. The cliffs in the distance include the Bosworth, Arctomys, and Eldon formations, which are thrust at a high angle over the dark Devonian beds forming the crest of the ridge above Forty-mile Creek Canyon.

Locality. At *H* on map, plate 26. Sawback Range, 9 to 10 miles (14.5 to 16.1 km.) west-northwest of Banff, Alberta.

FIG. 2.—Southwesterly inclined Ozarkian and Cambrian beds in the Sawback Range, passing beneath the overthrust Lower Cambrian quartzites of Castle Mountain, in the canyon of Johnston Creek.

Locality. About 6 miles (9.7 km.) southeast of *F* on map, plate 26, at the head of Johnston Creek, 12 miles (19.3 km.) southeast in an air line from Lake Louise Station, Alberta.

(457.2 m.) or more down the north slope, where the strata of both the Devonian and Ozarkian limestones are nearly vertical. The upper *Ozarkispira* fauna of the Mons occurs about 30 feet (9 m.) below the contact, and no traces of the Sarbach formation were seen between the Devonian and the Mons either up the ravine or on the north side of Ranger Canyon opposite the ravine, where there is an outcrop of the Devonian and Ozarkian limestones, but about 2 miles (3.2 km.) to the north on the west side of the northward extension of Ranger Canyon, there is in places a dark arenaceous shale about 6 feet (1.8 km.) thick at the base of the Devonian and below that the siliceous and cherty gray limestones of the Sarbach. I searched in vain for evidence of an unconformity between the Devonian and the Sarbach which here has a thickness of 120 feet (36.6 m.). To the eastward, where the Devonian is again thrust up, there is much more disturbance of the strata and the upper layers of the Mons appear to vary in strike and dip from the Devonian. The upper massive magnesian limestones of the Sarbach formation are absent.

DEVONIAN

DISCOMFORMITY

CANADIAN

	Feet	Meters
SARBACH FORMATION		
1*a*. Lead-gray, compact limestone in layers 2 to 10 inches (5 to 25.4 cm.) thick with many cherty and magnesian limestone stringers and irregular partings. Layers of dark gray, buff-weathering magnesian limestone 3 to 8 inches (7.6 to 20.3 cm.) thick are intercalated at irregular distances from each other below 48 feet (14.6 m.) from the top................	124	37.8
From about 30 feet (9.1 m.) to 80 feet (24.3 m.) down, annelid trails nearly cover the surface of the rock and some layers have annelid borings running through them in all directions. These are filled in with siliceous, magnesian limestone that weathers out on the surface in strong relief.		

OZARKIAN

	Feet	Meters
MONS FORMATION		
1*a*. Thin layers of gray limestone, with many small irregular concretions containing minute fragments of an *Obolus*-like shell and bits of trilobite test...................	236	71.9
1*b*. Thick-bedded, rough-weathering, gray limestone interbedded with shaly limestones and calcareous shale. At 354 feet (107.9 m.) below the summit, thin layers of bluish-gray, shaly limestone occur in bands between the thicker layers.		

	Feet	Meters
The same character of bluish-gray shale and limestone, and gray, compact, banded limestone continues down to base of 1*b*	750	228.6
Total of Mons formation	986	300.5

Fauna.—The Mons has not yielded very good collections at this locality, but the presence of *Ozarkispira, Keytella* and *Symphysurina* has been proved. The *Kainella* zone has not been noted. Lower Ozarkian ?

Unnamed Formation

	Feet	Meters
1*a*. Massive-bedded, gray limestone breaking down on weathering into thin and shaly layers	190	57.9

From 10 to 15 feet (3.0 to 4.6 m.) above the base, two thick layers occur carrying *Cryptozoa* on their upper surface. These vary from 6 inches (15.2 cm.) to 14 inches (35.6 cm.) in diameter and can be collected only by blasting the solid compact limestone.

	Feet	Meters
1*b*. Thin layers of compact, hard, gray limestone with shaly limestone and calcareous shale interbedded in thin bands	120	36.6

Fauna.—(66k): *Eoorthis iophon* Walcott, together with gastropods and a number of undescribed trilobites, including the genera *Hardyia* and *Saukia*.

	Feet	Meters
1*c*. Thick-bedded, gray oolitic limestone, with coarse botroidal structures in lower layer. This belt and the thin layers just above weather rusty brown and form reddish-brown débris slopes	90	27.4

Strike N. 5° W. Dip W. 5° S. 70°.

A few bands of shale occur as partings between the bands of limestone.

	Feet	Meters
Total	400	121.9

Fauna.—Fossils were most abundant and best preserved in the lower 30 feet (9.1 m.) of 1*c*. (66j): Fauna similar to preceding, containing species of the genera *Eoorthis, Agnostus, Briscoia,* and *Platycolpus.*

This formation, 400 feet (121.9 m.) thick, was first assigned to the Upper Cambrian, but a study of the faunas indicates that they represent a Lower Ozarkian horizon.

UPPER CAMBRIAN

Lyell Formation

1*a*. Gray arenaceous and magnesian limestone in thin and massive layers.

At 378 feet (115.2 m.) down, a band of dark, lead-colored, rough-weathering magnesian limestone oc-

	Feet	Meters
curs, 3.5 feet (1.06 m.) thick and 4 feet (1.21 m.) below a thicker band of 45 feet (13.7 m.). The gray, light-weathering limestone then continues down with alternating bands of darker magnesian limestone.....	1,325	403.9
2a. Gray oolitic limestone in layers 3 inches (7.6 cm.) to 18 inches (45.7 cm.) thick with partings of calcareous and magnesian limestone shale......................	145	44.2
Fauna.—(661) and (64r): The Lyell fauna is still almost entirely undescribed. Among the fossils in it the following genera may be recognized: *Lingulepis, Idahoia,* and forms of *Agnostus.* Certain cystid plates have proved useful for correlation purposes.		
Total	1,470	448.1

BOSWORTH FORMATION

	Feet	Meters
1a. Dark bluish-gray compact limestone in layers ranging from 1 to 10 inches (2.5 to 25.4 cm.) thick with considerable interbedded magnesian buff-weathering limestone in the upper 20 feet (6 m.)..............	165	50.3
Total Bosworth formation......................	165	50.3

ARCTOMYS FORMATION

	Feet	Meters
1a. Greenish, very fine argillaceous shale..................	9	2.7
1b. Steel-gray, hard limestone weathering light gray and buff in bands that break down on weathering into shaly and thin layers..............................	44	13.4
2a. Alternating bands of purple and gray-colored arenaceous shale and thin layers of purplish red sandstone, the surfaces of which are usually ripple marked and checked by sun cracks that were filled in by fine sand and silt. A few small annelid trails occur on the shaly sandstone but no other traces of life were observed...	42	12.8
The ripple marks and the sun and wind dried, cracked surface all indicate a shallow sea, the bottom of which was exposed to the air between tides.		
Total Arctomys formation......................	95	28.9

MIDDLE CAMBRIAN

ELDON FORMATION

	Feet	Meters
1a. Thin-bedded, steel-gray magnesian limestone, weathering dove-gray. No traces of life seen in or on the layers. Estimated	300 +	91.4 +

The total thickness of the strata between the Devonian and the base of the Cambrian is 3,540 feet (1,078.9 m.) and includes:

	Feet	Meters
Sarbach formation	124	37.8
Mons formation	986	300.5
Unnamed formation	400	121.9
Lyell formation	1,470	448.1
Bosworth formation	165	50.3
Arctomys formation	95	28.9
Eldon formation	300 +	91.4 +
Total Ranger Canyon Section	3,540 +	1,078.9 +

Wild Flower Canyon Section

The name "Wild Flower Canyon" is derived from the luxuriant growth of wild flowers in the vicinity of a small spring-fed pond about 2.5 miles (4 km.) from the mouth of the canyon. Mrs. Walcott identified 82 species in blossom in July within a short distance of the pond.

The canyon enters Baker Creek Canyon about 9 miles (14.5 km.) in a direct north-northeast line from where Baker Creek joins the Bow River. It extends back into the mountain in a southeasterly direction for 3.5 miles (5.6 km.) and heads on a pass leading over into Johnston Creek Canyon. The section is 5 miles (8 km.) south-southeast of Fossil Mountain and about 16 miles (25.7 km.) north-east of Ranger Canyon. It is an unusually fine one and should be studied in detail when a good topographic map of the Sawback Range area is available.

The most northerly spur of the Castle Mountain massif terminates between Baker Creek and Wild Flower Canyons. It forms a high ridge on the southwest side of Wild Flower Canyon and is composed of massive-bedded, cliff-forming Middle Cambrian limestones of the northeast side of the broad Castle Mountain syncline. On the north-east side of Wild Flower Canyon the highly inclined limestones of the Ozarkian Mons formation rise to 9,000 feet (2,743.2 m.) or more. The *Ozarkispira* zone of the upper Mons is finely exposed northwest of and a little below the Johnston Pass, and the *Kainella* and *Symphysurina* faunules occur a little lower in the section in the outcrops on the cliffs above and northeast of Wild Flower Pond. About 2 miles (3.2 km.) from the mouth of the canyon a small tributary canyon cuts back northeasterly through the Mons and subjacent Upper Cambrian, Lyell, Bosworth, and Arctomys formations. It is practically a repetition of the Ranger Canyon section except that

FIG. 1.—Looking north over Johnston-Wild Flower Canyon Pass. The high point on the left is the upturned northeastern side of the Castle Mountain syncline; it is formed of Middle and Lower Cambrian strata thrust over the Canadian (Sarbach beds) in the pass. The ridges on the right of the pass are formed of Upper Cambrian and Ozarkian beds (see fig. 25).

Locality.—About 6 miles (9.7 km.) southeast of *F* on map, plate 26. At the head of Johnston Creek, 12 miles (19.3 km.) east-southeast in an air line from Lake Louise Station, and 22 miles (35.4 km.) northwest of Banff, Alberta, Canada.

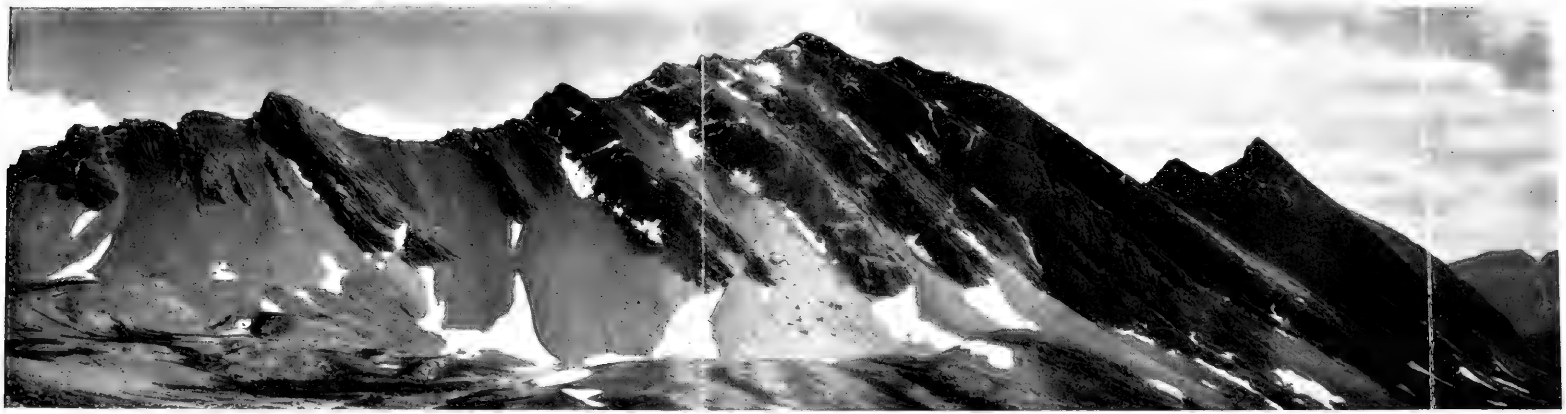
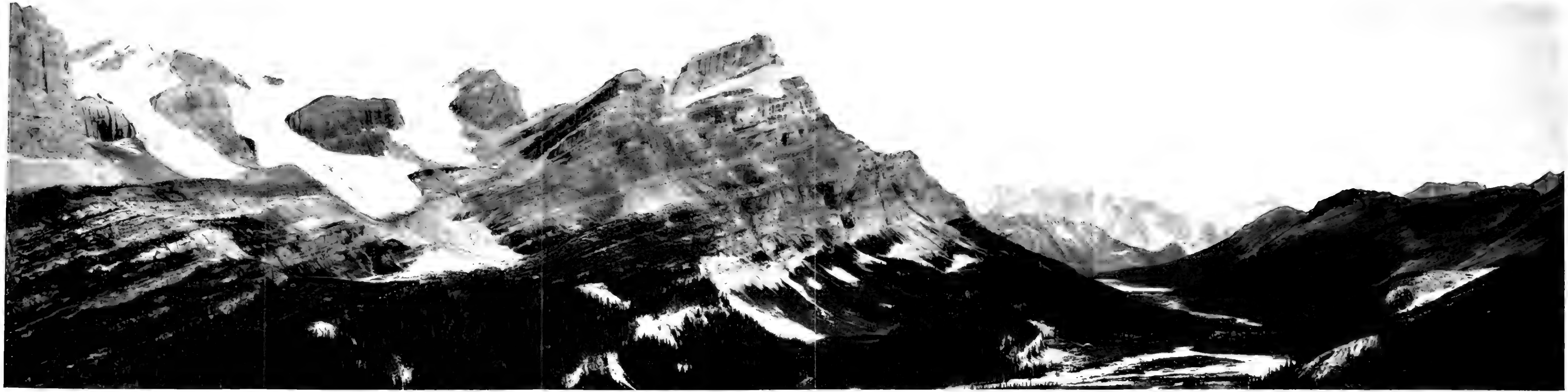


FIG. 2.—Upturned Canadian (Sarbach), Ozarkian (Mons), Cambrian (Bosworth and Eldon), and Devonian (Messines) formations southwest of Badger Pass. At the left, the Middle Cambrian Eldon limestones have been pushed over the Devonian.

Locality.—About 9 miles (14.5 km.) southeast of *F* on map, plate 26. Southeast side of canyon leading up from Johnston Creek to Badger Pass in Sawback Range. Position of camera about 10 miles (16.1 km.) in air line east of Lake Louise Station, and 16 miles (25.7 km.) northwest of Banff, Alberta, Canada.



the Lower Cambrian quartzites are thrust over onto the upper Mons, and the Sarbach and Devonian of the Fossil Mountain section are cut out by the fault which extends north-northwest to Baker Creek Canyon and south-southeast down Johnston Creek to Bow Valley. These two canyons mark the dividing line between the massive-bedded Middle Cambrian limestones of Castle Mountain and the Ordovician Sarbach and Ozarkian Mons limestones of the southwesterly ridges of the Sawback Range massif. The relations of the Castle Mountain strata to those of the Sawback Range are well shown at the Johnston Creek-Wild Flower Canyon Pass. At this point the Lower Cambrian quartzite beneath the Middle Cambrian limestones forms the floor of the pass and extends a short distance down Wild Flower Canyon. It is thrust on to cherty and siliceous layers of limestone such as occur in the Sarbach formation of Ranger Brook Canyon and Bonnet Peak sections. The strata are somewhat broken and displaced, but the strike and dip are essentially the same above and below the quartzite. The dip of the Mons limestones is about 45° to the southwest for 2 miles (3.2 km.) or more along Wild Flower Canyon, while the Cambrian limestones dip at about 30°. At the pass between the *Ozarkispira* zone of the upper Mons and the magnesian limestone next to the fault and beneath the Cambrian there are 200 feet (61 m.) of thin arenaceous limestones and shales with annelid trails and borings that correspond to similar shallow water deposits above the Mons limestone and shale in the Ranger Canyon and Douglas Canyon sections, where they are referred to the Sarbach.

A diagrammatic section across the strike of the strata on the Johnston Creek Pass is illustrated by text figure 25.

CANADIAN

Sarbach Formation

On the Johnston-Wild Flower Canyon Divide, the Lower Cambrian Fort Mountain quartzite of Castle Mountain is thrust over the cherty and siliceous annelid limestones of the Sarbach formation. Adjoining the line of the fault (Johnston) the layers of limestones are more or less crushed, crumpled, and broken, but 50 feet (15.2 m.) from the outcrop of quartzite, the northeast dip of 35° to 45° prevails and is maintained down through the Sarbach to the gray Mons limestones beneath. The middle and upper portions of the Sarbach as seen on Fossil Mountain 7.5 miles (12.1 km.) to the northwest are here cut out by the Johnston fault, or are absent as in the Bonnet Peak section 4 miles (6.4 km.) to the north-

FIG. 25.—Northeast-southwest diagrammatic section of stratigraphic section at Johnston-Wild Flower Canyon Pass from the southwest.

The Lower Cambrian quartzitic sandstones and shales have been thrust to the northeast over and against the more or less irregular siliceous and cherty limestones of the Sarbach formation that underlie the fine, gray, fossiliferous limestones of the Mons.

Locality.—At the head of Johnston Creek, 12 miles (19.3 km.) east-southeast in an air line from Lake Louise Station and 22 miles (35.4 km.) northwest of Banff, Alberta, Canada.

	Feet	Meters
east, where the Devonian limestone is superjacent to the Lower Sarbach annelid limestone, and in the Ranger Canyon section of the Sawback Range 14 miles (22.5 km.) to the southeast of the Johnston-Wild Flower Canyon Divide.		
1*a*. Hard, dark, dirty gray and bluish-black limestone, with some nodules and stringers of dark-weathering chert, in layers up to 3 feet (.9 m.) thick, that split into thin, irregular layers in the weathered outcrops...........	225	68.6
Fauna.—Annelid trails and borings in and on nearly every layer that are usually more or less replaced by dark-weathering chert and finely arenaceous limestone. An irregular layer of bluish-gray limestone 4 to 6 inches (10.2 to 15.2 cm.) thick, 127 feet (38.7 m.) below the top of 1*a* contains a *Megalaspis* fauna in which a species of Orthoid brachiopod is very abundant. This fauna is to be compared with (21x) and (69a) of the Fossil Mountain section.		
1*b*. Light gray, compact, rough-weathering, more or less cherty and siliceous limestones in thick layers that split into thinner layers on weathered slopes..........	135	41.1
Fauna.—Abundant annelid trails and borings, with Orthoid brachiopods, and *Lecanospira* (69h).		
1*c*. Hard, dirty gray, irregular siliceous limestone in thick layers that split into thin layers .5 to 3 inches (1.3 to 7.6 cm.) in thickness, the surfaces of which are usually fretted with a network of annelid trails and borings that are replaced by chert and hard, siliceous, dark, buff-weathering limestone	5	1.5
Fauna.—Annelid trails and borings with sections of gastropods on eroded surfaces. In a bluish-gray layer 2 to 4 feet (.6 to 1.2 m.) above the base of 1*c* apparently the same fauna as the preceding zone (69i).		
1*d*. Thin layers of cherty and siliceous limestone with a few layers of interbedded dove-gray limestone......	6	1.8
Fauna.—(69j): same as preceding.		
Total	371	113.0

OZARKIAN

Mons Formation

Several hundred feet of thick layers of bluish-gray to dove-colored limestone outcrop on the southeast slope of the Pass down to the bottom of the cirque at the head of Johnston Creek. These beds contain the *Ozarkispira* fauna.

Bonnet Peak Section

This section is at the head of Lake Douglas Canyon Valley in the northwestern portion of the Sawback Range, 15 miles (24 km.) north-northwest of Ranger Canyon section and nearly 6.7 miles (10.8 km.) east-southeast of Fossil Mountain section. The dark massive beds of Middle Devonian Messines limestones form great northward-facing cliffs overlooking the upper alpine valley of Douglas Creek, 6 miles (9.7 km.) south of Lake Douglas and about 1.5 miles (2.4 km.) north of Bonnet Peak (10,615 feet, 3,235.5 m.). (See pl. 35.) The high cliffs extend west and north on the western side of Douglas Canyon Valley until they merge into the cliff slopes of Mounts St. Bride (11,220 feet, 3,419.9 m.) and Douglas (11,015 feet, 3,357.4 m.). (See pl. 37.)

The Ghost River formation, which appears to be represented at Fossil Mountain section by 35 feet (10.7 m.) of cherty magnesian limestone, is represented by not more than 10 feet (3 m.) of a drab, buff-weathering, finely arenaceous shale. This shale readily breaks down and disintegrates to form a well-defined zone at the base of the Devonian cliffs. The conditions here are similar to those in the Ranger Canyon section where a thin bed of shale is all that occurs between the Devonian and the subjacent Sarbach formation. There is no evidence of an unconformity between the Devonian and Sarbach at either locality.

DEVONIAN

Disconformity

CANADIAN

Sarbach Formation

The only recognizable beds that can be referred to the Sarbach formation are layers of cherty limestones beneath the Devonian shale, which are similar to a series of beds above the Mons formation as it occurs 15 miles (24.1 km) to the south-southeast in the Ranger Canyon section (see p. 264). These limestones break down and form a broad, irregular, rough slope towards the cliffs above Lake Gwendolyn. The section was measured across this slope and down to the lake and across the brook to the slope leading to the amphitheater beneath and west of Halsted Pass, where the upper beds of the Upper Cambrian Lyell formation are exposed.

Only a few fossils were collected as none of them was striking or well preserved. The entire thickness of the Sarbach was found to be about 520 feet

A nearer view of the left end of plate 32, figure 2. The massive beds of the Eldon limestones have pushed and crushed thinner layers up against the thick-bedded Devonian limestones that form the cliffs on the south side of Badger Pass.

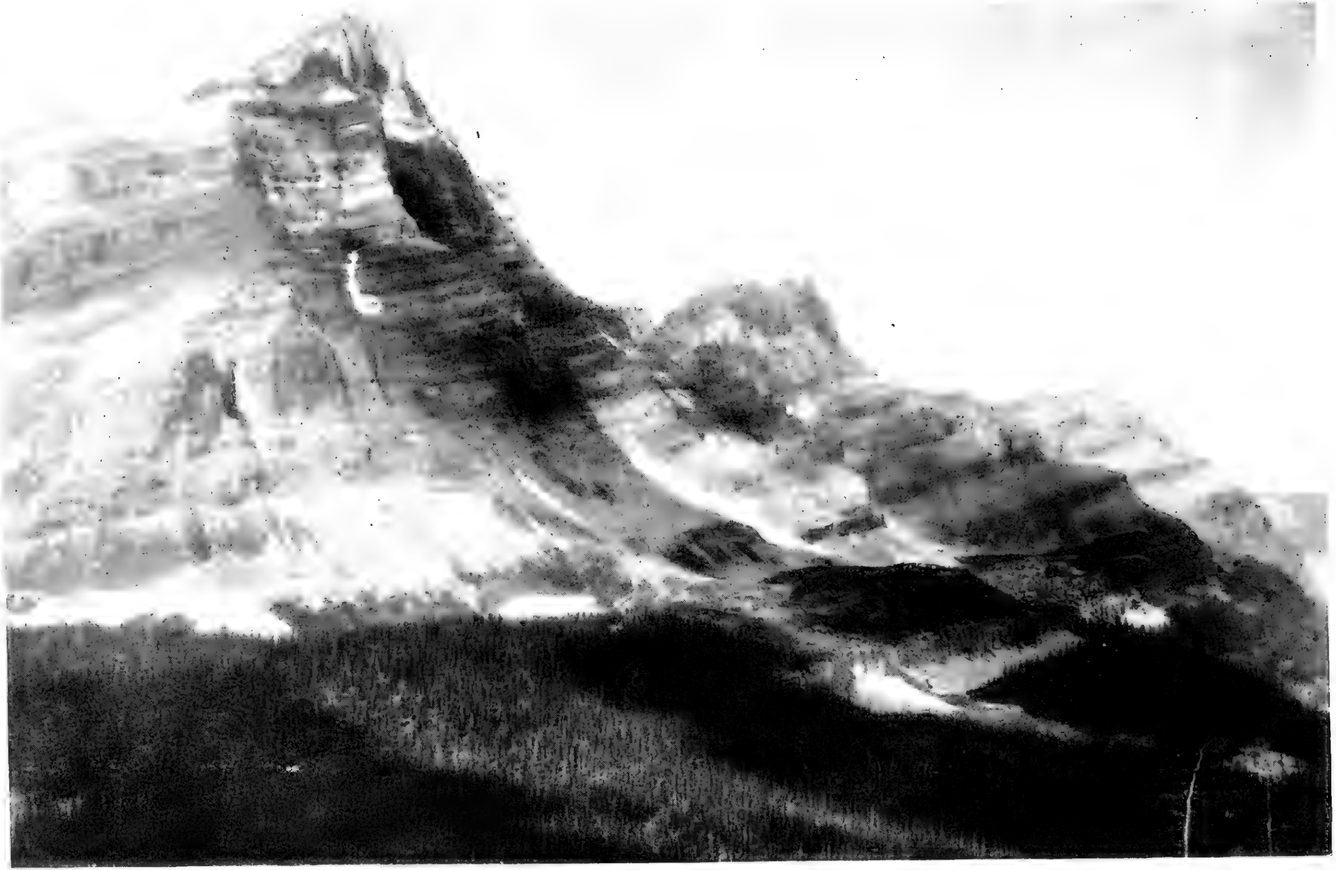
Locality.—Same as plate 32, figure 2.

North side of Mount Douglas (11,015 feet, 3,357.4 m.) capped with thick-bedded Devonian limestones that are superjacent at about halfway down the left hand slope to Canadian limestones of the Sarbach formation.

Locality.—About 3 miles (4.8 km.) northeast of *F* on map, plate 26. Upper Red Deer River 11 miles (17.7 km.) in air line northeast of Lake Louise Station, Alberta.

Gwendolyn glacier on upper Douglas Creek and Overlook Point. The latter is on the divide at the head of Panther River and is capped by Devonian limestones that extend down to the base of the upper cliff, which is superjacent to the siliceous shaly beds of the Sarbach with the Mons limestones beneath.

Locality.- At *G* on map, plate 26. Near the head of Douglas Creek, north of Bonnet Mountain, about 15 miles (24.1 km.) in an air line east-northeast of Lake Louise Station, Alberta.



Cliffs of Mount St. Bride (11,220 feet, 3,419.9 m.) and Mount Douglas (11,015 feet, 3,357.4 m.) from the southeast. The massive-bedded Devonian limestones overlooking Lake Douglas (6,250 feet, 1,905 m.) and the Red Deer River Valley (see pl. 33) form the upper cliffs with the Sarbach, and Mons limestones in the cliffs and slopes below.

Locality.—At *G* on map, plate 26. East side of Douglas Canyon, 13.5 miles (21.7 km.) north-northeast of Lake Louise Station, Alberta.

	Feet	Meters
(158.5 m.) as compared with 124 feet (37.8 m.) in the Ranger Canyon section 15 miles (24.1 km.) to the south-southeast.		
1a. Gray, more or less siliceous limestones, with thin layers and stringers of dark-weathering impure chert and great profusion of annelid borings and trails, replaced by ferruginous cherty matter. The beds are 1 to 3 feet (.3 to .9 m.) thick, breaking up into thin and shaly layers on weathered exposures......................	280	85.3
The section is here covered by débris and by the waters of Lake Gwendolyn.		
Eoorthis and sections of gastropods, *Lecanospira* were noted 70 feet (21 m.) from top, also 170 feet (51.8 m.) down, weathered out on surface of arenaceous limestone.		
Thickness of concealed strata based on measured dip and strike	205	62.5
Total of *1a*..................................	485	147.8
1b. Thick-bedded coarse gray magnesian limestones. Strike N. 50° W. (Magnetic), Dip 20° SW..............	35	10.6
Total of Sarbach	520	158.4

OZARKIAN

Mons Formation

	Feet	Meters
1a. At the outlet of Lake Gwendolyn, thin and shaly-bedded, light gray, compact limestones occur, with thicker layers irregularly interbedded; also large and small thick lenticular masses of hard, light gray limestone (one, 18 inches × 4 feet [45.7 cm. × 1.2 m.] in size). Bands of calcareous shale begin to appear 30 feet (9 m.) from the top. At 60 feet (18 m.) down, a massive layer of limestone 22 feet (6.7 m.) thick occurs. At 476 feet (145.1 m.) down, the section is cut off by stream bed and drift............	476	145.1
Fauna.—About 200 feet (60.9 m.) from summit in bluish-gray limestones weathering pearl gray, (67q) contains the *Kainella* fauna, which extends to the bottom of the formation.		
1b. Covered space. Thickness calculated from dip........	57	17.4
1c. Gray limestone, interbedded in calcareous shale similar to that above.....................................	62	18.9
1d. Thin-bedded and shaly, slightly arenaceous and ferrugineous limestone weathering reddish-brown and forming a reddish-brown talus slope...............	18	5.4
Fauna.—Locality (67s) contains a peculiar undescribed fauna, the significance of which is not yet understood.		

	Feet	Meters
1*e*. Massive-bedded, gray limestone breaking up into thinner layers and ½ inch to 8 inches (1.3 to 20.3 cm.) thick, with a few layers 4 to 8 feet (1.2 to 2.4 m.) thick and with many large (8 to 12 inches, 20.3 to 30.5 cm.) concretionary forms. At 75 to 90 feet (22.9 to 27.4 m.) from bottom the *Kainella* fauna occurs in soft gray limestone layers (67t)	170	51.8
Total of Mons	783	238.6

UPPER CAMBRIAN

Lyell Formation

1*a*. Thick-bedded, coarse, gray dolomitic limestone forming high cliffs overlooking the headwaters of Panther River (see pl. 36).

Section broken by fault line.

Castle Mountain Section

The bold, castellated southwest front of Castle Mountain overlooks the Bow River Valley, its higher towers appearing like the ruins of a great castle rising to an elevation of 9,976 feet (3,040.7 m.) or 4,000 feet (1,219.2 m.) above the Bow River. There is a large amphitheater near its southeastern end that has a high ridge on its northeastern side (Helena Ridge, 9,390 feet [2,862.1 m.]) and an elevated point at its northwestern end (Stuart Knob, 9,300 feet [2,834.6 m.]) which is formed of a remnant of one of the hard limestones of the Bosworth formation.

The measured section began at the southwest base and extended around the point of the mountain into the large amphitheater on the northeast side, and thence northwest to the summit of Stuart Knob.

The strata of the main mountain dip slightly to the north-northwest and those of Helena Ridge to the west-northwest, forming a shallow syncline at the head of the amphitheater. This structure aids in giving very fine exposures of the quartzitic sandstones of the Lower Cambrian at the base of the mountain to the summit of the section.

UPPER CAMBRIAN

Bosworth Formation

	Feet	Meters
1*a*. Gray and bluish-black limestone, with interbedded siliceous layers and numerous small concretions	50	15.2
Fauna.—58n: Annelid trails and undescribed trilobites.		
1*b*. Compact gray to drab siliceous limestone in layers ¼ inch to 6 inches (.6 to 15 cm.) thick, with interbedded bands of dark arenaceous shale	45	13.7

Southwestern face of Castle Mountain (9,976 feet, 3,040.7 m.), the citadel of the Bow Valley, from the Banff-Windermere automobile road below Vermilion Pass. The massive Eldon limestones form the upper tier of cliffs; the thin-bedded Stephen limestone the narrow terrace; and the Cathedral limestones the lower tier of cliffs down to the steep, broken slopes of the Lower Cambrian shales and sandstones that overlie the pre-Cambrian Hector formation.

Locality.—At *T* on map, plate 26. The view was taken from below Vermilion Pass, 18 miles (28.9 km.) in an air line west-northwest of Banff, Alberta.

East and southeast face of Castle Mountain (9,976 feet, 3,040.7 m.), showing a broad synclinal structure with Stuart Knob (9,612 feet, 2,929.7 m.) at about the center. The pre-Cambrian rocks form the round wooded hill of the foreground upon which Lower Cambrian quartzites rest, and these are succeeded by the massive cliff-forming Middle Cambrian limestones of the Cathedral, Stephen, and Eldon formations that continue to the summit of the mountain.

Locality.—At *T* on map, plate 26. From a point on the northeast side of Bow Valley about 15 miles (24.1 km.) in an air line west-northwest of Banff, Alberta.

FIG. 1.—Helena or northeast ridge of Castle Mountain with glacial lake between it and the main mountain. The cliffs above the lake are formed of the Eldon formation limestones, and the snow covered points above include the limestones of the Bosworth formation. The distant point on the left is Stuart Knob.

Locality.—About 4 miles (6.4 km.) north-northwest of Castle Mountain Station (at *T* on map, pl. 26) on the Canadian Pacific Railway, Alberta, Canada.

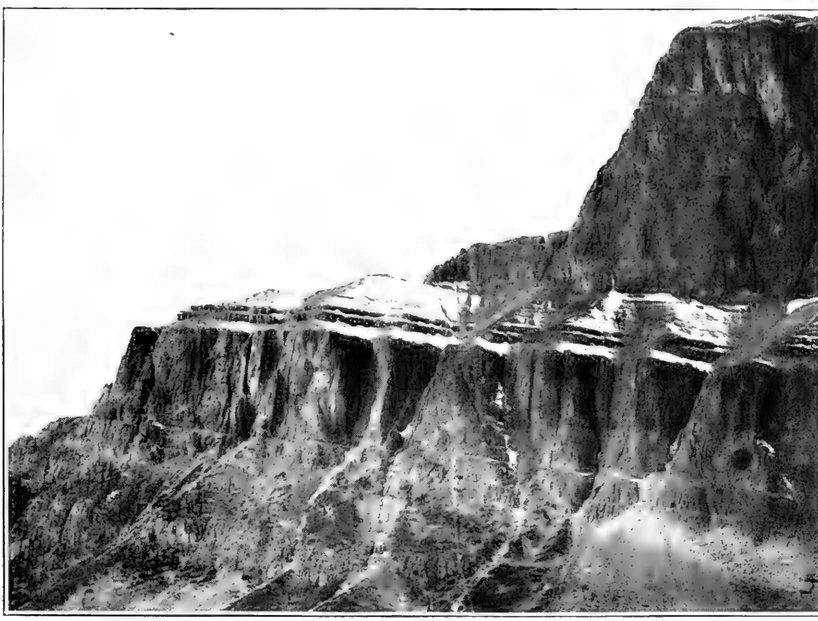


FIG. 2.—Profile of southeast end of Castle Mountain. The upper cliff is formed of the Eldon formation limestones: the terrace with snow on it, the Stephen formation, and the lower cliff and broken slope the limestones of the Cathedral formation.

Locality.—One mile (1.6 km.) north-northeast of Castle Mountain Station (at *T* on map, plate 26), Alberta, Canada.

	Feet	Meters
Fauna.—(58b): small fauna of undescribed forms.		
1*c*. Arenaceous, purple shale, with interbedded gray shaly limestone in thin layers	265	80.8
The highest of the purple layers occur near the summit of 1*c*.		
1*d*. Siliceous, fine-grained, thin-bedded, buff-weathering limestone	63	19.2
Total Bosworth formation	423	128.9
ARCTOMYS FORMATION		
1*a*. Arenaceous and calcareous shale, purple- and gray-colored with thin, intercalated buff-weathering calcareous layers. Mud cracks, ripple marks, and the pseudomorphs of large salt crystals occur in the arenaceous beds	158	48.2
1*b*. Thin-bedded, compact, drab-colored limestone	60	18.3
Total Arctomys formation	218	66.5

MIDDLE CAMBRIAN

	Feet	Meters
ELDON FORMATION		
1*a*. Thin-bedded (2 to 6 inches [5 to 15 cm.]), gray siliceous limestone	265	80.8
Fauna.—Numerous large and small annelid trails and borings.		
1*b*. Bluish-black and gray fossiliferous limestone becoming more or less arenaceous toward the top	260	79.2
Fauna.—(58e): Annelid trails, and two or three species of trilobites.		
1*c*. Steel-gray weathering light gray arenaceous limestone in thin layers	55	16.7
1*d*. Massive-bedded, light gray, finely granular, arenaceous limestone which weathers more like a compact granular sandstone than a limestone. This limestone is usually very massive, but between 540 and 575 feet (164.6 and 175.3 m.) above the base it is thin-bedded.	1,065	324.6
This is the great cliff-forming limestone of the mountains and ranges in this region. It forms the upper cliff of Castle Mountain.		
Fauna.—Numerous annelid trails and borings occur at various horizons.		
1*e*. Massive-bedded, cliff-forming, dark and light gray arenaceous limestone, the massive layer breaking up into thin layers on broken cliffs and talus slopes. The dark-colored band forms the lower 200 to 250 feet (60.9 to 76.2 m.), the line of demarcation between the dark band and the lighter gray being irregular	260	79.2
Total Eldon formation	1,905	580.5

	Feet	Meters
Stephen Formation		
1*a*. Gray, buff-weathering, compact limestone	1	.3
1*b*. Drab and greenish argillaceous shale	57	17.4
Fauna.—(58u): *Obolus mcconnelli* Walcott, *Hyolithes*, and trilobites.		
1*c*. Calcareous and arenaceous, gray-weathering, buff and yellow shale	170	51.8
Fauna.—*Obolus mcconnelli* Walcott		
1*d*. Thin-bedded, bluish-black and bluish-gray, fossiliferous limestone, with a few interbedded oolitic layers 6 to 12 inches (15 to 30 cm.) thick	138	42.1
Fauna.—A *Glossopleura* fauna.		
Total Stephen formation	366	111.6
Cathedral Formation		
1*a*. Massive-bedded, gray arenaceous limestone with dark irregular annelid borings in many of the layers. At 165 feet (50.3 m.) from the base, a band of bluish-gray limestone occurs in thin layers for a thickness of 10 to 12 feet (3 to 3.7 m.)	435	132.6
1*b*. Thin-bedded, bluish-gray limestone, most of which is similar to the limestone of 1*a*	270	82.3
Total Cathedral formation	705	214.9
Ptarmigan Formation		
1*a*. Bluish-black fossiliferous limestone	12	3.7
Fauna.—This fauna is peculiar for the small size of its fossils. It contains, among other trilobites, *Albertella* and *Dorypyge*.		
1*b*. Gray arenaceous limestone that in nearly every bed is marked by large, irregular, dark annelid borings. About 75 feet (22.9 m.) from the base the limestone passes into gray quartzitic sandstone	260	79.2
Total Ptarmigan formation	272	82.9

LOWER CAMBRIAN

	Feet	Meters
Mount Whyte Formation		
1*a*. Bluish-black, thin-bedded limestone	40	12.2
Fauna.—(58d): some undescribed trilobites.		
1*b*. Bluish-gray, thin-bedded limestone, with oolitic layers 1 to 8 inches (2.5 to 20.3 cm.) thick	96	29.3
Fauna.—Many indeterminate fragments of trilobites.		
1*c*. Gray and dirty brown, thin-bedded sandstone	22	6.7
Fauna.—A typical upper Mount Whyte fauna. This fauna appears to be similar to that of the same horizon on Mount Bosworth and Mount Stephen.		

	Feet	Meters
1*d*. Shaly limestone with thicker oolitic limestone layers interbedded. The limestones become more arenaceous in the lower part..................................	6	1.8
1*e*. Gray and dirty brown, thin-bedded sandstones with coarse annelid trails and mud cracks on the surface of many of the layers. Eight feet (2.4 m.) from the top two calcareous layers occur, and another 9 feet (2.7 m.) from the base...........................	27	8.3
1*f*. Shaly, gray and brownish sandstones passing down into drab-colored argillaceous and arenaceous shales with thin layers of hard sandstone. Eleven feet (3.4 m.) from the top there is a thin band of purple shale.....	57	17.4
Total Mount Whyte formation.................	248	75.7

Fauna.—(58y): many fragments of *Olenellus* occur in the lower 20 feet (6.1 m.) of the interbedded sandstones.

St. Piran Formation

	Feet	Meters
1*a*. Gray quartzitic sandstones in layers 1 to 3 feet (.3 to .9 m.) thick weathering rough on the surface.......	55	16.8

Fauna.—(58x): fragments of *Olenellus*.

In the cliff at the southwest end of the mountain, about 200 feet (60.9 m.) of quartzitic sandstones are exposed that may belong to the Fort Mountain formation.

SLATE MOUNTAIN GROUP

Ptarmigan Peak Section

The Ptarmigan Peak massif, 5.4 miles (8.7 km.) north-northeast of Lake Louise Station on the Canadian Pacific Railway, is formed of Middle and Lower Cambrian limestones and quartzitic sandstones that are superjacent to sandstone and shales of the pre-Cambrian Hector formation of the Algonkian. The pre-glacial, glacial, and post-glacial erosion has cut away the Hector sandstones and shales close up to the quartzites of the Lower Cambrian, which rise as cliffs nearly all around the base of the massif. These cliffs are surmounted by castellated towers and bold cliffs, eroded from the hard, thick-bedded limestones of the Cathedral formation that form the summits of Ptarmigan Peak (10,070 feet, 3,069.3 m.), Mount Richardson (10,125 feet, 3,086.1 m.), and Pika Peak.

The Cathedral limestone is superjacent to the Ptarmigan formation, with the Mount Whyte below, which is clearly outlined above the St. Piran sandstones and shales.

A thick-bedded, quartzitic series with some *Scolithus* and fine quartz conglomerate represents the Fort Mountain quartzite which occurs on Redoubt (Fort) Mountain, 2 miles (3.2 km.) to the southeast.

The narrow, sharp south ridge of Mount Richardson merges into a rounded ridge of pre-Cambrian sandstones and arenaceous shales of the Hector formation, the actual contact of the two formations being obscured by débris from the Fort Mountain quartzitic sandstones.

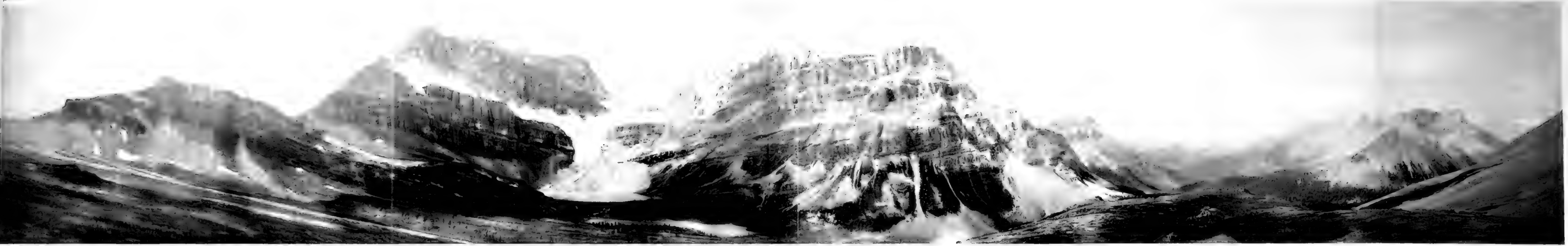
A beautiful glacial cirque, Richardson Cirque, occurs between the south ridge of Mount Richardson and the slopes of Pika Peak on the northeast. At the foot of the cliffs is a small, sapphire-blue lake, fringed in July with *Caltha* and a luxuriant emerald green sod. The lake is only a mile (1.6 km.) from the Ptarmigan Pass trail, and the brook flowing from it crosses the trail at the upper camp site a half mile (.8 km.) below the Pass.

The typical section was measured on the east and northeast face of Ptarmigan Peak above Ptarmigan Pass and Lake from the summit of the peak down to the lake and on the northeast slope down and into the pre-Cambrian.[1]

MIDDLE CAMBRIAN

	Feet	Meters
CATHEDRAL FORMATION		
1. Massive-bedded, arenaceous, cliff-forming limestone, mostly of a light gray color, but with a few dark, lead-colored bands of more or less irregular boundaries above and below. The dark bands are usually formed of more thinly bedded and finer arenaceous limestone	2.100	640.1
Fauna.—No fossils except traces of annelid borings.		
The thickness of 2,100 feet (640.1 m.) is an estimate based on the height of the mountain and the height of the base of the light gray arenaceous limestone above Ptarmigan Lake.		
PTARMIGAN FORMATION		
1*a*. Thin-bedded, fine-grained, hard, dark, gray to grayish-black arenaceous limestone	46	14.0
Fauna.—(63b): *Zacanthoides cimon* Walcott; *Neolenus constans* Walcott		
This bed usually breaks down to form a slope beneath the massive Cathedral limestone, but in places it forms a steep, low escarpment.		

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



Panoramic view of northeast side of Ptarmigan Peak (10,060 feet; 3066 m.) and northeast ridge ([illegible] feet; 2743.2 m.) that extends to Little Pipestone Creek. On the right, Skoki Valley and Mountain (8,750 feet; 2667 m.) and in the distance the snow-clad summit of Cyclone Mountain (9,530 feet; 2904.7 m.). For Cambrian formations of Ptarmigan Peak and massif, see legend of plate 43. For Skoki Mountain see plate 40. Locality = At Z on map plate 2. View taken from west slope of Fossil Mountain a little below Skoki Pass 6.5 miles ([illegible] km.) northeast in an air line from Lake Louise Station, Alberta.

	Feet	Meters
1*b*. Finely arenaceous limestone in thick, alternating bands of a light gray and dark lead-gray color. The lower 20 feet (6.1 m.) is a light gray, finely arenaceous, laminated limestone, the lamellae showing finely on the weathered surface	270	82.3
Fauna.—Traces of annelid borings occur abundantly within the layers and on their surfaces. The Ross Lake shale member of the Ptarmigan formation was not seen, but if present would probably occur about 100 feet (30.5 m.) down in this section.		
1*c*. Massive-bedded, bluish-gray and light gray, more or less finely arenaceous limestone, with many dark layers of oolitic limestone, the oolites varying from 5 to 25 mm. in diameter	110	33.5
Fauna.—A few minute fragments of trilobite tests were seen.		
Total of Ptarmigan formation	426	129.8

LOWER CAMBRIAN

MOUNT WHYTE FORMATION

	Feet	Meters
1*a*. Thin-bedded, dark, bluish-gray limestone that may or may not be included in the cliff	28	8.5
Fauna.—(63d): *Lingulella* sp. undt.; *Wimanella* ?; "*Ptychoparia*" *cilles* Walcott; *Crepicephalus chares* Walcott		
1*b*. Finely laminated and shaly bluish-gray limestone, with a few intercalated thin, hard layers	62	18.9
This band of almost fissile limestone and shale is a marked feature in the section. It is crossed diagonally by joint planes that cause it to weather into projecting points, giving the effect of the irregular surface of dogtooth spar. This may be seen on the face of the cliffs of Ptarmigan Peak for a long distance; also on Redoubt Mountain on the southeast side of the Pass.		
1*c*. Dark gray, oolitic limestones in bands from 1 to 8 inches (2.5 to 20.3 cm.) thick, alternating with hard, thin-bedded and shaly sandstones. At the top a band of finely oolitic limestone occurs beneath the cliff-forming limestone of 1*b*	135	41.1
Fauna:—In the upper band of oolitic limestone (63a): *Nisusia* (*Jamesella*) *lowi* Walcott; *Wimanella catulus* Walcott; *Hyolithes billingsi* Walcott; *Ptychoparia cercops* Walcott; *Crepicephalus cecinna* Walcott		

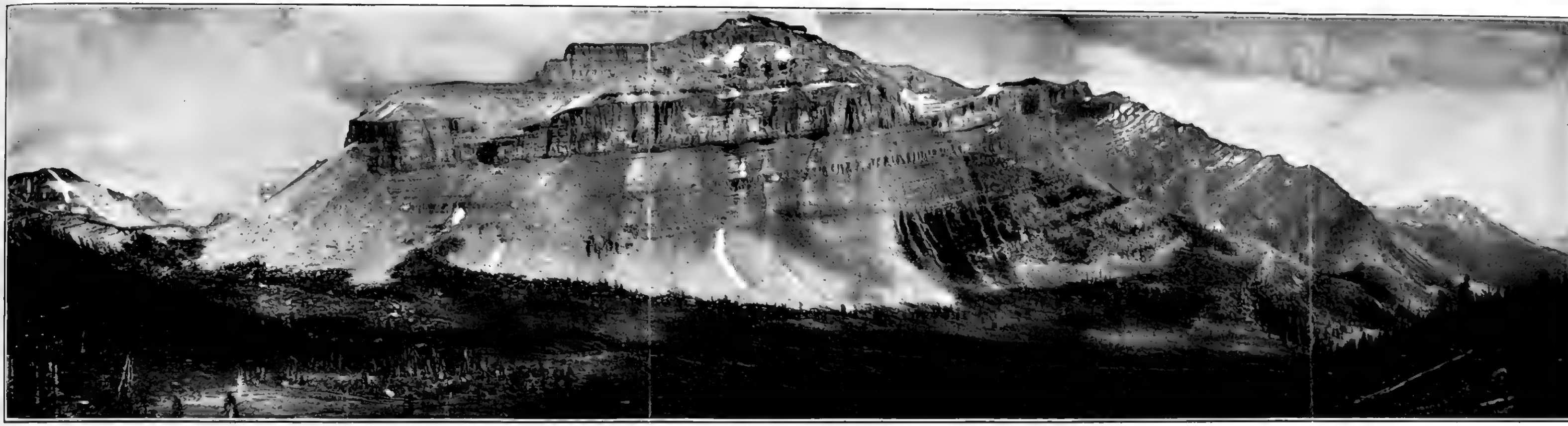
	Feet	Meters
At 62 feet (18.9 m.) from the base, numerous fragments of trilobite tests occur but are too much broken up to permit recognition of genus or species.		
The fauna near the summit is the same as that in the oolitic limestone in the section of the Mount Whyte formation at McArthur Pass and Mount Stephen.		
2. Thin bands of dark gray, arenaceous shale, alternating with thin layers of hard, uneven, greenish, brownish-gray sandstone	57	17.4
This band forms a low cliff on the slopes of Ptarmigan, Richardson, and Redoubt Mountains when not covered by talus of the limestone cliffs above.		
Fauna.—(60e): the surface of the sandstones is thickly marked by casts of annelid trails and borings.		
Ptychoparia cercops Walcott		
Olenopsis crito Walcott		
3. Fine-grained, dirty-gray to greenish arenaceous shale..	43	13.1
Fauna.—Fragments of trilobites.		
4. Thin-bedded gray, more or less calcareous, hard sandstone	17	5.2
Fauna.—(35b):		
Olenellus canadensis Walcott		
Mesonacis gilberti (Meek)		
Bonnia fieldensis (Walcott)		
Total of Mount Whyte formation	342	104.2

St. Piran Formation

	Feet	Meters
The upper portion of the St. Piran formation is exposed in the Pass beneath the calcareous sandstones of the Mount Whyte formation and a little to the north on the northeast slope of Ptarmigan Peak the section is exposed down to the pre-Cambrian rocks. The section faces Ptarmigan Lake and may be seen in its entire extent from the southeast side of the lake.		
1. Cross-bedded, gray, brownish-weathering sandstone...	68	20.7
2. Thick-bedded, hard, light gray, quartzitic cliff-forming sandstone	430	131.1
Fauna.—(60c):		
Scolithus sp.		
Mesonacis gilberti (Meek)		
3. Shaly and thin-bedded, light, brownish to gray sandstone	57	17.4
4. Thick-bedded, light gray, quartzitic, cliff-forming sandstone	230	70.1
Fauna.—Fine *Scolithus* occur in immense numbers in many layers that vary from 2 inches to 2 feet (5.1 cm. to .6 m.) in thickness.		
Total of St. Piran formation	785	239.3

NS

Mountain with cliffs of Middle Cambrian limestone above, and on the south side, the
44 and 46.)



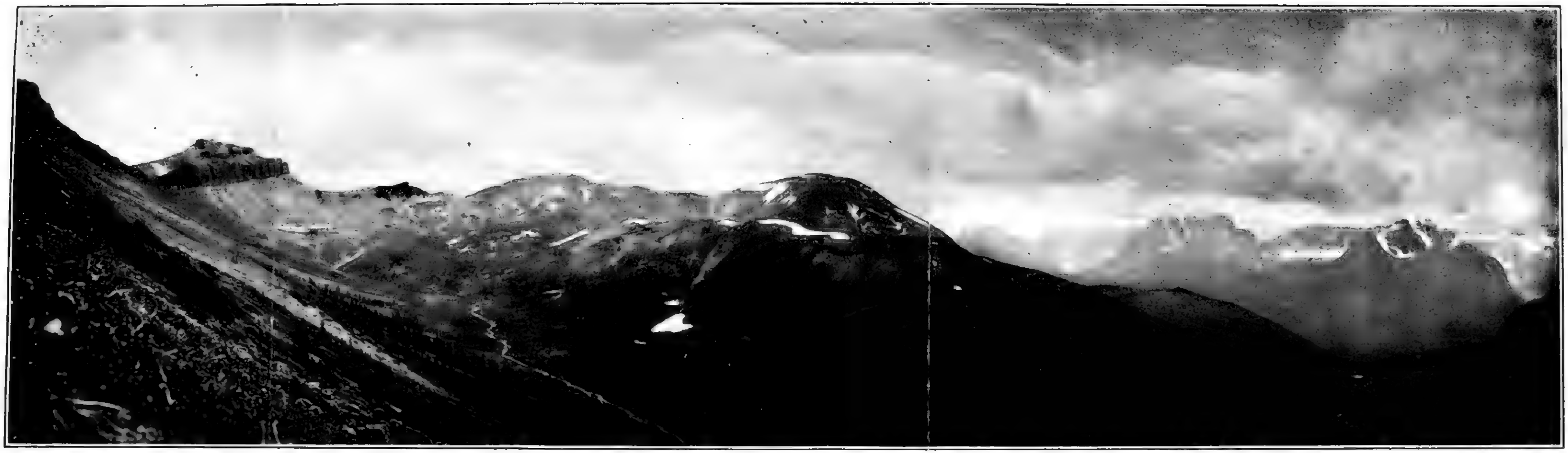
On the left the south slope of Redoubt Mountain (pl. 43) with a dark cliff of Lower Cambrian sandstones that are superjacent to the pre-Cambrian shales and sandstones of the Hector formation. The pre-Cambrian beds form the hills down to the Bow Valley and pass beneath the peaks of the Bow Range on the south (right side).

Locality.—Northeast of Lake Louise Station, Alberta.

upturned Lower Cambrian sandstones that are superjacent to the pre-Cambrian
Locality.—About 5 miles (8 km.) northeast of Lake Louise Station, Alberta.

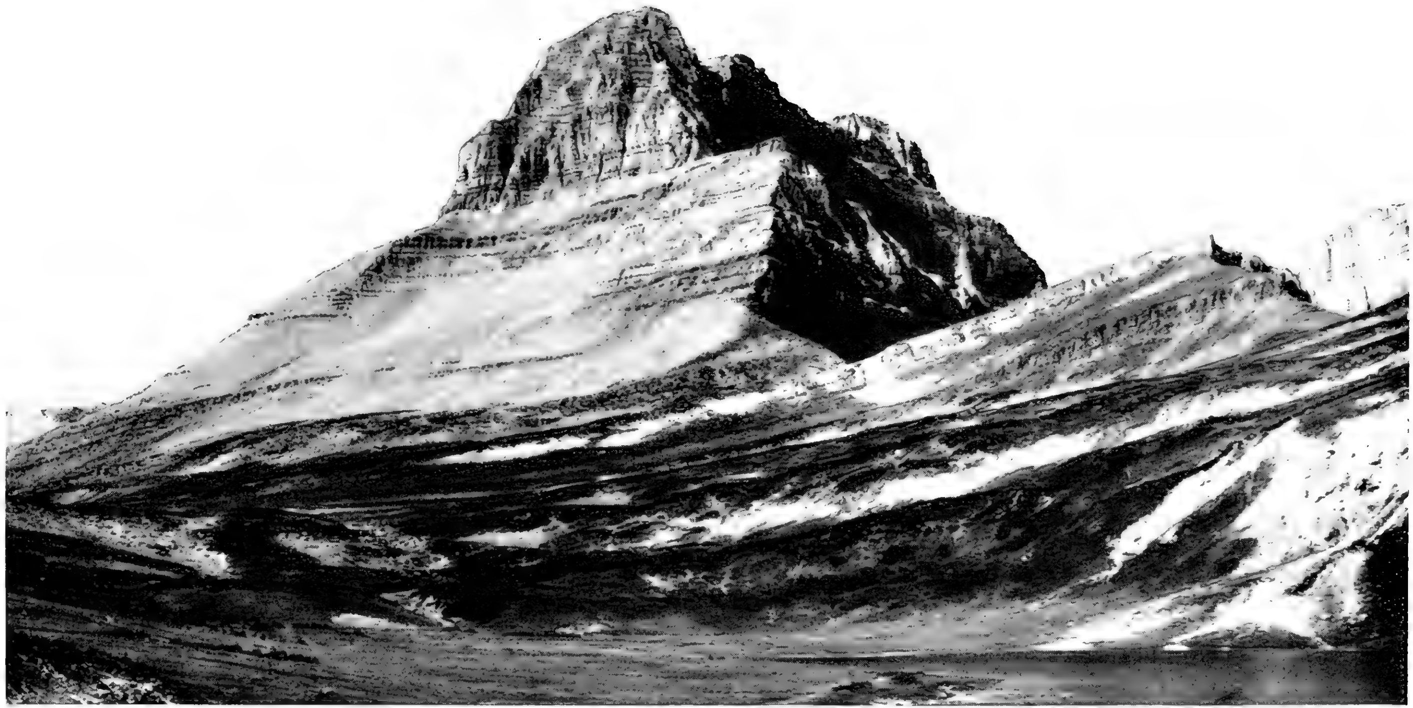
Southwest and south cliffs of Redoubt Mountain. The contact of the Lower Cambrian quartzitic sandstones with the pre-Cambrian Hector shaly sandstones is at the base of the lower dark cliff at the east (right) end of the mountain. This cliff extends along the entire south side.

Locality.—About 4.5 to 5 miles (7.2 to 8 km.) east-northeast of Lake Louise Station, Alberta, and 2.5 miles (4 km.) southwest of *F* on map, plate 26.



Western side of Redoubt Mountain with cliffs of Middle Cambrian limestone above, and on the south side, the upturned Lower Cambrian sandstones that are superjacent to the pre-Cambrian Hector formation. (See pls. 44 and 46.)

Locality.—About 5 miles (8 km.) northeast of Lake Louise Station, Alberta.



Ptarmigan Peak (10,060 feet, 3,066.3 m.) with Ptarmigan Lake at its base. The Middle Cambrian Cathedral limestones form the upper 2,100 feet (640.1 m.) of the mountain, with the subjacent Ptarmigan formation 516 feet (157.3 m.) and the Lower Cambrian Mount Whyte formation 252 feet (76.8 m.) thick extending down to the quartzitic sandstones of the St. Piran formation, which form the low, sharply defined ridge on the right. The latter is thrust over the arenaceous shaly beds of the pre-Cambrian Hector formation.

Locality.—1.5 miles (2.4 km.) west of *F* on map, plate 26. The summit of Ptarmigan Peak is 6 miles (9.7 km.) in an air line, northeast of Lake Louise Station, Alberta.

Panoramic view of south side of the Baker and Ptarmigan Lakes valley. On the left Brachiopod Mountain (Devonian). In center Quartzite Mountain (Lower Cambrian and pre-Cambrian). At the right Redoubt Mountain (Middle and Lower Cambrian).

Locality.—At *F* on map, plate 26. About 5.5 to 7 miles (8.8 to 11.3 km.) northeast of Lake Louise, Alberta.

	Feet	Meters
LAKE LOUISE SHALE		
Dark, siliceous shale	28	8.5
Fauna.— *Cruziana* sp. *Planolites* sp.		
FORT MOUNTAIN FORMATION		
1. Thick-bedded, light gray, occasionally cross-bedded, quartzitic sandstone with a little trace of purple color in a few layers	260	79.2
2. Light gray to brownish-gray sandstone in thin layers	22	6.7
3. Massive-bedded conglomerate with white quartz pebbles and bits of dark and greenish shale in coarse sandstone matrix. Several irregular lentils and thin bands of shale occur in the lower portions	170	51.8
Total of Fort Mountain formation	452	137.7

DISCONFORMITY

ALGONKIAN

HECTOR FORMATION

Greenish gray, siliceous shale with a massive-bedded, very coarse conglomerate about 400 feet (121.9 m.) below the Cambrian.

The section is here cut off by a fault.

Fossil Mountain Section

The sections southeast of Ranger Brook in the Sawback Range were not measured, nor those on the south side of Bow River nor to the northwest for a distance of 18 miles (28.9 km.), as they are essentially the same from Bow Valley to the head of Douglas Lake Canyon. At Fossil Mountain, 21 miles (33.8 km.) northwest of Ranger Canyon section, the strata beneath the Devonian are readily accessible, and the section of the Sarbach and the upper portion of the Mons is excellently exposed. The section was first examined on the southeast face of the mountain about 3 miles (4.8 km.) south of the Red Deer River and 8 miles (12.9 km.) northeast of Lake Louise Station on the Canadian Pacific Railway (see pl. 48).

Fossil Mountain rises abruptly from the north side of Baker Lake and slopes at about 25° to 30° to the west and more rapidly to the east because the broken cliffs extend from near the summit down to the long talus slopes. The strike of the strata on the east face of the mountain is about north 15° to 20° west with a dip of 60° to 65° south, 30° west. On the west side a mass of reddish-brown sandstones and arenaceous shales of the Hector formation of the pre-Cambrian Beltian series has been thrust eastward so as to lie against and on the Devonian limestones; the latter have been crushed together on the north and south axis of the mountain so as to form a rather sharp syncline at the summit (see pl. 48). On the east face the bedding and dip are uniform down to the shaly beds of the Mons formation, in which the broad canyon valley between Fossil Mountain and Oyster Peak has been eroded (see pl. 48). The western side of Oyster Peak, as well as its southern ridge, is formed of the hard, compact, thick-bedded, gray arenaceous and magnesian limestones of the upper part of the Lyell formation. On Oyster Mountain, directly east of the summit of Fossil Mountain, a great glacial cirque extends back for nearly a mile (1.6 km.) into the ridge, exposing the Upper Cambrian Lyell formation, some of the Bosworth and Arctomys, and the Middle Cambrian Eldon formation. A fault here interrupts the section in about the same manner as in the Ranger Brook section, 19.5 miles (31.4 km.) to the southeast.

From the summit of Fossil Mountain down the eastern side there is an estimated thickness of 600 feet (182.9 m.) of thick-bedded, dark gray, rough-weathering Devonian limestones that correspond in appearance and in the presence of Middle Devonian corals to the Messines formation of the Clearwater section 16.5 miles (26.5 km.) to the north-northwest.

The presence of Devonian corals and stromatoporids in abundance in the talus of the south side of Fossil Mountain, undoubtedly suggested its name.

DEVONIAN

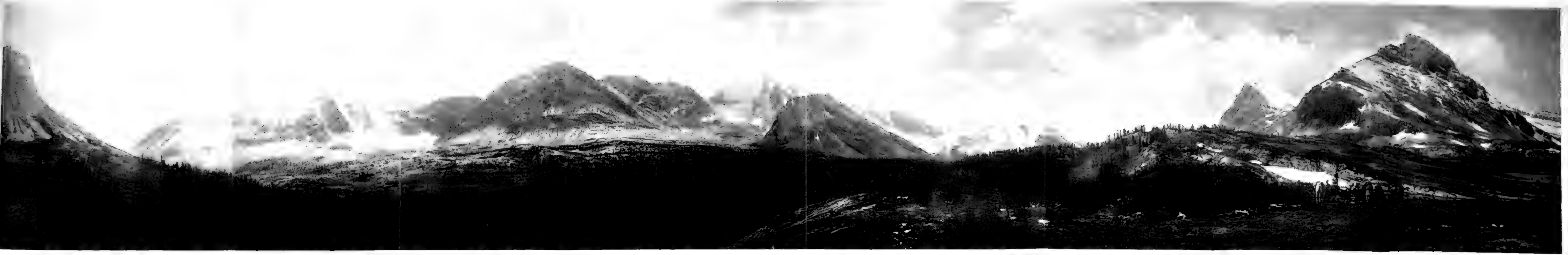
	Feet	Meters
Disconformity		
No apparent physical unconformity exists between the rough-weathering, dark lead-gray limestones carrying numerous corals and stromatoporids of the Middle Devonian Messines formation and the subjacent strata.		
Ghost River Formation?		
Beneath the Devonian there is a series of thin layers of magnesian limestone with layers of chert 1 to 2 inches (2.5 to 5.0 cm.) thick which may be between the layers or form part of them......................	35	10.7
The dark, coarse Devonian Messines limestone above and the light gray relatively soft Ordovician Sarbach limestone beneath these cherty magnesian beds define the latter as a formation unlike either, and as one deposited under dissimilar conditions. It may be the representative of the Ghost River formation of the Ghost River section (p. 261).		

L. 48

et, 3,066.3 m.) to the left o
Locality.—At F .

Panoramic view of east and south face of Fossil Mountain (9,655 feet, 2,942.8 m.) on the right, Ptarmigan Peak (10,060 feet, 3,066.3 m.) to the left of it, with its basal beds thrust over the limestones of Fossil Mountain, and at the left side the end of Brachiopod Mountain (8,750 feet, 2,667 m.) with a great mass of limestone that has broken away from the mountain.

Locality.—At *F* on map, plate 26. Baker Lake in central foreground is 7.25 miles (11.7 km.) northeast of Lake Louise Station, Alberta.



Panoramic view starting from the left with Fossil Mountain (9,665 feet; 2,945.9 m.), then over the Low Red Deer-Baker Creek Divide to Oyster Peak (9,110 feet; 2,776.7 m.) and Ridge with Cotton Grass Cirque, Tilted Mountain and Cirque, then the upturned ridges of Sawback Range to Anthozoan (9,070 feet; 2,764.5 m.) and Brachiopod Mountains on the west side of Baker Creek Canyon.
Locality.—At *L* on map, plate 26. View taken from the east end of Baker Lake (7,5[illegible] feet; 2,3[illegible]1.4 m.) at a point 8 miles (12.9 km.) north of Lake Louise Station, Alberta.

DISCONFORMITY

ORDOVICIAN

SKOKI FORMATION

The Skoki limestone was not recognized in this section although the upper part of 1*a* of the Sarbach formation may include it.

CANADIAN

SARBACH FORMATION

	Feet	Meters
1*a*. Thick-bedded, gray limestone, weathering light gray, passing down into massive bands of gray dolomitic limestone that form two high cliffs on east front of mountain. Numbers 1*a-d* of section at the northeast shoulder of Fossil Mountain may correspond to the upper part of 1*a* of this section	840	256.0
1*b*. Light gray magnesian limestone in thin layers, with a few irregularly alternating layers 1 to 3 feet (.3 to .9 m.) in thickness	147	44.8
Strike N. 30° W. Dip W. 30°, S. 30°.		
1*c*. Light gray magnesian limestone, with nodules and stringers of chert	55	16.8
1*d*. Thick layers of cherty quartzite that breaks down on conchoidal fractures into small fragments	48	14.6
Total Sarbach formation	1,090	332.2

The upper 840 feet (256 m.) was measured rapidly and may be in error 50 feet (15.2 m.). Only a few fragments of fossils were observed, but 1 mile (1.6 km.) to the south near the east base of Brachiopod Mountain several layers in the lower part contained brachiopods and fragments of trilobites. Among the genera represented are *Lecanospira* and *Goniurus*.

OZARKIAN

MONS FORMATION

	Feet	Meters
1*a*. Light gray, thick-bedded limestone, with bands and partings of calcareous shale	320	97.5

Fauna.—From 10 to 30 feet (3.0 to 9.1 m.) below the top, several layers carry fragments of trilobites, a few traces of small gastropods, and numerous specimens of *Syntrophia*. The fauna includes (66 o):

Protorthis iones Walcott
Clarkella isis Walcott
Clarkella nisis Walcott
Clarkella nonus Walcott
Hystricurus sp.
Keytella sp.

At 255 feet (77.7 m.) from the top a strongly marked fauna occurs in a number of layers (66n):

Syntrophia isis Walcott
Syntrophia nonus Walcott
Syntrophia perilla Walcott
Ozarkispira leo Walcott
Ozomia lucan Walcott
Keytella eupator Walcott
Apatokephalus sp.
Hystricurus sp.

In addition there are numerous gastropods and several cephalopods.

	Feet	Meters
1b. Limestones similar to those of *1a*, but in thinner layers and interbedded with thicker bands of shale, the shale predominating	355	108.2
Total Mons formation exposed	675	205.7

Fauna.—At 95 feet (28.9 m.) from the base of *1b* a small fauna occurs (66p):

Cystid fragment
Protorthis porcia Walcott
Symphysurina ? sp.
Hystricurus sp.

The fauna 30 feet (9.1 m.) above the base of *1b* includes (66r):

Straparollus sp.
Kainella billingsi (Walcott)

In a gray limestone layer arbitrarily taken as a base of *1b* the fauna still partakes of the character of the upper zone of the Mons formation (66q):

Obolus sp.
Eoorthis sp.
Syntrophia isis Walcott
Syntrophia nonus Walcott
Kainella sp.
Leiostegium keytei Ulrich MSS
Leiostegium truncatum Ulrich MSS

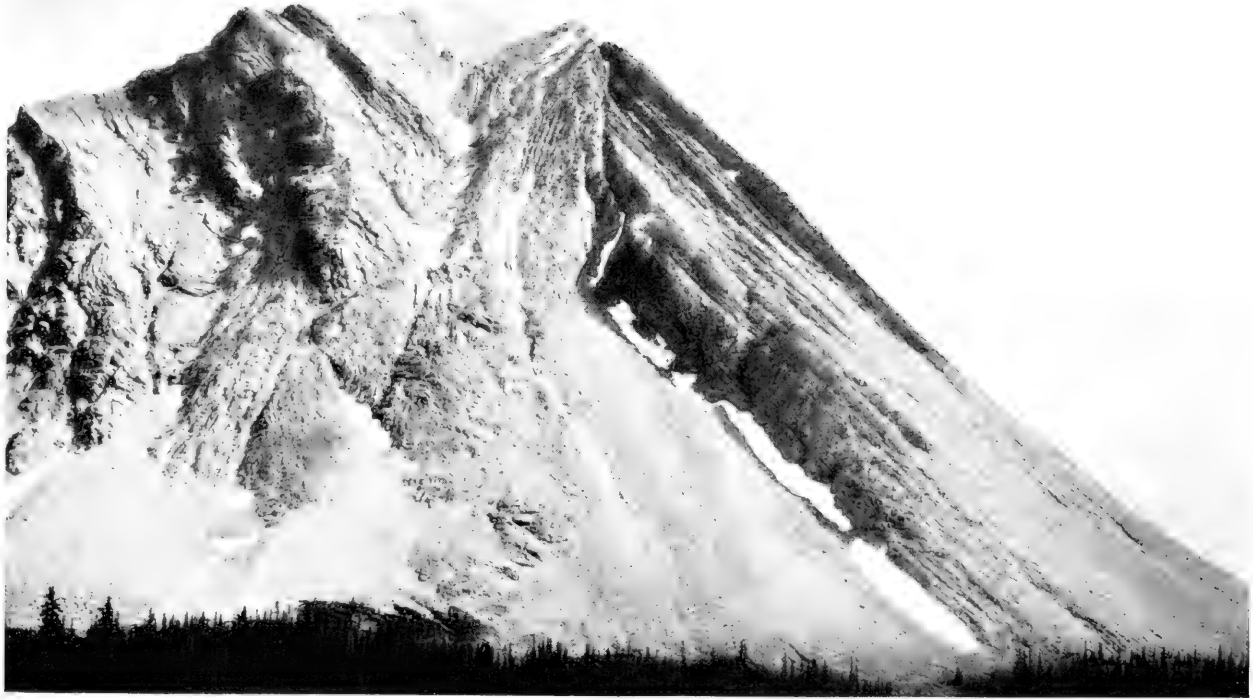
The section below *1b* is more or less covered by glacial and wash deposits in the bottom of the broad canyon valley between Fossil Mountain and Oyster Mountain on the eastern side of the canyon. In the central portion, on the low divide between Red Deer River and Baker Creek, and in the northern 2 miles (3.2 km.) of the canyon, the lower half of the Mons is almost entirely concealed. In the southern part, opposite and east of Brachiopod Mountain, above where Baker Creek enters its narrow steep canyon, isolated outcrops of thin-bedded, dark bluish-gray limestone, interbedded in calcareous shales of the characteristic lower Mons, are of frequent occurrence.

FIG. 1.—The St. Bride-Douglas massif reflected in a pool of the Red Deer River (see pls. 35 and 37).

Locality.—The camera was located about 15 miles (24.1 km.) northeast in an air line from Lake Louise Station, Alberta.

FIG. 2.—Skoki Mountain (8,750 feet, 2,667 m.) from the northwest slope of Fossil Mountain. The highly inclined Devonian limestones form the mountain down to about the middle of the right hand talus slope, where the basal beds rest on the Skoki limestones.

Locality.—Just above *F* on map, plate 26. 9 miles (14.5 km.) northeast of Lake Louise Station, Alberta (see pl. 41).



North end of Oyster Mountain, showing the lower limestones of the Upper Cambrian Lyell formation thrust against the more shaly beds of the Bosworth formation, which are folded into a sharp syncline. This thrust and displacement are also well preserved in the cliffs on the north side of the Red Deer River about 2 miles (3.2 km.) to the north, but do not occur one mile (1.6 km.) southward in the Cotton Grass Cirque (see pl. 47).

Locality.—Head of Red Deer River, 10 miles (16.1 km.) in an air line northeast of Lake Louise Station, Alberta.

Looking south across the upper Red Deer River. On the left, the snow clad summit of Mount Douglas (11,015 feet, 3,357.4 m.), capped by massive Devonian limestones; in the center, Oyster Mountain (9,100 feet, 2,773.7 m.); and on the right, Fossil Mountain (9,655 feet, 2,896 m.).

Locality.—About 2 miles (3.2 km.) north of *F* on map, plate 26. Upper Red Deer River 11 miles (17.7 km.) in air line northeast of Lake Louise Station, Alberta.

From the strike and dip, it is estimated that there may be 200 to 300 feet (60.9 to 91.4 m.) in thickness beneath the lowest beds of the Mons as exposed east of Fossil Mountain and the Upper Cambrian Sabine formation. This would give 875 to 975 feet (266.7 to 297.2 m.) in thickness for the Mons, or about 100 feet (30.5 m.) greater than is found 4 miles (6.4 km.) to the eastward in the Bonnet Peak section.

In the lower part of the Mons, a species of *Symphysurina* occurs in a layer of limestone that projects from a débris-covered slope 500 feet (152.4 m.) or more west of the Lyell limestone at the west foot of Cotton Grass Cirque.

UPPER CAMBRIAN

The uppermost Cambrian beds, if present in this section, are concealed by débris and drift deposits, but on the strike one mile (1.6 km.) to the south, they are finely exposed on Tilted Mountain Brook, where the boundary between them and the superjacent Mons may be seen below the foot of the falls where the brook enters the canyon valley of Baker Creek.

The thick-bedded, hard, light gray and coarse magnesian limestones of the Lyell formation form the western side of the high, long ridge of which Oyster Peak on the north and Tilted Mountain on the south are points rising above its average height. This ridge is on the eastern side of the Upper Red Deer-Baker Lake Canyon Valley, of which Fossil and Brachiopod Mountains form the western limits, except where the broad east and west Baker Lake depression comes in between them. A mile (1.6 km.) south of the summit of Oyster Peak and again at the north base of Tilted Mountain, a large, deep glacial cirque has cut back into the ridge exposing sections of the Upper Cambrian formations. For the Oyster Peak Ridge cirque I am proposing the name Cotton Grass, and for the Tilted Mountain cirque, Tilted Mountain. These cirques are illustrated on plates 50 to 55. The section at Tilted Mountain Cirque is about the same as that of Cotton Grass Cirque.

Lyell Formation	Feet	Meters
The section exposed below the Mons is shown in a few small outcrops of shale and an occasional thick layer of gray pebble or interformational conglomerate limestone,[1] and beneath the latter the thick layers of the Lyell limestone form the slope up to the mouth of the cirque.		

[1] The pebbles or nodules in these limestones appear to have been formed of rolled pieces of calcareous mud of about the same character as their matrix. They often contain bits of fossils similar to those in the matrix.

	Feet	Meters
1a. Gray, rough-weathering magnesian limestone in layers 6 inches (15.2 cm.) to 4 feet (1.2 m.) in thickness that dip to the west-southwest 35° to 40°	195	59.4
1b. Thick-bedded, gray and reddish-buff-weathering, rough-surfaced limestones	380	115.9
At 200 feet (60.9 m.) from the top, 3 or 4 thick layers are covered on the upper surface with the ends of large, more or less cylindrical growths of *Collenia*[1] (see fig. 28).		
1c. Massive series of light gray, thick-bedded, hard, rough-weathering magnesian limestones that form the high western front face of the ridge of Oyster Peak and Ridge	980	298.7
Fauna.—Only a few traces of large annelid borings and trails.		
The lower strata of the Lyell form the narrow, sharp ridge of Oyster Peak, east of which the subjacent softer, arenaceous limestones and shales disintegrate into a fine talus slope that extends down to the bottom of Cotton Grass Cirque.		
2a. Reddish-brown, more or less arenaceous shales and friable thin-bedded, arenaceous limestone with a few thin, hard layers	190	57.9
Fauna.—Fragments of broken-up trilobite tests. At this zone in Tilted Mountain Cirque, about a mile (1.6 km.) south on the strike of the strata, a small collection was made that included recognizable cranidia of *Kingstonia* sp.		
2b. Thin layers and beds of steel- and bluish-gray limestone, with a few layers of oolitic limestone of varying thickness	310	94.5
Fauna.—Many fragments of trilobites in oolitic and bluish-gray limestone. In the Tilted Mountain Cirque section, a small fauna found at this horizon (21w) gave fragments of *Conaspis* and *Kingstonia.*		
Total Lyell formation	2,055	626.4

ARCTOMYS FORMATION

	Feet	Meters
1a. Thin layers and shales of arenaceous and calcareous purplish, buff, and gray beds, with partings and bands of shale, all of the belt breaking down into fine, sandy débris that extends down the slope to the little lake in the south side of the cirque	215	65.5
Ripple marks, mud cracks, and casts of salt crystals occur on the surface of the more compact layers. (See Ranger Canyon section, p. 264, and Mount Bosworth section, p. 308.)		

[1] Smithsonian Misc. Coll., Vol. 64, No. 2, 1914, pl. 10, fig. 3; pl. 17, figs. 1, 2.

	Feet	Meters
1*b*. Thin-bedded, light gray to cream-colored, hard, thin-bedded, fine, siliceous silt-like mud rock, with a few thin layers of bluish-gray limestones containing many fragments of trilobite tests........................	510	155.4
Strike N. and S. Dip in lower part 35° W.		
Measured 210 feet (64.0 m.) in thickness and estimated that the upper portion was 300 feet (91.4 m.) thick.		
Total Arctomys formation....................	725	220.9

MIDDLE CAMBRIAN

Eldon Formation

1*a*. Thick-bedded, rough-weathering, siliceous and finely arenaceous limestones in dark and light gray bands 100 feet (30.5 m.) or more in thickness.

Thickness not measured.

At the eastern upper end of Cotton Grass and Tilted Mountain Cirques, the Eldon limestones rise high above the shales and limestones of the Arctomys and abut against the Devonian limestones, which are upturned against them in Cotton Grass Cirque and downward in Tilted Mountain Cirque on the line of a westward sloping fault[1]. (See diagrammatic outline fig. 25).

Section on Northeast Shoulder of Fossil Mountain

This section is 2 miles (3.2 km.) north of the Fossil Mountain section proper. It is capped by dark Middle Devonian limestones (Messines), which are conformably superjacent to the light gray-weathering limestones of the Skoki formation. There are no traces of any distinct deposit, such as the Ghost River formation or the Mount Wilson quartzite above the Skoki, but there is a thin bed of shale at the base of the Devonian.

The Skoki and Sarbach formations are excellently exposed, and several zones with characteristic fossils were located, the most important of which is the *Isoteloides* of the lower Sarbach. The limestones are about 400 feet (121.9 m.) thicker than 2 miles (3.2 km.) south, apparently owing largely to the development of the Skoki formation.

[1] Smithsonian Misc. Coll., Vol. 77, No. 2, 1925, fig. 1, frontispiece; fig. 7, p. 5; fig. 13, p. 10; and fig. 17, p. 11.

DEVONIAN (MIDDLE)

	Feet	Meters
Messines Formation		
This section is essentially the same as that at Clearwater Canyon, 17 miles (27.4 km.) northwest, except that it is not overlain by the Pipestone formation of the Upper Devonian. I did not attempt to measure it.		
Disconformity		

ORDOVICIAN

	Feet	Meters
Skoki Formation		
1a. Light gray siliceous and magnesian limestones in layers 15 to 24 inches (38.1 to 60.9 cm.) thick. In the lower part the limestone is very fine, smooth, and with thin layers and nodules in layers of bluish-gray chert that weathers to a buff and reddish-brown color.........	380	115.8
Fauna.—Annelid trails on surface of layers and borings in the coarser layers.		
1b. Thick-bedded, light gray, slightly arenaceous limestones in layers from 2 to 3 feet (.6 to .9 m.) thick	12	3.7
1c. Light gray, hard, compact limestone, with thin layers, stringers, and nodules of chert similar to that in *1a*..	42	12.8
1d. Light gray, slightly arenaceous limestone in layers 2 to 6 feet (.6 to 1.8 m.) thick, which split up on weathered outcrops into thinner layers..................	66	20.1
Total of Skoki formation.....................	500	152.4

CANADIAN

	Feet	Meters
Sarbach Formation		
1a. Fine-grained, dark, steel-gray, magnesian limestone in layers 3 to 5 feet (.9 to 1.5 m.) thick. A few irregular, thin layers and small lentils of bluish-gray, hard limestones occur within the thick layers, which give a striped appearance on fresh breaks and a banded effect where the magnesian layers weather out in relief in rusty buff and brown colors...............	36	10.9
Fauna.—A few thin layers of a softer gray limestone occur as an irregular band about 6 inches (15.2 cm.) thick 18 feet (5.5 m.) from the base of *2a*. (21z): *Megalaspis* fauna.		
1b. Hard, gray, compact limestone with finely crystalline structure in layers 12 to 40 inches (30.5 to 101.6 cm.) thick, which break down into thin, irregular layers and fragments on weathered outcrops.............	90	27.5
1c. Soft gray limestone in layers 6 to 30 inches (15.2 to 76.2 cm.) thick, which break down into small fragments that quickly disappear on weathered talus slopes	105	32.0

	Feet	Meters
Fauna.—The fossils collected occur from 30 to 40 feet (9.1 to 12.2 m.) above the base, where there are some compact regular layers. (69b).		
1*d.* Gray limestone somewhat similar to 2*b* in appearance and bedding but harder, more regular and on weathering breaking down into blocks, thin layers and angular fragments. On the weathered sections of the thicker layers the laminated character of the original deposit is finely shown by the unequal erosion of the calcareous and magnesian lamellae. The magnesian lamellae are from $\frac{1}{8}$ to $\frac{1}{4}$ inch (.3 to .6 cm.) in thickness and stand out in relief from the softer gray limestone and weather to a buff and brown color, which adds to their striking appearance. The thick layers split up with irregular surfaces on the lines of the lamellae	24	7.3
Fauna.—(21x): *Phyllograptus ilicifolius major* Ruedemann (MSS); *Didymograptus pacificus* Ruedemann (MSS); *Lingula* sp.; *Ophileta* sp.; *Eopteria* sp.; *Eccyliopterus* sp.; *Megalaspis.* sp.; *Goniurus* sp.		
Dr. Rudolph Ruedemann, in commenting on this faunule, said, "These two graptolites suggest that the formation is comparable to graptolite horizons 2 or 3 of the Deep Kill shale and is therefore of Beekmantown (Canadian) age." (January 19, 1923).		
1*c.* Thick-bedded, gray limestones that have more or less of the character of both 2*c* and 2*d*. The lamination is more irregular than that of 2*d*, and the magnesian lamellae proportionally thicker. At 126 feet (38.4 m.) from the top a few of the gray limestone lamellae increase in thickness to 4 inches (10.2 cm.) or more, and numerous fragments of trilobites occur in them.	145	44.2
Fauna.—(69c): *Megalaspis* fauna		
Total of 1..................................	400	121.9
2. Steel to dirty gray, finely arenaceous magnesian limestone, with included thin layers, nodules, and stringers of gray, dark rusty brown-weathering chert.........	95	28.9
Fauna.—Large annelid trails on surface of layers, and borings within the layers.		
3*a.* Light gray, compact limestone, with considerable cherty matter in thin, irregular and often inosculating lamel-		

	Feet	Meters
lae, small nodules, and occasionally a thin, regular layer. Some of the thick layers contain so much dark-weathering chert that they give a dark rusty brown color to cliffs. The purer gray limestone lamellae thicken in places so that layers several feet in thickness occur without cherty inclusions..........	175	53.3
3*b*. Limestones concealed by talus slope but exposed a mile (1.6 km.) south....................................	60	18.3
Limestone at base similar to 4*a*..................	8	2.4
3*c*. Fine-grained, smooth, dove-colored limestone in thin, even layers from 2 to 4 inches (5.1 to 10.2 cm.) thick	14	4.3
3*d*. Similar to 3*a*...	48	14.6
Total of 3...	305	92.9

Fauna.—At 35 feet (10.7 m.) below summit of 3*a*, a thin layer of gray limestone yielded fragments of trilobites. (69d) same as (69a).

A thin layer of bluish-gray limestone at 110 feet (33.5 m.) below summit gave a few imperfect fragments and a similar layer 140 feet (42.7 m.) below the summit gave (69a) a *Megalaspis* fauna.

In central portion of 3*d* occurs a small faunule, the same as (69a), (69e).

4. Steel-gray magnesian limestone in layers 2 to 4 feet (.6 to 1.2 m.) thick, and weathering yellowish buff in color	110	33.6
Total thickness of Sarbach formation..........	910	277.3

The line between the Sarbach and the subjacent bluish-gray and dirty gray-weathering light gray limestones of the subjacent Mons formation is strongly marked by the contrast in color and character of the limestones, and the *Ozarkispira* fauna of the upper Mons is not known in the Sarbach.

The above section of the Sarbach is the best that I have encountered. It is most accessible, and there is a fine camp site to the north side of Fossil Mountain at the foot of Skoki Mountain, which is 10 miles (16.1 km.) by trail from Lake Louise Station.

OZARKIAN

Mons Formation

1. Bluish-gray and dirty gray-weathering light gray limestones in layers 2 to 4 feet (.6 to 1.2 m.) thick, with a little chert in small fragments and as replacement of fragmentary fossils. Measured 150 feet (45.7 m.) to foot of débris and dirt slope. Small out-

Eldon. Devonian. Middle Cambrian. (Eldon). Arctomys. Bosworth. Lyell.

Panoramic view of Tilted Mountain Cirque as seen from southwest slope of Fossil Mountain above Skoki Pass (see pl. 41). The formations exposed are indicated on figure 27.

Locality.—Western side of Sawback Range opposite outlet of Baker Lake, which is 7.9 miles (12.7 km.) in an air line northeast of Lake Louise Station, Alberta.

North and northeast side of Tilted Mountain Cirque, with small glacial lake. The geologic section is the same as on the south side of the cirque (see pl. 47).

Locality.—At *F* on map, plate 26. Western side of Sawback Range opposite outlet of Baker Lake, which is 7.9 miles (12.7 km.) in an air line northeast of Lake Louise Station, Alberta.

Ridges a little south of Tilted Mountain and sloping towards Baker Creek Canyon opposite Brachiopod Mountain.
Locality.—Western side of Sawback Range about 9 miles (14.5 km.) in an air line east-northeast of Lake Louise Station, Alberta.

FIG. 1.—View of the head of Tilted Mountain cirque showing the Eldon tilted up against the Devonian limestones (see fig. 27).

Locality.—Western side of Sawback Range opposite outlet of Baker Lake, 7.9 miles (12.7 km.) in an air line northeast of Lake Louise Station, Alberta.

FIG. 2.—Tilted Mountain Brook Falls, where the thick-bedded dolomitic limestones at the summit of the Lyell dip westward beneath the Mons. Tilted Mountain in the distance above the falls.

Locality.—About 1 mile (1.6 km.) east-southeast of the outlet of Baker Lake, 7.9 miles (12.7 km.) in an air line northeast of Lake Louise Station, Alberta.

crops of calcareous shale and bluish-gray limestone of the Mons occur as scattered ledges down to the stream bed. See p. 284 for note on outcrops in Baker Creek Canyon Valley.

Tilted Mountain Brook Section

Tilted Mountain is 1.7 miles (2.7 km.) east-northeast of Brachiopod Mountain, about 2 miles (3.2 km.) southeast of Fossil Mountain (see F on map, pl. 26), 2.8 miles (4.5 km.) south-southeast of Oyster Mountain, and 9.5 miles (15.3 km.) east of Lake Louise Station on the Canadian Pacific Railway.

Tilted Mountain Brook flows from a small glacial lake in the bottom of a large cirque through a channel eroded in the upper Lyell magnesian limestones and down through the calcareous shales and limestones of the Sabine formation. It enters the broad upper canyon valley of Baker Creek, about .5 miles (.8 km.) west of the small lake, the waters of the brook sliding and falling over the thick magnesian limestone layers that form the first sloping cliff above the broad bottom of Baker Creek Canyon. A diagrammatic section of this portion of the section is shown by figure 26. About 130 feet (39.6 m.) down from the base of the Mons the upper zone (20d) of the Sabine fauna occurs, and below this the typical Franconia *Ptychaspis* fauna, in the midst of which the *Collenia* zone occurs. It gave us a thrill of delight when these faunules were discovered, ending the long search at this horizon for a distinct fauna.

The *Collenia* zone was traced north to a point below Cotton Grass Cirque, opposite Fossil Mountain.

This section is essentially the same as that at Cotton Grass Cirque 1.5 miles (2.4 km.) to the north, at the south end of Oyster Peak Ridge (see p. 285), except that the upper fossiliferous portion of the Sabine formation is not well developed west of Cotton Grass Cirque.

UPPER CAMBRIAN

The Mons formation extends across the floor of the canyon valley east of Baker Lake to the west base of Tilted Mountain.

Sabine Formation	Feet	Meters
1*a*. Gray, hard, arenaceous shale, with interbedded thin layers of arenaceous dolomitic limestone	15	4.6
1*b*. Thick-bedded, hard, rough-weathering, gray and buff dolomitic limestone	115	35.0
1*c*. Light gray, thin-bedded, somewhat irregular limestone	16	4.9

	Feet	Meters
Fauna.—(20d): large *Saukia*, etc.		
Eurekia sp.		
Dikelocephalus sp.		
Illaenurus sp.		
1*d*. Thick-bedded, buff magnesian limestone similar to 1*b*..	62	18.9
1*e*. Arenaceous shales, with thin layers of dolomitic and a few of gray limestone..........................	45	13.7
Fauna.—(20j):		
Saukia sp.		
Ptychaspis sp.		
Irvingella sp.		
Conaspis sp.		
1*f*. Thick-bedded, gray, buff-weathering magnesian limestone similar to 1*b* and 1*d*........................	58	17.7
Fauna.—At 30 feet (9.1 m.) down, the upper surface of a thick layer (3 feet, .9 m.) is covered with the ends of a columnar species of *Collenia* similar to that at the same horizon 1.5 miles (2.4 km.) to the north.		

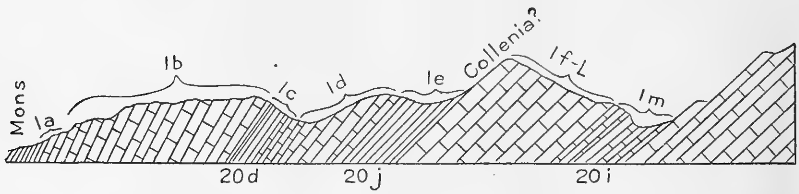


FIG. 26.—Diagrammatic outline of the upper 400 feet (121.9 m.) of the Lyell formation of the Tilted Mountain Brook section. Three fossil zones of the section are indicated by the locality numbers (20d), (20i), (20j), and the divisions of the section by number and letter, 1*a* to 1*m*.

Locality.—About one mile (1.6 km.) east of the base of *F* on map, plate 26.

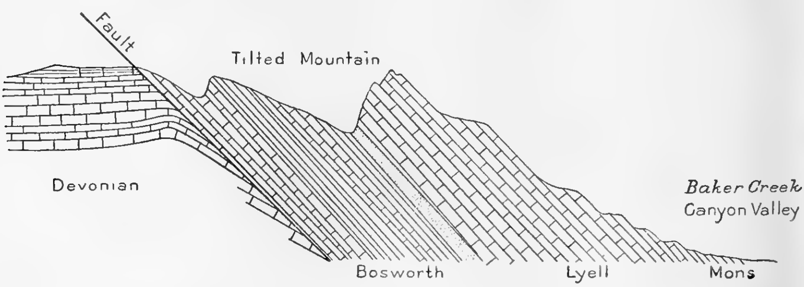


FIG. 27.—Diagrammatic outline of section on south side of Tilted Mountain Cirque from the Mons down through the Lyell, Bosworth, Arctomys, and Eldon formations to a fault separating the latter from the Devonian limestones (see pls. 52-55).

	Feet	In.	Meters
1*g*. Arenaceous shales with thin layers of bluish-gray limestone	6		1.8
1*h*. Irregularly-bedded gray limestone in layers of varying thickness. The three layers composing it are 3 feet			

	Feet		Meters
(.9 m.), 1 foot, 4 inches (.4 m.) and 4 feet (1.2 m.) thick	8	4	2.5
1*i*. Thin-bedded, bluish gray limestone with shaly partings	5	6	1.7
1*j*. Limestone similar to 1*h*	4	6	1.4
Fauna.—Comminuted tests of small trilobites.			
1*k*. Similar to 1*i*	19	0	5.8
1*l*. Similar to 1*h*	2	6	.8
Fauna.—(21v): *Billingsella* sp. *Agnostus* *Conaspis* sp. *Irvingella* sp.			
1*m*. Similar to 1*i*	21	0	6.4
1*n*. This stratum is very much like that of 1*h*. It is composed of three more or less irregularly-bedded layers of gray limestone. The upper layer has a *Stromatoporid*-like structure that gives its upper side a mammillated surface, a character also shown on the upper layer of 1*h*. Small fragments of thin layers of limestone occur in places to an extent sufficient to suggest interformational conglomerate. This and the irregular arrangement of the fragments of fossils and their matrix suggests strong current action. Locally the limestone weathers to a yellow-buff color, which indicates a magnesian content similar to that in the thick layers of magnesian limestone below	3	2	.9
Fauna.—In the lower layer, near its base, a number of fossils were collected (21s): *Billingsella* sp. *Ptychaspis* sp. Cf. *Saratogia wisconsensis* *Ellipsocephalus curtus* Whitfield			
1*o*. Thin-bedded and shaly, compact, hard, bluish-gray limestone, with partings of dark argillaceous shale	17	0	5.1
The thin-bluish-gray limestones interbedded in the shales were unfossiliferous as far as observed.			
1*p*. Thick layers of gray limestone that break up into irregular layers on exposure to weathering. The limestone varies in thickness from 16 to 24 inches (40.6 to 60.9 cm.) in a distance of 30 feet (9.1 m.)	2	0	.6
Fauna.—(20i): this is the most prolific in fragments of fossils of the several gray limestone layers in the section. It appears to carry the same fauna as (21s) of 1*n* of section. *Billingsella* sp. *Ptychaspis* sp. Cf. *Saratogia wisconsensis* *Ellipsocephalus curtus* Whitfield			
1*q*. Limestone and shale similar to 1*o*	1	0	.3

	Feet		Meters
1*r*. Hard gray limestone, with irregular streaks of buff-weathering magnesian limestone. Varies in thickness from 9 to 12 inches (22.9 to 30.5 cm.)	1	0	.3
1*s*. Thin-bedded, bluish-gray limestone interbedded in dark argillaceous shale	13	0	3.9
Fauna.—(21t): a 3 to 5 inch (7.6 to 12.7 cm.) layer, 6 feet (1.8 m.) from the base, yielded a few fossils, with fragments of rather large trilobites. *Idahoia* sp. At 8 feet (2.4 m.) above the base of 1*s* a few fragments of fossils were collected from a layer of gray limestone (21u).			
Thickness of Sabine formation	415	—	126.5

Beneath the Sabine, thick-bedded, buff and gray magnesian limestones of the Lyell formation extend down in the section as at Cotton Grass Cirque, 1 mile (1.6 km.) to the north. These beds dip 40° west with a strike of north 15° west.

Algal Growth

A few of the layers of the upper part of the Sabine limestone (see p. 227) carry a large and varied series of columnar-like, supposedly algal growths, similar in outward form to objects in the pre-Cambrian Siyeh limestone of Glacier National Park referred to the genus *Collenia*.[1] They are clearly exposed in and on several layers of a cream- to buff-colored, fine-grained magnesian limestone, 280 to 300 feet (85.3 to 91.4 m.) below the summit of the formation. The layers carrying the *Collenia* ? below Cotton Grass and Tilted Mountain Cirques slope to the west-southwest at an angle of about 45°. They are slightly more resistant to erosion than those above them, with the result that along an outcrop of 1,000 feet (304.8 m.) or more, the upper surface of one or more of the layers is exposed to a height of from 10 to 30 feet (3.05 to 9.2 m.). These are well shown by the photographs reproduced on plates 56, 57. The columns in the highest layers in which they occur are larger and longer than in the layer immediately beneath. They vary from 8 to 14 inches (20.3 to 35.6 cm.) in diameter at the upper end, and from 4 to 8 inches (10.2 to 20.3 cm.) in the layer beneath. The latter is underlain by a thick layer of compact, hard, fine-grained magnesian limestone in which no traces of the columnar forms or algal deposits were seen, but in the next subjacent layer, large and very irregular columnar forms occur.

[1] Bull. Geol. Soc. Amer., Vol. 17, 1906, pl. 11; Smithsonian Misc. Coll., Vol. 64, No. 2, 1914, pl. 10, fig. 3.

FIG. 1.—*Collenia ? prolifica*, new species. View of one of the larger exposures of columns *in situ*.

FIG. 2.—*Collenia ? prolifica*, new species. Upper surface of one of the layers from which the covering limestone has been removed by weathering. This shows the upper ends of the columns with their central depression and small pits. Layers dip 35° to 40° west-southwest.

Formation and Locality.—Upper Cambrian, Sabine formation, about 3 miles (4.8 km.) east of *F* on map, plate 26, and 9 miles (14.5 km.) in an air line northeast of Lake Louise Station, Alberta.

FIG. 1.—*Collenia ? prolifica*, new species. Nearer view of a few of the columns, illustrating their mode of growth, form, and occurrence.

FIG. 2.—*Collenia ? prolifica*, new species. Illustrates a bed of large columns underlain by a very evenly arranged bed of smaller columns.
Formation and locality.—Same as plate 56.

In some of the denuded and partially broken down layers, the columns are shown closely packed together; in places they slope at an angle of 5° to 10° to the surface of the layer, and many of them expand slightly from base to summit, varying in length from 20 inches (50.8 cm.) to 4.5 feet (1.3 m.). In form, some are round and others hexagonal and irregular in cross section; they may be crowded together or have spaces between them filled with the limestone matrix. Nearly all reach the upper surface of the layer, but a few are shorter and the laminations of the sediment now forming the matrix arch over these as though they projected above the bed of the sea when the sediment was deposited. The only structure preserved is a convex lamination with a slight depression at the center of each column.

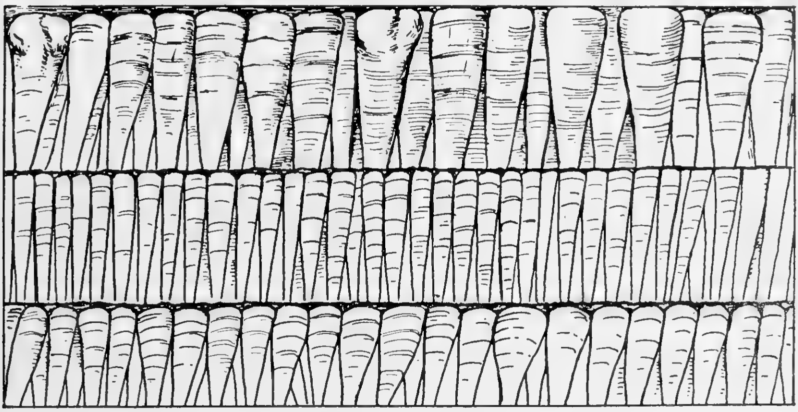


FIG. 28.—*Collenia ? prolifica* new species. Diagrammatic outline of *Collenia ?* beds in which three layers of the deposit are outlined. The middle bed may represent a form distinct from *Collenia ? prolifica*, but slender growths occur in the beds above and below and an occasional broadly expanded column in the middle bed. The only structure features observed are the lamellae of growth.

Formation and locality.—Same as plates 56, 57.

In the section of the Sabine formation above Tilted Mountain Falls (p. 291), there are two thick layers of irregular columns somewhat similar to those below Cotton Grass Cirque, and a form more like *Cryptozoa* occurs in the limestones of the Sabine formation of the Ranger Canyon section (p. 264); also either in the Sabine or Lyell formation on the upper side of the motor road, 5 to 10 miles (8 to 16.1 km.) west of Banff. The outcrops of the Sabine formation occur at Ten Mile Canyon of the Sawback Range above the motor road west of Banff.

Origin of columnar structure.—The origin of the columnar structure was presumably the same as for the cellular, pipe-like *Graysonia* and *Copperia* of the pre-Cambrian,[1] which I considered owed their origin to the agency of algae closely allied to the *Cyanophyceae* (blue-green algae).

MOUNT ASSINIBOINE REGION

Wonder Pass is on the Continental Divide between Gog Lake and Marvel Lake on a branch of Bryant Creek, a tributary of Spray River. The Pass is about 18 miles (28.9 km.) southwest of Banff, Alberta, and 3 miles (4.8 km.) northeast of Mount Assiniboine.

The measured section is from the summit of the ridge down to the level of Gog Lake (7,200 feet, 2,194.6 m., above sea level). The

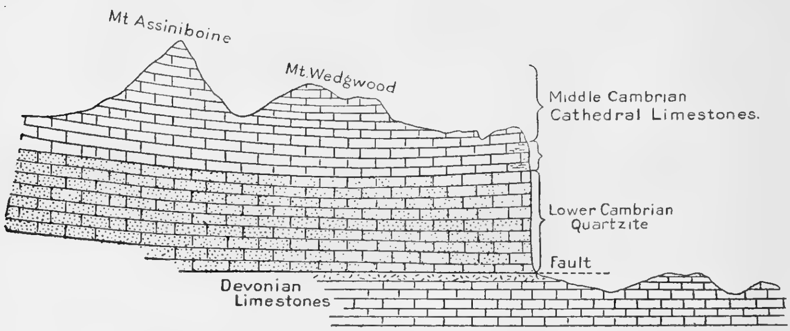


FIG. 29.—Diagrammatic section of the Assiniboine massif showing the thrust fault, on the line of Mount Assiniboine and Mount Wedgwood. The massive Lower Cambrian quartzites are thrust over the Devonian limestones. At Wonder Pass, about 3 miles (4.8 km.) east of Mount Wedgwood cliff, a narrow band of the pre-Cambrian Hector arenaceous shales occurs between the basal Cambrian conglomerate and the thrust fault. (See pl. 60, figs. 1-2.)

summit of the ridge is formed of massive-bedded arenaceous limestones of the Cathedral and Ptarmigan formations. About 400 feet (121.9 m.) of the arenaceous limestone remains on the north section of the ridge, and 1,500 feet (457.2 m.) or more on the south end, which rises to 9,400 feet (2,865.1 m.) at Naiset[2] Mountain. I endeavored to examine the strata of the Cathedral, but just after reaching the top of the Mount Whyte formation, the first snow squalls came and drove me out of the region for the season.

[1] Smithsonian Misc. Coll., Vol. 64, No. 2, 1914, pp. 100-104. pls. 17-19.

[2] The name Naiset, Indian name for Sunset, was proposed in 1916 for the mountain west of Wonder Pass, the same being the northeastern end of the ridge of Mount Assiniboine. This name has been approved by the Geographic Board of Canada.

On Mount Assiniboine, the Mount Whyte formation is concealed by ice, snow, and talus, or exposed in practically inaccessible cliffs, but in the spur or ridge that extends to the eastward from the main peak toward Wonder Pass, excellent exposures may be examined.

The profile of the section beneath the Cathedral cliff-forming limestone, through the Ptarmigan and Mount Whyte formations, is usually a series of broken cliffs. These topographic features continue for many miles both north and south of Mount Assiniboine. On all the higher peaks, the Ptarmigan, Cathedral, or other superjacent Middle Cambrian limestones form cliffs above the Mount Whyte.

To the northwest of Mount Assiniboine, the Mount Whyte formation forms a broken terrace on the front of the range, or is partly merged into a great cliff with the Cathedral and Ptarmigan limestones; usually, however, it stands out from the strata above by change in topographic outline or in color.

MIDDLE CAMBRIAN

	Feet	Meters
CATHEDRAL FORMATION		
1. Light and dark gray arenaceous limestone in massive layers that form cliffs and, on the summits of ridges, slender pinnacles, massive irregular broken walls, and often fantastic figures....................Estimated	1,000 +	304.8 +
PTARMIGAN FORMATION		
1. Bluish-gray, arenaceous limestone, alternating with bands of dark, bluish-black limestone made up of thin layers ....Rough estimate	350	106.7
Fauna.—(63n): *Poliella chilo* Walcott		
1*a*. Buff-weathering, rough, gray, arenaceous limestone....	26	7.9
Total Ptarmigan formation....................	376	114.6

LOWER CAMBRIAN

	Feet	Meters
MOUNT WHYTE FORMATION		
1. Gray oolitic limestone in layers 2 to 8 inches (5 to 20.3 cm.) thick....................................	23	7.0

Fauna.—(62w):

Archaeocyathus atreus Walcott
Kutorgina cf. *cingulata* (Billings)
Paterina labradorica (Billings)
Jamesella lowi Walcott
Acrotreta sagittalis taconica Walcott
Helcionella elongata Walcott
Scenella varians Walcott
Hyolithes billingsi Walcott
Crepicephalus cecinna Walcott
Kochiella cleora (Walcott)

	Feet	Meters
2. Dark gray, siliceous shale, with interbedded hard gray siliceous limestone	17	5.2
No fossils observed.[1]		
3. Gray, buff-weathering, siliceous shales	45	13.7
4. Banded, greenish, siliceous shales, very hard, with hard, finely arenaceous, thin layers alternating at intervals of .5 to 2 inches (1.3 to 5 cm.)	190	57.9
No fossils observed.		
5. Hard, calcareo-arenaceous, greenish, drab-weathering shales, forming massive layers	315	96.0
Fauna.—(62x):		
Gogia prolifica Walcott		
6. Hard, dark gray to black, siliceous shale, weathering buff, and sometimes chocolate-colored bands	195	59.4
Total measured Mount Whyte formation	785	239.2
St. Piran Formation		
1. Massive-bedded, light gray compact quartzite	235	71.6
2. Thin-bedded, gray quartzite, with some shaly partings.	290	88.4
Fauna.—Several large imperfect trilobite heads (*Olenellus*) were noted on a thin slab of quartzite.		
Total St. Piran formation	525	160.0
Lake Louise Shale		
1. Dark, siliceous shale forming a well-marked band in the cliffs	70	21.3
Fort Mountain Formation		
1. Massive-bedded, compact gray quartzite	480	146.3
2. Basal conglomerate in several layers, the bottom one 18 feet (5.5 m.) thick	46	14.0
Total Fort Mountain formation	526	160.3

Unconformity

PRE-CAMBRIAN

Dark, siliceous, hard shale, about 10 feet (3 m.) exposed just above south end of Gog Lake. The upper surface of the shale shows erosion, but in the 40 feet (12.2 m.) of exposure, the strike and dip of the shale and superjacent Cambrian conglomerate appear to be about the same.

[1] Frequent snow-squalls made it almost impossible to search for fossils in this portion of the section.

Panorama of Mount Assiniboine (11,870 feet; 3,617 meters) and [illegible] Lake Magog [illegible] altitude about 7,100 feet [illegible] [illegible] carved from a massive block of Middle and Lower Cambrian [illegible] sandstones. The line of a great overthrust fault along which the Lower Cambrian quartzites have been pushed over the Devonian limestones, curves through Wonder Pass (see pl. 59) on the left, and crossing beneath the [illegible] the base of the Great Wall [illegible] [illegible] At [illegible] on map, plate 26. 22 miles (35.4 km.) in an air line south of Banff, Alberta.

Looking southeast through Wonder Pass on the Continental Divide. Wonder Mountain on the left is formed of Devonian limestones that dip beneath the quartzitic sandstones and basal conglomerate of the Lower Cambrian and a subjacent band of arenaceous shales of the pre-Cambrian Hector formation (see pl. 60). On the right of the pass, Naiset Mountain and glacier of the Assiniboine Massif.

Locality.—At *U* on map, plate 26. 22 miles (35.4 km.) in an air line south of Banff, Alberta.

FIG. 1.—Siliceous conglomerate at the base of the Lower Cambrian and unconformably superjacent to arenaceous shales and sandstones of the pre-Cambrian Hector formation. The hat is below the conglomerate.

FIG. 2.—Nearer view of quartzose conglomerate at base of Lower Cambrian.

Locality.—At *U* on map, plate 26, north side of Wonder Pass at northeast base of Naiset Point, about 22.5 miles (36.2 km.) in an air line south of Banff, Alberta.

Northern ridge of Wedgwood Peak, with its great Cambrian quartzite cliff that forms the northern end of the Assiniboine Massif. The geologic formations are outlined by the diagrammatic section, figure 29.

Camp of Walcott party at edge of forest.

Locality.—At *U* on map, plate 26. 22 miles (35.4 km.) in an air line south of Banff, Alberta.

Only the upper Mount Whyte is represented in this section. Collections from talus slopes near Mount Assiniboine, now in the National Museum, indicate the possible presence of the Stephen formation in some of the cliffs above the Cathedral.

Phareo Peaks Section

About 20 miles (32.2 km.) northwest of Mount Assiniboine, there are two sharp points in front of the main range which Mr. Arthur O Wheeler named Phareo Peaks. Their upper portion is formed of the Mount Whyte formation, and the saddle between the Peaks and the main range is eroded in the greenish and purplish sandy shales and thin interbedded quartzitic sandstones. As at Wonder Pass, there is very little, if any, calcareous matter in the Mount Whyte except near the top, where in places a band of arenaceous and oolitic limestone occurs. Owing to local faulting, the upper portion of the section is broken and split up, and in places absent.

Fauna.—Annelid trails of various sizes and numerous trilobite tracks and burrows occur on the surface of the greenish arenaceous shales. An abundant life was present in the sea, but the currents drifted the shells of the animals elsewhere or destroyed them by attrition.

Rocks of the same general character constitute the Mount Whyte formation for a long distance. It may be seen on Mount Ball, Storm Mountain (see pl. 63), Mount Bident above Consolation Valley, and the spurs projecting from them.

BOW RANGE AREA

Vermilion Pass Section

The ascent to the Pass up Little Vermilion Creek from the Bow River is over drift for two miles (3.2 km.) or more, and then on the shales and sandstones of the pre-Cambrian Belt Series. The contact of the Cambrian basal conglomerate and the gray saponaceous shale of the Beltian is in the canyon southeast of Boom Mountain, about ¼ mile (.4 km.) above the large lake on the creek. The basal conglomerate is in massive layers, alternating with beds of coarse sandstone. The conglomerate extends up the creek, past a small pond, and dips about 25° SW. A band of purplish, arenaceous, slaty shale is superjacent to the conglomerate and above that the massive-bedded, compact, slightly cross-bedded, light gray and purplish sandstones of the Fort Mountain formation. The section gives an excellent opportunity to examine each bed in detail. Well-marked *Scolithus* occur in the sandstone just below the shale.

At the lower end of the upper pond on the north side of the Pass a fine outcrop of Lake Louise shale occurs, and above that the sandstones of the St. Piran formation. At the upper (south) end of the upper pond, numerous Lower Cambrian fossils occur in a light gray, thin-bedded sandstone (60b) of the St. Piran formation:

Obolella vermilionensis Walcott
Orthotheca adamsi Walcott
Wanneria gracilis Walcott

This same fauna occurs in the lower St. Piran formation at the base of Wiwaxy Peaks (61e) on Lake O'Hara, 7 miles (11.2 km.) south of Hector on the Canadian Pacific Railway, British Columbia.

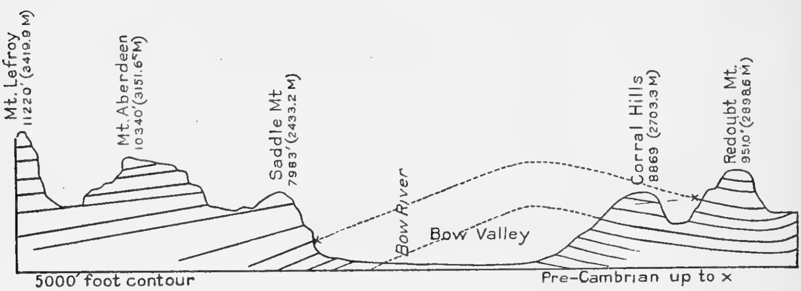


FIG. 30.—Diagrammatic outline sketch of a section from Mount Lefroy on the southwest side of the Bow River Valley, northeast across the valley, about a mile (1.6 km.) southeast of Lake Louise Station, *R* on map, plate 26, and up over the high, rounded hills of pre-Cambrian (Hector and Corral Creek) rocks and the Middle Cambrian limestones of Redoubt Mountain. The position of the broadly rounded Bow Valley anticline is hypothetically indicated by the dotted arched lines. There are several local faults and displacements of strata in the pre-Cambrian of the valley floor that have not been studied or mapped but the broad, general structure appears to be as represented.

A direct line between Mount Lefroy and Redoubt Mountain would pass up the canyon of Corral Creek, so the line of the section is carried over the high Corral Hills on the south side of the creek.

It may be that the strata on the northeast side of the valley, now forming the Corral Hills north and south of Corral Creek, were raised in relation to the mountains of the Bow Range on the southwest side of the valley by a major fault that continues down the valley past Castle Mountain. At Castle Mountain, however, the contact between the base of the Cambrian and the pre-Cambrian is lower than on the southwestern side below Vermilion Pass between Boom and Storm Mountains, which is the opposite of its relative elevation on the line of the Lefroy-Redoubt Mountain section.

The St. Piran sandstones form cliffs back from the Pass on the west side in Boom Mountain and the high ridges north of Storm Mountain on the southeast side. There is a fine section up to the base

Panoramic view of the Bow Valley, showing the broad, almost flat bottom of the valley, and on the south side (left), Mount Fairview (9,001 feet, 2,743.5 m.), with the Victoria glacier and Mount Victoria (11,355 feet, 3,461 m.) above it. To the right, Mount Whyte (9,776 feet, 2,979.7 m.) and Mount Niblock (9,754 feet, 2,973 m.). In the distance, Mount Bosworth (9,093 feet, 2,771.5 m.), the Daly glacier, Mount Daly (10,322 feet, 3,146.1 m.), and the peaks of the Waputik Range.

Locality.—View taken from the lower pre-Cambrian hills on the north side of the valley 2 miles (3.2 km.) northeast of Lake Louise Station, Alberta.

of the limestones of the Mount Whyte formation and continuing up to the massive limestones of the Cathedral formation, which form the summits of Storm Mountain on the east and Mount Whymper and Boom Mountain on the west and northwest.

The Mount Whyte formation on Mount Whymper has a few layers of oolitic limestone interbedded in bluish-black, thin-bedded limestone in which I found a few fragments of trilobites. The limestones measure about 60 feet (18.3 m.) in thickness.

At no point within 5 miles (8 km.) southwest of the Pass do the limestones reach the canyon bottom, and the *Olenellus gilberti* and *O. canadensis* zone is 1,000 feet (304.8 m.) or more up on the sides of the mountains.

Mount Temple Section

On the southwest end of Mount Temple at Sentinel Pass, the Mount Whyte formation is reduced to its minimum known thickness, and the St. Piran is largely a siliceous shale. The Mount Whyte formation is overlain by massive-bedded limestones.

LOWER CAMBRIAN

Mount Whyte Formation

	Feet	Meters
1. Thin-bedded, impure, bluish-gray limestone...........	22	6.7
2. Greenish arenaceous and siliceous shale in massive beds.	107	32.6
Fauna.—(63g): *Obolus,* small and large species.		
3. Thin-bedded, dirty gray arenaceous limestone..........	3′ 6″	1.1
4. Cross-bedded, gray sandstone........................	5′ 6″	1.7
5. Coarse, reddish and gray calcareous sandstone with numerous fragments of *Olenellus*..................	23	7.0
6. Greenish siliceous shale............................	3	.9
7. Reddish-brown and gray sandstone, with some layers nearly calcareous and almost made up of fragments of *Olenellus*	7	2.1
Total Mount Whyte formation................	171	52.1

St. Piran Formation

Alternating bands of gray quartzitic sandstone and greenish and gray siliceous shale. Several hundred feet in thickness exposed. The lower portion of the section is formed of the massive-bedded Fort Mountain quartzitic sandstones. These may be seen at the Giant Stairs and at outcrops on the west side of the upper portion of Paradise Valley, and to the north they rise in the bold cliffs facing Bow Valley.

Lakes Louise and Agnes Section

This section was examined on Mount St. Piran and Mount Whyte in the vicinity of Lake Agnes, and on the Beehive down to Lake Louise, and on the northeast face of Fairview Mountain.

	Feet	Meters
MIDDLE CAMBRIAN		
Cathedral Formation		
1. Massive-bedded, arenaceous limestone forming summit of Mount Whyte........................Estimated	1,500	457.2
Ptarmigan Formation		
The Ptarmigan formation had not been recognized when this section was examined. Judging from the section at Ross Lake, 3 miles (4.8 km.) west-northwest of Lake Louise, 500 feet (152.4 m.) or more of the limestones included in the lower part of the Cathedral formation on Mount St. Piran and Mount Whyte should be referred to the Ptarmigan formation.		
LOWER CAMBRIAN		
Mount Whyte Formation		
1. Gray, oolitic limestone in thin beds, with interbedded, banded, bluish- and steel-gray limestone, the steel-gray, dolomitic layers weathering to a buff color.....	103	31.4
On Mount Bosworth and Mount Stephen, a considerable fauna was collected from this zone.		
1*a*. Shaly and thin-bedded, hard, gray sandstones, with a few thin layers of bluish-gray limestone interbedded, giving a banded appearance to many of the sandstone layers.	66	20.1
Fauna.—Annelid trails and trilobite tracks.		
1*b*. Greenish siliceous shale, with a few layers of dirty gray arenaceous limestone interbedded at irregular intervals	38	11.6
1*c*. Greenish siliceous shales in massive layers. The lower two feet (.6 m.) of this formation is a dark gray siliceous shale with numerous fossils..................	64	19.5
Fauna.—(35m): *Lingulella* sp.; *Iphidella wapta* Walcott; *Obolus parvus* Walcott; *Acrothele clitus* Walcott; *Hyolithes billingsi* Walcott ?; *Kochiella agnesensis* (Walcott); "*Ptychoparia*" 3 sp.; *Poliella primus* Walcott		
1*d*. Calcareous, thin-bedded, arenaceous, dark, dirty gray limestone, with numerous small concretions and a few bands of greenish siliceous shale from 6 inches to 2 feet (15.2 cm. to .6 m.) thick....................	115	35.1
Fauna.—Fragments of *Olenellus* throughout.		

West face of Storm Mountain (10,309 feet, 3,142.2 m.) from the east slope of Mount Whymper at about 2.5 miles (4 km.) below Vermilion Pass. This view illustrates two hanging valleys eroded in the Eldon formation limestones. *Locality.*—8 miles (12.9 km.) southwest of *T* on map, plate 26, Castle Mountain Station, Alberta.

South side of Bow Valley from the hills on the north side above Corral Creek, Alberta. Mount Temple (11,626 feet, 3,543.6 m.), the highest point of the Bow Range, and several of the "Ten Peaks" illustrate the massive limestone mountains with deeply eroded canyons tributary to the Bow Valley.

Locality.—6 miles (9.7 km.) south of Lake Louise Station, Alberta.

Mount Whyte (9,776 feet, 2,979.7 m.), with Lake Agnes on its northeastern side. The Mount Whyte formation occurs in the middle cliff, and is covered by snow below the cliff to the right.

Locality.—At *R* on map, plate 26. The sharp ridge is the eastern ridge of Mount Whyte and is about one mile (1.6 km.) west of Lake Louise, Alberta.

	Feet	Meters
1*e*. Brownish and gray sandstones, with thin partings of greenish siliceous shale	72	21.9
Fauna.—(58v): *Scenella varians* Walcott; *Orthotheca* sp.; *Olenellus* sp.; *Bonnia* sp.		
Total of Mount Whyte formation	458	139.6
St. Piran Formation		
1*a*. Massive-bedded, quartzitic sandstone	710	216.4
1*b*. Greenish siliceous shale, with an occasional interbedded layer of quartzitic sandstone	143	43.6
1*c*. Thick-bedded, gray quartzitic sandstone	33	10.1
1*d*. Greenish and gray siliceous shale and thin-bedded sandstone layers	24	7.3
1*e*. Massive-bedded, quartzitic sandstone, usually light gray and containing a few partings of gray arenaceous shale	875	266.7
1*f*. Thin-bedded, quartzitic sandstones, with some shaly partings and a band of shale about 10 feet (3 m.) thick towards the base	295	89.9
Fauna.—(60d): *Hyolithes* sp.; *Orthotheca* sp.; *Mesonacis gilberti* (Meek); *Olenellus canadensis* Walcott		
1*g*. Massive-bedded, light gray quartzitic sandstone. *Scolithus* borings.	44	13.4
1*h*. Massive-bedded, purple quartzitic sandstone	85	25.9
1*i*. Quartzitic sandstone in layers 1 inch to 6 inches (2.5 to 15 cm.) thick, with some shaly, siliceous partings	423	128.9
Total St. Piran formation	2,632	802.2
Lake Louise Shale		
Gray, hard siliceous shale	105	32.0
Fauna.—*Micrometra (Iphidella) louise* Walcott; *Cruziana*; Annelid trails		
Fort Mountain Formation		
Thin and thick layers of gray quartzitic sandstone	940 +	286.5 +

Fairview Mountain Section

On the north face of Fairview Mountain above Lake Louise, the Lake Louise shale forms a slight break in the cliffs, affording a foothold for small coniferous trees and a covering of mosses and lichens. Below this shelf the hard quartzitic sandstones of the Fort Mountain formation form a mural face that is present on the north face of Saddle Mountain and eastward in the cliffs of Mount Temple and in the Valley of the Ten Peaks, above Moraine Lake. The measured section on Fairview Mountain below the Lake Louise shale is as follows:

	Feet	Meters
1. Massive-bedded, purplish, hard, cliff-forming, fine-grained, quartzitic sandstone in layers 6 inches (15.2 cm.) to 3 feet (.9 m.) thick, forming a vertical cliff in its upper 150 feet (45.7 m.). Color gray in upper layers, gradually becoming purplish with gray bands. Some layers are slightly cross-bedded	350	106.7
On Mount Temple the sandstone has a strong purple color, and in the lower portion, bands of purple arenaceous shale.		
2. Hard gray, rather coarse-grained sandstone in the upper 200 feet (60.9 m.) with layers varying from shaly beds to a foot or more in thickness. Below, the sandstone becomes coarser and passes into a fine quartz conglomerate in massive layers	570	173.7
3. Gray and greenish-gray siliceous shale. Slope covered with débris to the pre-Cambrian	20 +	6.1 +
Total	940 +	286.5 +

On the north slope of Saddle Mountain a mile southeast of Fairview Mountain, the shale has a thickness of 28 feet (8.5 m.), and below it, about 100 feet (30.5 m.) in thickness of coarse gray sandstone down to fine conglomerate is exposed. On the north slope of Mount Temple, 2.5 miles (4 km.) northeast of Saddle Mountain, the basal beds of fine conglomerate of the Fort Mountain rest on dark, pre-Cambrian arenaceous shales. The section above is not readily accessible for examination. Ten miles (16.1 km.) farther to the southeast, on Little Vermilion Creek, the basal conglomerate occurs in massive layers, but its contact with the pre-Cambrian is obscured by débris.

On the north side of the Bow Valley, at the south end of Redoubt Mountain, 6 miles (9.7 km.) northeast of Fairview Mountain, the basal conglomerate has a thickness of 360 feet (109.7 m.), and is much coarser than on Saddle Mountain or Mount Temple. It is in contact with the pre-Cambrian, and above it is a band of shale 44 feet (13.4 m.) thick.

Three miles (4.8 km.) to the north-northeast, on the northeast side of Ptarmigan Peak, the Fort Mountain formation is much thinner. A measured section gave:

	Feet	Meters
1. Thick-bedded, light gray, occasionally cross-bedded quartzitic sandstone with a little trace of purple color in a few layers	260	79.2
2. Light gray to brownish-gray sandstone in thin layers	22	6.7
3. Massive-bedded conglomerate, with white quartz pebbles and fragments of dark and greenish, fine arenaceous shale in a coarse sandstone matrix	170	51.8
Total	452	137.7

Mount Odaray Section

The northeast cliff of Mount Odaray, 7.5 miles (12.1 km.) southwest of Mount Whyte, gives a section estimated at over 3,000 feet (914.4 m.):

	Feet	Meters
Stephen formation	200	60.9
Cathedral and Ptarmigan formations	1,200	365.8
Mount Whyte	250	76.2
St. Piran	1,500	457.2
Total	3.150	960.1

Mount Schaffer Section

LOWER CAMBRIAN

Mount Whyte Formation

The Mount Whyte formation on the southwest slope of Mount Schaffer, on the trail to Lake McArthur, 7.5 miles (12.1 km.) south of Hector Station on the Canadian Pacific Railway, and 4.75 miles (7.6 km.) south-southwest of the Mount Whyte section, was hastily measured in 1910. The thin-bedded arenaceous limestones that extend up to the massive-bedded Cathedral limestone were not measured. They may represent the Ptarmigan formation of the Ptarmigan Peak section.

	Feet	Meters
1. Gray arenaceous and siliceous limestone, with irregular cherty stringers in line of bedding	20	6.1
2. Gray arenaceous thin-bedded limestone, with finely oolitic layers of purer limestone	15	4.6

Fauna.—(61d): (collections from more than one zone.)

Paterina labradorica (Billings)
Iphidella pannula (White)
Acrotreta sagittalis taconica Walcott
Jamesella lowi Walcott

Scenella varians Walcott
Shafferia cisina Walcott
Bonnia senectus (Billings)
Agraulos unca Walcott
Mesonacis gilberti (Meek)

	Feet	Meters
3. Massive-bedded, gray arenaceous limestone	65	19.8
4. Chocolate brown and grayish, fine-grained sandstone, passing at 28 feet (8.5 m.) into a grayish, granular sandstone	28	8.5
5. Massive bed of gray arenaceous limestone, containing fragments of *Olenellus*	22	6.7
6. Shaly, brownish sandstone with fragments of *Olenellus*.	10	3.0
Total	160	48.7

Ross Lake Section

Ross Lake is situated on the south side of the Canadian Pacific Railway, 1 mile (1.6 km.) south-southwest of Stephen Station on the Continental Divide. The section was measured on the northeast and northwest sides of the amphitheater above Ross Lake, which is at the north end of the northern spurs of Mount Niblock. The base rests on the purplish-colored massive quartzites of the St. Piran formation on the west slope of the east spur and about 500 feet (152.4 m.) above Ross Lake. The summit as used in this paper is on the east face of the west spur.

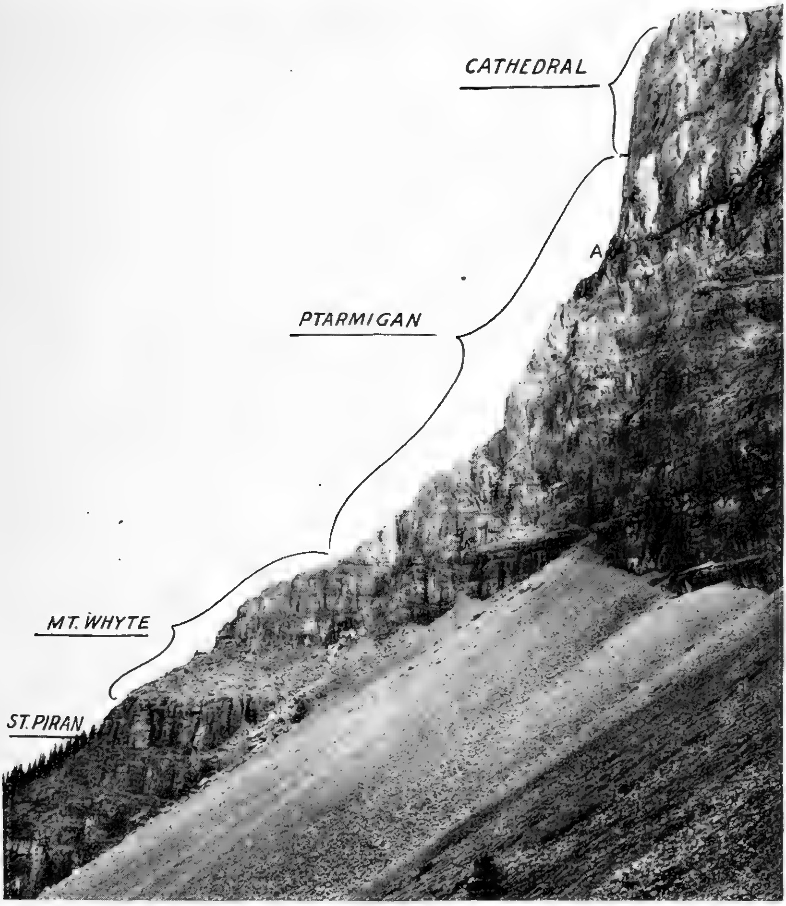
MIDDLE CAMBRIAN

Cathedral Formation

Cliffs of massive-bedded, rough arenaceous limestone rise one above the other to the summit of the ridge. These beds belong mainly to the Cathedral formation, but some collections from the talus would indicate the presence of some beds of the Stephen.

Ptarmigan Formation [1] (including Ross Lake Shale)	Feet	Meters
1. Thin-bedded, more or less arenaceous and mottled limestone	155	47.2
1*a*. Bluish-gray limestone in thin, irregular layers interbedded in a greenish siliceous shale	3	.9
2. Greenish and dark gray, compact siliceous shale, weathering to light gray when long exposed. The shale forms compact, solid, hard layers from 2 to 3 feet (.6 to .9 m.) thick that break first into blocks on joint planes and then split up into shale on long exposure to the weather	7	2.1

[1] There are now included in the Ptarmigan formation, Nos. 1*d*, 1*e*, and 1*f* of the Cathedral formation, and 1*a* (120 feet [36.6 m.]) of the subjacent Mount Whyte formation (see Smithsonian Misc. Coll., Vol. 53, No. 5, p. 212, 1908).



Profile of cliffs at north end of ridge above the southeast side of Ross Lake, British Columbia. The end of the ridge is capped with the cliff-forming limestones of the Middle Cambrian Cathedral formation. The position of the Ross Lake shale member of the Ptarmigan formation with the *Albertella* fauna is at *A*. The Mount Whyte formation is superjacent to the St. Piran formation, which forms the base of the section.

Locality.—1 mile (1.6 km.) south-southeast of Stephen Station on the Continental Divide at Kicking Horse Pass, Alberta.

	Feet	Meters
This bed is the Ross Lake shale, and the remains of the *Albertella* fauna occur abundantly in it in several localities. The fauna includes (63j):		
Siliceous sponge spicules *Eocystites* ? sp. *Micromitra* (*Paterina*) *wapta* Walcott *Obolus parvus* Walcott *Acrothele colleni* Walcott *Wimanella simplex* Walcott *Hyolithellus flagellum* (Matthew) *Hyolithes cecrops* Walcott *Agraulos stator* Walcott *Kochiella* cf. *americanus* Walcott *Vanuxemella nortia* Walcott *Albertella bosworthi* Walcott *Albertella helena* Walcott *Bathyuriscus rossensis* Walcott		
On the slope of Mount Bosworth, the shale is a little thicker and we collected 10 of the above species *in situ* (63 m).		
From the boulders (35c) found below the outcrop on the south slope of Mount Bosworth in earlier years, there have been collected 13 of the above species and an additional one, *Hyolithellus hectori* Walcott.		
3. Massive-bedded, gray and mottled, rough-weathering arenaceous limestone	160	48.8
4. Compact, dove-gray colored limestone in thin layers	12	3.7
5. Massive-bedded, dirty gray colored, rough-weathering, calcareous sandstone	275	83.8
6. Alternating layers of bluish-black and steel-gray, hard limestone	52	15.8
Total referred to Ptarmigan formation	664	202.3

LOWER CAMBRIAN

Mount Whyte Formation

	Feet	Meters
1. Gray to grayish-black, thin-bedded oolitic limestone	43	13.1
Fauna.—Many small fragments of trilobites.		
2. Finely banded, gray sandstone, and hard arenaceous limestone	5	1.5
3. Gray, finely oolitic limestone in thick beds that break down into thin, irregular layers	18	5.5

Fauna.—At 15 feet (4.6 m.) from summit (63k):

Nisusia (*Jamesella*) *lowi* Walcott
Pelagiella sp. undt.
Helcionella elongata (Walcott)
Scenella varians Walcott
Hyolithes billingsi Walcott
"*Ptychoparia*" *cecrops* Walcott.

	Feet	Meters
"*Ptychoparia*" *pia* Walcott		
Kochiella agnesensis Walcott		
4. Banded sandstone and finely arenaceous shale in massive beds that break down on weathering into shaly arenaceous layers, usually covered more or less thickly with annelid trails and, more rarely, tracks of trilobites	70	21.3
5. Greenish, drab and buff-colored, very fine siliceous shale, with partings of thin layers of compact sandstone...	85	25.9
Fauna.—Noted a valve of *Micromitra* and cranidium of *Ptychoparia* ? sp.		
6. Calcareous sandstone, with dirty brown and rusty layers and shaly sandstone partings	27	8.2
Fauna.—(63l):		
Bonnia fieldensis Walcott		
Olenellus canadensis Walcott		
Olenellus (many fragments)		
Total of Mount Whyte formation	248	75.5

St. Piran Formation

Massive-bedded, purplish quartzitic sandstones that form cliffs above Ross Lake. (Not measured)

The Ross Lake section is 5.5 miles (8.8 km.) north-northwest of the Mount Temple section; it has much more calcareous matter in the form of limestones and calcareous sandstones than the latter.

At Lake O'Hara, 5.5 miles (8.8 km.) south of the Ross Lake Section, and 15 miles (24.1 km.) west-northwest of Vermilion Pass, at the level of the lake and a little east of its outlet, a cliff of gray, hard quartzitic sandstone outcrops at the base of Wiwaxy Peaks, in which I found the same lower St. Piran fauna as at Vermilion Pass.

The Wiwaxy Peaks rise 2,200 feet (670.1 m.) above Lake O'Hara. The upper 200 feet (60.9 m.) is formed of arenaceous limestone of the Mount Whyte formation. The southwest slope of the east Wiwaxy Peak exposes full 2,000 feet (609.6 m.) of the St. Piran formation.

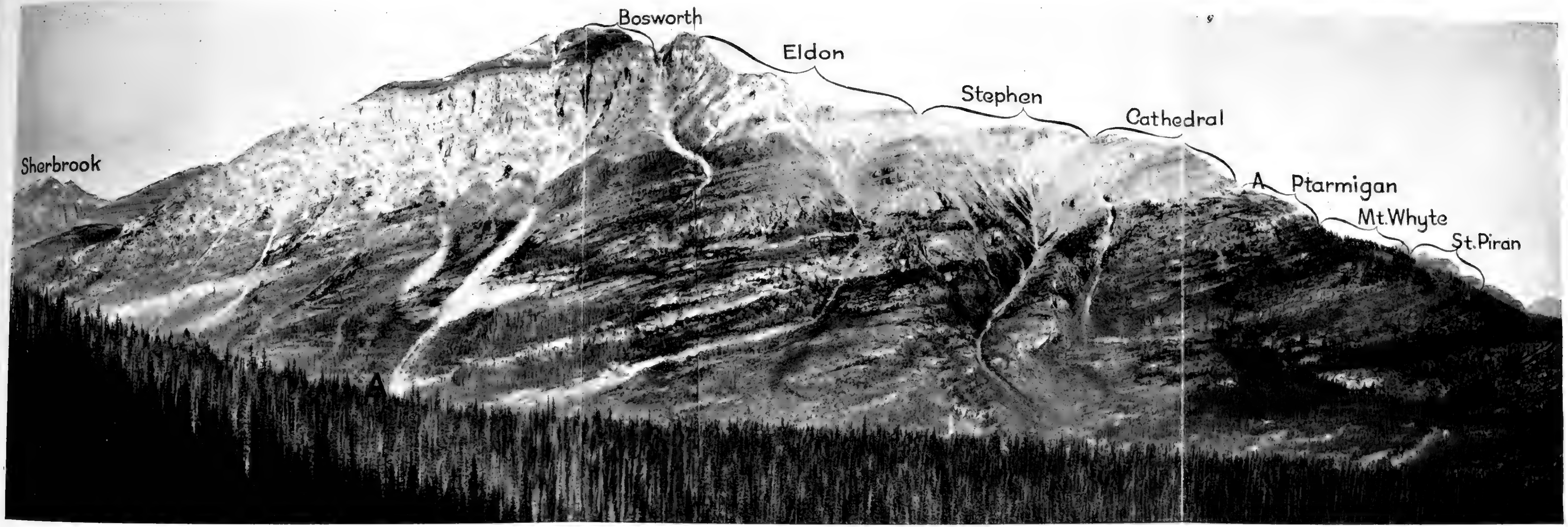
The Eldon limestone just caps Mount Huber. It is about 600 feet (182.9 m.) thick on Mount Victoria and 800 feet (243.8 m.) on Mount Lefroy.

Mount Bosworth

Mount Bosworth lies immediately north of the head of the Kicking Horse River, on the main crest of the ranges and north of the Bow Range. It contains one of the largest and most complete Cambrian

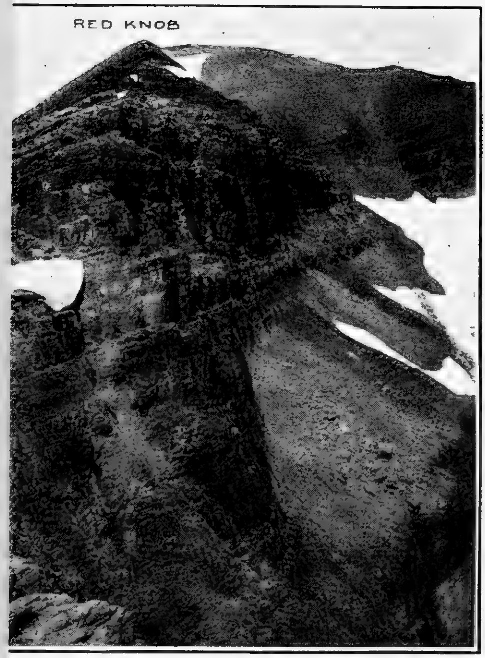
of Sherbrook Ridge west of Mount Bosworth. The summit of the ridge at (*a*) is for
mbrian Sherbrook formation; the latter extends down nearly to the foot of the cliffs,
exposed.[1] The dolomitic limestones and shales of the Bosworth formation extend fron
little west of Buff Point a fault with a downthrow to the west has dropped the base of the
-At *Q* on map, plate 26. About 1.5 miles (2.4 km.) north of Hector Station, British C

nd of plate 19, Smithsonian Misc. Coll., Vol. 53, 1908, tentatively refers the limestones f



South side of Mount Bosworth on the Continental Divide, from Ross Lake Cirque, looking north over Kicking Horse Pass. This view includes the Lower Cambrian St. Piran sandstones on the east (right side) and the Upper Cambrian Sherbrook limestones on the west (left side) a thickness of over 12,000 feet (3,657.6 m.) of conformable strata. The approximate position of the various formations is indicated.

Locality.—Mount Bosworth rises above Wapta Lake and Hector Station on the Canadian Pacific Railway, Alberta.



med of limestones that may be referred to where the upper limestones of the Paget ı Buff Point to the base of the cliff below Paget formation about 500 feet (152.4 m.). ;olumbia.

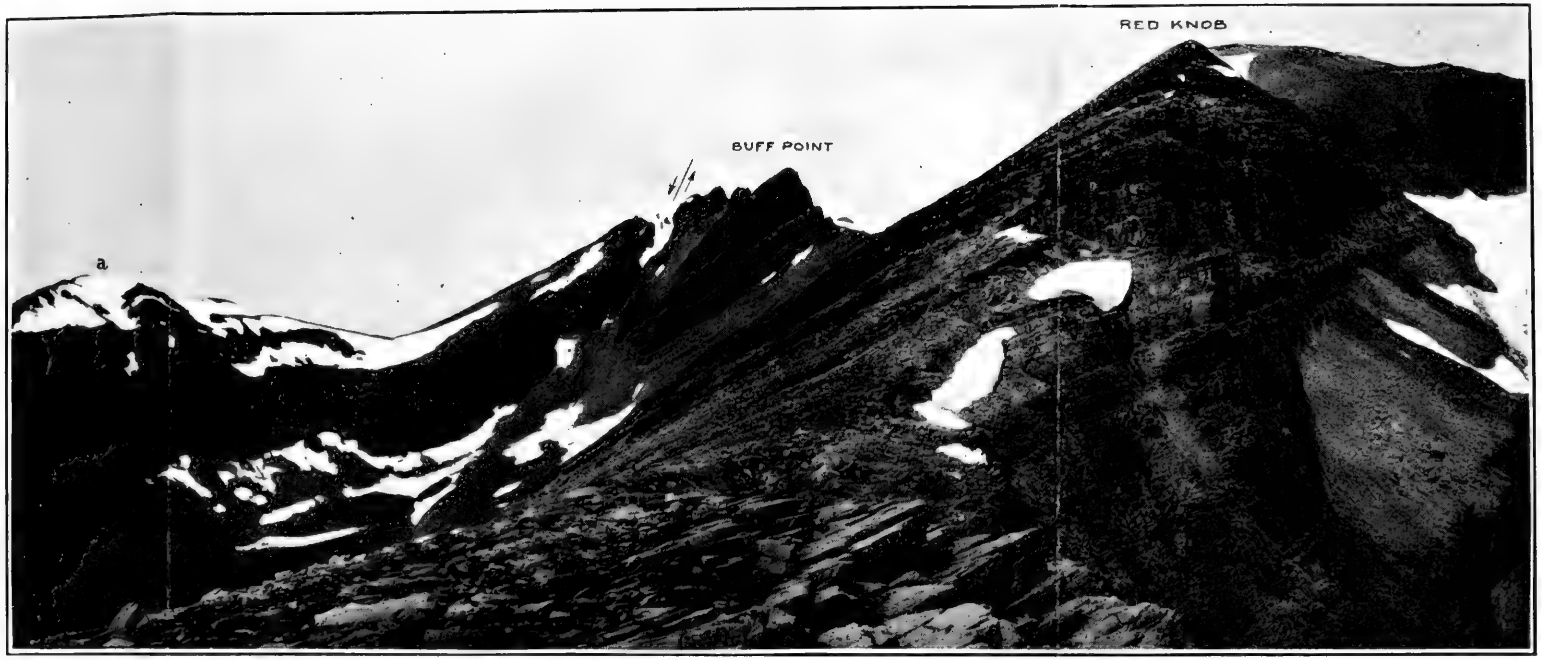
'orming the ridge at (*a*) to the Ordovician.

sections in the Canadian Rockies. North of Mount Bosworth, the sequence and character of the formations, as expressed throughout the Bow Range, begin to change, and the section loses its completeness.

UPPER CAMBRIAN

Sherbrook Formation	Feet	Meters
1. Massive-bedded, bluish-gray limestone, with some cherty matter in the form of small nodules and stringers; also irregular partings and fillings of annelid borings by gray dolomitic limestone weathering buff........	175	53.3
Fauna: Annelid borings and trails. Fragments of undetermined trilobites.		
2*a*. Gray oolitic limestone in thick layers, with bluish banded limestone intercalated at irregular intervals. The banded appearance of the non-oolitic layers is due to the buff weathering of the thin dolomitic layers....	190	57.9
Fauna.—(57z):		
Crepicephalus ? sp.		
Two new genera of trilobites		
2*b*. Greenish-drab and gray siliceous shales, with interbedded oolitic limestone in bands of layers from 6 inches (15.2 cm.) to 4 feet (1.2 m.) thick; also a few bands of thick-bedded, bluish gray limestone that breaks up into shaly limestone on weathering........	335	102.1
Fauna.—(57d): in green shales near summit		
Lingulella cf. *isse* (Walcott) (1905, p. 330)		
Fauna.—(58f): in oolitic layers.		
Agnostus, sp. undt.		
Kingstonia sp.		
This species was also found in a loose block of oolitic limestone on the slope just beneath the outcrop of 2*b* (58 o).		
2*c*. Gray oolitic limestone, with thin bands of interbedded shaly, blue-gray limestone. Gray, dolomitic, buff-weathering, flattened nodules, stringers, and thin layers of limestone occur in a very irregular manner.......	65	19.8
Fauna.—(57p):		
Agnostus sp.		
Kingstonia sp.		
Total of 2..................................	590	179.8
3. Arenaceous, dolomitic, steel-gray limestone weathering light gray and buff-gray..........................	610	185.9

The line of demarcation between 3 and the bluish-gray limestones below is irregular. The gray beds of 3 extend along the cliff and abruptly change to bluish-gray. In the upper 100 feet (30.5 m.) of 3, irregular



East side of Sherbrook Ridge west of Mount Bosworth. The summit of the ridge at (*a*) is formed of limestones that may be referred to the Upper Cambrian Sherbrook formation; the latter extends down nearly to the foot of the cliffs, where the upper limestones of the Paget formation are exposed.[1] The dolomitic limestones and shales of the Bosworth formation extend from Buff Point to the base of the cliff below Red Knob. A little west of Buff Point a fault with a downthrow to the west has dropped the base of the Paget formation about 500 feet (152.4 m.).

Locality.—At *Q* on map, plate 26. About 1.5 miles (2.4 km.) north of Hector Station, British Columbia.

[1] The legend of plate 19, Smithsonian Misc. Coll., Vol. 53, 1908, tentatively refers the limestones forming the ridge at (*a*) to the Ordovician.

	Feet	Meters
masses of bluish-gray limestone occur like great lentils, as though they were cores left in the general alteration (dolomitization) of the strata.		
Total of Sherbrook formation	1,375	419.0

Paget Formation

	Feet	Meters
1. Massive-bedded, dark bluish-gray limestone forming base of cliff on the west side of the amphitheater on the west slope of Mount Bosworth, and, with 3 of the Sherbrook formation, the upper cliffs of Paget Peak and Mount Daly	60	18.3
2. Massive beds of oolitic limestone, with irregular, interbedded bands of green siliceous shale. Thin layers, irregular stringers, and nodules of gray, buff-weathering dolomite occur in the oolitic limestones	300 +	91.4 +

The base of 2 is covered by talus slope on line of the section. It is well exposed on the southeast face of Mount Daly and Paget Peak. The thickness is estimated at 300 feet (91.4 m.), which I think is less than the actual thickness. Over 200 feet (60.9 m.) was measured.

Fauna.—(570):

Hyolithes sp.
Agnostus sp.
Crepicephalus 2 sp.

	Feet	Meters
Total of Paget formation	360 +	109.7 +

Bosworth Formation

	Feet	Meters
1. Massive-bedded, gray and bluish-gray arenaceous dolomitic limestone. Several bands of steel-gray, yellowish-buff-weathering bands of strata occur in the lower half	600 +	182.9 +

These limestones form the base of the high cliffs on the southeast face of Mount Daly and Paget Peak.

The lower portion of 1 was measured and the upper parts estimated. The thickness given is probably at least 100 feet (30.5 m.) less than the actual thickness.

	Feet	Meters
2a. Shaly and thin-bedded, gray and dove-colored, compact, fine-grained dolomitic limestone weathering buff and light gray. Thicker layers occur in bands from 1 to 6 feet (.3 to 1.8 m.) thick	422	128.6
2b. Greenish siliceous shale, with thin interbedded layers of siliceous, compact, gray limestone	48	14.6
2c. Limestones similar to *2a*	517	157.6
Total of 2	987	300.8
Total of Bosworth formation	1,587	483.7

	Feet	Meters
Arctomys Formation		
1. Variable arenaceous shales with alternating bands of color—greenish, deep red, buff, yellow and gray. Numerous mud cracks and ripple-marks occur on many of the layers, and a few casts of salt crystals on some of the buff-colored arenaceous shaly layers....	268	81.7
Total Arctomys formation......................	268	81.7

MIDDLE CAMBRIAN

	Feet	Meters
Eldon Formation		
1*a*. Irregularly-bedded, gray siliceous and arenaceous limestone in thick layers above and thin layers below; at 192 feet (58.5 m.) from the base, a bed of bluish-black limestone is fossiliferous. Above the fossiliferous bed, the strata become more massive, arenaceous, steel-gray in color, weathering to light gray..	410	125.0
Fauna.—(57x): 192 feet (58.5 m.) above the base. *Agnostus* sp. "*Ptychoparia*" 2 species *Bathyuriscus*-like pygidium		
1*b*. Light and dark gray, thin-bedded arenaceous limestone, weathering to a light gray color....................	110	33.5
1*c*. Massive-bedded, siliceous, fine-grained, compact, dark bluish-gray limestone	197	60.1
Two yellowish-buff-weathering bands of limestone 2 to 3 feet (.6 to .9 m.) thick stand out in color on the face of cliffs.		
Fauna.—(57w): near the summit. *Billingsella* ? sp. *Neolenus*-like pygidium		
1*d*. Massive-bedded limestone much like that of 1*c*........	71	21.6
Total of 1....................................	788	240.2
2. Thin-bedded, bluish-gray limestone, with irregular layers and stringers of gray, buff-weathering, dolomitic limestone	95	29.0
At 24 feet (7.3 m.) from the base a shaly, bluish-gray, siliceous limestone about 2 feet (.6 m.) thick is interbedded.		
Fauna.—(in shaly limestone): *Obolus mcconnelli* Walcott; *Obolus membranaceous* Walcott; *Lingulella* sp.; *Isoxys* cf. *argentea* (Walcott); *Elrathia* sp.		
3. Massive-bedded, dark gray, arenaceous limestone....	190	57.9
4. Massive-bedded, cliff-forming, light gray arenaceous limestone. At several horizons occur bands of thinner		

	Feet	Meters
layers, from a few feet to 30 feet (9.1 m.) in thickness. One of these, 480 feet (146.3 m.) from the base forms a slight terrace	1,655	504.4
Total of Eldon formation	2,728	831.5

STEPHEN FORMATION

	Feet	Meters
1. Thin-bedded, dark gray and bluish-black limestone	315	96.0
Fauna.—(57c):		
Micromitra zenobia Walcott		
Obolus mcconnelli (Walcott)		
Nisusia alberta (Walcott)		
Hyolithes carinatus Matthew		
Agnostus sp.		
Elrathia ? sp.		
Dorypyge sp.		
Bathyuriscus sp.		
2*a*. Greenish siliceous shale	23	7.0
Fauna.—(57y):		
Obolus (*Westonia*) *ella* ? (Hall and Whitfield)		
2*b*. Thick-bedded, bluish-gray limestone, breaking up on weathering into thin layers ½-inch to 3 inches (1.3 to 7.6 cm.) thick	22	6.7
Fauna.—(58z):		
Micromitra zenobia Walcott		
Nisusia alberta Walcott		
2*c*. Greenish siliceous shale	70	21.3
2*d*. Alternating bluish-gray, bedded, compact limestone, siliceous and arenaceous shale, mostly shale below	210	64.0
Fauna.—(57g):		
Cruziana sp.		
Micromitra (*Iphidella*) *pannula* (White)		
Obolus (*Westonia*) *ella* (Hall and Whitfield)		
Hyolithes sp.		
"*Ptychoparia*" sp.		
Glossopleura boccar (Walcott)		
Total 2	325	99.0
Total Stephen formation	640	195.0

The siliceous and arenaceous shale containing the Ogygopsis fauna on Mount Stephen has not been recognized in the Mount Bosworth section. I looked for it in 2*a-d* (above), but did not find a similar shale or fauna. It was probably a local deposit.

CATHEDRAL AND PTARMIGAN [1] FORMATIONS

	Feet	Meters
1*a*. Thin-bedded, gray to lead-gray arenaceous limestones, weathering buff-gray to dull light gray	404	123.1

[1] Many fine fossils of the *Albertella* fauna as it is typically developed to the south above Ross Lake, were collected in the drift on the south slope of Mount Bosworth, indicating the presence of the Ptarmigan formation here

	Feet	Meters
1*b*. Massive-bedded, steel-gray-weathering, light gray arenaceous limestone. In some localities, thinner layers appear at various horizons, and large lentils of dark lead-gray colored beds occur very irregularly........	682	207.9
1*c*. Similar to 1*a*..	126	38.4
Fauna.—Annelid borings and trails occur in some of the layers of 1*c*.		
Total Cathedral and Ptarmigan formations......	1,212	369.4

LOWER CAMBRIAN

Mount Whyte Formation

1*a*. Thin-bedded, bluish-gray, slightly arenaceous limestone.	120	36.6
Fauna.—Numerous annelid trails and borings.		
1*b*. Gray oolitic limestone in layers 3 to 6 inches (7.6 to 15.3 cm.) thick..................................	44	13.4
Fauna.—(57s) : 4 feet, 1.2 m., from base. *Nisusia* (*Jamesella*) *lowi* Walcott *Eodiscus* sp. *Acrotreta sagitallis taconica ?* (Walcott) *Agraulos* sp. "*Ptychoparia*" *cleodas* Walcott *Olenopsis agresensis* Walcott *Olenopsis cleora* Walcott		
1*c*. Massive-layers made up of banded bluish-gray limestone and sandstone in layers ½ inch to 2 inches (1.3 to 5 cm.) thick..............................	60	18.3
Fauna.—(57q) : "*Ptychoparia*" *adina* Walcott *Crepicephalus ? celer* Walcott		
Total of 1..................................	224	68.3
2. Gray and brownish-gray sandstone in thin and massive layers	31	9.4
Fauna.—(58u) : *Hyolithes* sp. "*Ptychoparia*" *cleodas* Walcott		
3. Siliceous shale, with a few interbedded thin layers of compact, hard, gray sandstone....................	115	35.1

in well developed form, even though it is not definitely shown in the sections above, on which the field-work had been done prior to the establishment of this formation with its peculiar fauna. I am sorry not to be able to completely clarify the confusion Dr. Walcott left at this point where the manuscript had not yet been brought altogether up to date.—C. E. R.

	Feet	Meters
4. Interbedded layers of gray fossiliferous limestone and greenish-gray siliceous shale........................	20	6.1

Fauna.—(35h):

Nisusia festinata (Billings)
Scenella sp.
Hyolithellus sp.
"*Ptychoparia*" *pia* Walcott
Agraulos ? *thia* Walcott
Bonnia fieldensis Walcott
Olenellus canadensis Walcott
Mesonacis gilberti Meek

Total thickness of Mount Whyte...............	390	118.9

St. Piran Formation

The formation next subjacent to the Mount Whyte is finely exposed on the eastern slope of Mount Bosworth, also at Mount Temple and west to Lake O'Hara.

1*a*. Greenish siliceous and arenaceous shales in layers 1 to 3 inches (2.5 to 7.6 cm.) in thickness, interbedded in shaly and thin-bedded, gray and brownish-gray sandstone, with a thick layer of compact, gray sandstone, near the top....................................	68	20.7
1*b*. Irregularly-bedded, brownish, dirty gray, and occasionally purplish-colored sandstones, more or less compact and quartzitic and in massive and thin layers that break down readily on slopes..................	310	94.5

Fauna.—

Annelid trails and borings (*Scolithus*)
Hyolithes sp.
Olenellus canadensis ? Walcott
"*Ptychoparia*" (2 species)

1*c*. Massive-bedded, compact, light gray and pinkish quartzitic sandstones	125	38.1

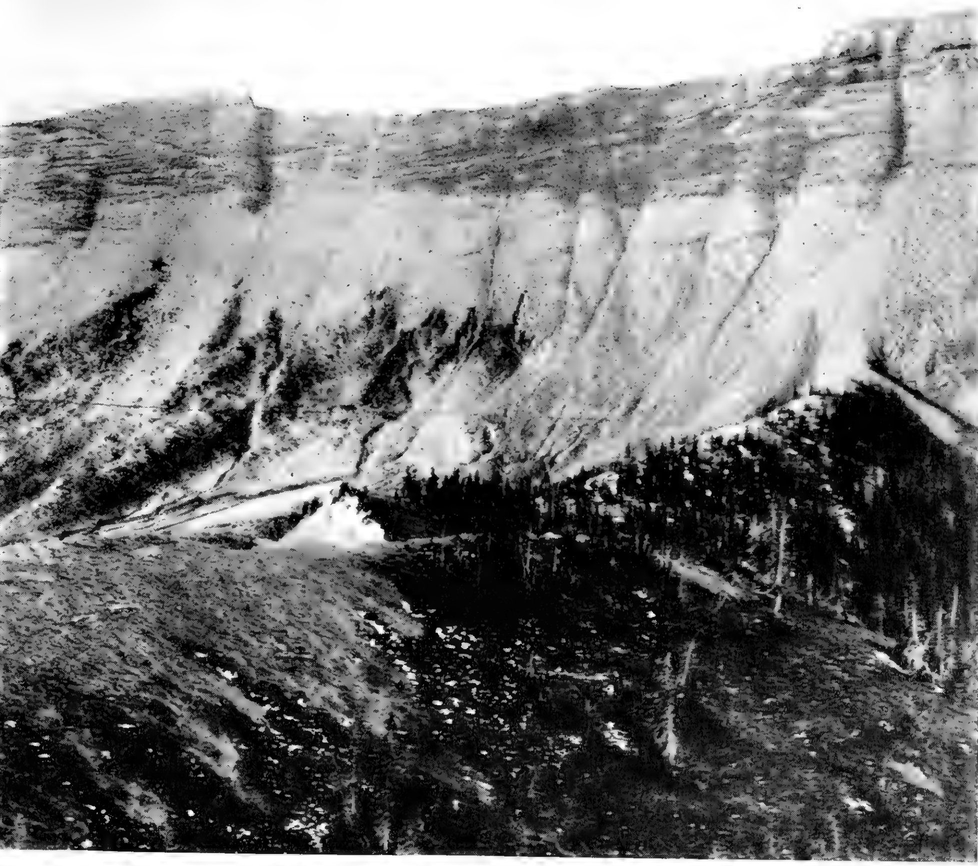
Fauna.—

Annelid trails and borings (*Scolithus*)
Hyolithes sp.
Olenellus canadensis ? Walcott (fragments)

Total St. Piran exposed on Mount Bosworth....	503	153.3
In the Lake Agnes and Louise section about 5 miles (8.0 km.) southeast of Mount Bosworth, the total thickness of the St. Piran formation is 2,705 feet (824.5 m.), which is assumed as its maximum thickness	2,705	824.5

Fort Mountain Formation

1. Alternating bands of thick and thin layers of gray, brownish-weathering, compact quartzitic sandstones. Estimated thickness	600 +	182.8 +



ridge and mountains are capped by the massive Eldon limestone which is superjacent to the St
8 miles (12.9 km.) by trail north of Field, British Columbia.

Panoramic view of the upper half of the northwest side of Mount Stephen (10,485 feet, 3,195.8 m.), and the northern face of Mount Dennis (8,326 feet, 2,537.8 m.) and, in the foreground, the ridges extending westward nearly to Ottertail River. In the distance at the right Mount Hurd (9,265 feet, 2,823.9 m.) and Mount Vaux (10,881 feet, 3,316.5 m.) of the Ottertail Range. On the southwest slope of Mount Stephen the continuity of the section is broken between the nearly horizontally bedded strata of the mountain and the southwesterly dipping strata forming the ridge leading to Mount Dennis Ridge, which is formed of Upper Cambrian shales and interbedded limestones. (See pl. 71.)

Locality.—At *P* on map, plate 26. Southeast and south of Field, British Columbia.

ephen formation. The Burgess shale fossil quarry is at ★.

Mount Stephen Section

The section extends from the summit of the mountain down its northeast and north slopes to the track of the Canadian Pacific Railway at the tunnel east of Field.

The massive siliceous dolomitic limestone (Eldon formation) forming the upper portion of the mountain was not measured above the upper bluish-gray limestone and shaly band. Its thickness is estimated at 2,700+ feet (822.9+ m.). It is 2,728 feet (831.5 m.) thick on Mount Bosworth. An attempt was made to measure the Cathedral formation, but owing to step-faulting, the result is not satisfactory. This formation has a thickness of 1,595 feet (486.2 m.) on Mount Bosworth so the measured and estimated thickness of 1,680 feet (512.1 m.) on Mount Stephen is given in the section. No attempt was made to carry the section from Mount Stephen across to Mount Dennis, owing to faulting, displacement, and alteration of the strata in Mount Dennis.

MIDDLE CAMBRIAN

Eldon Formation (Summit of Mountain)	Feet	Meters
1*a*. Massive-bedded, gray siliceous and dolomitic limestone .... Estimate	2,700 +	822.9 +
Total Eldon formation	2,700 +	822.9 +

Stephen Formation

1*a*. Bluish-gray limestone with bands of dark siliceous shale in lower portion	190	57.9

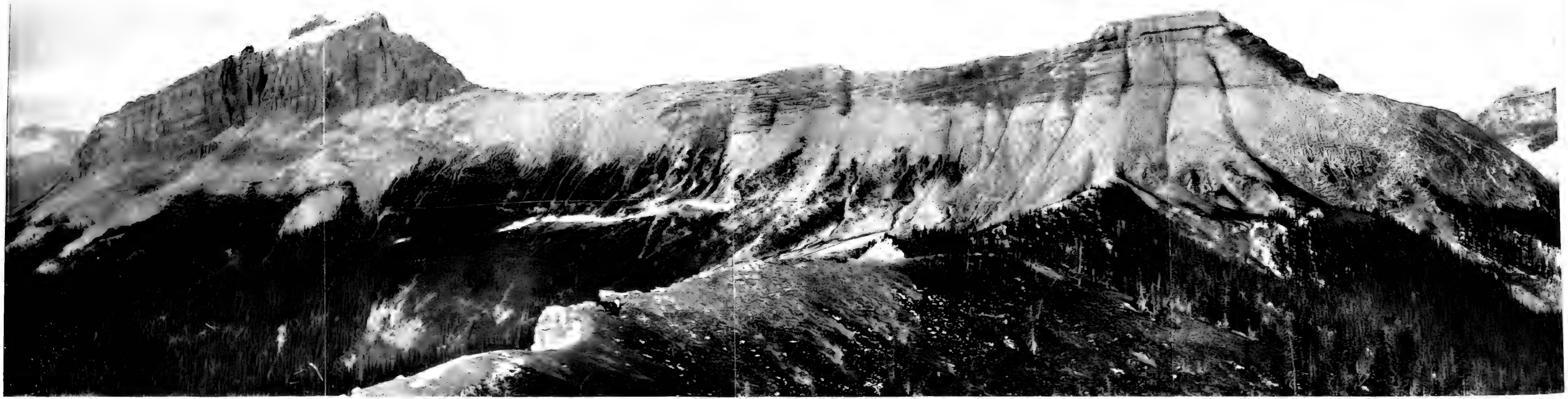
Fauna.—Middle Cambrian: the fossils are very poorly preserved, but the following have been recognized (57n):

Protospongia (spicules)
Obolus cf. *mcconnelli* (Walcott)
Hyolithes, sp.
Agnostus cf. *montis* Matthew
"*Ptychoparia*" sp.
Bathyuriscus (pygidium)
Ogygopsis (pygidium)

On Mount Bosworth a band of limestone 315 feet (96 m.) similar to 1*a* occurs beneath the Eldon formation, but a subjacent arenaceous limestone on Mount Stephen is not present. The latter is probably a faulted down block of the Eldon formation, the fault probably cutting out the lower portion of 1*a*.

1*b*. Calcareous and siliceous shales	150	45.7

This shale is given the name of Ogygopsis shale from its most predominating trilobite, *O. klotzi*. A detailed description with its contained Middle Cambrian fauna follows this section.



View from base of cliffs on the west side of Burgess Pass looking east towards the west side of the ridge between Mounts Field and Wapta. The ridge and mountains are capped by the massive Eldon limestone which is superjacent to the Stephen formation. The Burgess shale fossil quarry is at ★.
Locality.—A little north of *P* on map, plate 26. About 8 miles (12.9 km.) by trail north of Field, British Columbia.

	Feet	Meters
In a siliceous shale of this zone, about ½ mile (.8 km.) east of the great fossil bed, the following species were found (57f):		
Obolus mcconnelli (Walcott)		
Nisusia (*Jamesella*) cf. *nautes* Walcott		
Hyolithes carinatus Matthew		
Orthotheca sp.		
Scenella varians Walcott		
"*Ptychoparia*" sp.		
2*a*. Thin-bedded, bluish-black limestone, forming dark broken cliffs in many sections	325	99.1
Fauna.—Middle Cambrian: in the upper portion of this division just beneath the Ogygopsis shale, in a bluish-black shaly limestone that outcrops in the amphitheater between Mount Stephen and Mount Dennis, the following species were found (58r):		
Obolus mcconnelli (Walcott)		
Acrotreta depressa Walcott		
Hyolithellus annulata Matthew		
Elrathia sp.		
Dorypyge sp.		
Neolenus serratus (Rominger)		
Ogygopsis klotzi (Rominger)		
At a locality just east of the great fossil bed, the following species were collected (57j.):		
Micromitra sp.		
Nisusia alberta Walcott		
Hyolithes sp.		
Bathyuriscus rotundatus (Rominger)		
Neolenus serratus (Rominger)		
Ogygopsis sp. ?		
2*b*. Massive-bedded, gray limestone, breaking down into thin layers on weathering	37	11.3
3*a*. Gray and greenish siliceous shale	47	14.3
3*b*. Gray oolitic limestone in layers 6 inches (1.5 cm.) to 2 feet (.6 m.) thick	4′ 6″	1.4
Fauna.—Middle Cambrian:		
Micromitra (*Iphidella*) *pannula* (White)		
Nisusia alberta ? Walcott		
Hyolithes sp.		
Microdiscus sp.		
3*c*. Greenish siliceous shale	15	4.6
3*d*. Gray oolitic limestone	6′ 6″	1.9
3*e*. Gray, impure dolomitic limestone, compact, fine-grained, and weathering buff and yellow	38	11.6
3*f*. Greenish siliceous shale	1	.3
3*g*. Similar to 3*e*	52	15.8
3*h*. Gray oolitic limestone	2′ 2″	.7
3*i*. Similar to 3*e*	3	.9

	Feet	Meters
3*j*. Gray oolitic limestone	4′ 2″	1.3
3*k*. Similar to 3*e*	5′ 8″	1.7
3*l*. Gray oolitic limestone	2′ 3″	.7
3*m*. Similar to 3*e*	5	1.5
3*n*. Gray oolitic limestone	3′ 9″	1.2
3*o*. Thin-bedded, bluish-gray limestone, weathering buff	10	3.0
Total of 3	200	60.9
Total Stephen formation	902	274.9

CATHEDRAL FORMATION

	Feet	Meters
1. Massive-bedded, dark gray arenaceous limestone	60	18.3
2. Massive-bedded, arenaceous, siliceous dolomitic limestone. At 495 feet (150.9 m.) from the base, the beds are thinner and of a dark gray color for 30 to 40 feet (9.1 to 12.2 m.). At 825 feet (251.5 m.) the massive layers are banded with light and dark gray colors	1,560	475.5

Owing to small step faults, the thickness of this series of strata is uncertain. The entire thickness on the northeast side was measured and an allowance made for duplication by faulting.

This great limestone series forms bold, high cliffs on the east face of Mount Stephen and the west side of Cathedral Mountain.

Fauna.—Annelid borings and trails at a few horizons.

	Feet	Meters
3. Massive-bedded, arenaceous, dolomitic limestone	60	18.3
Total Cathedral formation	1,680	512.1

LOWER CAMBRIAN

MOUNT WHYTE FORMATION

	Feet	Meters
1. Thin-bedded, bluish-black and gray limestone	3	1.0

Fauna.—(From 1 and the interbedded limestones at the top of 2) (58k):

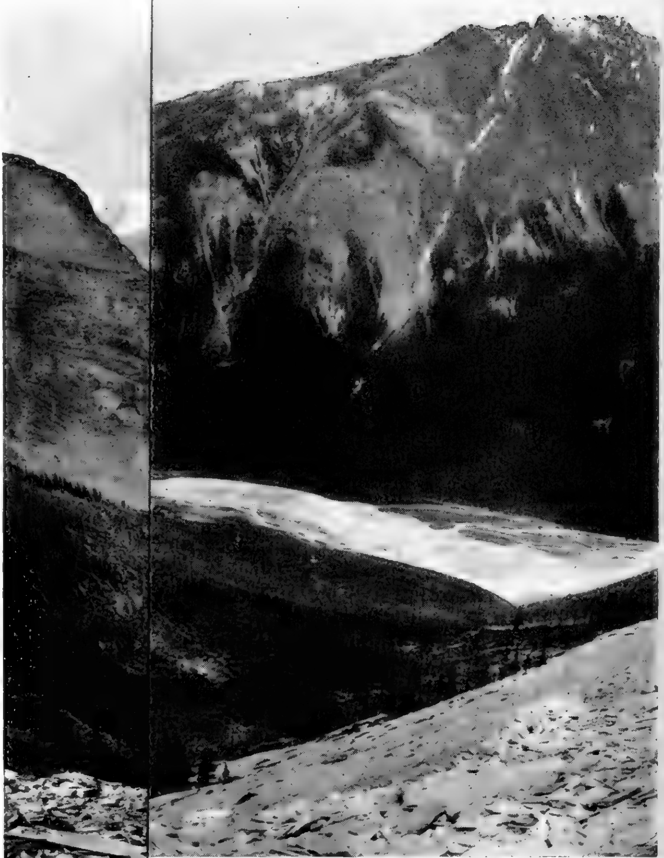
Acrotreta (Sagitallis) taconica Walcott
Nisusia (Jamesella) lowi Walcott
Stenotheca elongata Walcott var.
Scenella varians Walcott
Hyolithes billingsi Walcott

	Feet	Meters
2. Gray siliceous shale, with interbedded gray fossiliferous limestone in layers 5 inches (12.7 cm.) to 2 ft. (.6 m) thick in the upper portion	108	32.9

Fauna.—(In the shale of the central portion) (57m):

Cystid plates
Paterina sp.
Acrotreta sagittalis taconica Walcott
Nisusia (Jamesella) lowi Walcott
Hyolithellus sp.

	Feet	Meters
Scenella varians Walcott		
Olenellus canadensis Walcott		
3. Thin-bedded, compact, hard, dark, bluish-gray limestone, with a little interbedded, gray siliceous shale and a few beds of coarser gray limestone 6 to 10 inches (15.2 to 25.4 cm.) thick	52	15.9
Fauna.—(Near the top) (57e):		
Acrothele colleni Walcott		
Acrotreta sagittalis taconica Walcott		
Scenella varians Walcott		
Stenotheca elongata Walcott var.		
Olenellus (fragments)		
Poliella primus Walcott		
Fauna.—(Near the base) (58s):		
Paterina labradorica (Billings) var.		
Iphidella pannula (White)		
Acrothele clitus Walcott		
Acrotreta sagittalis taconica Walcott		
Scenella varians Walcott		
Helcionella elongata Walcott		
Poliella primus Walcott		
Olenellus canadensis Walcott		
"*Ptychoparia*," 3 species		
4. Brownish-gray, quartzitic sandstone in layers 2 to 4 inches (5 to 10.1 cm.) thick	32	9.8
Fauna.—(57i):		
Microdiscus sp. undt.		
Olenellus (fragments)		
"*Ptychoparia*" sp. undt.		
Bonnia sp.		
5. Gray siliceous shale	102	31.1
Fauna.—(57t, 58q):		
Hyolithes billingsi Walcott		
Scenella varians Walcott		
"*Ptychoparia*" 2 species		
Kochiella agnesensis (Walcott)		
6. Bluish-black and gray limestone	18	5.5
Fauna.—(35f):		
Iphidella pannula (White)		
Acrotreta sagittalis taconica Walcott		
Kutorgina cingulata Billings		
Nisusia festinata Billings		
Hyolithes billingsi Walcott		
Scenella varians Walcott		
Agraulos, sp.		
"*Ptychoparia*" 3 species		
Olenellus canadensis Walcott		
Total Mount Whyte	315	96.0



View 1 Burgess (8,463 feet, 2,579.5 m.) in the center, M
(9,106 feet Peak (10,049 feet, 3,062.9 m.), and on the left the
in rounded e low land near the river.

View looking northwest from the "Fossil Bed" on Mount Stephen over Kicking Horse River to Mount Burgess (8,463 feet, 2,579.5 m.) in the center, Mount Field (8,645 feet, 2,634.9 m.) on the extreme right, the top of Mount Wapta (9,106 feet, 2,775.5 m.), and back in the distance, Michael Peak (8,834 feet, 2,302.6 m.) and Vice President Peak (10,049 feet, 3,062.9 m.), and on the left the peaks and ridges of the Van Horn Range. The north ridge of Mount Dennis rises in rounded cliffs from the river in the left side of the foreground. (See pl. 69.) The town of Field is on the low land near the river. *Locality.*—A little north of *P* on map, plate 26. Field, British Columbia.

ount Field (8,645 feet, 2,634.9 m.) on the extreme right, the top of Mount Wapta
peaks and ridges of the Van Horn Range. The north ridge of Mount Dennis rises
Locality.—A little north of *P* on map, plate 26. Field, British Columbia.

St. Piran Formation	Feet	Meters
1. Massive-bedded quartzitic sandstone..................	300 +	91.4 +
Section concealed beneath débris slope.		

MIDDLE CAMBRIAN

Ogygopsis Shale Member of Stephen Formation

This term is applied to the local development of an arenaceous and calcareous hard gray shale member at the top of the Stephen formation on the northwest slope of Mount Stephen.[1] The shale band (lentil) has a maximum thickness of about 150 feet (45.7 m.). It thins out to the northeast and is faulted out to the southwest. At its maximum thickness (2,800 feet, 853.4 m., above Field) it carries immense numbers of trilobites, especially *Ogygopsis klotzi* (Rominger), *Bathyuriscus rotundatus* (Rominger), *Neolenus serratus* (Rominger), *Zacanthoides spinosus* (Walcott), and, in addition, sponges, cystids, brachiopods, pteropods, and gastropods. The shale is less rich in fossils ¼ mile (.4 km.) northeast on the strike; also to the northwest. Lentils of gray quartzitic sandstone and gray siliceous limestone occur in the shale, and the entire shale band appears to be a lentil between the thin-bedded blue limestones and the superjacent, massive, arenaceous Eldon limestone formation. There is no trace of the Ogygopsis shale on Mount Bosworth 6 miles (9.7 km.) northeast, at the same horizon, or at Castle Mountain, 20 miles (32.2 km.) east-southeast, but on Mount Field, about 4 miles (6.4 km.) north of the Ogygopsis shale on Mount Stephen, the Burgess shale member of the Stephen occurs in a corresponding stratigraphic position.

There is a sharp anticline, with a northeast-southwest axis, in the Ogygopsis shale and the thin-bedded Stephen limestones beneath, on the northwest slope of Mount Stephen (see pls. 71, 72, 73). The southeast limb is crushed and the rocks much altered and cut out by a fault before reaching the amphitheater at the head of Field Brook. On the northwest limb the shales are unaltered and slope down the side of the mountain for 1,800 feet (548.6 m.), thus affording a great exposure of the shale and contained fossils. The fauna in the shale includes (14s):

Hyolithellus flagellum (Matthew)
Hyolithellus annulatus (Matthew)
Orthotheca corrugata Matthew
Orthotheca major Walcott

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 210.

Looking west from the "Fossil Bed" on Mount Stephen. The distant summits of the Van Horn Range are shown on the right, and below, the Kicking Horse River. The cliffs of the northwest ridge of Mount Dennis rise from the river and extend up to Dennis Pass. They are formed of Upper Cambrian shales and thin beds of limestone that are superjacent to the Middle Cambrian Eldon limestones of Mount Stephen. The broken down shales of the "Fossil Bed" are finely exposed and at the top on the left layers of the shale occur *in situ*.

Locality.—At *P* on map, plate 26. The "Fossil Bed" is about 3,000 feet (914.4 m.) above the town of Field, British Columbia.

Hyolithes carinatus Matthew
Stenotheca wheeleri Walcott
Platyceras romingeri Walcott
Platyceras bellianus Walcott
Acrotreta depressa (Walcott)
Iphidella pannula (White)
Obolus mcconnelli (Walcott)
Nisusia alberta Walcott
Philhedra columbiana (Walcott)
Scenella varians Walcott
Anomalocaris canadensis Whiteaves
Anomalocaris ? whiteavesi Walcott
Anomalocaris ?? acutangula Walcott
Agnostus montis Matthew
Dorypyge dawsoni (Walcott)
Bathyuriscus rotundatus (Rominger)
Bathyuriscus pupa Matthew
Bathyuriscus occidentalis (Matthew)
Bathyuriscus ornatus Walcott
Bonnia ? stephenensis (Walcott)
Neolenus serratus (Rominger)
Ogygopsis klotzi (Rominger)
Oryctocephalus reynoldsi Reed
Burlingia hectori Walcott
Elrathia cordillerae (Rominger)
"Ptychoparia" palliseri Walcott
Zacanthoides spinosus Walcott

Burgess Shale Member [1] of Stephen Formation

The massive-bedded arenaceous limestones of the Eldon formation form the summit of the ridge between Mount Field and Mount Wapta, and the Burgess shale member of the Stephen formation dips eastward beneath the Eldon. Although only 4 miles (6.4 km.) from the Mount Stephen section, the Burgess shale member has a very different series of shales and interbedded limestone between the Eldon above and the subjacent shaly and thin-bedded, bluish-black and gray limestones of the Stephen formation which are somewhat similar to those beneath the Ogygopsis shale member of the Stephen formation on Mount Stephen.

	Feet	Meters
1. Greenish-colored argillaceous shale....................	6	1.8
Annelid trails		
2. Gray arenaceous limestone...........................	3.6	1.1
3. Bluish-black and gray, finely arenaceous shale, and thin layers of gray, rough sandstone in massive layers....	24.6	7.5

[1] Name mentioned in Smithsonian Misc. Coll., Vol. 57, No. 5, 1911, p. 110 also No. 6, 1912, p. 148.

	Feet	Meters
4. Gray, arenaceous (magnesian) limestone in massive beds, that break up into thin, irregular layers. Some of the thin layers weather buff and others dirty gray, passing gradually into more and more shaly beds of bluish-gray color, weathering buff..............................	22.0	6.7
Fragments of fossils and trails.		
5. Coarse, highly arenaceous limestone..................	4.0	1.2
6*a*. Gray siliceous shale in beds 2 to 4 feet (.6 to 1.2 m.) thick, weathering grayish-buff and banded..........	42	12.8
Fauna.—Fragments of trilobites.		
6*b*. Finer grained shales than in 6*a*, and with thin layers of gray, siliceous, slightly calcareous shale..........	80	24.4
Fauna.— *Micromitra* sp. Sertularian sp. *Hyolithes* cf. *billingsi*		
6*c*. Bluish-gray, exceedingly fine-grained, strong siliceous shale. At 65 feet (19.8 m.) the shales grow darker (*Nisusia* and *Microdiscus* appear). About 90 feet (27.4 m.) down the shales become thinner and darker and in the lower 12 feet (3.7 m.) are black...........	228	69.5
Fauna.—Between 30 and 40 feet (9.1 and 12.2 m.) from the base the Phyllopod fauna occurs in great abundance.		
Total section of Burgess formation..............	410	125.0

Thin-bedded, shaly, bluish-gray limestones of the Stephen formation outcrop from beneath the Burgess shale and extend down the slope of the mountain for 200 feet (60.9 m.) or more. The limestone is in layers from 2 to 3 feet (.6 to .9 m.) thick that split into thin, very irregular, shaly layers, largely made up of crushed and broken trilobites of the genera *Neolenus, Bathyuriscus* and "*Ptychoparia*." These limestones bend down to the westward at nearly a right angle, and are nearly vertical along the Yoho trail at a point north of the Burgess shale fossil quarry.

The lower portion of the great shale bed (6*c*) is an exceedingly fine, compact, hard, black shale, a portion of which has been named the Phyllopod bed. The detailed section, as measured, is as follows.[1]

	Feet	Inches	Meters
1. Bluish-gray siliceous shale, with partings of dirty-gray shale	1	9	.5
2. Dirty-gray shale	0	8	.2
3. Bluish-gray shale in compact layers 3 to 4 inches (7.6 to 10.1 cm.) thick.............................	1	0	.3
4. Dirty-gray shale	0	2	.05
5. Bluish-gray, tough, brittle shale.....................	0	2	.05

[1] Smithsonian Misc. Coll., Vol. 57, No. 6, 1912, p. 152.

	Feet	Inches	Meters
Eldonia ludwigi layer.			
6. Compact layer of bluish-gray, hard rock that splits more or less evenly	0	8	.2
7. Alternating dirty- and bluish-gray shale	0	9	.2
Hymenocaris perfecta bed.			
8. The same character as 6: Compact layer of bluish-gray, hard rock that splits more or less evenly	0	8	.2
9. Dirty-gray, earthy shale	0	2	.05
10. The same character as 6: Compact layer of bluish-gray, hard rock that splits more or less evenly	1	4	.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	.05
12. Bluish-gray, tough, brittle shale	0	1.5	.05
	7	7	2.3

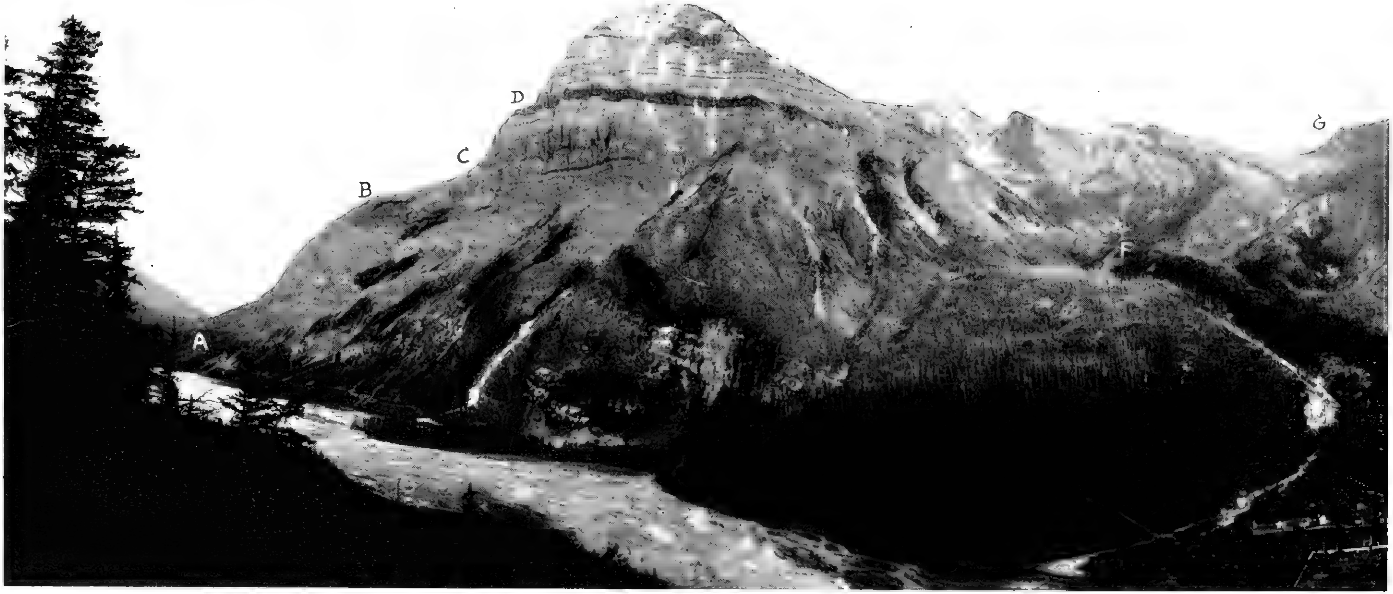
This is the prolific *Marrella splendens* layer.

A few feet below the base of the quarry a calcareous shale in layers 2 to 4 feet (.6 to 1.2 m.) thick, with thin layers of limestone, is almost made up of comminuted fragments of trilobites. These beds extend down for 200 feet (60.9 m.) or more, and appear to represent the Ogygopsis shale of the Mount Stephen section. The strata above the shale in the quarry up to the Eldon limestone do not appear to have been deposited at Mount Stephen. A mile (1.6 km.) west of the quarry at Burgess Pass the section beneath the Eldon limestone is composed of compressed and partly altered calcareous shales without traces of either the Ogygopsis shale fauna or that of the section at and above the fossil quarry on the west slope of the ridge between Mount Field and Mount Wapta.

The student will find a description and discussion of the origin of the Burgess shale in Smithsonian Miscellaneous Collections, Volume 57, Number 6, 1912, page 148, and papers on the fauna in Volume 57, Numbers 2, 3, and 5, 1911; Volume 67, Number 5, 1919, and Number 6, 1920.

OTTERTAIL RANGE

This range lies west of the Bow Range and south of the Kicking Horse River. It is strange that it does not contain any rocks or faunas related to those in the surrounding ranges. The three formations deposited there are enormously thick, and must have been laid in a seaway which had no connection with those in which the strata of either the Bow Range to the east, or the Stanford-Brisco Range to the west, were laid.



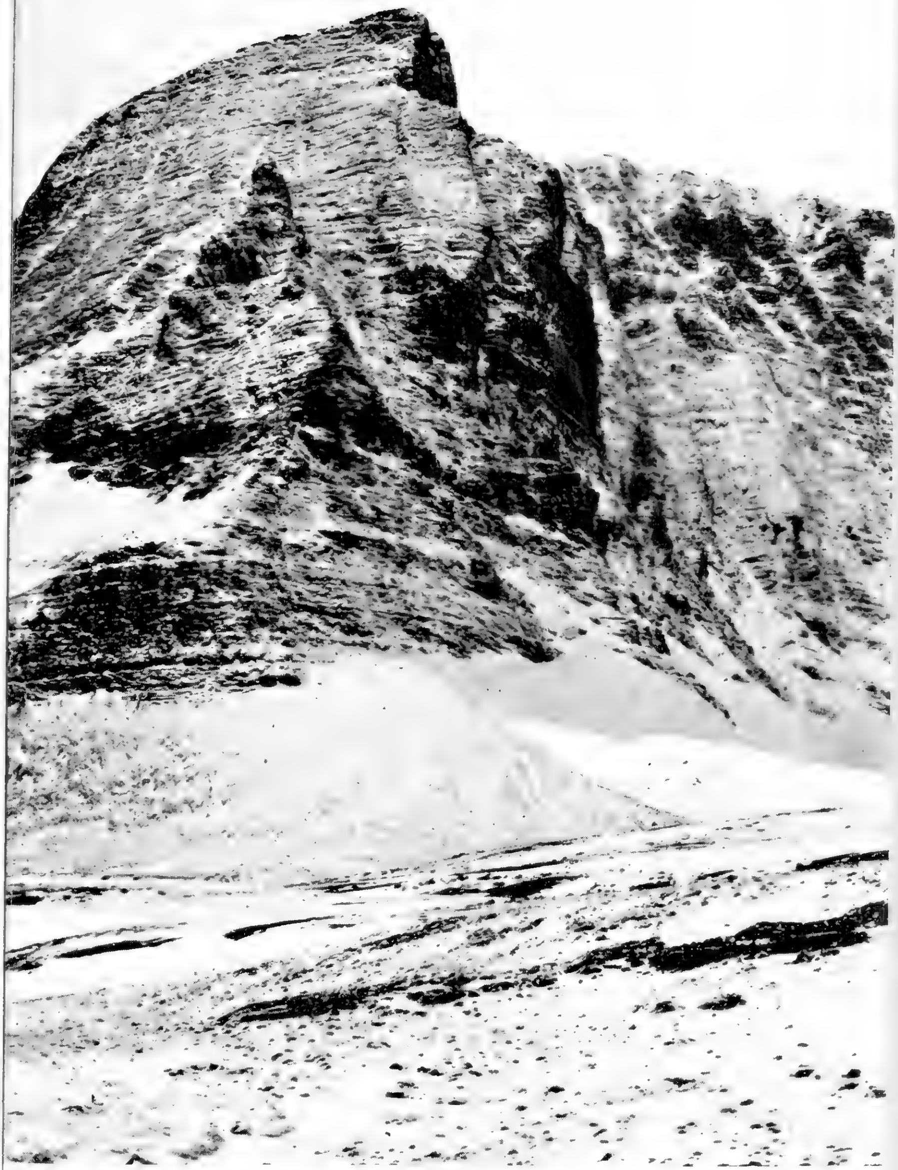
Northwest side of Mount Stephen (10,485 feet, 3,195.8 m.), viewed from the slope of Mount Burgess north of Field.

The geologic section from the Canadian Pacific Railway track a little below *A* to the top of the mountain includes over 5,800 feet (1,767.8 m.) of quartzitic sandstones, limestones and shales of Cambrian age. Near the base at *A* the Lower Cambrian Mount Whyte formation is superjacent to thick layers of quartzitic sandstone of the St. Piran formation. The Mount Whyte formation is succeeded by the great arenaceo-dolomitic limestone series of the Middle Cambrian Cathedral limestone which forms the northeast shoulder of the mountain up to about *B*, where the limestones and shales of the Stephen formation begin and extend up about 800 feet (243.8 m.) to the top of *C*, which is at the base of the Eldon dolomitic limestone, the thick layers of which form the summit of the mountain above a dark horizontal band of bluish-black limestone at *D*. At *E* the celebrated Mount Stephen "Trilobite Bed" occurs.

Locality.—At *P* on map, plate 26. Mount Stephen rises over 6,400 feet (1,950.7 m.) above Field, British Columbia.

Burgess shale fossil quarry on steep west slope of ridge between Mount Wapta and Mount Field, at about 7,700 feet (2,346.9 m.) altitude (see pl. 70). The high peaks of the Ottertail Range are seen in the distance southwest of Mount Dennis. This view shows the appearance of the hard siliceous shale *in situ*.

Locality.—7 miles (11.3 km.) north-northeast by trail from Field, British Columbia.



y Peak (9,000 feet, 2,743.2 m.), and in the distance, through the Pass, the Beaverfoot
map, pl. 26), Alberta.

Rounded ridges formed of the shales of the Chancellor formation in the foreground with cliffs of the superjacent Ottertail limestone at the left in Washmawapta Ridge. In the distance, to the right of the center, peaks of the Bow Range, that are eroded in the Middle Cambrian limestones of the Eldon, Stephen, and Cathedral formations.

Locality.—View taken from a low mountain northeast of Wolverine Pass, British Columbia, and about 16.5 miles (26.5 km.) southwest of Castle Mountain Station (at *T* on map, pl. 26), Alberta.

Range.

UPPER CAMBRIAN

Goodsir Formation (See p. 232.) After Allan	Feet	Meters
1. Thin-bedded, alternating bands of buff and gray, soft argillaceous and calcareous shales, with harder bands of siliceous and dolomitic shale weathering to a fawn and light yellow color. The preceding applies to the formation in Striped Mountain and in the Beaverfoot Valley. On Mount Goodsir the formation consists of cherty limestones, banded cherts, shales, thin-bedded siliceous and dolomitic limestones interbedded with siliceous shale	6,040	1840.9

Fauna.—The known fauna (*Housia*) is confined to the lower 300 feet (91.4 m.) of the formation and, as far as can be determined, includes essentially the same forms at all the localities discovered. The most prolific locality gave the following forms:

Obolus mollisonensis Walcott
Lingulella moosensis Walcott
Lingulella sp.
Agnostus several species
Moosia degener Walcott
Moosia grandis Walcott
Housia allani Walcott
Housia canadensis (Walcott)
Housia gracilis Walcott

Ottertail Formation [1]

	Feet	Meters
1. Massive blue limestone weathering gray	425	129.5
2. Massive blue limestone, with a few shaly bands	408	124.4
Thickness of 1 and 2 estimated	833	253.9
3. Massive limestone, some beds 15 feet (4.6 m.) thick	100	30.5
4. Massive limestone, with a few interbedded dolomitic bands	99	30.2
5. Blue limestone, thinly bedded, with oolitic layers 6 to 10 feet (1.8 to 3 m.) thick	26	7.9
6. Massive bed of blue limestone, shows irregular lentils on weathered surface	112	34.1
7. Concretionary, bluish limestone, weathers dark gray	62	18.9
8. Shaly blue limestone, weathers into lens-like fragments	90	27.4
9. Massive blue limestone in thick beds	100	30.5
10. Arenaceous limestone, with calcite stringers	6	1.8
11. Limestone beds about 5 feet (1.5 m.) thick, some gray lentils on weathered surface	25	7.6
12. Thin, alternating layers of calcareous and dolomitic limestone weathering gray and black	10	3.1

[1] Section copied from Allan as it occurs in the Ottertail Escarpment, Geol. Surv. Canada, Mem. No. 55, 1914, pp. 91, 92.

	Feet	Meters
13. Massive beds of blue limestone weathering gray and showing bluish, irregular lentils; interbedded with beds of shaly limestone and calcareous shale. Other bands are thin-bedded limestone	150	45.7
(The relative amounts of the various types in the above 150 feet could not be distinguished. A dark green dyke cuts vertically through these lower beds, and pinches out in a distance of a few yards.)		
14. Thin-bedded limestone weathering into gray and blue bands; the former are more argillaceous	52	15.9
15. Exposed to west of section: cherty limestone weathering with hard nodules, and interbedded limestones weathering into roughly pitted shaly fragments with a graty feel. In contact with slates and shales of the overlying formation	160	48.8
Total thickness measured	992	302.4
Total thickness estimated	833	253.9
Total thickness for Ottertail formation	1,825	556.3

The Ottertail formation seems to have a thickness of about 2,450 feet (746.8 m.) in Limestone Peak, which means a considerable thickening of the formation to the southeast of the Ottertail escarpment.

Fauna.—Dr. Allan found only a few fragments of fossils. In 1918 Mrs. Walcott and I found at Wolverine Pass near the base of the formation the following (63x):

Obolus myron Walcott
Lingulella siliqua Walcott, together with undescribed trilobites.

CHANCELLOR FORMATION

	Feet	Meters
1. Thinly-laminated, gray argillaceous and calcareous shales, weathering reddish, yellowish, and fawn-colored in the upper half of the formation; these are superjacent to highly sheared gray shales, slates, argillites, and phyllites in the Ottertail Valley	4,500 +	1,371.6 +

Fauna.—Faint traces of *Agnostus* sp.

BOW LAKE SECTION

This section was measured on the east slope of the mountain, directly north of the head of Bow Lake and about 3 miles (4.8 km.) northeast of Mount Thompson on the Continental Divide. It is 22 miles (35.4 km.) north-northwest of Mount Bosworth, and about 27 miles (43.4 km.) in a direct line from Mount Whyte. The thick-bedded Cathedral limestones form the summit of the mountain and extend down 800 feet (243.8 m.) or more. Their lower contact with

Looking west and southwest over Bow Lake to the Waputik Range, which is formed of Middle and Lower Cambrian formations. *Locality.*—At *S* on map, plate 26. 19 miles (30.6 km.) north-northwest of Lake Louise, Alberta.

the Ptarmigan bluish-gray limestones is clearly defined. Both limestones strike about north 40° west, and dip 15° to 20° to the southwest.

MIDDLE CAMBRIAN

	Feet	Meters
CATHEDRAL FORMATION		
Massive-bedded, coarse, gray, rough-weathering limestone.		
PTARMIGAN FORMATION		
1. Bluish-gray, thin layers in massive beds	108	32.9
Fauna.—Neolenus (fragments).		
2. Ross Lake shale. Dark siliceous shale, with *Albertella* fauna	6	1.8
Fauna.—(63w): *Acrothele colleni* Walcott; *Wimanella simplex* Walcott; *Vanuxemella nortia* Walcott; *Agraulos stator* Walcott; *Albertella* sp.		
3. Thin layers of bluish-gray limestone in massive beds, breaking down on slopes. It quickly becomes more massive-bedded and cliff-forming, and passes below into a gray coarse rock	154	46.9
4. Deep, bluish-gray, massive-bedded, coarse limestone, more or less mottled on weathered surface. In bands that break up into thin beds	144	43.9
5. Light gray more or less mottled, rough-weathering limestone in massive layers, 6 to 50 feet (1.8 to 15.2 m.) thick. Annelid borings	122	37.2
Total Ptarmigan formation	534	162.7

LOWER CAMBRIAN

	Feet	Meters
MOUNT WHYTE FORMATION		
1. Thin-bedded, rough surfaced, bluish-gray limestone, passing into coarser magnesian, buff-weathering, thin-bedded limestone	60	18.3
2. Massive bed of gray limestone, with stringers and nodules of magnesian limestone	12	3.7
3. Coarse, siliceo-argillaceous shale, dirty-gray in color	5	1.6
4. Bluish-gray limestones in beds varying 2 inches (5.1 cm.) to 2 feet (.6 m.) in thickness. Some beds oolitic near the summit, and carrying *Nisusia, Hyolithes,* and fragments of large and small trilobites	32	9.8
5. Rough, arenaceous shale with annelid trails. Gray-weathering, dirty, buff-brown. Thin layers of bluish-gray limestone interbedded in lower portion	36	10.9
6. Light gray limestone, with stringers and splotches of buff-weathering magnesian limestone	6	1.8

	Feet	Meters
7. Dirty-green, earthy, siliceous shale	24	7.3
8. Similar to 6	48	14.6
9. Similar to 7	30	9.1
10. Spotted, blotchy, bluish-gray limestone, passing into banded, arenaceous and calcareous massive layers	120	36.6
11. Thin-bedded, rough sandstone and shale, with a few calcareous layers	32	9.8
12. Massive-bedded, oolitic, hard, gray limestones that break up into thin, irregular layers	44	13.4
13. Quartzitic sandstones in layers ½ inch to 14 inches (1.3 to 35.6 cm.) thick, with arenaceous, shaly partings[1]	60	18.3
14. Greenish siliceous shale	12	3.7
15. Massive-bedded, gray, more or less oolitic limestone	68	20.7
16. Greenish siliceous shale	3	.9
17. Masive-bedded, gray, hard limestone with many oolitic layers, with the massive beds breaking up into rough layers 1 inch to 8 inches (2.5 to 20.3 cm.) thick on weathered slopes	72	21.9
18. Greenish siliceous shale, with oblique cleavage	44	13.4
19. Steel-gray, rough-weathering, hard, fine-grained siliceous limestone	24	7.3
20. Slightly calcareous, coarse, massive-bedded sandstones	30	9.1
Total Mount Whyte formation	762	232.2

St. Piran Formation

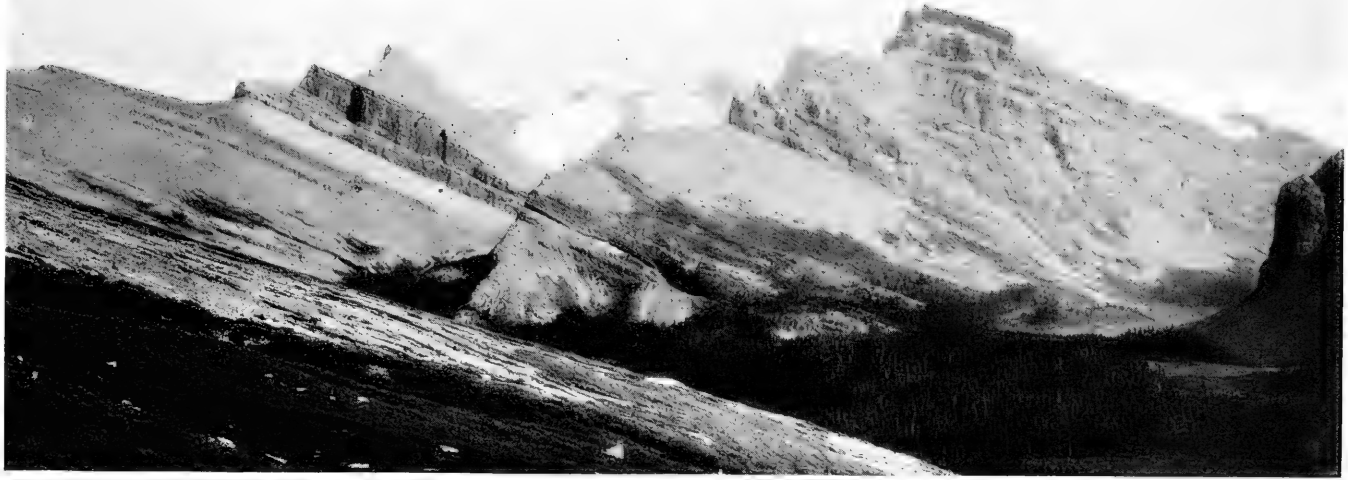
Massive, purplish-colored quartzitic sandstones 20 to 30 feet (6 to 9.1 m.), and then light gray quartzitic sands with occasional bands of greenish, finely arenaceous shale to débris at foot of cliffs.

The above section is characteristic of the cliffs for a long distance to the northwest of Bow Pass, and also of the cliffs on the west side of the Upper Pipestone River, and for twenty miles (32.2 km.) or more on the west side of the Siffleur River north of Pipestone Pass. The massive Eldon limestones cap some of the higher points and ridges, but I did not attempt to measure the section until the Saskatchewan Valley was entered. The character of the cliffs and mountain slopes is illustrated by plate 77.

CLEARWATER CANYON AREA

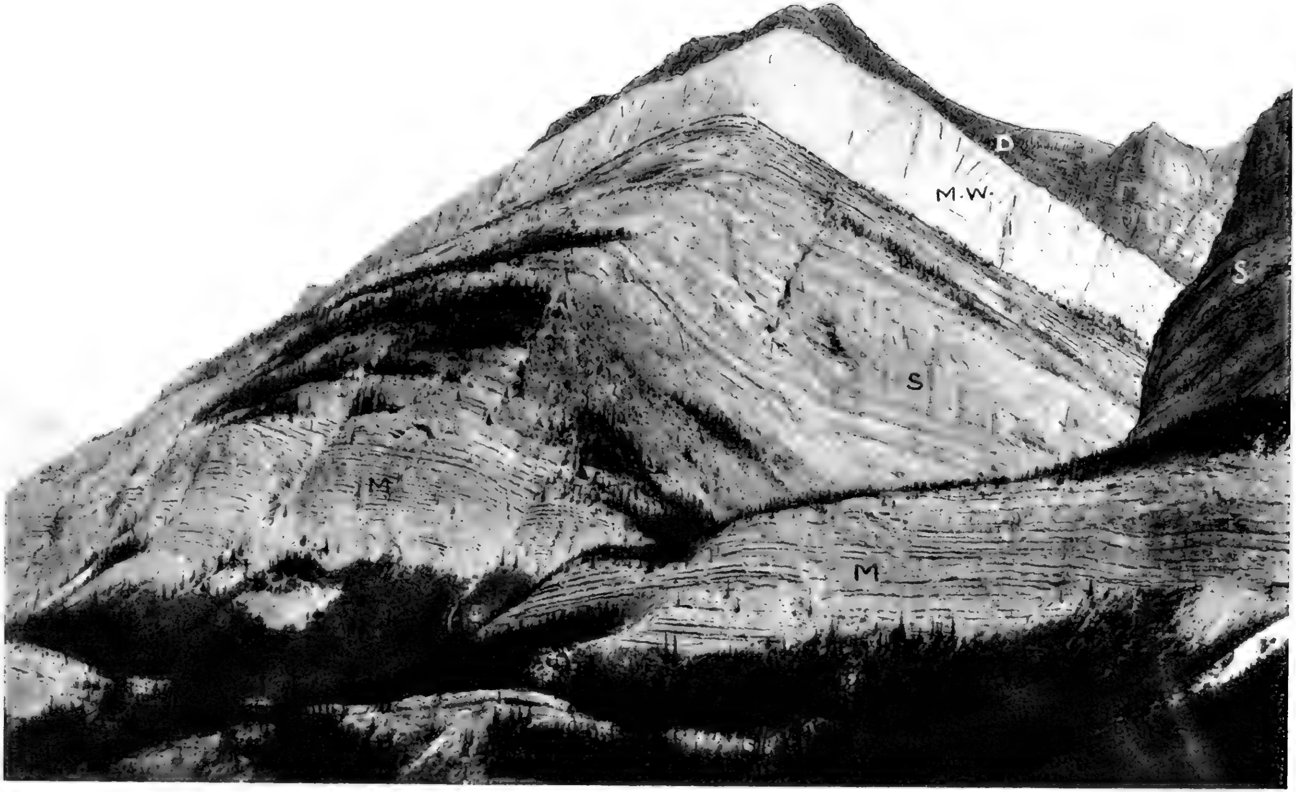
This section (*D.* on map, pl. 26) near the head of the Clearwater Canyon is 33 miles (53.1 km.) east-southeast of Glacier Lake section; 20 miles (32.1 km.) south-southeast of Siffleur section; 54 miles

[1] A small fault of from 50 to 70 feet (15.2 to 21.3 m.) here cuts the section, but the two parts are exposed in the cliffs facing north and above the talus slopes of a small glacier.



Looking east down upper canyon valley of Clearwater River to the western ridges of Shadow Mountain (10,174 feet, 3,101 m.), which are about 4 miles (6.4 km.) northeast of Pipestone Pass. The upper dark band of rock on the mountain at the right is formed of limestones of Devonian age. Beneath this, the broken cliffs formed of Sarbach limestones extend down to the smooth slope formed by the thin-bedded limestones and shales of the Ozarkian Mons formation. The river flows to the north (left) at the foot of the steep cliff, where the west and south branches come together.

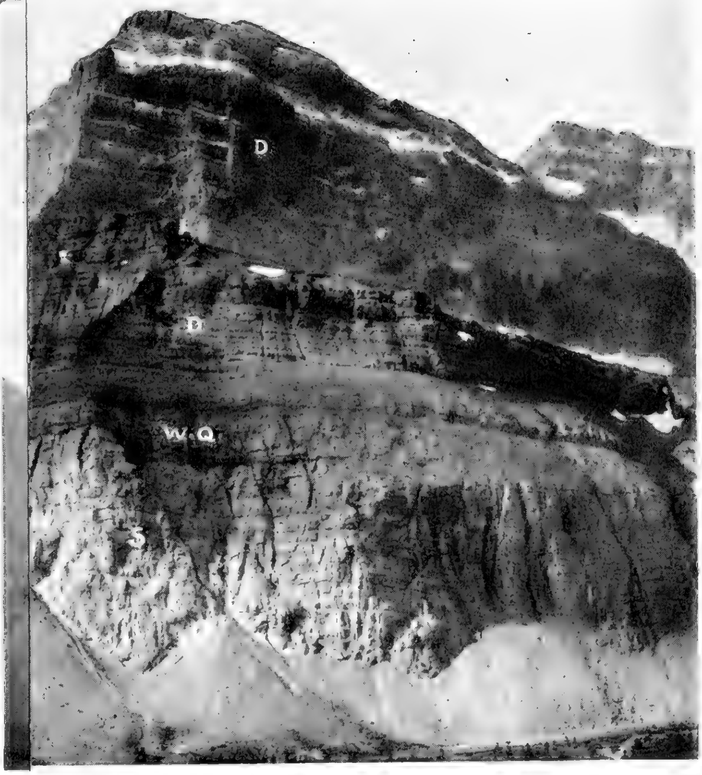
Locality.—At *E* on map, plate 26. The cliffs are about 20 miles (32.2 km.) north of Lake Louise Station, Alberta.



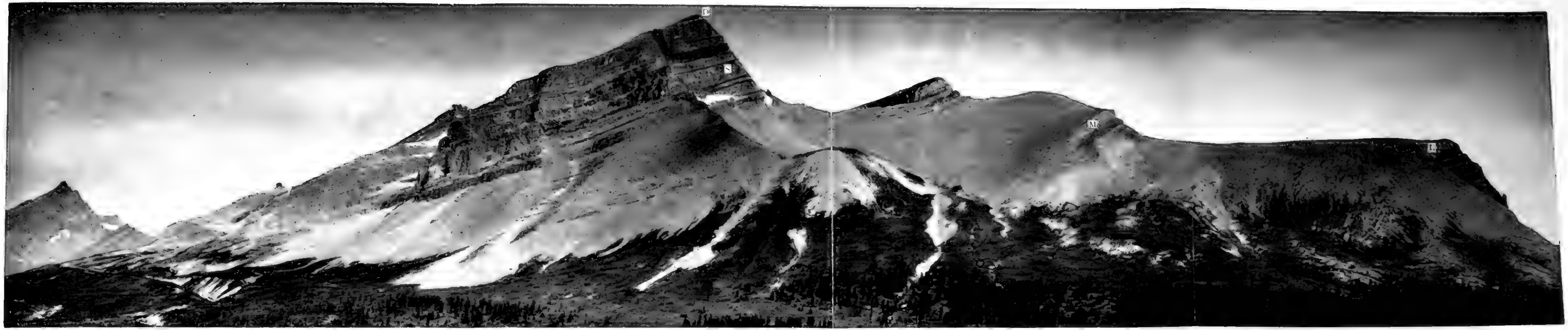
Cliffs on the south face of Mount Wilson, showing the light colored band of the Mount Wilson quartzite (*M. W.*), with dark Devonian limestones (*D*) above, and the gray limestones of the Sarbach (*S*) and Mons (*M*) beneath.

Locality.—At *C* on map, plate 26. This was photographed from the low hills on the north shore of the Saskatchewan River, about 48 miles (77.2 km.) northeast from Lake Louise Station, Alberta. (See pl. 82, fig. 2.)

SM



er Devonian Pipestone formation limestones (*U. D.*) form Devon
subjacent Mount Wilson quartzite (*W. Q.*) of the Ghost River
down to the foot of the dark lower cliffs on the left of the phot
) north of Lake Louise Station, Alberta.



South face of Section Mountain, on north side of Clearwater Canyon. It is capped by Middle Devonian limestone (*D*), resting on the subjacent Sarbach formation (*S*), which extends down to the subjacent Mons formation (*M*). The latter continues down the gentle slope on the right to the long horizontal cliff line formed by the massive limestones of the Lyell formation (*L*).

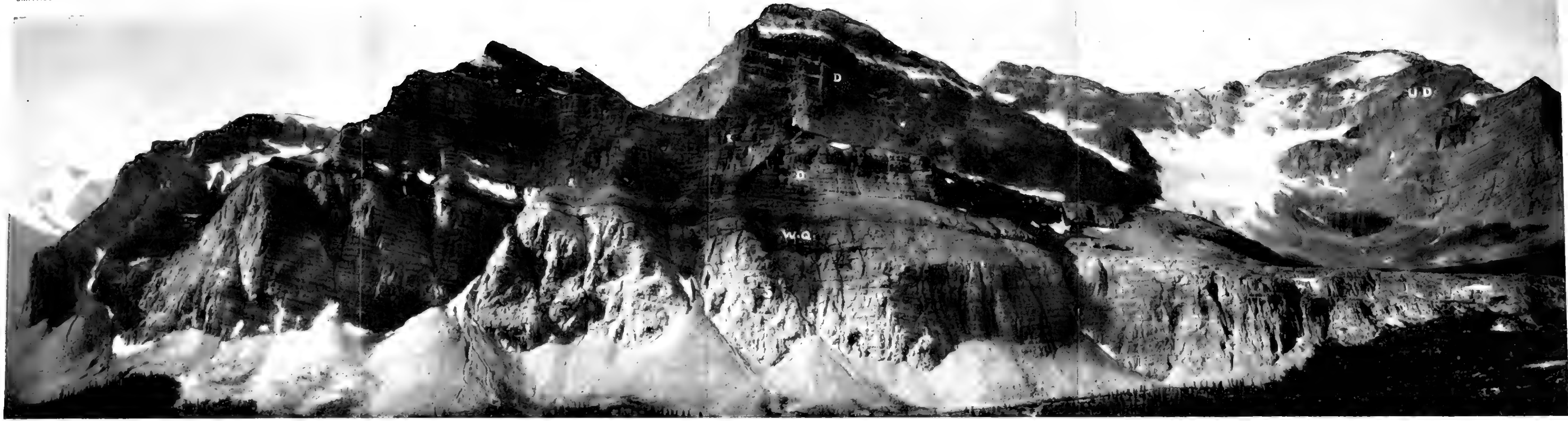
Locality.—At *E* on map, plate 26. Head of Clearwater River Canyon about 20 to 21 miles (32.2 to 33.8 km.) north of Lake Louise Station, Alberta.

Mountain and the spur extending northeast (left) to the south fork of the broad
nterval is well exposed below the outlet of the small glacial lake in the bottom
graph (see pl. 80).

FIG. 1.—Mount Wilson and glacier from the southeast, with the eastern section of the broad syncline, of which Mount Wilson is the western section on the right. The southern and western slopes of the eastern section are shown by plate 79.

Locality.—At *C* on map, plate 26. View taken from south shore of Saskatchewan River about 2 miles (3.2 km.) east of Mistaya Creek and 47 miles (75.6 km.) northwest of Lake Louise Station, Alberta.

FIG. 2.—Resting in camp near the head of Clearwater River, Alberta. A typical camp 500 feet (152.4 m.) below timber line.



Northeast side of Devon Mountain (9,855 feet, 3,003.8 m.), with Devon glacier and Amphitheater on the right. The upper Devonian Pipestone formation limestones (*U. D.*) form Devon Mountain and the spur extending northeast (left) to the south fork of the broad upper canyon valley of the Clearwater River. The contact of the dark Middle Devonian (Messines) limestone (*D*) with the subjacent Mount Wilson quartzite (*W. Q.*) of the Ghost River interval is well exposed below the outlet of the small glacial lake in the bottom of the amphitheater, and also the thick-bedded light colored magnesian limestones (*O*) of the Sarbach formation that extend down to the foot of the dark lower cliffs on the left of the photograph (see pl. 80).

Locality.—At *E* on map, plate 26. South side of head of Clearwater River Canyon, about 19 to 20 miles (30.6 to 32.2 km.) north of Lake Louise Station, Alberta.

Wilson quartzite cliffs at western top of north ridge of Mount Wilson, from flats of North Fork of Saskatchewan River. The cliffs are capped by dark Devonian limestone (see pl. 79), and are superjacent to light gray Ordovician limestones (Sarbach formation).

Locality.—At *C* on map, plate 26. View taken from the river flats of the North Fork about 7 miles (11.3 km.) north of the Saskatchewan River and 55 miles (88.5 km.) northwest of Lake Louise Station, Alberta.

Alexandra glacier, with Mount Alexandra (11,215 feet, 3,418.3 m.) in the mist in the distance on the north (right) side, back of Queens Peak (10,990 feet, 3,349.8 m.). On the south (left) of the glacier, Mount Donai (10,230 feet, 3,118.1 m.). The glacier heads on the Continental Divide. Gravelly flood plain of Alexandra River in foreground.

Locality.—Near head of Alexandra River, a west tributary of North Fork of Saskatchewan River. Mount Alexandra is about 59 miles (94.9 km.) in an air line northwest of Lake Louise Station, Alberta.

(86.9 km.) northwest of Ghost River section; and 26 miles (41.8 km.) north-northeast of Mount Dennis section of Allan. It is about 20.5 miles (33.0 km.) in an air line north of Lake Louise Station. It includes the Devonian beneath the Banff shale of the Carboniferous; the Ordovician, Sarbach formation; the Ozarkian, Mons formation; and the Upper Cambrian, Lyell formation.

The upper broad canyon of the Siffleur River north of Pipestone Pass is largely eroded in the Banff shale, which is superjacent to the light gray Devonian limestone well exposed at Pipestone Pass, in Devon Mountain and its northward extension to the head of Clearwater Canyon; the latter cuts through the Devonian beds nearly at right angles to their strike, and southwesterly dip.

Clearwater Canyon Section

The Pipestone formation of the Devonian of Devon Mountain[1] was not measured in detail, but it was estimated to be at least 1,200 feet (365.8 m.) in thickness. The measured section began about 1.5 miles (2.4 km.) east of the Divide at the head of Clearwater Canyon, which is formed of an old lateral moraine of the glacier that flowed down the Siffleur Canyon from Pipestone Pass. Clearwater Canyon has an east and west trend for about 4 miles (6.4 km.) before curving to the north-northeast. The section was studied and measured on the south side of the canyon down to 2 of the Sarbach formation (see pl. 78), and then along the north side down into the Lyell formation (pl. 80).

DEVONIAN

Pipestone Formation (Upper Devonian)	Feet	Meters
1. Light gray, evenly-bedded limestone in layers from 3 inches (7.6 cm.) to 2 feet (.6 m.) in thickness. Estimated	1,200 +	365.8 +

Fauna.—I collected a few fossils in upper part at Pipestone Pass, which Dr. Edwin Kirk of the U. S. Geological Survey identified as follows:

Pachyphyllum woodmani (White)
Cyathophyllum sp.
Heliophyllum sp.
Striatopora sp.

[1] The sharp point rising on the east side of Pipestone Pass is named Devon Mountain (9,300 + feet, 2,834.6 + m.), and the glacier on its northeast side, facing Clearwater Canyon, Devon glacier. The peak is formed of Devonian rocks, and the glacier rests in a cirque eroded in the same. Name approved by Geographic Board of Canada, February, 1924.

Cladopora sp.
Romingeria sp.
Atrypa reticularis (Linn.)

The line between the light gray limestones of the Pipestone formation and the dark lead-gray of the Messines formation is strongly marked and can be recognized miles away by the contrast in color; the two formations also give rise to different topographic forms, as the upper division breaks down more readily into terraces and low cliffs when the dip is nearly horizontal, while the lower division forms dark cliffs with a steep dip; the upper division forms sharp high points or ridges, and the lower division a more or less broken cliff, capping the light gray pre-Devonian beds beneath.

Messines Formation (Middle Devonian)

1. Section measured from top downward.
Strike N. & S., Dip W.

	Feet	Meters
1*a*. Dark arenaceous, more or less bituminous limestone in beds breaking down in layers 3 to 6 inches (8 to 15 cm.) thick	45	13.7
1*b*. Gray and buff-weathering, shaly gray limestone	30	9.1
1*c*. Purplish, finely arenaceous shale, with thin layers of limestone	24	7.3
1*d*. Thick-bedded, dark arenaceous limestone	110	33.5
1*e*. Dull lead-gray, finely arenaceous limestone, with corals and *Stromatopora* very abundant	184	56.1
1*f*. Similar to 1*d*, with *Stromatopora* bed, 20 feet (6.1 m.) thick, 35 feet (10.7 m.) from base	270	82.3

Fauna.—At from 100 to 105 feet (30 to 32 m.) from the base of 1*f*, fossils are abundant. Dr. Kirk considers them to indicate the Middle Devonian (Jefferson limestone):

Stromatopora sp.
Crinoid columns
Gomphoceras sp.
Palaeoneilo sp.
Atrypa reticularis (Linn.)
Stropheodonta sp.

	Feet	Meters
Total of 1	663	202.0

The Devonian terminates at its base in thin-bedded, dark dirty-gray layers; at 25 to 30 feet (7.6 to 9.1 m.) from the base, a band of bluish-black, compact limestone is quite fossiliferous as well as the shaly partings between the layers.

Fauna.—

Diaphorostoma sp.
Palaeoneilo sp.
Atrypa reticularis (Linn.)
Gomphoceras sp.

	Feet	Meters
The limestones rest on the somewhat hummocky and uneven surface of the subjacent Mount Wilson quartzite, which is all that there is representing the Ghost River formation between the base of the Devonian and the subjacent massive limestones of the Ordovician Sarbach formation.		

DISCONFORMITY

MOUNT WILSON QUARTZITE

	Feet	Meters
1. Massive-bedded, light gray to white quartzite.........	24	7.3

This 24 feet (7.3 m.) of quartzitic sandstone represents the 5,000 feet (1,524 m.) in thickness of deposits that occur elsewhere to the southwestward between the Sarbach and the Devonian; also the 285 feet (86.6 m.) in thickness of the dolomite of the Ghost River section (see p. 259). It thickens to 40-50 feet (12.1 to 15.2 m.) east of where the section was taken, and then thins out and disappears on the strike at the top of the high cliff on the south side of the canyon (see pl. 83).

CANADIAN

SARBACH FORMATION

UPPER DIVISION [1]

	Feet	Meters
1*a*. Gray and purplish-tinted, compact, massive-bedded, lavender-weathering limestone breaking with a conchoidal fracture and on weathering into large blocks and a few thin layers............................	32	9.8

Purple mottling occurs throughout some of the beds.

Annelid trails on surface of some layers, and borings more or less scattered through the layers.

Dip 35° S. 20° W. (Magnetic).

1*b*. Same as 1*a* except that the color is a more uniform dove tint, with occasional interbedded purplish tinted thin layers.

At 198 feet (60.4 m.) from top, noted fragments indicating coiled shells (gastropods).

At 282 feet (85.9 m.) from top, a few cherty nodules occur, and at 312 feet (95.1 m.), stringers and nodules parallel to bedding.

Fauna.—At 336 feet (102.4 m.) from top I found gastropods (65r).

[1] This series of beds should possibly not be referred to the Sarbach, but may be considerably younger. The fauna has not yet been sufficiently studied to permit its being placed into any exact stratigraphic position. Dr. Walcott intended to study these fossils further, particularly since they are not represented in the collections from other localities.—C. E. R.

	Feet	Meters
At 510 feet (155.5 m.) numerous sections of a flat coiled gastropod occur. (65s): *Girvanella* sp. *Maclurites* ? sp. *Orthoceras* sp. At 540-550 feet (165.3-167.6 m.), *Receptaculites* ? and sections of gastropods (65t): *Receptaculites* ? sp.[1] *Maclurites* sp. undt. *Eccyliomphalus* ? sp. undt. At 680-720 feet (207.2-219.4 m.), small *Stromatopora,* slender tubes, and sections of gastropods seen on surface of thick layers. At the horizons where fossils occur the layers carrying them are darker and more granular; this is at 336, 510, and 680 feet (102.4, 155.5, and 207.2 m.) from top of limestone 1*b*	730	222.5
Total of 1	762	232.3
The base of 1*b* usually occurs at a terrace formed by the breaking down of the subjacent thinner layers and shaly partings. Where a sharp ridge occurs, the massive limestones form a great cliff, the beds below making a gentle slope or saddle to the next massive and more compact band of layers.[2]		
LOWER DIVISION		
2*a*. Gray and bluish-gray, thin-bedded limestone, with many fossils	60	18.3
Fauna.—(65u): *Callograptus* sp. *Receptaculites* ? sp. *Calathium* ? Orthoid *Maclurites* ? sp. *Lecanospira* ? sp. ?		
2*b*. Thin-bedded, gray, hard siliceous limestone, with interbedded bands of shale and shaly limestone	310	94.5
2*c*. Bluish-gray, shaly, and thin-bedded limestones	40	12.2
Fauna.—(65w): *Megalaspis—Bellfontia* zone. Numerous annelid trails on surface and fragments of trilobites.		
Total of 2	410	125.0
Total of Sarbach formation[3]	1,172	357.3

[1] These are not true *Receptaculites* but appear to belong to the Receptaculidae.

[2] The section from the base of 1*b* was taken across to north side of Clearwater Canyon, as the latter is eroded almost at right angles to the strike. Its continuity is assured by the topography, lithology, succession of strata, and the presence of similar fossils.

[3] The fossils found in the Sarbach were tentatively identified by Dr. E. O. Ulrich.

OZARKIAN

Mons Formation	Feet	Meters
1*a*. Hard, steel-gray and dark gray limestone in massive beds above with about 50 feet (15.2 m.) of thin layers below	232	70.7

Fauna.—In the lower portion are numerous annelid trails. (65z).

Eoorthis sp.
Syntrophia ? sp.
Hyolithes sp.
Orthotheca sp.
Ozomia lucan Walcott
Ozarkispira leo Walcott
Endoceras ? *robsonensis* Walcott
Liostegium sp.
Keytella marginata Ulrich MSS.

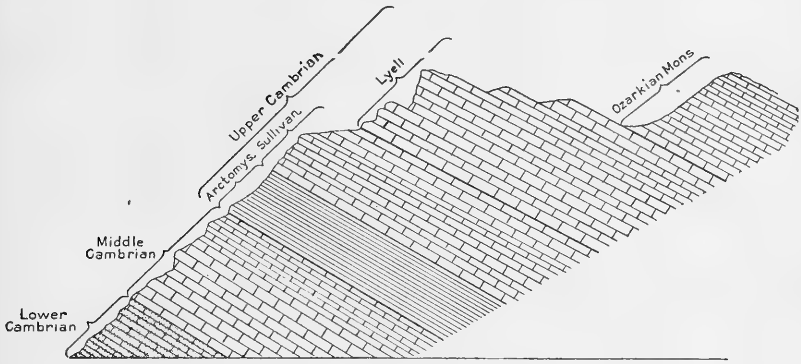


FIG. 31.—Theoretical diagrammatic section of the formations composing the cliffs on the east and west sides of the lower Siffleur River canyon, just before the river bends to the west. All of the formations indicated occur in the ridges of Mount Sedgwick on the west side of the Siffleur, but only the Lower and Middle Cambrian were measured in the Siffleur Canyon cliffs. Fossils of the Sullivan, Lyell, and Mons formations were found in the débris washed down from the higher cliffs.

The Siffleur cliffs are illustrated by plate 85.

An outcrop of similar limestone at the foot of the cliffs on the southeast side of the canyon carries a similar fauna as found in fragments of limestone lying in the débris. (67k). *Ozomia* zone.

	Feet	Meters
1*b*. Gray and greenish calcareous shales, with thin-bedded and shaly gray limestone intercalated...............	498	151.8

Fauna.—Immense numbers of annelid trails and small fragments of large trilobites, none of which could be identified.

	Feet	Meters
1*c*. Light gray, calcareo-argillaceous shale, with beds of intercalated gray interformational conglomerate in layers 1 to 12 inches (2 to 30 cm.) in thickness; also considerable shaly gray limestone..................	528	160.9

	Feet	Meters
Fauna.—At 288 feet (87.7 m.) from the base, fragments of a large Asaphoid trilobite occur; also a few brachiopods. (65y):		
Obolus sp. (fragments)		
Lingulella cf. *manticula* White		
Protorthis iones Walcott		
Agnostus sp.		
Hystricurus sp.		
Kainella sp.		
Symphysurina sp.		
1*d*. Pearl-gray calcareous shales, with a few thin layers of limestone weathering gray and buff.................	62	18.9
1*e*. Gray limestone in thin uneven layers, with parting of arenaceous and calcareous shale. A few layers of interformational conglomerate limestone also occur..	18	5.5
Fauna.—(65v):		
Syntrophia cf. *calcifera* Billings		
Symphysurina sp.		
Total of Mons formation.....................	1,338	407.8

UPPER CAMBRIAN

Lyell Formation[1]

	Feet	Meters
1*a*. Gray, buff-weathering, slabby dolomitic limestone, with thin, interbedded, gray limestone....................	8	2.4
Fauna.—(65x):		
Syntrophia cf. *calcifera* Billings		
Maladia americana Walcott ?		
Corbinia horatia Walcott		
Corbinia valida Walcott		
1*b*. Thin-bedded, coarse, dolomitic limestone, resting on massive-bedded, dolomitic limestone................	48	14.6
Strike W. 30° N., Dip 20° S. 30° W. (Magnetic)		
2*a*. Massive-bedded, steel-gray magnesian limestones, with a dark lead-color limestone breaking down in bands of thin layers 2 to 6 inches (5 to 15 cm.) thick.........	910	277.4
2*b*. Thin-bedded, hard, gray, finer-grained limestones than 2*a*, in thin layers................................	140	42.7
Total Lyell	1,106	337.1

Sullivan Formation

	Feet	Meters
1*a*. Thin-bedded, gray limestone, with some bluish-gray softer layers and oolitic layers 3 to 8 inches (7 to 20 cm.) thick......................................	130	39.6
1*b*. Thin-bedded, hard, gray limestone, with a few shaly layers	145	44.2

[1] Some of these beds may prove to be Lower Ozarkian rather than Upper Cambrian.—C. E. R.

	Feet	Meters
1*c*. Massive-bedded, steel-gray, hard, rough-weathering limestone	500 +	152.4 +
Section cut off by an E. and W. fault and overthrust.		
Total Sullivan	775 +	236.2 +

Of the 500 feet (152.4 m.) of 1*a*, 125 feet (38.1 m.) were measured and 375 feet (114.3 m.) estimated.

Fragments of fossils occur in many layers of limestone, but none was identified as to genus and species.

Siffleur River Section

The Siffleur River heads on the north side of Pipestone Pass 18 miles (29 km.) north of Lake Louise Station on the Canadian Pacific Railway. It flows north through a canyon valley for 22 miles (35.4 km.), then west for 5 miles (8 km.), and thence to the Saskatchewan River at the southwest side of Siffleur Mountain.[1]

At Pipestone Pass, the Pipestone limestone of the Devonian forms the eastern ridge down to the lowest part of the Pass, and the superjacent Banff shale forms the western side up to where the overthrust Lower and Middle Cambrian strata form high cliffs that extend north for 20 miles (32.1 km.) on the west side of the Siffleur River. On the eastern side, the Pipestone limestones form high, sharp ridges for 16 to 18 miles (25.7 to 28.9 km.), and then the Ozarkian, and Upper and Middle Cambrian limestones rise with a southwest dip in high cliffs facing west and north above the Siffleur River (pl. 85), and a canyon valley through which a small stream from the north flows to the Siffleur. The westward dipping Middle Cambrian strata on the west side of the Siffleur are broken by an east and west fault about 20 miles (32.1 km.) north of Pipestone Pass; they rise towards Siffleur Mountain with a southwest dip and expose to view the Lower Cambrian quartzites at the northern base of the cliffs facing Siffleur River and Mountain. These cliffs with the ridges and peaks above form a mountain mass east of Mount Murchison from which they are separated by a canyon extending south from the Saskatchewan Valley; on the south side the mountain mass is defined by a strong deep canyon that cuts westward from Siffleur canyon, and heads near

[1] The Canadian Land Office maps show the Siffleur River flowing directly north to the Saskatchewan on the eastern side of Siffleur River, but the river turns due west and flows 5 miles (8 km.) along the south base of Siffleur Mountain before turning north to the Saskatchewan River. There is an old, probably preglacial, channel that crosses eastward from the bend of the Siffleur to Whiterabbit Creek that the land survey presumably mistook for the canyon of the Siffleur River.

the north side canyon. For this mountain mass formed of a lower group of northward facing cliffs and the ridges and peaks above, the name Sedgwick is proposed in recognition of the great English geologist Adam Sedgwick, whose work on the early Paleozoic formations of Wales gave the first clear separation of the Cambrian rocks from the superjacent post-Cambrian formations. Sedgwick's great rival, Murchison, is commemorated by Mount Murchison, and adjoining that mountain we now have Mount Sedgwick.

The measured stratigraphic section begins above at the summit of the Upper Cambrian Sullivan formation, the massive upper limestones of which constitute high cliffs above the cliffs of the subjacent Cathedral (Middle Cambrian) limestone. The section terminates below in the quartzitic sandstones of the Lower Cambrian St. Piran formation, which are exposed on the north side of the Siffleur River Valley opposite Siffleur Mountain.

The Lyell, Mons, and Sarbach formations are present above the Sullivan and beneath the Devonian limestones, but they were not studied or measured, as the object of this section was to obtain data to fill in the break between the base of the section at Glacier Lake and the pre-Upper Cambrian formation beneath. The Glacier Lake section terminates below with a thin-bedded, bluish-black limestone referred to the Murchison formation of the Upper Cambrian, the stratigraphic position of which in relation to the Middle Cambrian was unknown, owing to the fact that débris covered all but the upper portion of the formation. In the Siffleur section the Murchison formation was found to be conformably above the Middle Cambrian Cathedral limestone, and to occupy the position of the Stephen formation of the Mount Bosworth and Mount Stephen sections. Only fragments of fossils were found in it. It has a thickness of nearly 500 feet (152.4 m.) and is succeeded by the Arctomys formation. The great Eldon formation, 2,728 feet (831.5 m.) thick, of the Mount Bosworth and Mount Stephen sections, is not present between the Murchison and the superjacent Arctomys formation.

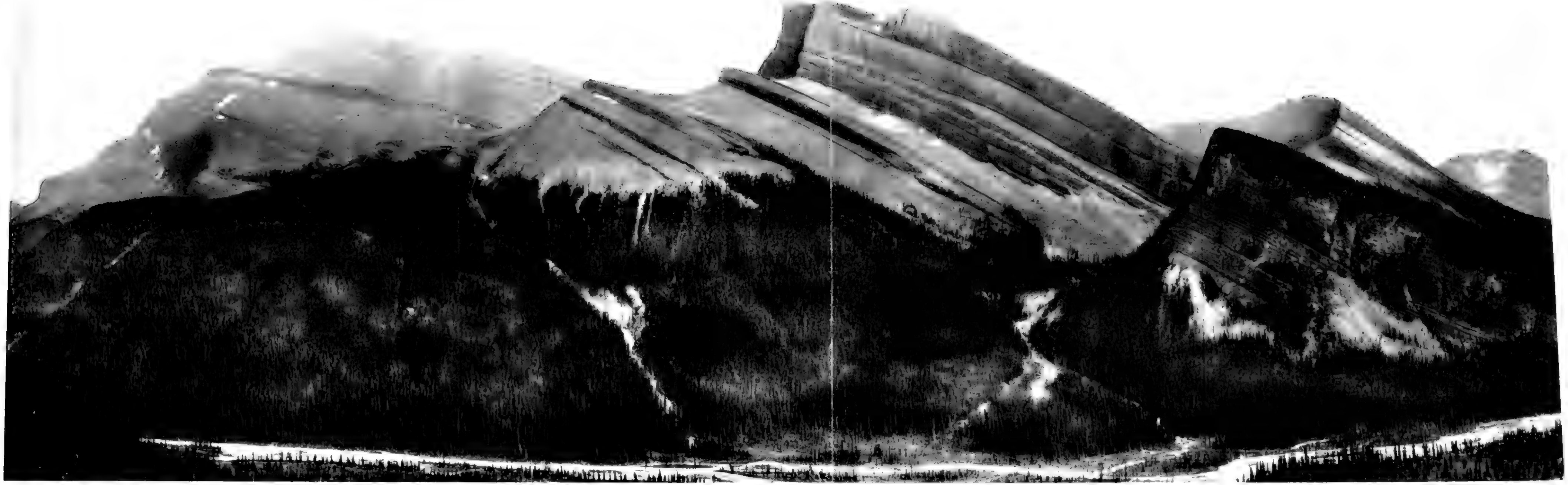
UPPER CAMBRIAN

Lyell Formation [1]

This is represented by a cliff of limestone that rises to form the highest points of the ridge above and south of the Siffleur River. The limestone in view was estimated to have a thickness of 400 feet (121.9 m.).

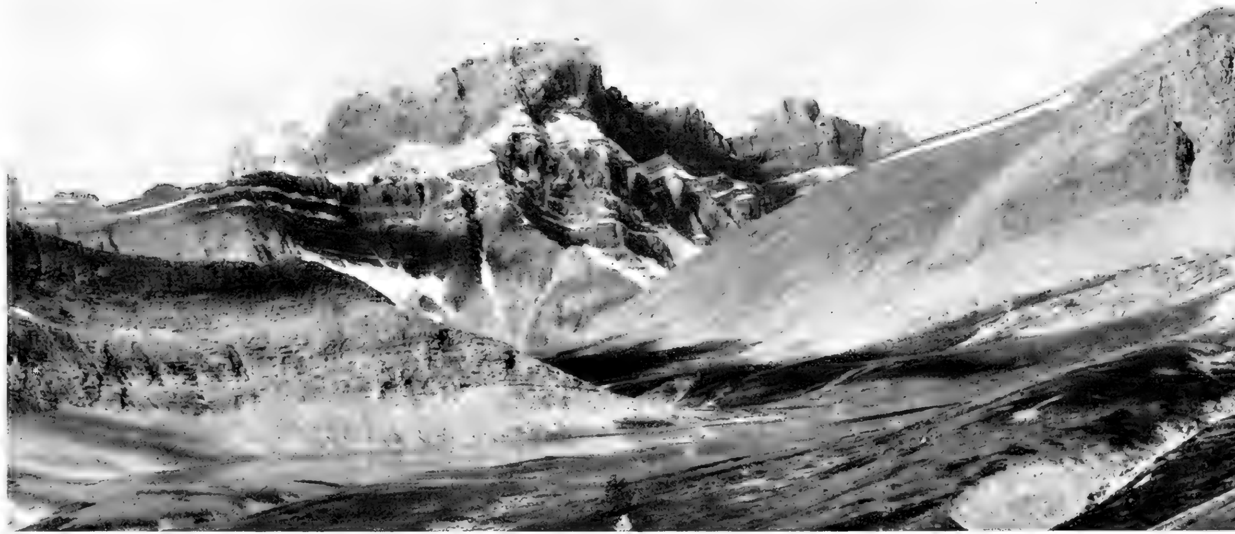
[1] The cliffs above the Sullivan formation were difficult of access, and as the purpose of making the section was accomplished below, an estimate was made of the thickness of the lower division of the Lyell.

SMI



Cliffs of Cambrian limestones on the east side of Siffleur River opposite Mount Sedgwick. Lower Cambrian quartzitic sandstones occur at the base of the northern cliffs (left) and above them the Middle Cambrian Cathedral and Murchison limestones, and the Upper Cambrian formations, Arctomys, Sullivan, and Lyell, and on the right in the higher cliffs, probably the Mons formation.

Locality.— At *D* on map, plate 26. East side of Siffleur River about 3.5 miles (5.6 km.) southeast of Saskatchewan River, and 40 miles (64.4 km.) in an air line north, 12° west, of Lake Louise Station, Alberta.



Looking westward through the pass at the head of the west branch of Clearwater River, across Siffleur River Canyon to the high cliffs of Middle Cambrian limestones, which are the extension of the cliffs on the west side of Pipestone River and Pass. The stratified rocks in the foreground are the Upper Devonian Pipestone formation limestones.

Locality.—About 2 miles (3.2 km.) west of *E* on map, plate 26. The divide at the head of Clearwater River Canyon is about 20 miles (32.2 km.) in an air line north of Lake Louise Station, Alberta.

Sullivan Formation	Feet	Meters
1*a*. Shale and thin layers of limestone 200 feet (60.9 m.) from summit	125	38.1
1*b*. Massive-bedded, steel-gray, rough-weathering, cliff-forming limestone in three thick bands	240	73.2
Fauna.—Fragments of trilobites and annelid trails on surface of some layers (64h) : *Obolus* *Lingulella isse* Walcott *Dicellomus nanus* Meek *Dicellomus politus* Hall		
1*c*. Thin layers of light-weathering, gray limestone, with darker siliceous layers interbedded, giving a narrowly banded or ribbon-like appearance to the surface of the cliffs	140	42.7
Fauna.—(64g) : Crinoid fragments *Lingulella isse* Walcott *Dicellomus politus* Hall		
1*d*. Rough-weathering, steel-gray limestone in thick layers.	30	9.1
1*e*. Dull to steel-gray, hard, compact limestone, with more or less interbedded gray, oolitic limestone. The layers are from 6 inches (15 cm.) to 3 feet (.91 m.) in thickness and form massive bands and a solid wall in face of cliffs	155	47.2
1*f*. Hard, dull gray, compact, oolitic limestones in layers varying from an inch (2.54 cm.) to 4 feet (1.2 m.) in thickness, with beds of shale separating nearly every layer of limestone, but bands occur with very little shale	570	173.7
Owing to shale bands this series breaks down readily and forms a long shelf on the cliffs when the dip is 20° or over.		
Fauna.—(65l) : *Dicellomus* sp. *Eoorthis* sp. *Hyolithes* sp. *Agnostus* sp. *Crepicephalus* sp. ?		
Total thickness of Sullivan formation	1,260	384.0

Arctomys Formation	Feet	Meters
1*a*. Dark gray, somewhat arenaceous limestone in bands of thin and thick layers. Many of the layers are almost made up of flat concretionary or interformational pebbles and small round concretions	255	77.7
1*b*. Massive-beds of steel-gray, fine-grained limestone, breaking down into slabby layers and weathering light gray	185	56.4

	Feet	Meters
1*c*. Shaly and slabby, hard, compact, gray, buff- and reddish-brown-weathering dolomitic limestone, with purplish-colored beds from 80 to 100 feet (24.3 to 30.4 m.) above the base; also dark and a few greenish bands of siliceous shale	285	86.9
Total thickness of Arctomys formation	725	221.0

The Arctomys formation was a shallow water deposit where the conditions were unfavorable for the existence of life, as no traces of trails or fossils were seen. It represents a period of deposition in shallow water—probably brackish or fresh water. The great Eldon limestone, 2,728 feet (831.4 m.) thick on Mount Bosworth 40 miles (64.3 km.) to the south, is not present below the Arctomys, owing probably to nondeposition, as no indications of a fault or of its having been removed by erosion were observed.

MIDDLE CAMBRIAN

Murchison Formation

	Feet	Meters
1*a*. Thin layers of bluish-black limestone below, passing gradually upward into a steel-gray fine-grained, compact limestone with thin bands of interbedded, bluish-black and gray limestone	132	40.2
1*b*. Compact, hard, irregularly-bedded, dove-colored and gray limestone in thin layers forming massive bands 15 to 20 feet (4.5 to 6 m.) thick	120	36.6
1*c*. Bluish-black, hard, shaly limestone, with annelid trails and fragments of fossils on the surface	140	42.7
Fauna.—(65q): *Glossopleura* sp.		
1*d*. Thin-bedded, dark, bluish-gray, more or less siliceous limestone, breaking down into small angular fragments	105	32.0
Total thickness of Murchison formation	497	151.5

The Murchison formation appears to represent the Stephen formation of the Mount Bosworth-Kicking Horse River section. The Eldon limestone is not present above it in this area.

Cathedral Formation

	Feet	Meters
1. Massive-bedded, dark and rough-weathering, more or less dolomitic limestone with a finely granular structure and surface, often breaking down into thin layers	520	158.5
Strike W. 20° N. Dip S. 20° W. (Magnetic).		
2*a*. Light gray limestone in massive layers more or less laminated on cliff exposures, often breaking down into low cliffs and terraces	350	106.7

	Feet	Meters
2b. Massive-bedded, light gray limestone, breaking down into layers 1 to 4 in. (2.5 to 10 cm.) thick and becoming granular on weathering....................	260	79.2
This belt with the one below occurs as a high, bold northward-facing cliff and unites with the belt above *2a* to form a great cliff 600 feet (182.4 m.) or more in height. Usually a shelf or terrace separates *2a* and *2b.*		
2c. Gray, rough dolomitic limestone, weathering on long exposure to a dark, reddish-brown, rusty color......	36	11.0
2d. Massive layers of gray, rough-weathering limestone, breaking down into thin, irregular layers near base...	74	22.6
Total thickness of Cathedral formation.........	1,240	378.0

It is quite possible that *2b, 2c,* and *2d* represent the upper part of the Ptarmigan formation, but of this no evidence was obtained in the cliff exposures.

PTARMIGAN FORMATION

	Feet	Meters
1a. Thin-bedded, gray limestone, with some shale and bands of oolitic layers..................................	306	93.3

Fauna.—(65 o):

Albertella sp.

LOWER CAMBRIAN

MOUNT WHYTE FORMATION

	Feet	Meters
1a. Greenish-gray calcareous shale, with a few thin layers of hard, dove-colored limestone....................	124	37.8
1b. Lead-gray oolitic limestone in layers 3 to 12 inches (7.6 to 30.4 cm.) thick...........................	16	4.9
Total thickness of Mount Whyte formation......	140	42.7

Fauna.—(65n):

Hyolithes
Scenella sp.
Olenellus cf. *thompsoni*
Bonnia sp.

ST. PIRAN FORMATION

	Feet	Meters
1a. Light gray quartzitic sandstone in layers 6 to 30 inches (15.2 to 76 cm.) in thickness......................	380	115.8
1b. Alternating bands of thin-bedded quartzitic sandstone and siliceous shale................................	90	27.4
1c. Massive-bedded, light gray quartzitic sandstone with band of arenaceous shale about 250 feet (76 m.) from summit	300	91.4
Total exposure	770	234.6

Talus slope to Siffleur River flats.

GLACIER LAKE AREA

The canyon valley in which Glacier Lake and River are situated is about 50 miles (80.5 km.) northwest of Lake Louise Station on the Canadian Pacific Railway. It is about 5 miles (8 km.) in length from the moraines at the foot of Southeast Lyell and Mons glaciers to the foot of the lake. High ridges rise from 2,500 to 3,500 feet (762 to 1,066.8 m.) above the lake and canyon bottom, those on the south forming part of the Mount Forbes massiff (pls. 88, 89), and those on the north leading up to Survey and Sullivan Peaks. The canyon is graded up for about 2 miles (3.2 km.) at its upper end with gravel and débris brought down by the glaciers at the head of the valley that extend down from the Continental Divide, and the lake occupies the lower 3 miles (4.8 km.) of its length.

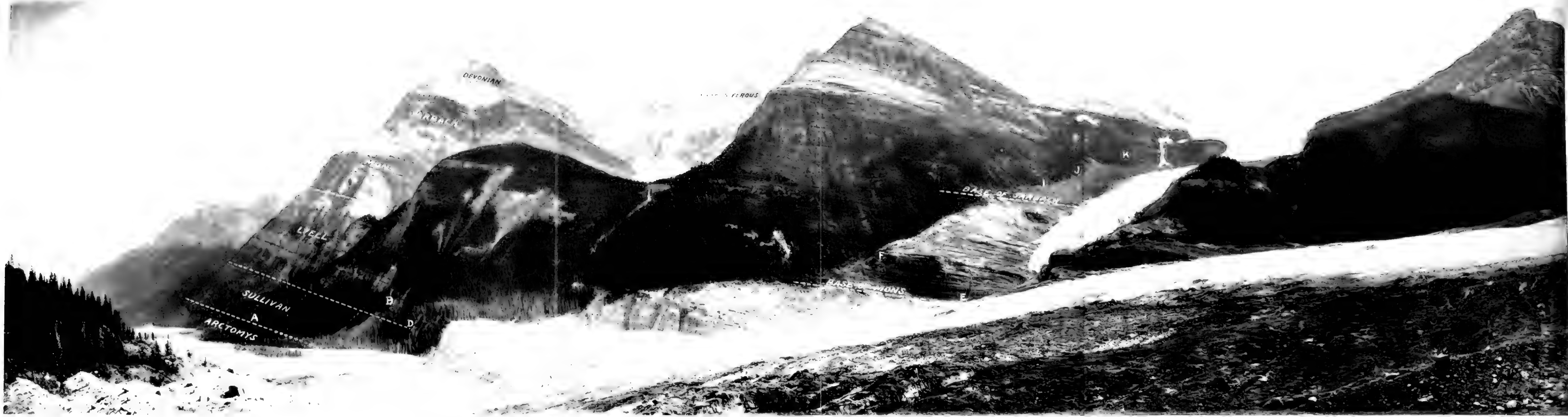
The measured stratigraphic section begins below and east of Mons Peak and extends down over the cliffs on the northwest and southeast sides of Mons glacier (pl. 87) to the cliff at the foot of Southeast Lyell glacier, through which the stream from Mons and Lyell glaciers passes in a narrow canyon. The ledges forming this lower cliff are well marked on both sides of the upper Glacier Lake canyon valley, rising from the foot of the glacier at an angle of 15° and continuing to the top of the ridge on the north side of the canyon, where the lower part of the section below the Lyell formation was measured; the cliff on the north side is divided midway by a band of thin-bedded limestone, forming a narrow terrace between the upper and lower walls, each of which is about 200 feet (60.9 m.) high; below this cliff the shales of the Sullivan formation form a slope, the upper part of which is usually covered by débris from the cliffs above, and the lower part by a forest of fir, spruce, and pine. To the eastward, the section continues down through the Sullivan formation to the limestones of the Arctomys formation, which latter form ledges on the mountain slopes along the western half of Glacier Lake. On the south side of the canyon valley, the section is finely developed in the cliffs and slopes rising up to Mount Forbes (pl. 89), but is not as easily accessible as on the north side.

The panoramic view of the south side of Glacier Lake Canyon Valley (pl. 87) extends from the ridge (left) above Howse River to Mons glacier on right. The two high points are the north ends of spurs extending nearly 2.5 miles (4 km.) north from Mount Forbes. The sharp snow-clad points between them, rising to a height of about 10,500 feet (3,200.4 m.), are directly north of Mount Forbes. The summit of the east (left) ridge is about 10,000 feet (3,048 m.),

end of Glacier Lake, about 48 miles (77.2 km.) northwest of Lake Louise Station, Alberta.

limestones beneath. The Canadian, Ozarkian, and Cambrian formations occur i

ap, plate 26. This view gives the side profile of the ridges extending north fron


DEVONIAN
SULLIVAN
ARCTOMYS
LYELL
A
B
D
E
F
J
K
BASE OF MONS

ı the spurs and
ı Mount Forbes

Upper part of Mount Forbes massif from the northeast. This illustrates the northerly extending spurs of the mountain, the lower extensions of which are shown by plate 87.

Locality.—At *B* on map, plate 26. The camera was located on the upper slope of Survey Peak, above the east end of Glacier Lake, about 48 miles (77.2 km.) northwest of Lake Louise Station, Alberta.

The higher peaks and ridges of Mount Outram (10,670 feet, 3,252.2 m.) on the left, and of Mount Forbes (11,902 feet, 3,627.7 m.) on the right, are formed of Carboniferous limestones with several thousand feet of Devonian limestones beneath. The Canadian, Ozarkian, and Cambrian formations occur in the spurs and ridges below the steep cliffs of the main ridges (see pl. 87).

Locality.—The view was taken from the south side of Saskatchewan River looking west up the river, a point about 47 miles (75.6 km.) northwest of Lake Louise Station, Alberta, and about 9 miles (14.5 km.) east of *B* on map, plate 26. This view gives the side profile of the ridges extending north from Mount Forbes and the canyons separating them.

Division Mountain, between southeast Lyell glacier (right) and Mons glacier (left), at the head of Glacier Lake Canyon Valley. Mons Peak (10,114 feet, 3,082.7 m.) is on the left above Mons glacier. The lower dark cliff is formed of limestones of the Mons formation, the second high cliff, the Sarbach formation, and the cliffs above, the Devonian.

Locality.—At *B* on map, plate 26. The view is from Glacier Creek west of the Lake, at a point about 48 miles (77.2 km.) in an air line northeast of Lake Louise Station, Alberta.

Shales and limestones of the Mons formation at foot of Mons glacier; the dip of the layers back into the mountain is 12° to 15°.

Locality.—At *B* on map, plate 26. The view was taken about 2.5 miles (4 km.) west of Glacier Lake, and about 50 miles (80.5 km.) northwest of Lake Louise Station, Alberta.

and of the west ridge (right) about 9,200 feet (2,804.2 m.). The spurs to the left are from the northeast slope of Mount Forbes and the north slope of Mount Outram (10,670 feet, 3,252 m.), a peak about 3 miles (4.8 km.) east-northeast of Mount Forbes. (Pl. 87.)

The glacier in the foreground is the lower section of Southeast Lyell glacier, and that above to the right is Mons glacier. The waters from the two glaciers and the snow-fields of the pinnacles unite to form Glacier River. The geologic section was measured approximately along the white dotted line from below the cliff at the base of the north spur of Mount Forbes to the upper cliff of the northwest spurs above Mons glacier.

The position of the base of each of the Messines, Sarbach, Mons, and Lyell formations is indicated; also the approximate position of the base of the Upper Cambrian Sullivan and Arctomys formations, the two latter from comparisons made with the section on the opposite (north) side of the canyon valley.

The places at which fossils were collected are indicated on plate 87 by the letters A to K, and their stratigraphic position by the locality numbers that may be found in the stratigraphic section.

Lettering.—A = (65k), B = (64j), C = (64d), D = (64i), E = (64f), F = (64n): G = (64p), H = (64 o), I = Sarbach, J = Sarbach, K = Messines.

The limestones and shales of the section are unusually well preserved, and the section may be studied wherever it is unbroken by faults or not mantled by débris. The fossils found were largely in a fragmentary condition, but careful search may lead to the discovery of localities where more favorable conditions prevailed, as at Mount Stephen and Burgess Pass 40 miles (64.4 km.) to the south-southeast. As yet we do not know of a finely preserved fauna of any considerable number of species from the Upper Cambrian or Ozarkian formations of the Cordilleran area in western North America.

To the north along the Continental Divide, the formations shown in Mount Forbes are finely exposed, especially at Thompson Pass and on the alplands southwest of Mount Saskatchewan.

DEVONIAN (MIDDLE)

Messines Formation

	Feet	Meters
1. Cliff-forming, massive-bedded, dark, rough-weathering magnesian limestone. Thickness estimated 1,000 feet (304.8 m.).		

	Feet	Meters
Fauna.[1]—The following species were collected from masses of rock brought down by Mons glacier.		
Stromatopora sp.		
Cyathophyllum sp.		
Atrypa reticularis (Linn.)		

DISCONFORMITY

CANADIAN

SARBACH FORMATION

	Feet	Meters
1. Thick-bedded, gray limestone breaking up into layers of varying thickness (1 to 16 inches, 2.5 to 40.6 cm.). Thickness estimated because of inaccessible cliffs...	700	213.3
Fauna.—		
Orthis 2 sp.		
Illaenus ? sp.		
2. Drab-colored, argillaceous shales weathering buff and yellow, and breaking down readily on weathering....	420	128.0

Fauna.—Fragmentary fossils occur in interbedded layers of limestone most of which are very hard and semi-crystalline, and often crowded with small concretions and irregular flattened nodules of limestone, with some cherty stringers and nodules.

Dr. E. O. Ulrich considered that the fossils indicated that the faunule was of Canadian (Beekmantown) age.

From a compact gray limestone beneath Devonian limestones on the east side of the canyon leading up to Wilcox Pass, 23 miles (37 km.) north of Glacier Lake and about 3 miles (4.8 km.) south of the Pass, the following faunule, referred to the Sarbach fauna, was collected (67h):

Protorthis cf. *porcias* Walcott
Isoteloides sp.

	Feet	Meters
Total of Sarbach formation..................	1,120	341.3

There is no apparent unconformity between the base of the Sarbach and the subjacent Mons shales.

OZARKIAN

MONS FORMATION

	Feet	Meters
1*a*. Massive strata formed of calcareous shale, with thin, compact, irregular layers of bluish-gray, hard limestone; layers of hard, semi-crystalline limestone 2 to 12 inches (5 to 30.5 cm.) thick are interbedded at irregular intervals. The series is very much like that below 1*c* in this section...........................	235	71.6

[1] Middle Devonian, equivalent to the Jefferson limestone.—Kirk.

	Feet	Meters
Fauna.—A large fauna was found in a gray limestone 18 feet (5.4 m.) below the summit of 1*a* (64p):		
Eoorthis sp.		
Syntrophia isis Walcott		
Ozarkispira leo Walcott		
Walcottoceras monsensis (Walcott)		
Endoceras robsonensis (Walcott)		
Keytella sp.		
At about the same horizon as (64p) on the west side of Mons glacier two smaller collections (65f and 65g) were made from blocks of limestone that had fallen on the glacier (65f):		
Eoorthis putillus Walcott		
Syntrophia isis Walcott		
Ozarkispira leo Walcott		
Plethopeltis sp.		
Hystricurus sp.		
Leiostegium sp.		
and from (65g) the following species:		
Eoorthis sp.		
Syntrophia isis Walcott		
Ozomia cf. *lucan* Walcott		
Hystricurus sp.		
At a lower zone 60 feet (18.3 m.) below the summit of 1*a* the collection included (66u):		
Lingulella sp. undt.		
Syntrophia		
Eoorthis		
Ozomia lucan Walcott		
Xenostegium eucerus Walcott		
Fragments of trilobites were seen in the limestones beneath the zone of (66u), but it was not until a layer was found six feet (1.8 m.) from the base of 1*a* that a few of them could be recognized. These included (64 o):[1]		
Agnostus sp.		
Plethopeltis sp.		
cf. *Plethometopus armatus* (Billings)		
1*b*. Massive-bedded, dull gray limestone, with much included fine arenaceous matter that gives the weathered surface a slightly roughened appearance............	740	225.6
Fauna.—None observed.		
Total Mons formation..........................	975	297.2

[1] The material from this locality was not found *in situ*. These fossils are not referable to the Mons but to the Lower Ozarkian.—C. E. R.

UPPER CAMBRIAN

Sabine Formation [1]	Feet	Meters
1*a*. Calcareous shale, with thin, irregular layers of compact, dark, bluish-gray limestone, and interbedded, thicker layers of a hard, semicrystalline limestone from an inch (2.54 cm.) up to 6 feet (1.8 m.) in thickness. Many of the layers are almost made up of flattened nodules and fragments of limestone of an intraformational conglomerate aspect..............	320	97.5

Fauna.—The fauna of 1*a* is limited, as far as known, to a thin layer of gray limestone 15 feet (4.5 m.) from the base (64n):

Obolus cf. *leda* Walcott
Briscoia splendens Walcott

1*b*. Calcareo-argillaceous shale, with oolitic and gray limestone layers 3 inches (7.6 cm.) to 2 feet (.6 m.) thick rather abundantly interspersed at irregular intervals	185	56.4

Fauna.—A layer of limestone 50 feet (15.2 m.) from the base contains (64f):

Cystid (fragment)
Eoorthis sp. undt.
Huenella sp. undt.
Scenella ?
Ptychaspis eurydice Walcott
Briscoia sp.

This fauna, although small and fragmentary, is typical of the Sabine formation.

In a block of limestone that fell from a cliff above the Mons glacier, on the south side of the canyon, a few fossils were found that appear to belong to the Sabine fauna (66w):

Eoorthis cf. *wichitaensis* Walcott
Syntrophia isis Walcott
Agnostus sp.
Saratogia ? sp.

Total Sabine formation.......................	505	153.9

Lyell Formation [2]

1*a*. Dark and medium-gray rough-weathering limestone in massive layers, with magnesian bands extending down 490 feet (149.4 m.) to where there is a band about 50 feet (15.2 m.) thick of a thinner-bedded, bluish-gray limestone.

[1] It is somewhat doubtful whether this is a true representative of the Sabine formation.—C. E. R.

[2] The faunas of this formation are not typically Lyell, the little knowledge we have pointing rather to a post-Sabine age.—C. E. R.

	Feet	Meters
Below this there are 160 feet (48.8 m.) of thick, solid layers and then 570 feet (173.7 m.) of thick-bedded, bluish-gray, compact limestones, breaking down into thin layers and small angular fragments on débris slopes. In cliffs, alternating bands of dark, bluish-gray, and buff color indicate blue limestone and bands of magnesian limestone.		
Total thickness of 1	1,270	387.1
Fauna.—None found.		
2*a*. Massive-bedded, hard gray limestone, with a bed of slabby limestone about 10 feet (3 m.) thick 50 feet (15.2 m.) from the top	220	67.0
Fauna.—170 feet (51.8 m.) from base (64d): *Lingulella* sp.; *Dendrograptus ramosissimus* Rued.; *Mastigograptus macrotheca* Rued.		
2*d*. Thin-bedded, gray, somewhat granular limestone	12	3.7
Fauna.—A small fauna was collected at about this zone on the north side of the canyon from blocks of limestone that had fallen out of the cliff. It includes (64l): *Wimanella occidens* Walcott; *Hyolithes* sp.; *Pelagiella* sp.		
2*c*. Massive-bedded, hard, gray limestone, with some softer, finely granular thin layers in the massive layers	198	60.3
Fauna.—6 feet (1.8 m.) above base of 1*c* two species of *Anomocarella* ? occur (65i).		
Total of 2	430	131.0
Total thickness of Lyell	1,700	518.1

SULLIVAN FORMATION [1]

	Feet	Meters
1*a*. Hard, gray, semi-crystalline, rather coarse limestone with bands of shale of varying thickness between them	325	99.0
Fauna.—Numerous fragments of trilobites occur in many of the layers and on the south side of the Glacier Lake Valley, some good specimens were found about 200 feet (60.9 m.) from the top (64k): Crinoidal fragments; *Lingulella isse* Walcott; *Dicellomus* sp.; *Hyolithes* 2 sp.; *Conaspis* sp.; *Dokimocephalus* sp. (Free cheek)		

[1] This part of the section was measured down a ravine, leading up to Sullivan Peak, 1 mile (1.6 km.) below foot of Southeast Lyell glacier on north side of Glacier Lake canyon valley, and on south slope of the ridge capped by Survey and Sullivan Peaks between Glacier Lake and the Valley of Lakes to the north.

	Feet	Meters
1*b*. Hard, gray, finely arenaceous shale, with interbedded layers of hard, gray limestone in the upper portion of the 370 feet (12.8 m.) of shale.		
Below, the interbedded limestone layers become more numerous, and extend down about 85 feet (25.9 m.). They are from 2 to 3 feet (.6 to .9 m.) thick and form little ledges in the shale.		
Fauna.—(64h) : a few layers of hard, gray, rather crystalline limestone occur, with numerous fossils, 107 feet (32.6 m.) from the base, similar to those in (64k) of 1*a* above. Fine, arenaceous, drab-weathering shale extends down to the base of 1*b*.		
Total of 1*b*..................................	975	297.2
1*c*. Hard, gray arenaceous shale.........................	78	23.8
At the top a few layers of interbedded, oolitic limestone occur which contain beautifully preserved *Dicellomus*.		
Fauna.—(64g) :		
Crinoidal fragments *Dicellomus* sp. *Lingulella* sp. *Agnostus* sp.		
In the shaly layers interbedded with the limestone, the following were collected (64g′) :		
Dicellomus sp. *Lingulella isse* Walcott		
About 4.5 miles (7.2 km.) east of locality (64g), on the south slope of Survey Peak, the following species were collected from the shale and interbedded limestone of 1*c* (64e) :		
Dicellomus sp. *Lingulella isse* Walcott *Crepicephalus* sp.		
1*d*. Shaly and thin-bedded, hard, gray sandstone weathering rusty brown; a few layers near the top are from 4 to 12 inches (10.2 to 30.5 cm.) thick.........	62	18.9
Total of Sullivan formation..................	1,440	438.9

The shales and interbedded limestone layers break down readily and usually form a sloping terrace on the mountain-side.

Section of part of 1*a* in more detail.—A few layers of the upper part of 1*a* of the section were exposed, by the melting back of the glacier on the north side of the canyon, at the foot of a cliff between an old moraine and the foot of East Lyell glacier, where there is a section of a portion of 1*a* of the Sullivan formation that is of interest on account of the contained fauna. Beginning at the top the exposed section includes:

	Feet	Meters
1*a*. Massive bed of hard, compact, dark gray limestone, with stringers and lamellae of buff-weathering magnesian limestone more or less parallel to the bedding....	9	2.7

Fauna.—The only trace of anything of possible organic origin is the occurrence of vertical slender columns from 1 to 3 inches (2.5 to 7.6 cm.) in diameter of clear, bluish-gray limestone, either single or bifurcating upwards as two branches. The lamellae of the layer are interrupted by the columns except near the top where they arch over them. These columns suggest a *Collenia*-like structure such as occurs in the Lyell formation of the Tilted Mountain section (see p. 291).

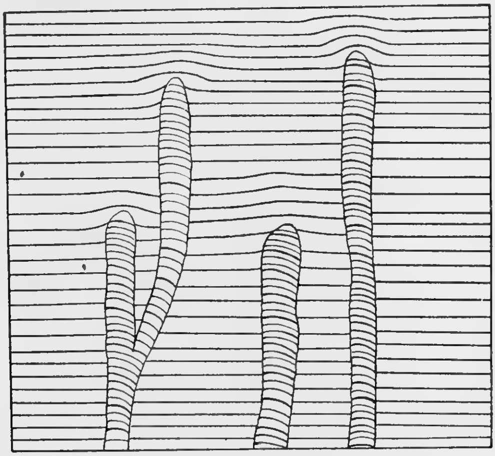


FIG. 32.—Diagrammatic sketch of a supposedly fossil algal growth of *Collenia*-like form similar to those from the upper part of the Lyell limestone. It occurs in the upper part of the limestone series referred to the Sullivan formation.

Locality.—At *B* on map, plate 26. Low cliff east of the lower lateral moraine of southeast Lyell glacier, which is about 50 miles (80.5 km.) northwest in an air line of Lake Louise Station, Alberta.

	Feet	Meters
1*b*. Massive-bedded, compact, gray limestone, with thin horizontal stringers of buff-weathering magnesian limestone distributed in a very irregular manner.........	34	10.2
Fauna.—A few fragments of trilobites scattered through.		
1*c*. Massive-bedded, gray limestone, with more or less closely packed concretions one to two centimeters in diameter and fragments of trilobites................	9.5	2.8
1*d*. Compact, gray limestones in two massive beds that weather light gray. Traces of small magnesian con-		

	Feet	Meters
cretions weathering buff, and 2 to 3 mm. in diameter, are abundant, and small fragments of trilobites occur throughout	18	5.4
1e. Massive-bedded, bluish-gray, dark limestone, with thin stringers of buff-weathering magnesian limestone....	37	11.1

Fauna.—Near base (64b):

Lingulella sp.
Obolus sp.
Crepicephalus sp.
Coosia sp.
Kingstonia sp.

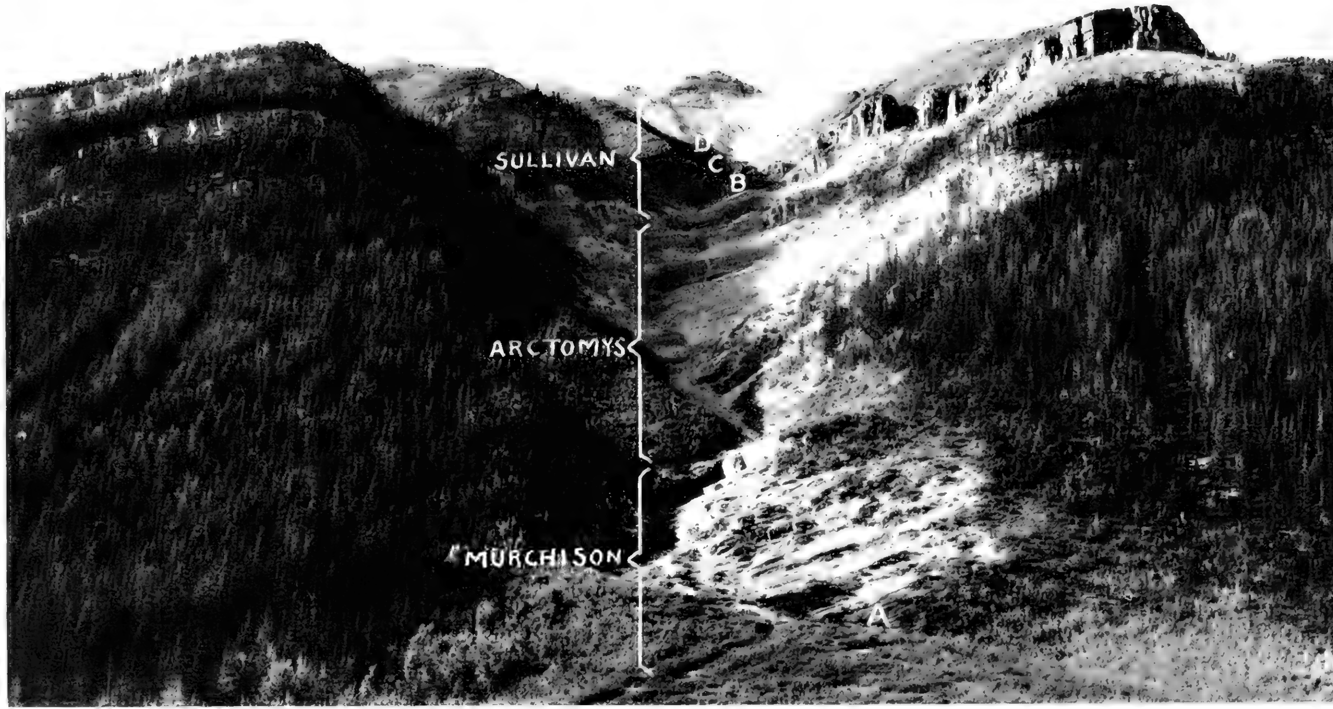
Thirty feet (9.1 m.) above (64b), dark, round, concretionary-like balls occur in profusion throughout a layer 5 feet (1.5 m.) thick. Above the concretionary layer, a layer 14 inches (35.5 cm.) thick of gray to dove-colored limestone contains a small and peculiar new fauna (64c):

Crepicephalus sp.
Kingstonia sp.

Arctomys Formation

The Arctomys formation appears to represent the period of deposition of a series of shallow, fresh-water deposits alternating with brackish-water and marine sediments such as would occur in a shallow sea near the mouth of a large river, bringing fine sand, mud, and slimes derived from glacial streams originating some distance from the shore line. These fine shales and sandstones alternate with more or less thin calcareous and arenaceous layers and have on their surfaces ripple marks, mud cracks, and casts of salt crystals. They represent, in the Bow Valley area, the period of transition from the massive Middle Cambrian Eldon limestone beneath to the magnesian limestones of the Upper Cambrian Bosworth formation above. At Glacier Lake, the Eldon is absent by nondeposition and the Arctomys is immediately superjacent to the Murchison limestones that represent the Middle Cambrian Stephen formation of the Bow Valley section. The shales and limestones of the Sullivan formation above the Arctomys are unlike the thick-bedded limestones of the Bosworth formation of the Kicking Horse-Bow Valley section (see p. 308).

	Feet	Meters
1a. Bluish-gray, irregularly laminated limestone. The lamellae are from .25 to 1.5 inches (.6 to 3.8 cm.) thick and alternate as buff-weathering magnesian and bluish gray limestone weathering light gray. The laminations disappear in some of the massive layers, which are a more or less thick-bedded, magnesian limestone.	520	158.5



View of an open ravine extending from about 300 feet (91.4 m.) above Glacier River to the top of a ridge a little south of Survey Peak, which is on the north side of Glacier Lake Canyon Valley between the latter and the "Valley of Lakes" to the north. The section exposed includes 2,180 feet (664.5 m.) of strata exclusive of that in the cliffs at the head of the ravine. The upper and lower limits of the three formations and their approximate thickness are outlined by white lines, and the fossil localities by letters.

Lettering: *A* = Number (64q) in section; *B* = (64e); *C* = (64h); *D* = (64h').

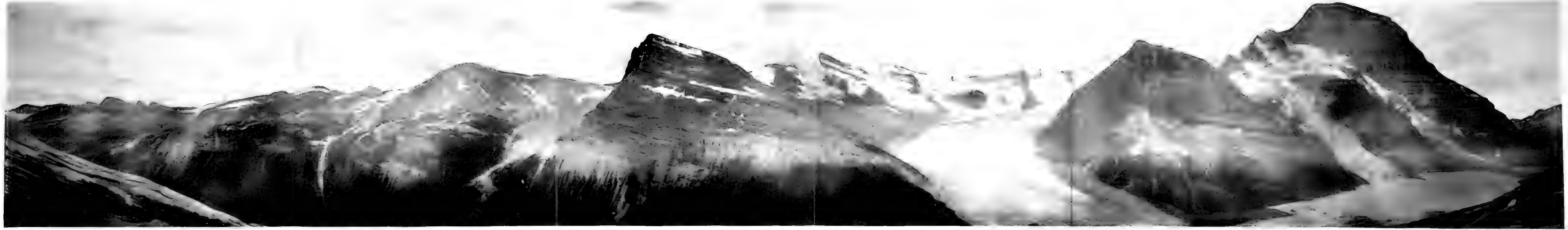
Locality.—At *B* on map, plate 26. About 1 mile (1.6 km.) east of the foot of southeast Lyell glacier, which is about 50 miles (80.5 km.) northwest of Lake Louise Station, Alberta.

North face of Mount Murchison (11,300 feet, 3,444.2 m.), with Carboniferous limestone forming upper peak, Devonian limestones down to base of second dark cliff above base, the Mount Wilson quartzite in the slopes beneath the latter, and in the lower slopes the Ordovician and Cambrian formations. On the left, the summit of Mount Sedgwick with its northward snow covered ridges is outlined.

Locality.—At *C* on map, plate 26. This view was taken from the base of Mount Wilson on the north side of the Saskatchewan River, about 48 miles (77.2 km.) northwest from Lake Louise Station, Alberta.

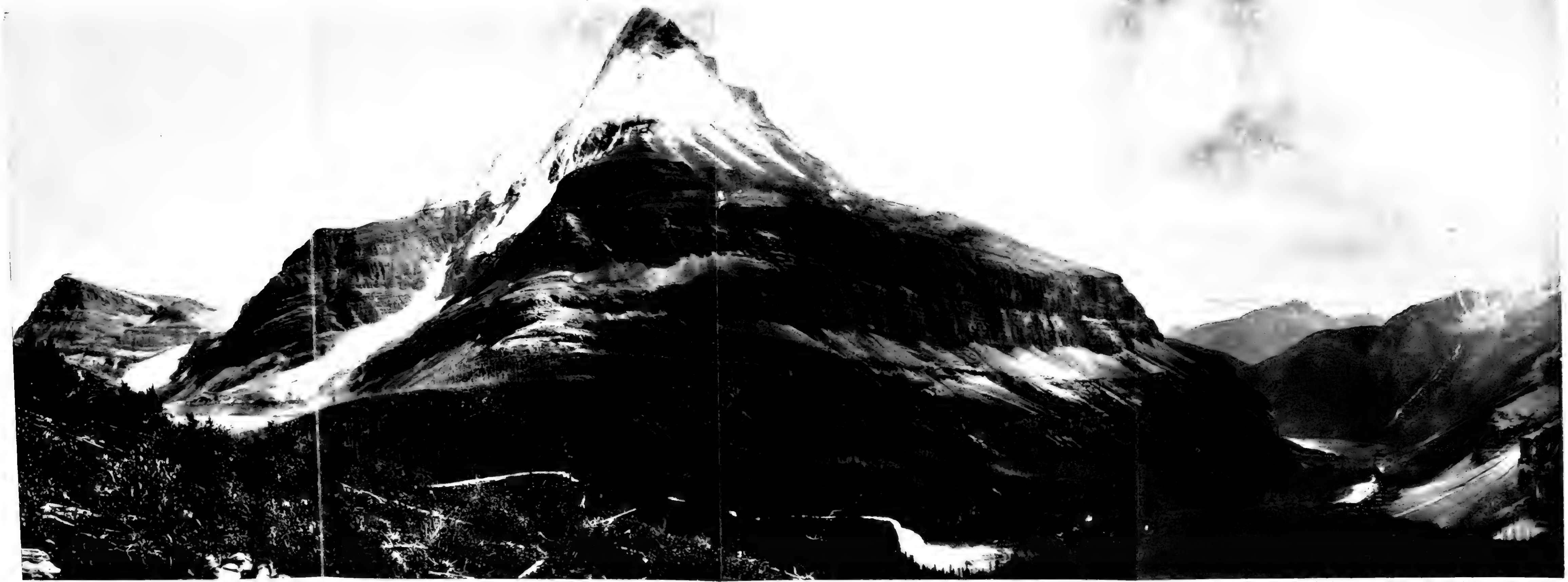
Photograph by R. C. W. Lett, Grand Trunk Pacific Railway, 1913.

net, and still farther to the left, Iyatunga Mountain (9,000 feet, 2,743.2 m.).



Panoramic view from the southwest slope of Mumm Peak looking over the valley of [illegible] River and Robson Pass. The view includes [illegible] Mountain, Mahto Mountain and the various ridges [illegible] (9,320 feet, 2,840.7 [illegible]), Chushina Mountain ([illegible] 2,014.2 m.), and [illegible] Mountain (10,171 feet, 3,101.6 m.), and the high ridge to Mount Resplendent (11,173 feet, 3,405.5 m.). Hunga glacier curves around Kiatunga Mountain (9,000 feet, 2,743.2 m.), and beyond is Robson Peak (13,068 feet, [illegible]) with the Helmet. Tumbling glacier [illegible] (5,380 feet, 1,639.8 m.) between it and [illegible]. *Locality.*—The camera was 4 miles (6.4 km.) north of Robson Peak at an elevation of about 7,300 feet (2,225 m.).

Northeast face of Robson Peak viewed from slope of Titkana Mountain, with the Helmet (11,160 feet, 3,401.6 m.), outlined against the Peak.

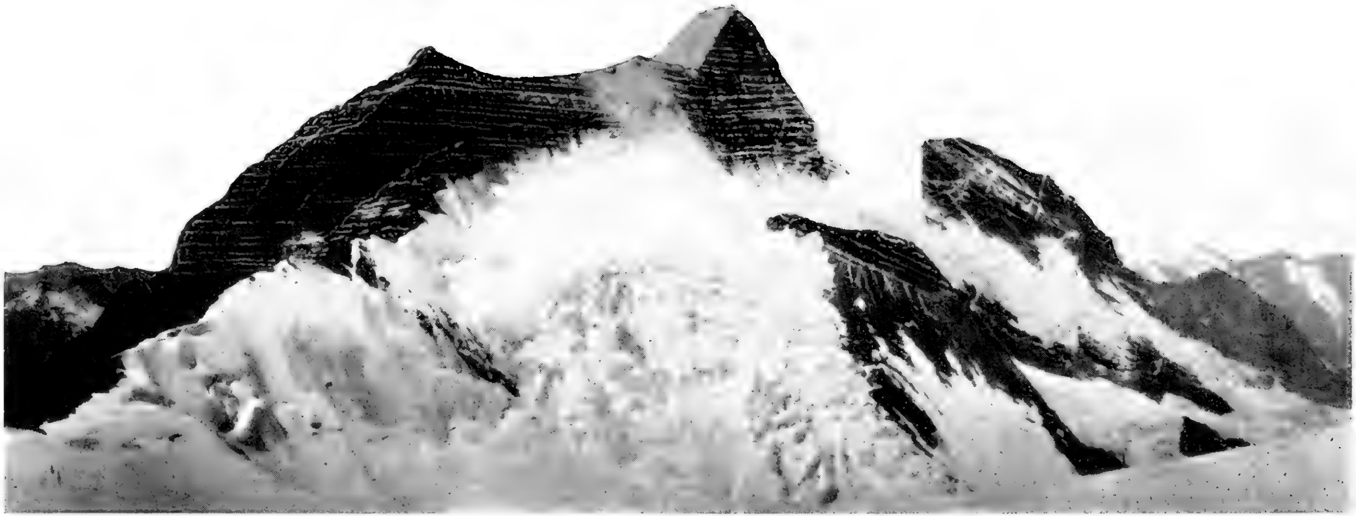


Photograph by R. C. W. Lett, Grand Trunk Pacific Railway, 1913.

Robson Peak from the northwest, showing its western side from the flat at the head of Lake Kinney (3,250 feet, 993.3 m.), to the summit (13,068 feet, 3,983.1 m.). Also, on the left of the peak, the Helmet, and still farther to the left, Iyatunga Mountain (9,000 feet, 2,743.2 m.). In the foreground, Berg Lake, and below, Emperor Falls.

Robson Peak from the south-southwest, illustrating the high south ridge, and the slope of the strata from the south towards the Peak. The rounded wooded slopes in the foreground are formed of Lower Cambrian quartzites that extend down across Rainbow Brook and pass beneath the limestones of the Peak.

Robson Peak Massif from the north showing the north and northeast face of the main peak (13,068 feet, 3,983.1 m.), and the Helmet, (11,160 feet, 3,401.6 m.). On left, Mount Resplendent (11,173 feet, 3,405.5 m.), and Tumbling glacier down to Berg Lake.



Photograph by Frank Waterman, New York.

Robson Massif from the northwest slope of Mount Resplendent. This view shows the pyramidal apex of Robson Peak, and the deep notch and break between it and the Helmet (see pl. 95).

	Feet	Meters
These limestones form cliffs on the upper edge of the mountain overlooking Glacier Lake Canyon valley.		
A few small fragments of trilobites were observed.		
2a. Purple-colored siliceous shale........................	18	5.4
2b. Thick layers of a compact, finely laminated, dove-colored limestone	73	22.2
2c. Gray and dove-colored, massive-bedded limestone that contains considerable arenaceous matter.............	155	47.2
2d. Purple, siliceous shale that passes by gradual intercalation of hard gray, finely grained limestone below....	90	27.4
Fauna.—(64h) : At 62 feet (18.9 m.) above the base a band of greenish gray, arenaceous shale contains a few specimens of a small *Obolus* and *Lingulella isse* (Walcott), and fragments of a small trilobite.		
2e. Limestone similar in character to *2b*.................	136	41.4
Three beds of ferruginous, arenaceous limestone 1 to 2 feet (.3 to .6 m.) thick are interbedded in the upper part of the limestone.		
2f. Greenish siliceous shale............................	9	2.7
2g. Limestone similar to *2h*...........................	52	15.8
2h. Greenish siliceous shale............................	11	3.3
2i. Limestone similar to *2b*............................	51	15.5
Minute fragments of trilobites and *Obolus* occur in several of the layers of limestone.		
2j. Greenish siliceous shale marked by numerous sun-dried mud cracks	8	2.4
2k. Limestone similar to *2b*............................	13	3.9
2l. Purple siliceous shale, with some interbedded greenish shale and calcareous shale........................	17	5.1
2m. Thick layers of dove-colored, compact, finely laminated limestone	12	3.6
This limestone and similar bands above appear to have been formed from a calcareous slime or mud spread in very thin layers rather slowly and evenly. It suggests a glacial mud precipitated from the waters derived from a glacial stream.		
2n. Greenish-drab and gray siliceous and partly argillaceous shales, with interbedded, hard, compact, buff-weathering, thin layers of gray limestone near the base.....	221	67.3
At about 25 feet (7.6 m.) from the base a massive bed of purple-colored, hard siliceous and argillaceous shale begins and continues on up nearly 200 feet (60.9 m.).		
Total of 2................................	866	263.8
Total of Arctomys formation.................	1,386	422.4

MIDDLE CAMBRIAN

Murchison Formation	Feet	Meters
Exposed beneath formation above.		
1*a*. Massive-bedded, gray, arenaceous limestone...........	20	6.1
1*b*. Massive-bedded, dark gray, very finely arenaceous limestone that breaks down into thin, irregular layers on weathering	95	28.9
Fauna.—Fragments of trilobites, one of which was a portion of the cephalic shield of a *Ptychoparia*.		
1*c*. Bluish-gray, thin, irregularly bedded limestone........	105	32.0
Total of Murchison formation..................	220	67.0

Below 1*c* the rocks are covered by talus down to the level of the canyon bottom.

The Murchison formation is best exposed in the Siffleur section, 25 miles (40.2 km.) east northeast of Glacier Lake.

A fine section is exposed on Mount Murchison (11,300 feet, 3,444.2 m.) from the Carboniferous down into the Sullivan formation of the Upper Cambrian, but it was not practicable for me to examine it (see pl. 93), and the Siffleur River section a few miles distant offered a much better opportunity to get at the Cambrian formations beneath the Arctomys formation down into the Lower Cambrian.

BEAVERFOOT-BRISCO RANGE

Note.—The outcrops of early Paleozoic rocks along the Rocky Mountain Trench that have been studied by Dr. Walcott were recently described by him. See Geological Formations of Beaverfoot-Brisco-Stanford Range, British Columbia, Canada. Smithsonian Miscellaneous Collections, Volume 75, Number 1, 1924.—C. E. R.

ROBSON PEAK AREA

The Robson Peak massif is one of the most beautiful and instructive mountain massifs in the Canadian Rockies. Its scenic qualities are unsurpassed, and for geological study it is almost unequalled (pls. 94-99). Eroded from a block of Cambrian limestones, sandstones, and quartzites, more than 12,000 feet (3,657.6 m.) in thickness, the peak is the source of a great glacier on its northeastern slopes (pl. 94) and minor glaciers on the northwest. On the southwest it rises 9,752 feet (2,972.4 m.) from Lake Kinney (pl. 95).

The massiveness of Robson is best illustrated by plate 95, which is a view from the northwest. It gives the profile of the mountain from Lake Kinney to the summit, in which the massive beds of limestone form cliff above cliff, separated by the talus slope where the softer, more easily broken down, thin-bedded limestones have given way. On the left a section of the mountain has been broken down, the strata sloping to the northeast, forming what is known as the Helmet. This is illustrated in detail by plates 96 and 98.

This displacement appears to have been caused by faulting on both the northeastern and southwestern side of the mass forming the Helmet. The northeastern fault appears also to have affected the position of the strata of Iyatunga Mountain in relation to Robson (see fig. 34). The strata on the summit of Iyatunga belong to the Lower Chushina formation, which is of the same age as the beds of Billings Butte on the opposite side of the great glacier.

My present impression is that the northeastern side of the Robson synclinorium broke, leaving a great block of unsupported strata that dropped down and tilted to the northeast. This break presumably shattered the strata to the southeast of the Helmet, and thus aided materially the erosion of the great cirque between Iyatunga and Mount Resplendent.

The geologic section exposed on the right (west) side of the peak above Lake Kinney is formed of Middle Cambrian limestones to the first long talus slope (pl. 95). From here up for about 3,000 feet (914.4 m.), the limestones are of Upper Cambrian age to the top of the low dark cliff at the foot of the talus slope of the higher portion of the cliffs. Above this, as far as known, the limestones are probably of Upper Cambrian and Lower Ozarkian age. This section is outlined by the diagrammatic drawing, figure 33.

The great cirque on the eastern slope of Robson is beautifully illustrated by plate 96, where the immense masses of snow accumulate on the upper slopes of Robson Peak and its southeastern ridge, joining it with Mount Resplendent (11,173 feet, 3,405.5 m.). The southwestern face of Robson is illustrated by plate 97, in which the regularity of the bedding of the limestone is beautifully shown; also, the steepness of the upper slopes of this side of the mountain. The appearance of the sandstones and quartzites that rise from beneath the peak on the southwest is shown by plate 97. It was not possible to obtain a photograph of similar sandstones and quartzites which rise from beneath the mountain upon the southern side and form high rounded hills north and south of Rainbow Brook.

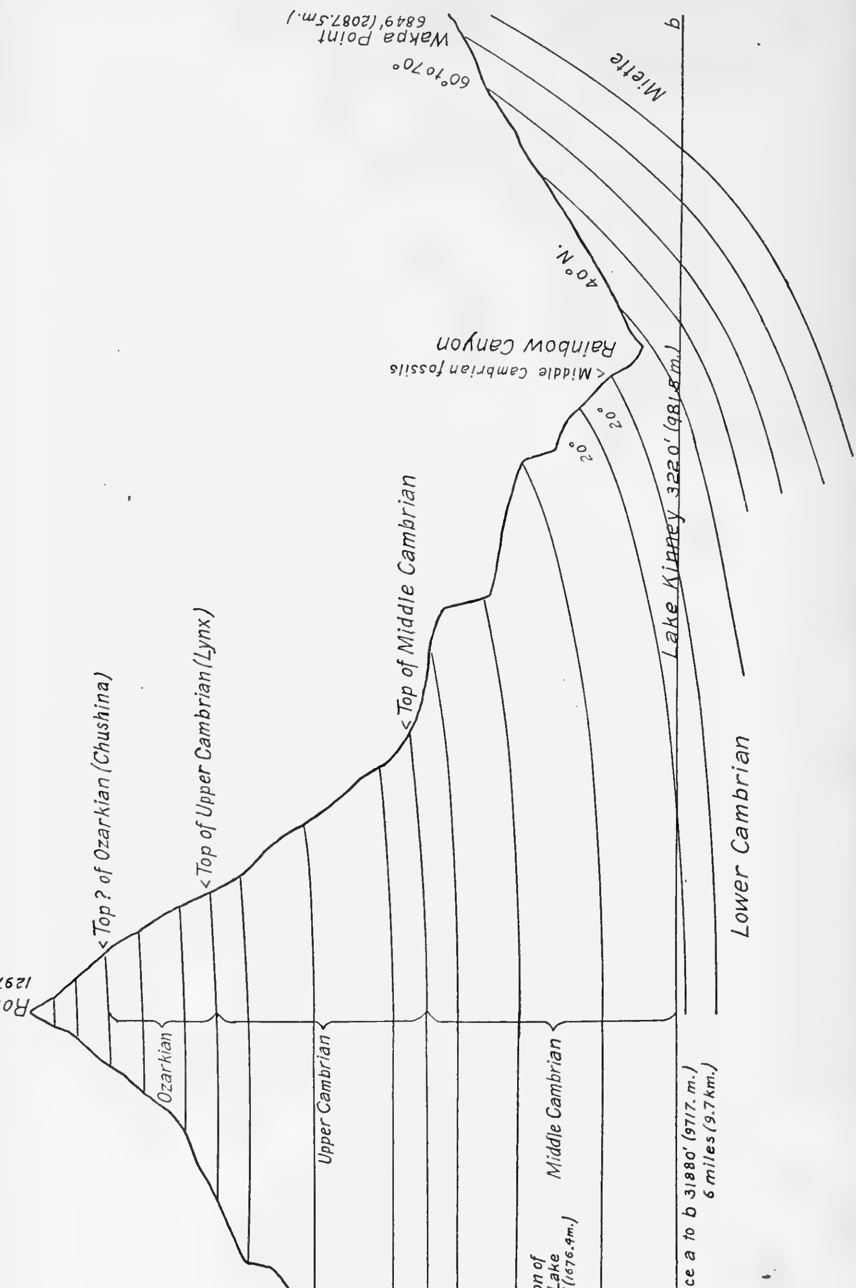


FIG. 33.—Outline of a theoretical section from Wapta Point (Lake Kinney Station, [6,849 feet, 2,087.6 m.] of Wheeler map), north and across Rainbow Canyon and up the southwest side of Robson Peak. The axis of the section is nearly north and south and passes beneath the apex of the Peak.

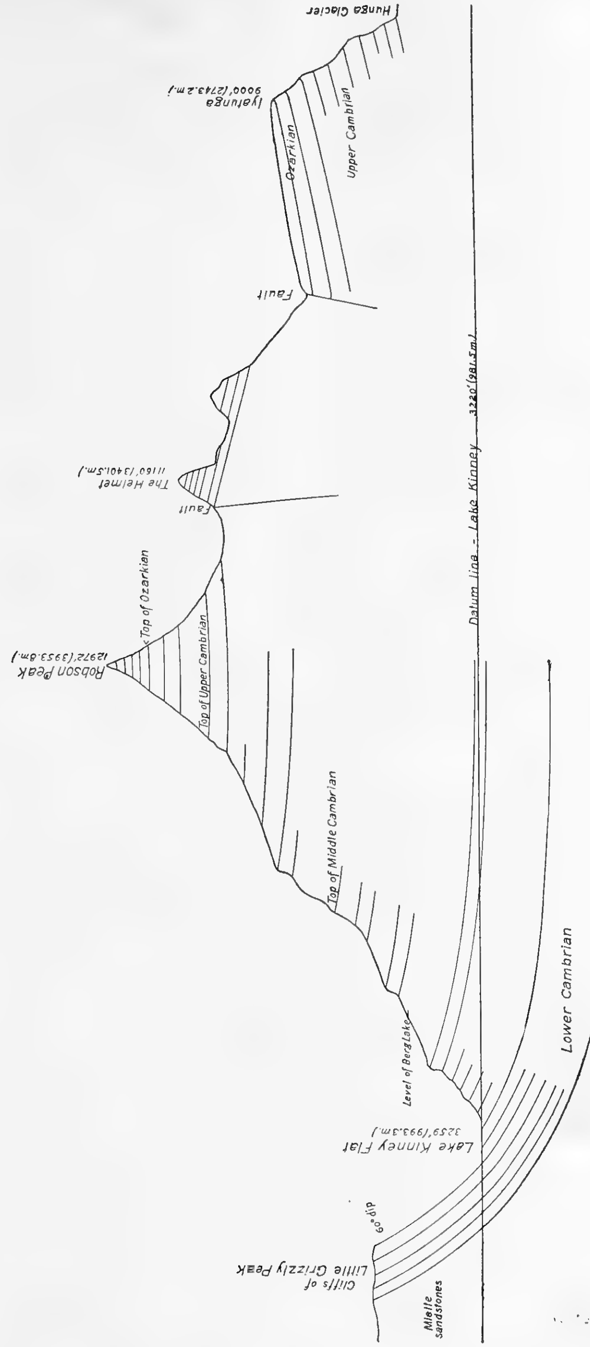


FIG. 34.—Theoretical section crossing from Robson West Station (7,330 feet, 2,234.2 m.) northeast across Lake Kinney Flat and over Robson Peak; then The Helmet, Iyatunga (Rearguard) Mountain, and Hunga (Robson) glacier. (See pls. 94, 95).

Glaciers.—The great glacier (Hunga) is best illustrated by plate 96, where it is shown from its origin in the great cirque on the slope of Robson and the northern slopes of Resplendent down to its termination at Robson Pass, a distance of 4 miles (6.4 km.). It is a fine illustration of a glacier passing over a high cliff, as seen between Iyatunga Mountain and Billings Butte. The glacier is about three-quarters of a mile (1.2 km.) in width between Iyatunga Mountain and Titkana Peak, and above the ice fall the cirque is nearly 4 miles (6.4 km.) across. The snow slopes and ice cliffs of Resplendent glacier are beautifully shown by plates 94 and 108. On the northwestern side of Robson, plate 98, Tumbling glacier descends from beneath the Helmet (11,160 feet, 3,401.6 m.) to Berg Lake, where it breaks off to form small bergs. This glacier is most appropriately named, for it virtually tumbles down the cliffs in a descent of over 5,500 feet (1,676.4 m.).

The southwestern face of the mountain is too steep for the accumulation of any considerable amount of snow. An incipient glacier is formed by the snow field clinging to the southern slope, and the débris from this accumulates to form a somewhat similar glacier beneath the great southern cliff. Most of the snow that falls on the upper western and southwestern face of the mountain is blown over by the prevailing westerly winds into the cirque on the eastern side.

NOTE ON THE STRATIGRAPHIC SECTION

During the summer of 1911, a Smithsonian Institution expedition, in cooperation with Mr. Arthur O. Wheeler of the Alpine Club of Canada, visited the Robson Peak District. My son Charles, who accompanied the party, brought back a few Middle Cambrian fossils picked up while hunting, and told me that ridge after ridge encircled the great Robson Peak with strata that sloped inward towards the peak. This suggested that there was an opportunity to study another great section in the Rocky Mountains 200 miles (321.8 km.) north of that along the line of the Canadian Pacific Railway. In the summer of 1912, I left my work on the Kicking Horse section near Field, British Columbia, and spent 23 days in a reconnaissance of the Mount Robson District from Moose Pass on the northeast to Mount Robson on the southwest. There was only time to locate a promising line for the great section of quartzites, sandstones, shales, and limestones, to take a series of photographs to indicate clearly the location of the section, to collect fossils from a few critical horizons, and to measure, estimate, and more or less arbitrarily locate and tentatively name ten geological formations in the 13,300 feet (4,053.8 m.) of strata between a great overthrust fault at Moose Pass and the summit of Robson Peak.

Beginning west of the Moose Pass fault above a few layers of the basal quartzite, the siliceous shales and limestones on the northeast slope of Tah Peak were examined and measured, and 800 feet (243.8 m.) of beds were referred to a formation that was named Tah when the section was prepared for publication.

Above the Tah, on the northeastern and southwestern slope of Tah Peak, a succession of quartzitic sandstones and grayish brown shales that extend across a brook into the northeastern face of Mahto Mountain[1] were measured, and a thickness of 1,800 feet (548.6 m.) was segregated and later named Mahto sandstones. No fossils were seen either in the Tah or Mahto on the line of the section.

Superjacent to the Mahto on Mahto Mountain, a belt of massive-bedded, arenaceous limestones was measured down the west-northwest spur of the mountain to Coleman Brook (pl. 102). For 800 feet (243.8 m.) of this series, the name Hota was proposed. On the west slope of Mahto Mountain, Lower Cambrian fossils (*Olenellus canadensis* Walcott) were found 500 feet (152.4 m.) from the base of the Hota, and fragments were seen at several horizons. The three formations, Tah, Mahto, and Hota, were included in the Lower Cambrian, with a total thickness of 3,400 feet (1,036.3 m.).

On the southwestern side of Coleman Brook (pl. 102), above the massive-bedded limestones of the Hota, bluish-gray, thin-bedded limestones 900 feet (274.3 m.) thick were estimated and in part measured, and the name Chetang was later applied to the formation. The *Albertella*[2] faunule was found 550 feet (167.6 m.) from the base.

Above the Chetang a massive-bedded, gray, siliceous and arenaceous limestone was estimated to be 800 feet (243.8 m.) thick; the name Tatei was given to the formation. No fossils were seen.[3] This carried the section to the top of Chetang cliffs (pl. 102), from where it was

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pl. 58, fig. 1.

[2] This is the first notice (Smithsonian Misc. Coll., Vol. 57, No. 12, 1913) of the discovery of the true horizon of the *Albertella* faunule which I had tentatively referred to the Lower Cambrian in 1908. Burling in 1915 found it in position on Mount Bosworth (Summary Rep. Geol. Surv. Canada for 1915 [1916], pp. 116-120).

[3] Comminuted remains of trilobites occur in more or less abundance in many of the limestones of the Middle and Upper Cambrian, but unless there was some prospect of getting an identifiable species, no note was made of them. The name Tatay as I used it in 1913 was subsequently changed to Tatei by the Geographic Board of Canada.

traced southwest, diagonal to the strike, along and down the slopes on the east side of Smoky River and Lake Adolphus to a point almost due north of Titkana Peak and about 1,500 feet (457.2 m.) east of the northeast end of Lake Adolphus (see pl. 94).

A series of thin-bedded, arenaceous and siliceous limestones interbedded in siliceous, arenaceous, and argillaceous shales superjacent to the Tatei were partly measured and estimated to a thickness of 1,700 feet (518.2 m.), and the name *Hitka* was given to them. No fossils were found in the one traverse made of this portion of the section. From the top of Tatei Cliffs, the strata referred to the Hitka appeared to continue across the Smoky River Valley into Mount Hitka northeast of Mount Mumm (see pl. 102), and this was assumed tentatively but not verified. At the north-northwest base of Titkana

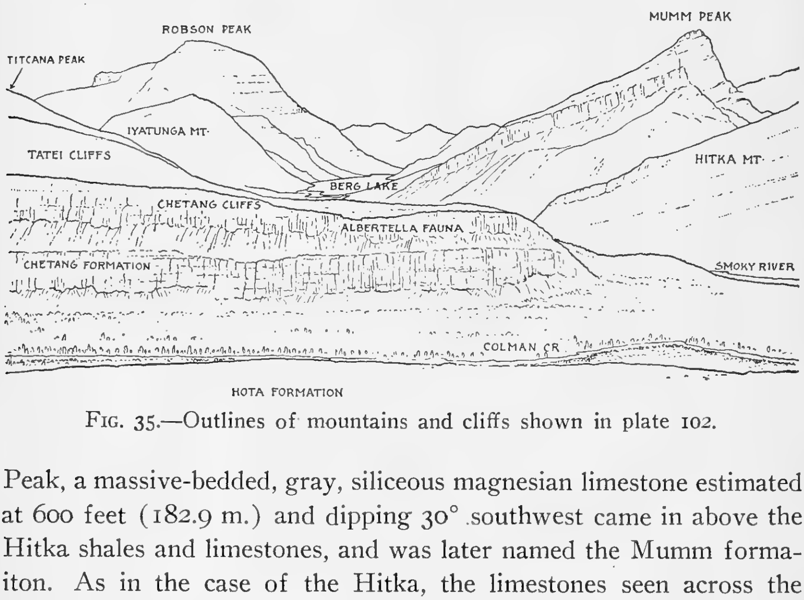


FIG. 35.—Outlines of mountains and cliffs shown in plate 102.

Peak, a massive-bedded, gray, siliceous magnesian limestone estimated at 600 feet (182.9 m.) and dipping 30° southwest came in above the Hitka shales and limestones, and was later named the Mumm formaiton. As in the case of the Hitka, the limestones seen across the Smoky River Valley 2 miles (3.2 km.) or more away in Mount Mumm were assumed to represent the same formation, but the supposed formation named Mumm was at the base of Titkana Peak. No fossils were seen, nor was there apparent evidence of a fault above or below them, but there are evidently one or more faults in the canyon valley of Smoky River between Titkana and Mumm Peaks (pl. 102), and probably a fault between Chetang Ridge and Titkana Peak. From my observations in 1913, I knew that there was dupli-

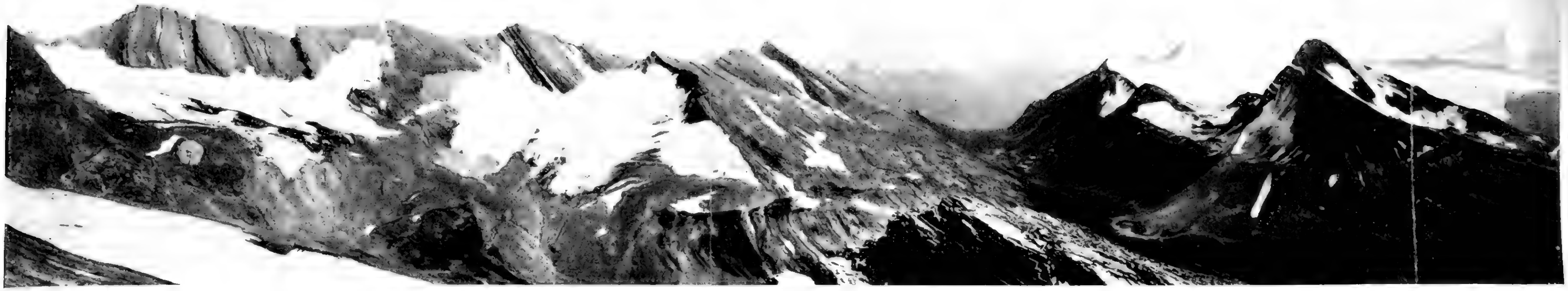


FIG. 1.—Panoramic view from Shio Point, looking southeast down Moose River Valley. The strata of Tah Mountain on the right of the Pass are of Lower Cambrian age, and those of Tokana Mountains on the left, of Upper Cambrian age. A fault line with a throw of about 9,000 feet (2,743.2 m.) has thrust the Lower Cambrian over the Upper Cambrian on the line of the Pass.

FIG. 2.—Panoramic view of Tah Peak, Mahto Mountain (*Ma*), and Calumet Creek (*C*). Tah Peak slopes to the northwest merging into Mahto Mountain (*Ma*), and beyond in the distance are Lynx Mountain (*L*), Titkana Peak (*T*), and Robson Peak (*R*). On the right, Calumet Creek (*C*), Mumm Peak (*M*), to the right of the Peak Mural glacier (*MG*), and Gendarme Mountain (*G*). At the lower left is Moose Pass (*MP*).

Locality.—Shio Point is 11 miles (17.7 km.) north-northeast of the summit of Robson Peak. It overlooks Moose Pass to the south and the headwaters of Calumet Creek, Robson Peak District, Jasper Park, Alberta, and British Columbia.

Photograph by R. C. W. Lett, Grand Trunk Pacific Railway, 1912.

Tah Peak (8,789 feet, 2,678.9 m.) rising above Moose Pass (6,700 feet, 2,042.2 m.), and to the left of the Pass, Tokana Mountains.

Locality.—The camera was about 11 miles (17.7 km.) north-northeast of the summit of Robson Peak. It overlooks Moose Pass to the south. Robson Peak District, Jasper Park, Alberta, and British Columbia.

Photograph by R. C. W. Lett, Grand Trunk Pacific Railway, 1913.

View from the thick-bedded arenaceous limestones of the Hota formation on the west slope of Mahto Mountain, looking over Coleman Brook to Chetang and Tatei Cliffs and the slope of Titkana Peak. Iyatunga Mountain (Rearguard) (9,000 feet, 2,743.2 m.) outlined against Robson Peak (13,068 feet, 3,983.1 m.). On the right across Smoky River Canyon, Mumm Peak (9,740 feet, 2,968.8 m.) and Hitka Mountain.

Locality.—The camera was 8.25 miles (13.3 km.) north-northeast of Robson Peak, Jasper Park, Alberta and British Columbia.

Lower Cambrian arenaceous limestones of Hota formation on lower (west) slope of Mahto Mountain, on left side of Coleman Creek, and limestones of Chetang formation in slope on right side of Creek.

Locality.—The camera was 8.25 miles (13.3 km.) north-northeast of Robson Peak, Jasper Park, Alberta and British Columbia.

Titkana Peak (9,320 feet, 2,840.7 m.) from the west. The summit it 3,500 feet (1,066.8 m.) above the flat of Robson Pass at the foot of the great Hunga glacier.

Locality.—Titkana Peak is 5.25 miles (8.4 km.) northeast of Robson Peak, Jasper Park, Alberta and British Columbia.

cation and that too great thickness had been given to the section between the Tatei and the Lynx formations, but as I desired in the short time available to secure fine photographs and collect more of the fauna from Billings Butte and the base of Mumm Peak above Mural Glacier, no detailed work on the section was undertaken, and the plan to return to make a thorough study later was put aside as the work in and north of Bow Valley absorbed all available time and funds. Meantime, in 1915 and 1917, L. D. Burling made two trips to the Robson District and found that I had duplicated parts of the section by including the Hitka and Mumm formations. He inferred that the two formations were based on the Mumm Peak section, which was not the case, but he was undoubtedly correct in stating that they do not occur there. A study of the photographs taken from the south-east slope of Mumm Peak in 1913 convinced me that I had not allowed for the dip of the Tatei limestones into the north base of Titkana Peak and that a portion of the Titkana formation had been segregated as the Mumm formation. Burling went over the section on another line where he found fossils and cleared the section up so that the names Hitka and Mumm are now discarded. The names Mural and Adolphus of Burling will probably follow Hitka and Mumm into the discard when someone studies my section of the Lower Cambrian, which Burling apparently did not do.

Superjacent to the Tatei limestones, a thick series of bluish-gray limestones in thick layers, that break down into thin layers, form the northwest and west slopes of Titkana Peak (pl. 104). Traces of fossils occur in many layers, and a well-marked Middle Cambrian fauna was collected in the lower portion and also 1,000 feet (304.8 m.) higher up. This series was partly measured and estimated, and 2,200 feet (670.6 m.) of it was segregated and later named the Titkana formation. (Burling estimated the Titkana at 2,500 feet [762 m.] in thickness).

The five (now three) formations from the Lower Cambrian to the top of the Titkana were placed in the Middle Cambrian.

The views on plate 94 show clearly the line of the section of the formations above mentioned from Moose Pass to the top of Tatei Cliffs.

The section above the Titkana was measured south to Snowbird Pass (pl. 105), and then partly estimated southwest along the rock exposures of the southwest side of "Phillips" Mountain (now Chushina Ridge) (9,542 feet, 2,908.4 m.) (Wheeler, Lynx Center Station) and the lower slopes of Lynx Mountain (10,471 feet, 3,191.6 m.) above Hunga glacier, to the base of Billings Butte (see pl. 108). For the estimated 2,100 feet (640 m.) of thin-bedded limestone and shale above the Titkana, the name Lynx was proposed. No attempt was made to collect fossils in this series, but the Lynx was arbitrarily placed in the Upper Cambrian. (Fossils were found in 1913 by me, and in 1915 by Burling.)

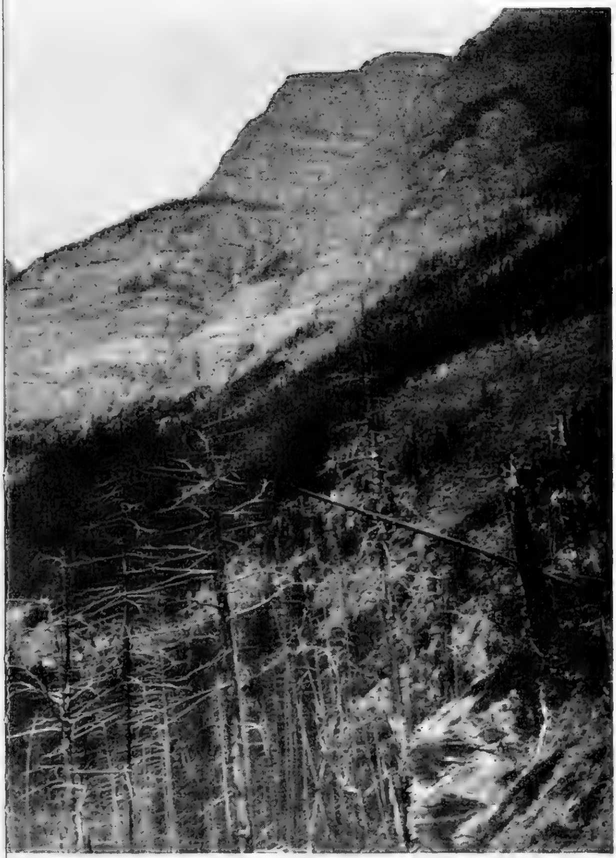
Immediately above the Lynx, thick layers made up of dark thin-bedded limestones alternating with thin bands of grayish shale form a banded cliff 300 feet (91.4 m.) or more high (Billings Butte, pl. 94). The limestone layers are very fossiliferous, and as the included fauna was not typically Cambrian, it was referred to the Ordovican in 1913. This dark band appears to form a cliff over which Hunga glacier flows, and which then slopes up to form the upper band of Iyatunga Mountain (pl. 105). This is very noticeable from Titkana Peak. This same dark band apparently extends across, although interrupted by the Helmet faults, into Robson Peak about halfway up between Berg Lake and the summit of the peak. As the Robson Peak rises 7,592 feet (2,314 m.) above Berg Lake (Wheeler map, 1925), I assumed that there was at least 3,000 feet (914.4 m.) between the Billings Butte fossiliferous beds and the summit of the peak. To these limestones the name Robson was given.

A preliminary study of the fossils collected from Billings Butte led to the faunule being placed in the Ordovician, despite the Upper Cambrian aspect of a number of the species. We now know that this same fauna extends from Robson Peak south as far as central Nevada, and that it is typical of a post-Cambrian, pre-Ordovician formation that has been named the Mons in the Cordilleran Trough of Alberta and British Columbia and referred to the Ozarkian.

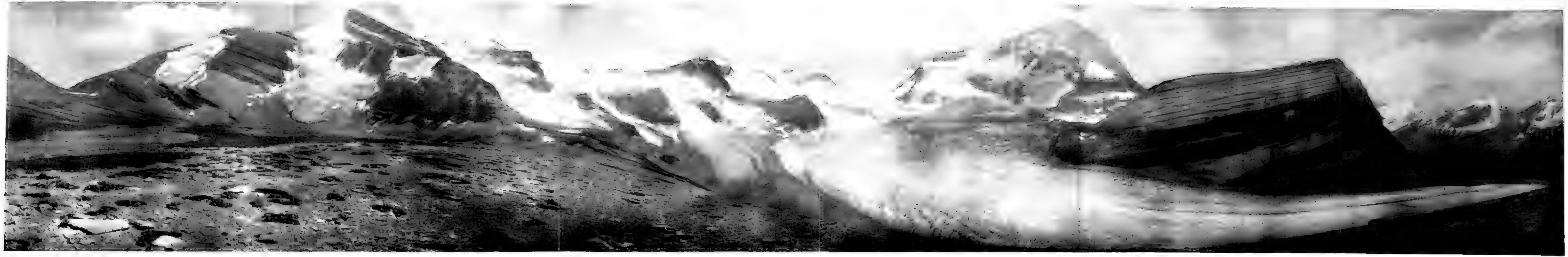
Recently this lower part of the Robson series has been separated as the Chushina formation,[1] the upper 500 ? feet (152.4 m.) retaining the name of Robson (see pls. 97, 99).

When I began the systematic study of the fauna of the Mons formation I wrote to the Director of the Geological Survey of Canada inquiring if the collections made by Burling were available for study, as Burling had resigned from the Survey. Dr. E. M. Kindle replied that the collections were largely in the boxes as they were packed and shipped from the field. The boxes were sent on to the United States National Museum to Dr. Charles E. Resser. He found numbered field labels indicating that the numbers were entered in Burling's field notebooks. These were asked for and received and the laborious work

[1] Smithsonian Misc. Coll., vol. 67, no. 8, 1923, p. 458.



n the left, Skuya Point (7,330 feet, 2,234.2 m.) = Robson



Panoramic view from the southwest slope of Titkana Peak, overlooking Hunga glacier. This view begins on the left at Snowbird Pass (8,010 feet, 2,441.4 m.) and passes to the right by Chushina Mountain (9,561 feet, 2,914.2 m.) with Chushina glacier below, next Lynx Mountain (10,471 feet, 3,191.6 m.) in the distance, and in the center the snow-capped Mount Resplendent (11,173 feet, 3,405.5 m.). Robson Peak (13,068 feet, 3,983.1 m.) is partially shrouded in mist. Iyatunga (9,000 feet, 2,743.2 m.) rises as a black mass above Hunga glacier, and to the right across Robson Pass, McLauren Mountain, with Mumm Peak (9,740 feet, 2,968.8 m.) at the extreme right. *Locality*.—Camera 4 miles (6.4 km.) northeast of Robson Peak, Jasper Park, Alberta and British Columbia.

View of Lynx Mountain (10,471 feet, 3,191.6 m.) from the slope of Robson Peak at 10,000 feet (3,048 m.). At the left, Snowbird Pass, and Chushina Ridge leading up to Lynx Mountain. The broken section between Chushina Ridge and Billings Butte (Extinguisher) is shown beneath the dark northwestern side of Lynx Mountain.

Looking north-northeast over Lake Kinney. On the right side, the southwest base of Robson Peak. In the distant center, Mount Whitehorn with south-southeast spur terminating in high point. On the left, Skuya Point (7,330 feet, 2,234.2 m.) = Robson west of Wheeler map

Mount Resplendent (11,173 feet, 3,405.5 m.), with the dark mass of Billings Butte (Extinguisher) more than 4,000 feet (1,219.2 m.) below.

Locality.—The summit of Mount Resplendent is about 3 miles (4.8 km.) southeast of Robson Peak.

of tying in the collections to the sections was undertaken. A number of the most essential lots from a stratigraphic standpoint were found to be merely comminuted fragments of no diagnostic value, while others were evidently rough pieces that might afford something of service when broken up and the fragments identified.

Burling did not publish his detailed field sections or list the fossils occurring in them. He made many generalizations, but did not present the evidence on which they were based.

My reconnaissance section of 1912 was written out and published in July, 1913, just as I was going in over the new trail to Robson Peak and Berg Lake for the purpose of collecting fossils from the limestones of Billings Butte and the Lower Cambrian of Mumm Peak and to take photographs. While camped on Rainbow Brook below Lake Kinney at the southwest base of Robson Peak, a brief study was made of the western side of the Robson massif where one of the great geologic sections of the lower Paleozoic formations in the Cordilleran Geosyncline is exposed to view. On its southwestern side the evenly bedded limestone and shales rise cliff above cliff, from the flat at the head of Lake Kinney to the apex of the peak, 9,752 feet (2,972.4 m.) above (pl. 99). To the thickness of strata from the summit to the level of Lake Kinney, there should probably be added a thickness of about 2,200 feet (670.6 m.) resulting from the 10° inward slope of the strata from Lake Kinney Flat to a point beneath the center of the peak, a horizontal distance of 2.5 miles (4 km.).

From beneath the western base of the limestone series of the peak, Lower Cambrian sandstones slope upward gently and then more steeply until the base of the Cambrian impinges at a high angle against the Miette sandstones of the pre-Cambrian (pl. 96). Altogether there are about 12,000+ feet (3,657.6+ m.) of strata in sight from below the outlet of Lake Kinney. Viewed from the outcrop, the northeast dip of the beds into the mountain is not noticeable along the strike, but seen from the south or north, one is soon convinced that the Robson massif is a syncline with the apex of the peak not far from its center.

Approaching the peak from the southwest, the Lower Cambrian sandstones are seen sloping north with a dip of about 30°, and fragments of *Olenellus* were found about 100 feet (30.5 m.) above the lake; on the southwest side of the lake, the sandstones dip northeast 45° to 60° to 63° as they approach the contact with the pre-Cambrian Miette beds on the summit of Robson west station of the Wheeler map of 1911 (7,290 feet, 2,222 m.), which is southwest of Lake Kinney. (See pl. 106, looking north-northeast over the lake.) On the south the

Lower Cambrian sandstones come in contact with the pre-Cambrian on the ridge above Rainbow Brook (Lake Kinney Station [6,849 feet, 2,087.6 m.] of Wheeler map). About midway of the lake, the greenish and gray shales and limestones above the sandstones dip 20° northeast into the mountain.

On the west and northwest side of Robson Peak, south of Emperor Falls, the limestones dip 10° east into the mountain. Looking south from the high ridge northwest of Berg Lake, the Robson massif has a broadly synclinal structure (see pl. 99, where it is partially shown), and on the northeastern side the dip is southwest and west into the mountain (see pl. 94).

Stratigraphic Section [1]

With the information now available it is possible arbitrarily to divide the Robson limestones of the 1913 section into an upper series, for which the name Robson is retained, and a lower series 1,500 feet (457.2 m.) thick, which is characterized by the distinctive fauna of the Ozarkian Chushina [2] formation, the upper series being tentatively referred to the Ordovician.

In 1913 I referred both the upper and lower series of the Robson limestones to the Ordovician, saying:

> The upper 1,500 feet [457.2 m.] of Robson Peak is 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 [241.3 km.] 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.

The section is now modified as follows:

	Feet	Meters
ORDOVICIAN ?		
Robson Formation		
Partly siliceous, arenaceous and dolomitic gray and buff limestones in layers varying from one inch to 18 inches (2.5 to 45.7 cm.) in thickness. (Estimate)..........	500	152.4
Fauna.—None found, as strata were inaccessible for collecting.		
OZARKIAN		
Chushina Formation		
1. Thin-bedded, gray limestones with interbedded bands of shale. (Estimated)..............................	1,500	457.2

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pp. 336-341.

[2] Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, p. 458.

Fauna.—In upper portion (61u):

Lingulella cf *manticula* White
Acrotreta sp.
Hyolithes sp.

In massive- and thin-bedded, gray limestone near base of formation (61n):

Lingulepis sp.
Bellefontia sp.

Below the *Lingulepis* zone, the limestones interbedded in calcareous shales contain a large and varied Ozarkian fauna that may be compared with that of the lower portion of the Mons formation 125 miles (201 km.) to the southeast.

From this zone at Billings Butte[1] (sometimes called Extinguisher), the following fauna was collected in 1912 (61q):

Lingulella ninus Walcott
Lingulella ibicus Walcott
Obolus ino Walcott
Acrotreta atticus Walcott
Acrotreta discoideus Salter
Eoorthis putillus (Meek)
Billingsella archeas Walcott
Syntrophia sp.
Endoceras robsonensis Walcott
Walcottoceras (?) *monsensis* (Walcott)
Moxomia hecuba Walcott
Hystricurus bituberculatus (Walcott) and other species
Apatocephalus sp.
Kainella billingsi Walcott and at least seven other species
Symphysurina, at least seven species
Xenostegium taurus Walcott
Leiostegium, at least six species of this and related genera

There are also many other species that have not been named.

UPPER CAMBRIAN

Below the calcareous shales of the Chushina formation there is a great thickness of cliff-forming limestones that compose the ridge of Chushina Mountain (see p. 358). Owing to limited time I was unable to make a search for fossils in 1912, but in 1913 when crossing the north slope of Chushina Ridge from Snowbird Pass, I found two localities (61y, 61z) on the line of

[1] Smithsonian Misc. Coll., Vol. 57, No. 12, 1913, pl. 57, fig. 2.

the section, and it is possible that a block of limestone found in the bed of Upper Moose River, 6 miles (9.6 km.) southeast of Moose Pass, may have been derived from the south-eastern extension of these limestones, as the fossils appear to be of Upper Cambrian age, including (61r):

Lingulella sp.
Lingulepis sp.
Hyolithes sp.
Kingstonia sp.

Lynx Formation

	Feet	Meters
1. Thin-bedded, bluish-gray limestones, with interbedded bands of light gray shale, and at the base a band of about 200 feet (60.9 m.) of gray, greenish, and reddish-brown shale	3,500[1]	1,066.8

A thorough study of the lower 1,000 feet (304.8 m.) of the Lynx formation may furnish data that will result in correlating the lower portion of the shales and limestones with the Arctomys formation of the Glacier Lake section. Wherever found, these arenaceous parti-colored shales and shallow-water deposits mark the boundary between the Middle and Upper Cambrian.

Fauna.—No fossils were found *in situ* in the Lynx formation in 1912, but in 1913, after the publication of my paper on the Robson section, I found at two horizons (61y), which is about 500 feet (152.4 m.) below the *Kainella* faunule of (61q) and (61z), and about 900 feet (274.3 m.) below (61q), a few fragments which unfortunately represent entirely new species.

The difficulty of getting a section of the Upper Cambrian strata on Chushina Ridge and Lynx Mountain is well shown on pls. 105 and 107. Not only are the strata concealed by snow and ice, but they are broken by cliffs and possibly by faults that are more or less concealed by small glaciers. On this account, the section on Iyatunga Mountain measured by L. D. Burling is repeated on page 366.

MIDDLE CAMBRIAN

Titkana Formation

	Feet	Meters
1. Massive-bedded, bluish-gray limestone in thin layers, interbedded with gray, siliceous, buff-weathering limestone that occurs in bands 50 to 100 feet (15.2 to 30.5 m.) thick	2,200	670.6

[1] This is 1,400 feet (426.7 m.) greater than the estimate made in 1912. See p. 245. The lower portion of this section was compared with the lower part of the Bosworth formation by me in 1913 and referred to as suggesting land deposits. (Problems of American Geology. The Cambrian and its Problems, December, 1913, Yale Univ. Press, 1915, p. 186.)

Feet Meters

This formation is best seen in the west slopes of Titkana Peak. 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 (61v) 1 mile (1.6 km.) east of summit of Titkana Peak in cliff above Hunga glacier:

Micrometra zenobia Walcott
Obolus mcconnelli Walcott
Obolus septalis Walcott
Acrotreta cf. *depressa* Walcott
Hyolithes carinatus Matthew
Selkerkia major Walcott
Agnostus montis Matthew
Zacanthoides spinosus Walcott
Dorypyge dawsoni (Walcott)

At a horizon estimated to be 1,000 feet (304.8 m.) lower than (61v), 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, Acrotreta, Agnostus, Dorypyge,* and *Zacanthoides.*

TATEI FORMATION

Thick-bedded, gray siliceous and arenaceous limestones... 800 243.8

Fauna.—No fossils found.

CHETANG FORMATION

Bluish-gray, thin-bedded limestones forming a cliff beneath the Tatei formation, a talus slope of about 100 feet (30.5 m.) and then a second cliff above Coleman glacier and Brook................................ 900 274.3

This formation is well shown in Chetang Cliff, 2 to 3 miles (3.2 to 4.8 km.) north of the summit of Titkana Peak.

Fauna.—At about 100 feet (30.5 m.) from the summit of the formation (61o):

Nisusia sp.
Zacanthoides sp.
Bathyuriscus sp.

At about 350 feet (106.7 m.) down in the formation, at top of lower cliff, the following fauna occurs (61p):

Albertella bosworthi Walcott (occurs at about same horizon in Mount Bosworth section).[1]

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

	Feet	Meters
In a drift block the following species were found (61w): *Albertella laevis* Walcott; *Agraulos* sp.		

LOWER CAMBRIAN

Hota Formation

	Feet	Meters
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	243.8

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 (91 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.

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:

Cystid ? sp.
Lingulella chapa Walcott
Lingulella hitka Walcott
Mickwitzia muralensis Walcott
Obolella nuda Walcott
Obolella cf. *chromatica* Billings
Hyolithes sp.
Callavia eucharis Walcott
Callavia perfecta Walcott
Wanneria occidens Walcott
Olenellus truemani Walcott
Hymenocaris sp.

Mahto Formation

	Feet	Meters
Massive-bedded, gray quartzitic sandstones, with thin-bedded, hard sandstones and dirty grayish-brown arenaceous shale in thin bands..........................	1,800	548.7

This series extends down the northeast face of Mahto Mountain and the slope of Tah Mountain nearly 800 feet (243.8 m.).

Fauna.—No fossils found.

	Feet	Meters
Tah Formation		
Hard, green and purple siliceous shales with irregularly intercalated massive beds of gray and purple, compact limestone interbedded in central portion.........	800	243.8
Fauna.—No fossils found.		
McNaughton Formation		
Light gray, massive-bedded quartzitic sandstone..........	500 +	152.4 +
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 (152.4 m.). This, however, is very uncertain, as it is difficult to determine the line of demarcation between the sandstone of Cambrian and pre-Cambrian (Beltian) age.

Unconformity

ALGONKIAN

BELTIAN SERIES

	Feet	Meters
Miette Formation		
Massive-bedded, gray sandstones, with thick bands of gray and greenish siliceous shales......................	2,000 +	609.6 +

The best exposures seen of the Beltian 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 sandstones 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 Beltian 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 (762 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, Hota 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.

	Feet	Meters
At the Pass the valley is essentially the same type as the valley of Bow River near Lake Louise Station. In both, the valley is eroded in the Beltian series of impure sandstones, and the Cambrian sandstones and limestones form high, bold mountains to the north and south of the valley.		

SUMMARY OF ROBSON DISTRICT SECTION

ORDOVICIAN

	Feet	Meters
Robson Formation		
1. Massive- and thin-bedded, gray limestones that are partly siliceous, arenaceous, and dolomitic..........	500	152.4

OZARKIAN

	Feet	Meters
Chushina Formation		
1. Thin-bedded, gray limestone........................	1,500	457.2

UPPER CAMBRIAN

	Feet	Meters
Lynx Formation		
1. Thin-bedded, gray and bluish-gray limestone, with bands of shale	3,500	1,066.8

MIDDLE CAMBRIAN

	Feet	Meters
Titkana Formation		
1. Massive beds of thin layers of bluish-gray limestone, interbedded with bands of dolomitic limestone.......	2,200	670.6
Tatei Formation		
1. Massive-bedded, gray arenaceous limestone...........	800	243.8
Chetang Formation		
1. Bluish-gray, thin-bedded limestones.................	900	274.3
Total Middle Cambrian........................	3,900	1,188.7

LOWER CAMBRIAN

	Feet	Meters
Hota Formation		
1. Gray arenaceous limestone, alternating with massive quartzitic sandstone (Mesonacidae), *Olenellus, Callavia,* etc.	800	243.8
Mahto Formation		
1. Massive-bedded quartzitic sandstone, with bands of siliceous shale	1,800	548.7
Tah Formation		
1. Siliceous shale and interbedded siliceous limestones....	800	243.8

	Feet	Meters
McNaughton Formation		
1. Quartzitic sandstones	500 +	152.4 +
Total Lower Cambrian	3,900 +	1,188.7 +
Total thickness, Cambrian sediments	11,300	3,444.2
Total thickness of section	13,300	4,053.8

Unconformity

PRE-PALEOZOIC SECTION

ALGONKIAN

BELTIAN SERIES

Miette Formation		
1. Massive gray sandstones, with interbedded siliceous shales	2,000 +	609.6 +
Base concealed.		

Lake Kinney Section

A diagrammatic outline sketch, made July 13, 1913, of a northeastern and southwestern section crossing the southeastern half of Lake Kinney is here reproduced; also one of a northwestern and southeastern section through the massif of Robson Peak. (See figs. 34, 35.)

As previously mentioned, the limestones at the west base of Robson Peak are superjacent to Lower Cambrian sandstones at the head of Lake Kinney (3,220 feet, 981.5 m.), and Middle Cambrian fossils occur in the limestones 600 feet (182.9 m.) above the sandstones at the southeast end of the lake. The dip of the limestones northeast under the mountain carries the contact with the sandstones deeper directly beneath the apex of the peak, but just how much is unknown, as the synclinorium flattens out more or less beneath the mountain. Berg Lake is 2,160 feet (658.4 m.) above the level of Lake Kinney, and to this we add 1,600 feet (487.7 m.) to obtain the thickness up to the level where L. D. Burling found a few Middle Cambrian (Stephen) fossils. This would give a thickness of 3,760 feet (1,146. m.) for the Middle Cambrian limestones, to which there probably should be added two or three hundred feet (60.9 or 91.4 m.) to carry the section up to the base of the Upper Cambrian. There then remains a thickness of 5,600+ feet (1,706.9+ m.) of limestones to the summit of the peak. The only unbroken reliable section of the Upper Cambrian is that of Burling for Iyatunga Mountain (p. 366), which has a thickness of about 3,000 feet (914.4 m.). Burling claims 5,000 feet (1,524 m.) for the Upper Cambrian, but that is obtained by adding another section totally disconnected and without satisfactory paleontological evidence.

The photographs of Robson Peak indicate the presence of a dark band that may represent the dark limestones of Billings Butte with their Lower Ozarkian fauna. The place to work this problem out is probably in the ridges east of Moose Pass where there are fine exposures of the limestones above the Middle and Upper Cambrian. I did not realize this until it was too late to return in 1913 (see pl. 100).

The above statements are based on our present information, and are subject to correction when a competent geological survey is made.

Iyatunga Mountain Section

L. D. Burling's section of Iyatunga (Rearguard) Mountain (see pl. 95), measured in 1917, is an important contribution to the stratigraphic section of the Robson District, as it includes in an unbroken series nearly 3,000 feet (914.4 m.) of Upper Cambrian strata and 875 feet (266.7 m.) of the superjacent Chushina formation of the Ozarkian. At the base of the section, in 2, the few fossils found by me in 1912 and those found by Burling in 1917 may be referred to the Upper Cambrian, but they are near the base, and the topography where Hunga glacier sweeps around the base of Iyatunga indicates readily eroded rocks beneath, of the character of the shales at the base of the Upper Cambrian Lynx formation at Snowbird Pass. I have added 500 feet (152.4 m.) to this part of the section as an estimate for the shaly and arenaceous beds at the base of the Lynx in the Titkana Peak and Chushina Ridge section of the Upper Cambrian that are not exposed in the Iyatunga section.

The section was measured by Burling when in the service of the Geological Survey of Canada, and is used by permission of the Director of the Survey. The Burling fossils were received from the Survey by the United States National Museum largely as they were packed in the field, and after being partially prepared, were studied and provisionally identified.

OZARKIAN

Chushina Formation (At the summit of mountain)

	Feet	Meters
1*a*. Shales with interbedded limestones, and near top, rusty brown nodules	75	22.9
(top of 29 of Burling's field section).		
Fauna.—(17-130): *Kainella* fauna of Billings Butte (Extinguisher). See Walcott's section, p. 358.		
1*b*. Series of thin-bedded greenish shales, with bands of limestone and intraformational conglomerate (29 of section)	200 +	61.0 +
1*c*. Massive, blue, cliff-forming limestone (28 of section)..	100	30.4

	Feet	Meters
1*d.* Black banded and blue-black thin-bedded and massive limestone (27 of section)	250	76.2
Fauna.—(17-129):		
Apatocephalus sp.		
1*e.* Rusty yellow-weathering series of massive limestones, with upper 115 feet (35.1 m.) yellow and arenaceous (26 of section)	250	76.2
Total thickness	875	266.7

UPPER CAMBRIAN

Lynx Formation

	Feet	Meters
1*a.* Irregularly-bedded and more or less lumpy, hard, bluish limestone (22-25 of section)	355	108.2
Fauna.—Drift near base on slope (17-127):		
Dikelocephalus sp.		
1*b.* Massive-bedded, blue-gray limestone, with pockets of rusty arenaceous and dolomitic rock (21 of section). No fossils.	200	61.0
1*c.* Pinkish- and purplish-gray arenaceous limestones (14-20 of section) No fossils.	345	105.1
1*d.* Dirty gray, cliff-forming limestone (Nos. 12 and 13 of section)	545	166.1
1*e.* Thin-bedded and shaly limestone interbedded in more or less calcareous shale (4-11 of section)	654	199.3
1*f.* Greenish shale series, with nodules and some limestone bands	666	203.0
Fauna.—A considerable number of fossils were collected in divisions 1*e* and 1*f*, but all are new genera and species; the only recognizable form being *Kingstonia.*		
2. Massive series of blue limestone (1 of section). Estimate	200	61.0
Fauna.—(17-133). Also Walcott (62b).		
Total of Lynx	2,965	903.7
Total	3,840	1,170.4

Titkana Peak Section

Titkana Peak rises 3,600 feet (1,097.3 m.) above Lake Adolphus, and the layers of limestone forming it have a slope to the southwest of nearly 20° (see pls. 94, 104), and from the southeast end of Lake Adolphus to the summit of the peak, the slope of the beds (diagonally across the dip of 20° southwest) is about 15° for a distance of 2 miles (3.2 m.), which carries the lowest layer exposed near the lower end of the lake 2,824 feet (860.8 m.) below the level of the lake as extended beneath the peak. This gives approximately a little over 6,000 feet (1,828.8 m.) in thickness for the strata exposed in Titkana Peak, from its northwest base to the summit north-northwest of Snowbird Pass. My section of 1912 for the same series was 6,200 feet (1,889.8 m.) as measured and estimated. This includes the Chetang, Tatei, and Titkana formations of the Middle Cambrian. From the top of Titkana Peak south, the strata are of the character of the beds at the base of the Upper Cambrian in the Mount Bosworth section,[1] where a series of ripple-marked, mud-cracked, arenaceous shales 268 feet (81.7 m.) thick occur at the base of the Upper Cambrian limestones. Burling's field notes indicate that he found a somewhat similar series of shales with interbedded thin layers of limestone extending from the south slope of Titkana Peak to Snowbird Pass and up the north slope of Chushina Ridge (see pl. 105) to its summit, the section measuring 449 feet (136.9 m.) in thickness. These shales of shallow, and probably brackish water origin, form the base of the Upper Cambrian Lynx formation in the Robson District, and also occur at a similar horizon in the Ranger Canyon section of the Sawback Range (see p. 264). Burling also measured a disconnected series of strata somewhat similar to that of the Lynx in a saddle west of Lynx Mountain, that apparently has no direct stratigraphic connection with the Snowbird Pass-Chushina section, and cannot, with the data available, be correlated with it. This section was probably seen up among the snow fields shown about Lynx Peak in plate 84.

The Robson District section is subject to a thorough revision. Much more work should be done on it, as my reconnaissance of 1912 and 1913, and Burling's work of 1915, 1917, are very inadequate.

[1] Smithsonian Misc. Coll., Vol. 53, No. 5, 1908, p. 208.

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