CAMBRIAN

GEOLOGY AND PALEONTOLOGY

V

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

(With Plates 1 to 8)

BY

CHARLES D. WALCOTT

(Publication 2756)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE 28, 1924
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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, siliceous, 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. 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.

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, Schofield, and Shepard appeared with a more or less detailed


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.


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 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.

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:


GENERALIZED SECTION OF SHEPARD

<table>
<thead>
<tr>
<th>Formation</th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mississippian</td>
<td>1,000</td>
<td>304.8</td>
</tr>
<tr>
<td>Devonian (Upper)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quartzite</td>
<td>500</td>
<td>152.4</td>
</tr>
<tr>
<td>Massive limestone</td>
<td>2,500</td>
<td>762.2</td>
</tr>
<tr>
<td>Silurian or Devonian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Massive limestone</td>
<td>900</td>
<td>274.3</td>
</tr>
<tr>
<td>Massive crystalline limestone</td>
<td>600</td>
<td>182.8</td>
</tr>
<tr>
<td>Boulder bed</td>
<td>300</td>
<td>91.4</td>
</tr>
<tr>
<td>Massive gray limestone</td>
<td>650</td>
<td>198.1</td>
</tr>
<tr>
<td>Richmond, Upper</td>
<td>2,200</td>
<td>670.5</td>
</tr>
<tr>
<td>Massive gray and black limestone</td>
<td>400</td>
<td>121.9</td>
</tr>
<tr>
<td>Richmond, Lower</td>
<td>950</td>
<td>289.5</td>
</tr>
<tr>
<td>Ordovician (Lowest)</td>
<td>1,600</td>
<td>487.6</td>
</tr>
<tr>
<td>Cambrian (Upper)</td>
<td>1,000</td>
<td>304.8</td>
</tr>
<tr>
<td>Massive pink weathered limestone</td>
<td>1,000</td>
<td>304.8</td>
</tr>
<tr>
<td>Cambrian (Upper or Middle)</td>
<td>1,500</td>
<td>457.2</td>
</tr>
<tr>
<td>Cambrian and Pre-Cambrian</td>
<td>5,000</td>
<td>1,524.</td>
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</table>

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 Beckmantown 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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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. 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
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. Beavertoot 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. 3.) The highly inclined thin-bedded limestones of the Motts are shown on the left side in the cliff above the bridge and in the ledge on which the bridge rests. The *Hungaria* 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 Beavertoot 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. = Beavertoot 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.

**Brisco Formation:**

<table>
<thead>
<tr>
<th>Silurian</th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>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</td>
<td>365.8</td>
<td></td>
</tr>
</tbody>
</table>

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 Beaver-foot (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-Taramon 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:**

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

**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: ³

- *Cohimnaria alveolata* Goldfuss
- *Columnaria* (Paleophyllum) *cf. stokesi* (Edwards and Haime)
- *Favosites* sp.
- *Streptelasma rusticum* Billings
- *Rhynchotheca argenteurbica* (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.
- *Rhynchotheca cf. capax* (Conrad)
- *Rhynchotheca argenteurbica* (White)
- *Zygospira cf. recurvirostris* Hall
- *Plectambonites cf. saxeus* (Sardeson)
- *Hebertella occidentalis* (Hall)
- *Dinorthis subquadrata* (Hall)
- *Macurina* sp.
- *Endoceras* sp.

³ As identified by Mr. Edwin Kirk.
Wonah Quartzite:

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:

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:

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 106 32.3

1c. Dark grayish black slightly and finely arenaceous shale 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 curvatus Gurley; also at 417 feet (127.1 m.) and 572 feet (174.3 m.). At 517 feet (157.5 m.) the following species
(locality 21g) were readily identified by Dr. R. Ruedemann as extremely closely related if not identical species to:

- *Trigonograptus ensiformis* (Hall)
- *Didymograptus caducus 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. *spinous* Ruedemann
- *Didymograptus* sp. (fragment)
- *Phyllograptus* (cf.) *ultimus* Ruedemann
- *Glossograptus* cf. *hystrix* Ruedemann
- *Cliniacograptus* 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. spinous* 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 tones 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.

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:

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 inter-bedded 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 cranidæ 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.

2. Mons limestones and shales concealed by debris on Wonah Ridge

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 .9 m.) 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.

Fauna.—At 170 feet (51.8 m.) below the top the Hungaia fauna 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
- *Eoothis putillus* Walcott
- *Hungaia* sp.
- *Symphysurina* sp.
- *Aptatokephalus* ? 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 percilla* Walcott
- *Acrotreta* sp. undt.
- *Billingsella coloradoensis* (Shumard)
- *Eoothis putillus* Walcott
Protorthis porcias Walcott
Cyrtolites mystes Walcott
Agnostus sp.
Hystericurus briscoensis n. sp.
Hystericurus cinctus n. sp.
Hystericurus dorsatus n. sp.
Hystericurus 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 south-west of the fault in the base of 3 (locality 2le).

Obolus cf. tctonensis Walcott
Eoorthis putillus Walcott
Syntrophia cf. calcifera Walcott
Symphysurina
Hystericurus
cf. Isotcloides

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.
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.
- *Ptychoptaria* 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
- *Agraules* sp.
- *Ptychaspis* sp.
- *Irvingella* ? sp.
- *Saratogia cf. wisconsinensis* Owen
- *Briscoia opimus* 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 maurs* 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.)
SUMMARY OF SECTION OF MONS IN SINCLAIR CANYON SECTION

<table>
<thead>
<tr>
<th>1. Limestone with shaly partings</th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>545</td>
<td>166.1</td>
<td></td>
</tr>
<tr>
<td>2. Concealed (estimated)</td>
<td>356</td>
<td>108.5</td>
</tr>
<tr>
<td>3. Limestone and shales</td>
<td>1,705</td>
<td>519.7</td>
</tr>
<tr>
<td>4. Shales with little limestone</td>
<td>1,220</td>
<td>371.9</td>
</tr>
<tr>
<td><strong>Total Mons</strong></td>
<td><strong>3,826</strong></td>
<td><strong>1,166.2</strong></td>
</tr>
</tbody>
</table>

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.

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. 3° 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 \( L. \) limestones 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 \( L. \) limestone. The position of the fault that has brought the lower limestones against the Lyell \( L. \) 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

Silurian:  
Brisco ................................................................. 1,200 365.8  
Beaverfoot ......................................................... 400 121.9  

Ordovician:  
Wonah Quartzite .................................................... 110 33.5  
Sinclair ............................................................... 1,655 504.4  

Ozarkian:  
Mons .................................................................. 3,8261/3 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.).
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 ......................................................... 70\(^{5}\) 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 conchooidal 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.)
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 rennis* 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

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
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.)

Fauna.—About 80 feet (24.3 m.) below the top of 7, a well marked faunule occurs that contains many specimens of *Syntrophia*. (17x.)

*Eooarthis* cf. *putillus lacvianus* Walcott
*Syntrophia* nonus Walcott

8. Alternating bands of gray limestone and drab gray argilaceous shale

Fauna.—Fragments of trilobites (*Xenostegium* sp.) in limestone about 190 feet (57.9 m.) from the top. (17o.)

9. Thick-bedded, dark gray limestone with a few oolitic layers

Fauna.—None observed.

10. Argilaceous shale with a few interbedded layers of hard bluish gray, more or less intraformational conglomerate limestone

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 nobis* Walcott
*Acrotrcta* sp. undt.
*Eooarthis* cf. *putillus* Walcott
*Briscoia sinclairensis* Walcott

Concealed by débris

Total Mons exposed

---

**SUMMARY OF SECTION OF MONS IN STODDART-DRY CREEK SECTION**

<table>
<thead>
<tr>
<th></th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>788</td>
<td>240.2</td>
</tr>
<tr>
<td>2.</td>
<td>648</td>
<td>197.5</td>
</tr>
<tr>
<td>3.</td>
<td>1,115</td>
<td>339.8</td>
</tr>
<tr>
<td>4.</td>
<td>250</td>
<td>76.2</td>
</tr>
<tr>
<td>5.</td>
<td>748</td>
<td>227.9</td>
</tr>
<tr>
<td>Concealed by debris</td>
<td>117</td>
<td>35.7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,666</strong></td>
<td><strong>1,117.3</strong></td>
</tr>
</tbody>
</table>

**UPPER CAMBRIAN**

**LYELL FORMATION (See p. 30):**

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.
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 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. 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 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

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

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

*Fauna.*—(See p. 11.)

**Beaverfoot Formation:**

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:**

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 ........................................... 136 47.6

*Fauna* (near top locality 17t.)

*Billingsella* origen Walcott

*Hueneilla jubu* 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 sophon* 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 unconformity 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.

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. 

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>170</td>
<td>51.8</td>
</tr>
</tbody>
</table>

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  

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
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</thead>
<tbody>
<tr>
<td>275</td>
<td>83.8</td>
</tr>
</tbody>
</table>

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. Ieda* Walcott
- *Acroclita* sp. undt.
- *Agnostus* sp.
- *Ptychaspis* sp.
- *Ellipsoscelus* ? sp.

Total Mons 

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>742</td>
<td>226.1</td>
</tr>
</tbody>
</table>

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:**

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

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
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</thead>
<tbody>
<tr>
<td>400</td>
<td>121.9</td>
</tr>
</tbody>
</table>

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

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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

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

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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:**

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,800</td>
<td>548.6</td>
</tr>
</tbody>
</table>

Thick-bedded, hard, gray magnesian limestone in ledges and broken down cliffs. (Estimate)

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:**

<table>
<thead>
<tr>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>121.9</td>
</tr>
</tbody>
</table>

Silicious and arenaceous shales with some calcareous layers in the upper part

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 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.

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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 macfarlani* 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:**

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

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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. caclatius* of Lapworth’s list), *Glossogr. horridus* (equals *G. ciliatus* of Lapworth’s list), *Diplogr. cuglyphus* (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 faunas, 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* (Linnarson)
*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 north 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.
NO. 1 FORMATIONS OF BEAVERFOOT–BRISCO–STANFORD RANGE 35

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 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:

<table>
<thead>
<tr>
<th>Formation</th>
<th>Feet</th>
<th>Meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenogle formation (estimate)</td>
<td>1,700</td>
<td>518.2</td>
</tr>
<tr>
<td>Sinclair formation</td>
<td>1,655</td>
<td>504.4</td>
</tr>
<tr>
<td>Sarbach ? formation</td>
<td>400</td>
<td>121.9</td>
</tr>
<tr>
<td></td>
<td><strong>3,755</strong></td>
<td><strong>1,144.5</strong></td>
</tr>
</tbody>
</table>

OZARKIAN

MONS FORMATION:

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 was discovered in 1922 but it was not until the middle of the field season of 1923 that

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 out-
crops 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 Cam-
brian 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 gastropods 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.

Figs. 6, 7, 8, and 9.—Outline figures of *Ozarkispira leu* (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:

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 super-jacent 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 quite 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

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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**

<table>
<thead>
<tr>
<th>Formation</th>
<th>Feet</th>
<th>Meters</th>
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<tbody>
<tr>
<td>Devonian:</td>
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<td></td>
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<tr>
<td>Limestones (only a portion)</td>
<td>400</td>
<td>121.9</td>
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<tr>
<td>Silurian:</td>
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<tr>
<td>Brisco Beaverfoot limestones</td>
<td>1,600</td>
<td>487.7</td>
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<tr>
<td>Wonah Quartzite</td>
<td>110</td>
<td>33.5</td>
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<tr>
<td>Ordovician:</td>
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<td></td>
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<tr>
<td>Shales of Glenogle</td>
<td>1,700</td>
<td>518.2</td>
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<tr>
<td>Sinclair</td>
<td>1,655</td>
<td>504.4</td>
</tr>
<tr>
<td>Limestones (Sarbach ?)</td>
<td>400</td>
<td>121.9</td>
</tr>
<tr>
<td>Ozarkian: Mons limestones and shales</td>
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<td>1,166.2</td>
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<td>Upper Cambrian ?:</td>
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<td></td>
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<tr>
<td>Limestones</td>
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<tr>
<td><strong>Total thickness as measured and estimated</strong></td>
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<td>3,215.9</td>
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**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 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.

FORMATIONS OF BEAVERFOOT–BRISCO–STANFORD RANGE 41

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. Ulrich¹ 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).

¹The Ordovician-Silurian Boundary. Congrès Geol. Int. Compte-Rendu de la XIIe 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 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 Glenoge graptolite shales are absent beneath the Wonah Quartzite, and at Sabine Mountain 36 miles (57.9 km.) still further south the Wonah quartzite, Glenoge 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 where the Swan Peak Quartzite, 500 feet (152.4 m.) in thickness is superjacent to the Garden City limestone in which an Ordovician (Beckmantown) 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 (Chazy) which indicates that the transgressing sea

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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

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\(^1\) Smithsonian Misc. Coll., Vol. 67, No. 8, 1923, pp. 463, 464.

(226.2 m.) thick at Sabine Mountain is 3,826 feet (1,166.2 m.) at Sinclair Canyon and 1,489 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-

yon. No fossils have been found in this lower limestone that cor-
responds 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 magnesium 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:

\[\begin{align*}
&\text{Halysites sp.} \\
&\text{Syringopora sp.} \\
&\text{Favosites sp.} \\
&\text{Atrypina sp.} \\
&\text{Spirifer sp.} \\
&\text{Stropeodonta sp.}
\end{align*}\]

**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

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\(^1\) Smithsonian Misc. Coll., Vol. 74, No. 5, 1923, p. 17.

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 Sabine¹ "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 Ozarkian² 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.

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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.

**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.
- *Palaconcilo* 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.

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**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.