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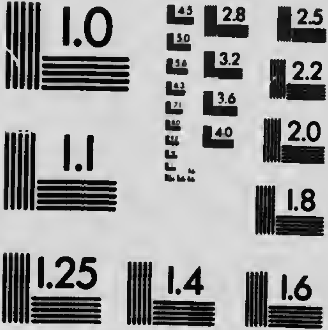


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DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

**MEMOIR 76**

No. 62, GEOLOGICAL SERIES

# Geology of Cranbrook Map-Area, British Columbia

BY

**Stuart J. Schofield**

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

No. 1505

PLATE I.

EXPLANATION OF PLATE I.

Morning on the Goat river.

CANADA
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# Geology of Cranbrook Map-area, British Columbia.

## CHAPTER I.

## INTRODUCTION.

### General Statement.

Mining was initiated in East Kootenay by the discovery of placer gold on Wild Horse creek near Fort Steele in the early sixties, and since then the district has advanced from the stage of uncertain placer mining to one of steady lode mining. According to the annual reports of the Minister of Mines of British Columbia, from the time official records were kept up to the close of 1912, the Fort Steele mining division of East Kootenay[1] has produced $20,212,709 in valuable metals, chiefly gold, silver, and lead.

The principal producing mines of the district are the Sullivan and the St. Eugene, while the minor properties which ship occasionally are the Society Girl, Aurora, Stemwinder, and North Star.

The study of the area embraced by the Cranbrook sheet was initiated in order to come to some conclusion as to the origin and possible future development of the ore deposits, so that prospecting might be directed in those areas in which the chance of discovery of similar deposits was the greatest. The examination of the great number of copper deposits associated with the Purcell sills proved to be not only of economic but of scientific importance.

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[1] East and West Kootenay are now combined, and form the electoral division officially known as Kootenay. In this report the name East Kootenay designates the former electoral division of that name.

The placer deposits which had been the source of the early wealth of East Kootenay, are now worked only spasmodically and in a small way. All energy is now devoted to lode mining, which early proved to be of great value in the industrial development of the region.

Clay deposits suitable for the manufacture of bricks, and other clay products, are widespread in the Kootenay valley; while limestone for building stone and for the manufacture of lime occurs in large quantities around Wardner.

## Field Work and Acknowledgments.

The field work upon which this report is based was carried on during the field seasons of 1909, 1910, 1911, 1912, and part of 1913. This length of time was necessary since the problems to be solved were for the most part regional, involving the examination of a wide extent of territory in almost inaccessible districts. A reconnaissance of the western portion of the Rocky mountains was made where the Pre-Cambrian sedimentary series (Galton series which are equivalent to the Purcell series) was in contact with the fossiliferous Palæozoics. A comparative study was made of the stratigraphy and ore deposits of the Coeur d'Alene district of Idaho where the geological conditions are so well known.

The officers of the Consolidated Mining and Smelting Company, Limited, and the owners of mineral properties in the region, at all times rendered every assistance in their power for the advancement of the work.

The writer wishes to record his indebtedness to his field assistants, Messrs. W. Galbraith, L. E. Wright, P. P. Baily, T. L. Tanton, M. F. Bancroft, and G. Hanson.

## Location and Area.

The Cranbrook map-area (Figure 1) lies in southeastern British Columbia and includes part of both the Fort Steele and Nelson mining divisions. It is bounded on the south by the International Boundary line which separates it from

Montana and Idaho. Its eastern border is formed by the Kootenay valley or Rocky Mountain trench which also constitutes the eastern limit of the Purcell range. The northern limit of the area is 49° 45′ north latitude and its western limit is marked by longitude 116° 30′ west. The total area enclosed is 2,535 square miles.

The chief town and distributing point of the region is Cranbrook (Plate XXVIII).

Map to illustrate the paper on the Nomenclature of a part of the
NORTH AMERICAN CORDILLERA
By REGINALD A. DALY.


Figure 1. Index map.

## Means of Communication.

The Crowsnest division of the Canadian Pacific railway passes through the area from Wardner to Kootenay Landing. Following the same route as the railway, a motor road forms a link in the projected transmontane highway from Calgary to Vancouver. From Cranbrook, a branch line of the Canadian Pacific railway runs to Kimberley, the centre of the Kimberley mining area. From Yahk, another line diverges along the Moyie river and crosses the International Boundary at Kingsgate on its way to Spokane and Portland. The Great Northern railway entering Canada from Montana at Gateway on the International Boundary line, runs north along the eastern bank of the Kootenay river and taps the Crowsnest Pass coal-fields through the Elk River valley.

The drainage area of the St. Mary river is accessible from Marysville by a wagon road as far as the ranch of W. Meachen. From here, trails have been constructed up the main branches of the St. Mary river, the trails on the south and west forks of which cross the summit of the Purcell range and finally reach Crawford bay and Kootenay lake. From the foot of St. Mary lake, a trail runs up Whitefish creek to Sanca on Kootenay lake. A branch trail diverges from the Whitefish trail, goes up Fiddle creek, crosses the St. Mary river—Goat River summit, and follows the Goat river to Kitchener on the Canadian Pacific railway.

The country south of Cranbrook will be made accessible by a projected wagon road from Cranbrook to Gateway through the Gold Creek valley. A trail branches off from the road up the south fork of Gold creek, enters the drainage area of the Yahk river and descends the East fork of the Yahk river where it joins the Boundary trail which leads to the town of Yahk on the Crowsnest branch of the Canadian Pacific railway.

All these trails although well defined and greatly used in the nineties, are now almost impassable because of fallen timber, which in the burned areas is especially troublesome. The Boundary trail which follows the International Boundary line as closely as the configuration of the country permits, in 1912 was utterly useless on account of fallen timber. It seems a pity that a trail so well built and of such historic interest should be useless as a means of travel.

## Previous Workers.

Bauerman,[1] who was connected with the International

[1] Bauerman, H., G.S.C. Report of Progress, 1882, p. 25 B.

Boundary Commission of 1859-1861, gave the first account of the geology of the Purcell range in southeast Kootenay. He describes the very thick, well-bedded, non-fossiliferous rocks occurring along the Boundary line between the two crossings of the Kootenay river. From the ripple marks, sun cracks, and false bedding, he classes them as shallow water deposits and the presence of casts of salt crystals he explains by the evaporation of a shallow sea which had no connexion with the ocean. Associated with these slaty rocks, he notes the occurrence of interbedded greenstones and amygdaloidal surface flows. Bauerman also describes the Carboniferous limestone occurring at Tobacco plains in the Kootenay valley and gives a list of the fossils found in them.

Dawson[1] describes the limestone which occurs near Wardner as probably Devono-Carboniferous in age from its resemblance to the Devono-Carboniferous on Crowsnest lake. He noticed the abundant crinoid fragments in the limestone. In this report, he puts the slaty unfossiliferous rocks of the Purcell range in the Cambrian. From the fragments of lignite occurring in the Kootenay River valley, he outlines an area of Tertiary rocks; but work by the writer subsequently revealed the lignite in place, and definitely places the lignite as Pleistocene; hence no Tertiary rocks have as yet been found in the Kootenay River valley.

In 1900, McEvoy[2] in a reconnaissance survey made a topographic and geologic map of East Kootenay. A description of the rocks and mineral properties is given.

Daly[3] during the field season of 1904, made a detailed study of the Purcell range in the vicinity of the International Boundary line. He defined the sediments of the Purcell range as the Purcell series (the greater part of Cambrian age) and subdivided them into the Creston, Kitchener, and Moyie formations in ascending order. In connexion with this work in the Purcell

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[1] Dawson, G. M., G.S.C., Ann. Rept. Vol. I, 1885, p. 148 B.
[2] McEvoy, J., G.S.C., Summary Report, 1899, p. 87 A.
[3] Daly, R. A., G.S.C., Ann. Rept., 1904, p. 91 A.
—G.S.C., Memoir 38, 1913, pp. 119-138.

range, he also studied in some detail the origin of the granite (micropegmatite) which occurs in the gabbro sills of that section.

The various reports issued by the British Columbia Bureau of Mines contain descriptions of the mines and mineral properties in East Kootenay.

The reports of the officers of the United States Geological Survey, on the Belt formations in Montana and Idaho, were of assistance in correlation.

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## CHAPTER II.

## GENERAL CHARACTER OF THE DISTRICT.

### *TOPOGRAPHY.*

#### Regional.

In the southern part of British Columbia the Interior Plateau region separates the North American cordillera in Canada into two main divisions, each of which, in contrast to the Interior Plateau region, is characterized by alpine mountain topography. Each division is subdivided into mountain systems which are separated from each other by well defined topographic features.

The eastern division includes from west to east, the Columbia, Selkirk, Purcell, and Rocky Mountain systems.

The Purcell range or system, that system which is mainly discussed in this memoir, according to Daly is an elliptical-shaped group of mountains about 250 miles long by 60 miles wide, lying between the Selkirk system on the west and the Rocky Mountain system on the east. Most of this range lies in British Columbia, the remainder in United States. The Purcell system is separated from the Selkirk system on the west by the Purcell trench in which occur Duncan river, Kootenay lake, and the north-flowing portion of the Kootenay river. From the Rocky Mountain system on the east the Purcell range is separated by the Rocky Mountain trench in which occur the north-flowing portion of Columbia river and a south-flowing part of Kootenay river. This latter river after flowing southwards into the United States swings through a semi-circle, and with a northward course crosses the International Boundary line again and empties into Kootenay lake. This semicircular valley forms the southern boundary of the Purcell Mountain system.

#### Local.

The area embraced by the Cranbrook map area includes the central part of the Purcell range in southeastern British Columbia.

In a view from one of the higher peaks in the western part of the range, the most striking feature is the accordance of mountain summit-levels, giving the impression of a deeply dissected upland surface with numerous projecting peaks of greater elevation and great trough-like valleys. On closer examination of details, this imaginary reconstructed surface appears to slope gently towards the Rocky Mountain trench on the east, and to be modified by recent glacial action. Three types of topography can be recognized. In the neighbourhood of the watershed of the range, the region is mountainous and rugged (Plate V) many peaks exceeding 9,000 feet in elevation. Towards the east, in the neighbourhood of the Kootenay River valley, the mountains are more subdued in character, having rounded wooded summits (Plate II) and finally ceasing altogether where the prairie land (Plate III) of the Kootenay River valley is reached. This valley in the neighbourhood of the St. Mary river, is 16 miles wide. In the background (Plate IV) the Rocky Mountain system rises wall-like to a height of 9,000 feet out of the valley which here has an elevation of about 3,000 feet.

In the central, alpine, mountainous region where the non-resistant rocks of the Kitchener formation outcrop, the waste covered slopes are gentle and more subdued than where the tough argillaceous quartzites of the Aldridge formation with their interbedded gabbro sills, are exposed. This difference in form of outcrop is a valuable aid in the field in distinguishing the formations at a distance. The form of outcrop assumed by the Aldridge formation is well exhibited in the mountains north of St. Mary lake which occur in the axis of the anticline where the strata are almost horizontal. Here, the intercirque divides or arêtes are saw-like in character and almost vertical. The alpine peaks have serrated summits and are subject to rapid erosion by the action of ice and snow. Valley head cirques or basins are very numerous throughout the mountainous district and are somewhat modified by the talus slopes which at times encroach upon the small tarns, so characteristic of these glacial amphitheatres (Plate XXXI). One small glacier exists within the confines of the Cranbrook sheet and is situated on a cliff above Hall lake (Plate VI).

To the east and southeast of this mountainous region lies the subdued mountain belt (Plates VII and VIII) characterized by rounded hills rising to a height of 7,000 to 7,500 feet above sea-level, holding here and there small cirques which in this region are few in number and not very conspicuous. On the ridge south of Perry creek, there is still some of the old upland surface preserved (Plate IX).

The entire drainage of the Cranbrook map-area is effected by the Kootenay river which rises in the north partly in the Rocky Mountain system and partly in the Purcell system. It flows southwards across the International Boundary line at Gateway into the United States where it pursues a semicircular course finally flowing northwards into British Columbia where it empties into Kootenay lake at Kootenay Landing.

The Rocky Mountain trench (Plate IV), that great and remarkable longitudinal depression whose southern portion lies between the Rocky Mountain system on the east, and the Purcell range on the west, extends from the state of Montana to the International Boundary line between Alaska and the Yukon. In the neighbourhood of the Cranbrook area the floor of this intermontane depression is a beautiful stretch of park-like country 16 miles wide containing numerous open meadows, lakes, and the meandering Kootenay river. Rising abruptly from the valley floor, the western Rocky Mountain front forms its eastern flank. In contrast to the wall-like character of its eastern border, the western flank is marked by rounded wooded foothills, which in turn give way to the rugged mountains of the Purcell range (Plates III and XXXII).

The five main tributaries of the Kootenay river draining the Purcell range in the Cranbrook map-area are the St. Mary river, Gold creek, Yahk river, Moyie river, and Goat river. Most of the streams tributary to the Kootenay river head in the numerous rock basins or glacial cirques in the mountainous region.

The St. Mary river (Plates X and XI) carrying the drainage of the northern part of the area, rises on the summit of the range in several heads, and flows eastwards into the Kootenay river at Fort Steele. In the upper part of their courses the tributaries of the St. Mary river flow over wide, rocky floors in trough-shaped valleys (Plates XXIX and XXX); but within variable distances from the St. Mary river (2 or 3 miles) they enter narrow box-like canyons where they plunge over falls from 50 to 75 feet in height. At these points they leave the hanging valleys of their upper courses and flow with decreased gradients to join the St. Mary river at grade. These lowest reaches are usually marked on either side by gravel cut-banks about 50 feet in height. Hanging valleys (Plates X and XXVII) characterize Whitefish, Hells Roaring, and Perry creeks which flow north into the St. Mary river; and Pyramid, Alki, Matthew, and Mark creeks, which enter the St. Mary river from the north. On Mark creek, a fall occurs in the normal position about 4 miles from its junction with the St. Mary river and in addition another fall is present within 200 yards of this junction.

The main St. Mary river (Plate X) pursues a meandering course in a wide valley floor, the walls of which rise abruptly to a height of from 4,000 to 5,000 feet. Above this elevation the slopes become more gentle indicating that the upland surface has been reached. The interlocking spurs so prominent in valley sculpture in non-glaciated regions are here lacking. The spurs have facetted fronts so that in a view up the valley the cross section is trough-like in character. In the western part of this main valley, the river flows eastwards in anastomosing channels through a flat valley bottom which in spring floods is covered with water. Approaching St. Mary lake (Plate XI) the valley floor is marshy and contains many oxbow lakes (Plate X). Where the river enters the lake, a delta has formed and it is very probable that the deposition of sediment by the river has greatly lessened the area of the lake which is at present 2 miles long by 1 mile wide. In the vicinity of St. Mary lake (Plate XI), the valley walls rise very abruptly on either side and are composed of Aldridge quartzites and intercalated gabbro sills dipping to the west or up the valley. The valley at this point is relatively narrow. It is probable that the outlet of this lake is located on a diorite sill. No terraces or benches are present around the lake; but as the Kootenay valley is approached to the east the terraces gradually make their appearance and the St. Mary river flows in a meandering course in a trough which it has cut in the stratified gravels and sands (Plate XII). The terraces are most prominent from Marysville to the junction of the St. Mary and Kootenay rivers. The bluffs which occur along the St. Mary are not of equal height, owing to the irregularities in the surface of the prairie at its junction with the river valley. These bluffs are occasionally ornamented with hoodoos.

Two additional streams drain the prairie belt within the Cranbrook map-area, Cherry creek, which flows east to join the Kootenay river and Luke creek, flowing south into the St. Mary river. The latter creek is located entirely within the prairie belt, and about half a mile from its mouth it disappears into the gravel and sands to reappear close to its junction with the St. Mary river which it joins by a series of cascades in a narrow gorge cut in the gravels. This non-accordance of grade between the two streams is evidently due to their different erosive powers. This disappearance of streams into the gravels is a common occurrence in the tributaries of the Kootenay river where a wide stretch of gravels has to be crossed before the main river is reached. The stratified floor-covering of the Rocky Mountain trench is also incised by the Kootenay river.

The Moyie river rises in the middle of the Purcell range, in close proximity to the headwaters of Perry creek and the eastern branches of Goat river and flowing first easterly and then southwesterly drains a large part of the southwestern portion of the map-area. For 12 miles it pursues an easterly course in a wide, mature, U-shaped valley; then the river plunges over a step about 75 feet high. Beyond, the river enters a narrow gorge cut into the gravels and bed-rock about 200 feet below the general surface of the valley floor and then turns abruptly at nearly right angles to its former course, and flows through a narrow, V-shaped valley from which gravels are absent. The sides of this young valley are very steep and precipitous. In this gorge it continues for 3 miles and then again enters a wide mature valley and finally empties into the upper Moyie lake.

The pre-glacial course is well defined and consists of a wide V-shaped valley containing vast quantities of glacial gravel and sand. This was once the site of a famous placer mining camp. It is probable that the old course was dammed by the great deposition of glacial material brought down by glaciers moving from the directions of Palmer Bar and Cranbrook and that the Moyie river was forced to seek another course over the low divides which existed between Nigger creek and Swansea.

The Moyie lakes (Plate XIII) together are about 7 miles long and occupy expanded and deepened portions of the Moyie River valley. Formerly only one lake existed, but later it was divided near the centre by the fans deposited by the two streams entering from the east and west side of the valley respectively, namely, Moyie creek and Lamb creek. The shores of Lower Moyie lake are characterized by a succession of terraces, the highest one being 270 feet above the level of the lake. After leaving the Moyie lakes the Moyie river flows in a U-shaped valley in a southwesterly direction, crossing the International Boundary line at Kingsgate, B.C. It continues its course in a southerly direction and joins the Kootenay river at a point 8 miles east of Bonners Ferry, Idaho.

The southwestern part of the map-area is drained in part by the Goat river which enters the Kootenay valley at the delta where Kootenay river empties into Kootenay lake. The Goat river rises in four main heads on the main watershed of the range in close proximity to the sources of the St. Mary and Moyie rivers. It flows southwards until it reaches Kitchener on the Canadian Pacific railway, then turns to the west, and finally joins Kootenay Lake valley at the delta near Creston. A narrow canyon and falls occur about 6 miles east of Creston at a point where the Goat River valley joins that of the Kootenay. Thus the Goat river occupies a hanging valley.

The Yahk river rises in three heads in the mountains south of the Canadian Pacific railway. The main river rises in the relatively high area which is surmounted by Yahk mountain with an elevation of about 7,000 feet. Yahk mountain shows the effect of alpine glaciation as numerous small cirques occur around its summit. The East Fork of Yahk river rises in a lake on a low divide at the head of the South Fork of Gold creek, flows westwards for about 4 miles, then swings rapidly through an angle of 90 degrees into a narrow, box-like canyon locally called "The Smuggler's Canyon." This canyon is 4 miles long and is cut in the almost horizontal quartzites of the Creston formation. This east branch joins the main Yahk river 1 mile north of the International Boundary line. The main river flows southwards into Idaho. The West Fork of the Yahk rises on a low divide at the head of Ripple creek, a branch of the Moyie, flows in a southeasterly direction, and crosses the International Boundary line about 6 miles west of the main Yahk river.

Gold creek, rising at a point about 10 miles south of Cranbrook, flows in a southeasterly direction in a wide, longitudinal valley to join the Kootenay river 5 miles north of the International Boundary line at Gateway. It is fed by three main tributaries from the west, which rise at the summit of the McGillivray range. The projection of each of these tributary valleys to the east is represented by a wind gap which penetrates through the most easterly ridge of the Purcell range into the Kootenay valley. These wind gaps are wide, park-like valleys containing streams only on their eastward slopes that flow into the Kootenay, and probably represent the old deserted river channels of the main tributaries of Gold creek. The main valley of Gold creek is characterized by open park-like country with abundant open meadows making a fine tract of grazing land. The hills on each side of the valley are rounded and covered with open timber.

## *FAUNA AND FLORA.*

East Kootenay, a few years ago, was one of the best game countries in British Columbia, in fact, the Kootenays were synonymous with big game, but now through indiscriminate slaughter, game is scarce except in almost inaccessible places. In order to make game again plentiful in this country by natural increase, a closed season over a period of some years should be established before it is too late.

The caribou are found on the high open and grassy basins on the summits near timber line, and occasionally in the deeper valleys during their season of migration. In the same places are found grizzly and cinnamon bears in the warm season of the year, while in early spring the "slides" on the sides of the mountains facing the south, are their favourite feeding grounds. The black bear usually roams the valley bottoms at lower altitudes. The members of the bear family are numerous in East Kootenay since their favourite food, berries of all kinds, is very plentiful over the area.

White-tail or virginia deer range in the open park-like country of the valleys of Gold creek and of the Kootenay and St. Mary rivers, while the black-tail or mule deer prefer the more mountainous districts.

Goats once plentiful throughout the region are now only found in the highest and almost inaccessible places.

The other fur-bearing animals include, the otter, beaver, cougar, lynx, marten, weasel, marmot (whistler), and skunk.

Mention must here be made of the splendid trout fishing found in all the mountain streams, and even some of the lakes in the higher basins abound in fish.

The whole region is heavily timbered below tree line with spruce, pine, fir, balsam, tamarack, cedar, and some hemlock, so that lumbering will prove to be a very valuable asset in the industrial future of the district.

## *CLIMATE AND AGRICULTURE.*

The variations in elevation from prairie land to alpine mountains which occur within the Cranbrook area make great differences in climate even in such a small district. Altogether, the climate of East Kootenay is exceptionally pleasant and healthful.

### Temperature, Precipitation, and Altitude.[1]

"The steady winter weather usually begins during December,

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[1] Hicks, H. B., Report of Minister of Lands for British Columbia, 1912, p. D150.

continuing through January and February, the temperature ranging from freezing point to zero, and occasionally, for a few days at a time, going as low as 20 or 25 degrees below zero. The snowfall is sufficient for sixty or seventy days' good sleighing. In a very exceptional year, the temperature may go to 30 degrees below zero during November, with 12 or 15 inches of snow, this low temperature lasting only one or two days. In the month of March all snow and ice will disappear from the lower flats and valleys. Generally, the rainfall is scattered through the months of April, May, June, September, and October; July and August are the dry and warm months. In exceptionally wet seasons it is necessary to irrigate but very little.

"Below is a table compiled from the records taken at Cranbrook and kept by the Meteorological Service at Victoria, giving the total precipitation for all of the year 1911 and eleven months of the year 1912. It may be noted that 10 inches of snow is equal to 1 inch of rain. I believe the total precipitation for the year 1911 would represent an average year. The total precipitation is not necessarily the governing factor in determining whether a year shall be called a wet or dry year. Two consecutive years might have the same precipitation; but if the rainfall were so distributed that during one season it was necessary to irrigate, and the next season it was not, they would be called respectively a dry and wet season.

"The elevation, together with the dryness of the atmosphere, makes the climate most agreeable and invigorating. The altitude of the lower valleys and benches will vary from 2,450 to 3,100 feet. The adjacent mountain-ranges vary in height from 7,000 to 9,000 feet."

### Irrigated and Irrigable Areas.[1]

"The district known as the 'East Kootenay,' a part of which is embraced in this report, is quite distinct from other parts of British Columbia, south of the main line of the Canadian

[1] Hicks, H. B. Report of Minister of Lands for British Columbia, 1912, p. D 150.

*Precipitation Records, Cranbrook, 1911 and 1912*

| | Jan. | Feb. | Mar. | April | May | June | July | Aug. | Sept. | Oct. | Nov. | Dec. | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1911** | | | | | | | | | | | | | |
| Inches of rain | 0·73 | | 1·63 | 0·05 | 1·26 | 2·35 | 0·40 | 1·84 | 2·10 | 0·17 | | | 10·53 |
| Inches of snow | 37·20 | 4·60 | 7·00 | 3·00 | | | | | | | 14·00 | 11·00 | 76·80 |
| Total precipitation | | | | | | | | | | | | | 18·21 |
| **1912** | | | | | | | | | | | | | |
| Inches of rain | | | 0·03 | 0·35 | 1·08 | 1·65 | 3·76 | 1·01 | 0·56 | 1·14 | | | 9·58 |
| Inches of snow | 11·00 | 2·00 | | | | | | | | | 11·60 | | 24·60 |
| Total precipitation | | | | | | | | | | | | | 12·04 |

Pacific railway, in respect to the extensive areas of evenly sloping lands lying between the rivers and the mountains. The figures given in the following table include not only such areas as may be readily irrigated from adjacent streams, but take into consideration the fact that, in the near future, systems of conserving the waste waters will be developed, making it possible to irrigate all the valley and bench lands:—

| Locality. | Irrigated or cultivated acres. | Irrigable (estimated) acres. |
|---|---|---|
| Bull River | 750 | 25,000 |
| Fort Steele | 833 | 18,000 |
| Wasa | 360 | 29,000 |
| Sheep creek | 260 | 18,000 |
| Skookum-chuck | 140 | 13,000 |
| Cherry creek | 750 | 20,000 |
| St. Mary prairie | 1,150 | 33,000 |
| Upper St. Mary prairie | 50 | 10,000 |
| Perry creek | 80 | 2,400 |
| Cranbrook | 830 | 30,000 |
| Upper Moyie | 200 | 5,000 |
| Lower Moyie | 50 | 12,000 |
| Total | 5,455 | 215,400 |

In addition to these localities the areas in the vicinity of Gold and Linklater creeks, contain the following acreages.[1]

| Locality. | Irrigated or cultivated acres. | Irrigable (estimated) acres. |
|---|---|---|
| Linklater creek | 170 | 6,500 |
| Gold creek | 300 | 17,408 |
| Total | 470 | 23,908 |

1 Biker, W. J. E., Report of the Minister of Lands for B.C., 1912, p. D154.

# CHAPTER III.

## GENERAL GEOLOGY.

### *GENERAL STATEMENT.*

The rocks of the Purcell range form the western part of the ancient group of sediments deposited in the Rocky Mountain geosyncline. These sediments, called the Purcell series, and of Pre-Cambrian Beltian age, consist of a great thickness of fine-grained quartzites, argillaceous quartzites, argillites, and limestones, all remarkable for their homogeneity. At various horizons in this series, shallow water characteristics, including ripple marks and mud-cracks, are very common. The Purcell series extends across the International Boundary line into Idaho and Montana, but geological exploration has, up to this time, been insufficient for the exact determination of the northern limits. To the west, on account of batholithic intrusions, the relations are not very clear, but there is some evidence to show the existence of numerous patches of acidic pre-Beltian schists in the Selkirk mountains. This ancient acidic terrane probably represents at least part of the old land from which the quartzitic Purcell series was derived. The stratified members of the Purcell series pass unconformably under the younger Palæozoic formations of the Rocky mountains to the east.

The small cross-cutting bodies of granite and porphyritic granite, which intrude the Purcell series, are believed to be small, cupola-like stocks bearing a genetic relationship to the great West Kootenay granite batholith.

The age, subdivision, and correlation of the great thickness of sedimentary strata, exposed in the Purcell range, have been the subjectof much study during thelast few years. The sedimentary series of East Kootenay forms a part of this greatly discussed series. Since no fossils have as yet been discovered in the Purcell series, the subdivision into formations is based solely on physical and lithological grounds; hence the dividing line between the subdivisions is purely arbitrary and the personal equation enters largely into the matter, especially as the formations pass conformably into one another. Along the International Boundary line, the Purcell series has been subdivided, in ascending order, into the Creston, Kitchener, and Moyie formations, by Daly.[1]

The table of formations given below represents equivalent sections in the Purcell range and in the western part of Rocky Mountain system in the neighbourhood of the Crowsnes ; ass. The Purcell series is here used to include all strata below the unconformity which marks the top of the Pre-Cambrian. The base though not yet discovered will probably be the unconformity at the base of the unmetamorphosed Purcell series where it rests on the pre-Beltian schists and gneisses. The Galton series of the Galton range, a western subdivision of the Rocky Mountain system, is the eastern phase of the Purcell series. For convenience an expanded geological column of the series exposed in the Purcell range is given; this will be followed by a full description of each formation.

[1] R. A. Daly, Summary Report, G.S.C., 1904.

*Table of Formations.*

| | | Purcell range | | Rocky mountains |
|---|---|---|---|---|
| Post-Glacial | | Stratified clays and sands | | |
| Glacial | | Wycliffe drift | | |
| Interglacial ? | | St. Eugene silts | | |
| Jurassic ? | | Dyke intrusion | | Dyke intrusion |
| | | Kootenay granite | | |
| Mississippian | | Wardner formation | | Wardner formation |
| Devonian | | Jefferson formation | | Jefferson formation |
| Middle or Upper Cambrian | | | | Elko formation |
| Middle Cambrian | | | | Burton formation |
| | | *Unconformity* | | *Unconformity* |
| | | | Galton Series | Roosville formation. |
| Pre-Cambrian (Beltian) | Purcell series | | | Phillips formation. |
| | | Gateway formation | | Gateway formation |
| | | Purcell lava and Purcell sills | | |
| | | Siyeh formation | | |
| | | Kitchener formation | | |
| | | Creston formation | | |
| | | Aldridge formation | | |

*Tabular Statement of Geological Record.*

| | | |
|---|---|---|
| Quaternary | Post-Glacial | Erosion; deposition of clays and sands in depressions in drift. |
| | Glacial | Erosion; deposition of Wycliffe drift. |
| | Interglacial ? | Erosion; deposition of St. Eugene silts, sands, and gravels (fossil plants). |
| Tertiary | | Erosion; uplift in early Tertiary; dissection of Cretaceous peneplain. |
| Cretaceous | | Erosion; formation of Cretaceous peneplain. |
| Jurassic (?) | | Orogenic movements; formation of Purcell range followed or accompanied by intrusion of Kootenay granite. |
| Carboniferous | Mississippian | *Wardner formation,* marine deposition of limestones and shaly limestones (fossils). |
| Devonian | | *Jefferson limestone;* marine deposition of grey or black magnesian limestones, heavy bedded (fossils). |
| Silurian | | Erosion. |
| Ordovician | | Erosion. |
| Cambrian | | Erosion; early Cambrian uplift. |
| | | *Gateway formation;* (continental deposition), sandstones, sandy argillites, some concretionary siliceous dolomite. |
| | | *Purcell lava, Purcell sills:* intrusion of gabbro accompanied by out- |

| | | |
|---|---|---|
| | | pouring of basalt over land surface. |
| Pre-Cambrian (Beltian) | Purcell series | *Siyeh formation:* (mainly continental some possibly marine deposition), red, purple, and green mud cracked argillites, sandstones, some limestones. |
| | | *Kitchener formation:* (continental and possibly marine deposition), calcareous argillites, argillaceous quartzites ripple marked, mud cracked, some limestones. |
| | | *Creston formation:* shallow water deposition, quartzites, argillaceous quartzites; mud cracks, and ripple marks. |
| | | *Aldridge formation:* argillaceous quartzites, some conglomerates. |

## *THE PURCELL SERIES.*

### General Statement.

The Purcell series of East Kootenay was first described by Daly in the Annual Report of 1904,[1] and this was again published in unchanged form in a memoir in 1913.[2]

The following is Daly's stratigraphic section:—

*Erosion surface.*

| | | feet. | |
|---|---|---|---|
| Middle Cambrian | Moyie | 3,400+ | |
| | Purcell lava | 465 | |
| | Kitchener, upper part | 6,000± | 7,400 |
| Lower Cambrian | Kitchener, lower part | 1,400± | |
| | Creston, upper part | 3,000± | 9,500 |
| Beltian | Creston, lower part | 6,500± | |

Base unexposed.

[1] Daly, R. A., Geol. Surv., Can., Ann. Rept., 1904, p. 91A.
[2] Daly, R. A., Geol. Surv., Can., Memoir 38, 1913, p. 119.

In 1911, Daly identified for the writer, the Kitchener and Creston formations, in the neighbourhood of Kingsgate, B.C., (see map) where the south-flowing Moyie river crosses the International Boundary line. Subsequent work by the writer in 1912, definitely proved that the so-called Kitchener rocks near Kingsgate are older and not younger than the Creston, and the name Aldridge formation was proposed for this group of rocks. Further work on the section in the neighbourhood of the Moyie lakes (see map) showed that a group of rocks lithologically similar to those described by Daly as Kitchener, overlies the Creston and underlies the Siyeh. The name Kitchener has hence been retained for those rocks which overlie the Creston and underlie the Siyeh.

The Moyie formation was examined over a wide area. The area of Moyie rocks outlined by Daly west of Kingsgate was found to rest conformably upon the same rocks which Daly identified as Kitchener, near Kingsgate, and which were subsequently proved to belong to the Aldridge formation. Hence, they cannot be Moyie as originally defined by Daly as lying conformably on the Kitchener. Lithologically, these so-called Moyie rocks are identical with the Aldridge and hence are classed as Aldridge. The Moyie in the vicinity of the Yahk river rests conformably on the Kitchener formation as defined by the writer, and in this region is lithologically similar to the lower part of the Siyeh formation and occupies the same stratigraphic position as the Siyeh south of Cranbrook, where it overlies the Kitchener and underlies the Purcell lava.

The Purcell lava is absent in the Boundary section but is present in the section south of Cranbrook (see map). Daly states that the Purcell lava is absent between the Kitchener and Moyie on the International Boundary line, since the flow did not extend as far west as the Yahk river. The writer concludes that the lava occupied a position above the Moyie and has been removed by erosion and that the Moyie is equivalent to the lower part of the Siyeh. Hence, the name Moyie has been dropped from the stratigraphic series of East Kootenay.

The following is the author's stratigraphic section:—

*Erosion surface.*

| | | |
|---|---|---|
| Pre-Cambrian............................. | Gateway | 2,000+ |
| | Purcell lava | 300 |
| | Siyeh | 4,000 |
| | Kitchener | 4,500 |
| | Creston | 5,000 |
| | Aldridge | 8,000± |
| | Base unexposed. | |

## Aldridge Formation.

*Distribution.*—The Aldridge formation is the oldest known member of the Purcell series. It embraces that succession of dark grey, argillaceous quartzites characterized by their rusty weathering colour, which underlies the greyish coloured, argillaceous, Creston quartzites. This homogeneous formation occupies a large area within the Cranbrook map-area. A northern belt embraces the greater part of the area drained by the St. Mary river, and there the strata form, in general, an anticline plunging to the north. The western border of this belt where it crosses the South fork (Baker creek) and the West fork of the St. Mary river, is a conformable contact with the overlying Creston formation. South of Baker creek, the metamorphosed Kitchener calcareous argillites are faulted into contact with the Aldridge formation. The northern border of the belt has not been explored but it is believed that there the Aldridge formation passes conformably under the Creston formation. The southern border is formed by a fault which brings the Aldridge and the overlying Creston formation and, farther east, the Aldridge and Kitchener, in contact. From Marysville this fault strikes on the one hand, southwest and on the other hand, east, and continues beyond the area of reconnaissance. The eastern portion of this belt passes under the Pleistocene deposits of the Kootenay valley.

The next area of the Aldridge formation to the south is separated from the northern area by a block of Creston argillaceous quartzites. Starting at Cranbrook where the northern edge is a conformable contact with the overlying Creston formation, this area of Aldridge strata strikes southwesterly and enlarges gradually to the west, forming a roughly wedge-shaped mass which reaches to Kootenay Lake valley (Purcell trench). Hence this band of Aldridge quartzites forms a belt which stretches nearly across the whole width of the Purcell range and it proved a fine field for studying the variation in sedimentation. In the most westerly portion of the belt, where the Goat river crosses the Aldridge formation, it contains many beds of conglomerates, consisting of well rounded pebbles of andesite and quartzite. In the eastern part of the belt the Aldridge formation contains no conglomerate and the rocks are all fine-grained argillaceous quartzites with very small amounts of grey argillaceous limestones.

The most southerly area of the Aldridge is an elliptical shaped mass of anticlinal structure whose greater portion lies southeast of the Canadian Pacific railway and west of the main Yahk river. The railway runs within this area along its western side and in the numerous rock cuts the strata are well exposed. The southern portion of this area lies in Idaho and was not visited. A small anticlinal area of the Aldridge lies east of the Yahk river in the neighbourhood of the International Boundary line.

*Thickness.*—The base of the formation was not seen and the upper part was so badly folded that only a rough estimate of its thickness can be given; this estimate is 8,000 feet.

*Lithology.*—The Aldridge formation is made up of a series of argillaceous quartzites, purer quartzites, and argillites (Plate XIV). The argillaceous quartzites form about three-quarters of the whole series and occur in beds with an average thickness of one foot. Megascopically, they are fine-grained rocks, dark grey on fresh fracture, and weather to a rusty brown colour due to their rather high content of iron oxide. Under the microscope, the argillaceous quartzite is seen to consist of small, angular, interlocking grains of quartz 0·05-0·1 mm. in diameter, thoroughly cemented together, in most cases, by argillaceous material which is altered to a network of sericite needles. Small amounts of striated feldspars occur as grains in most of the specimens examined. Muscovite, in lath-shaped individuals, and biotite in irregular plates are quite abundant in nearly all the argillaceous quartzites. Small garnets, 0·01 mm. in diameter, and often showing optical anomalies, complete the mineralogy of this rock type. In a few cases true sandstones were noticed in this formation. They are coarser-grained than the quartzites but consisted of the same constituents. The purer quartzites strongly resemble the argillaceous quartzites under the microscope except that biotite and argillaceous material were far less abundant in the purer variety. At the lower falls on Mark creek, several strata of greyish talcose limestone amounting to a thickness of 6 inches, are exposed at low water. The Aldridge formation exposed on the hill north of Cameron creek, a branch of the Goat river, contains numerous beds of conglomerate whose pebbles, varying in size from a fraction of an inch to 2 inches in diameter, consist of grey quartzites, black slate, and an altered igneous rock, probably volcanic, related to an andesite. Most of the pebbles are waterworn but many are angular and subangular.

*Metamorphism.*—The metamorphism of the rock types of the Aldridge formation, as might be deduced from its composition, has been for the most part very slight. On Matthew creek, at its junction with the St. Mary river, a belt of garnetiferous mica schist is exposed and represents the metamorphosed argillaceous quartzite of the Aldridge formation since this schist passes gradually, on all sides, into the normal argillaceous quartzite. In the hand specimen, it is a glistening rock containing a great quantity of muscovite and quartz. When studied microscopically, it is seen to be composed chiefly of the micas, biotite and muscovite, with subordinate amounts of garnet, quartz, and sillimanite. The sillimanite indicates the presence of an intrusive mass in the vicinity of the sillimanite schist, since this mineral is the stable form of aluminum silicate at high temperatures. According to Vernadsky,[1] the inversion temperature of cyanite into sillimanite is between 1320 degrees and 1380 degrees C. Geological evidence of the inversion point has been given by Barrow,[2] who described the conversion of cyanite into sillimanite by contact metamorphism.

Close to the granite intrusives, the Aldridge argillaceous

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[1] Vernadsky, Zeit. für kryst, Vol. 29, 1904.
[2] Barrow, J. Q.J.G.S., Vol. 49, 1893, p. 340.

quartzites are changed to a knotted quartzite, the knots consisting of the accumulation of carbonaceous material.

The Aldridge formation is characterized by the occurrence of economic deposits of silver-lead ores. The productive portion of these deposits occurs in heavy bedded, purer quartzites; while in the thin-bedded argillaceous members, the veins consist of quartz with minor amounts of the sulphides.

*Structure.*—The present attitude of the strata of the Aldridge formation shows that it has suffered some orogenic movements. In general, it is warped into a series of anticlines and synclines striking in a northerly direction. The Moyie valley in the neighbourhood of the Moyie lakes, has been eroded along the axis of an anticline which plunges to the north. The folds are usually gentie but occasionally, as in the mountains in the vicinity of the St. Mary river, minor overturned anticlines, mashing and faulting, modify the major folds. The compression to which these rocks has been subjected has not developed any signs of schistosity except in the argillites which separate the heavy bedded, purer quartzites.

## CRESTON FORMATION.

*Distribution.*—The Aldridge formation passes by gradual transition into the overlying Creston quartzites. The transitional zone averages 500 feet in thickness and is well exposed along the Crowsnest branch of the Canadian Pacific railway, 4 miles north of Moyie city. From this point, continuing north, the Creston formation outcrops in the many rock-cuts along the railway as far north as the northern end of Upper Moyie lake.

In the region examined, two main belts of Creston rocks, separated by a monoclinal fault block of the Aldridge formation, strike in a northeast-southwest direction across the Purcell range. The northern belt appears at Steele in the Rocky Mountain trench in contact with the Pleistocene. This belt of Creston rocks strikes almost due west for a distance of 16 miles, then swings to a southwesterly direction until it passes beyond the western boundary of the sheet. From a study of the West Kootenay map sheet, it is concluded that this belt of Creston rocks probably is cut off on the west by an intrusion of granite.

The southern belt pursues a semi-elliptical shaped course with its apex on Upper Moyie lake, and forms the outer portion of the anticline whose centre is composed of Aldridge strata forming the Yahk mountains. The western and northwestern outer border is bounded by the Moyie fault which brings up the Aldridge formation into contact with the Creston rocks. The northeastern and eastern outer boundary is formed by the conformable contact with the overlying Kitchener formation. About 5 miles north of the International Boundary the eastern portion of this elliptical shaped belt splits into two bands which form, respectively, the eastern and western limbs of a syncline whose centre is occupied by Kitchener and younger strata. The more easterly band again divides into two about 2 miles north of the boundary line where these two subdivisions form the limbs of an anticline whose centre is formed of Aldridge beds. Good exposures of the Creston formation occur on the Upper Moyie lake, in the Yahk River canyon, and on the mountain side east of the Moyie river at Kingsgate. The study of this southern area of Creston rocks was of very great service in the attempt to unravel the structure of the region and as well, had an important bearing on questions of correlation.

*Thickness.*—The section of the Creston formation along Upper Moyie lake is comparatively free from folding and faulting. One traverse was made across the formation at this locality and the thickness was found to be about 4,500 feet. All of the section was not exposed but it is believed that the thickness given closely represents the total thickness of the formation. Daly, from his measurements across the same formation along the International Boundary, estimates its thickness to be about 8,000 feet, and in his sections the base and the top of the formation were not exposed.

*Lithology.*—The Creston formation embraces that succession of greyish argillaceous quartzites which is included between the dark rusty weathering, argillaceous quartzites of the Aldridge formation and the thin-bedded calcareous rocks of the Kitchener. In general, the Creston formation consists of argillaceous quartzites, purer quartzites, and argillites, whose beds average about 1 foot in thickness. The formation as a whole, contains purer quartzites more abundantly than the underlying Aldridge formation and the quartzites are light grey on fresh fracture and weather in greyish tones so that, at a distance, the rock outcrops resemble limestone. In fact a common local name for these light grey quartzites is "bastard lime." Between these quartzites occur thin beds of argillite about 1 to 3 inches thick, which are darker in colour than the quartzites themselves, so that, in steep cliffs, a decided banding is a prominent feature. No limestone was found in the Creston formation. A progressive change from west to east is to be seen in the texture of the quartzites. The Creston rocks, where they cross the Goat river about 12 miles north of Kitchener, are made up of material resembling coarse sandstone; while in the neighbourhood of Moyie lake and on Perry creek, they consist of fine-grained, argillaceous quartzites. This change in texture is in accordance with that described above as characteristic of the Aldridge formation.

The most striking feature revealed by the microscope was the very small size of the grains which go to make up the rocks of this formation. The main constituent is quartz which occurs in small angular interlocking grains 0·05-1 mm. in diameter. However, in the true sandstones, which are present in small amount in the Creston formation, the grains are larger and spherical in outline. The argillaceous quartzites have an argillaceous cement which is usually altered to a dense network of sericite needles. The argillaceous cement is, in a few cases, replaced and also accompanied by calcium and magnesium carbonate, thus giving rise to calcareous and dolomitic quartzites. When the cementing material is lacking altogether, the rocks pass into the purer quartzite which is composed almost entirely of small interlocking grains of quartz, with a little striated feldspar. Muscovite is often present in dusty aggregates and sericite, in needle-like forms, is rather common. Small garnets sometimes appear sporadically in the argillaceous quartzites.

*Metamorphism.*—The members of the Creston formation are quartzites of different varieties which are themselves metamorphosed sandstones of various compositions. In a few cases, the quartz grains, by their optical properties, show that silica has formed around the grains since deposition. This indicates the process which cemented the quartz grains into a firm dense rock. In the argillaceous quartzite the sericitic material is the result of chemical rearrangement and recrystallization of the formerly existing argillaceous material. The argillaceous quartzites, and purer quartzites of the Creston formation are very resistant to the action of contact and regional metamorphism. Around the granitic intrusions, the only effect is the formation of knots of carbonaceous material, within 500 feet of the contact. The rocks farther away are normal in every respect. Regional metamorphism has induced a shearing at right angles to the bedding planes of the argillites which separate the thick-bedded purer quartzites.

*Structure.*—Since the Creston quartzites lie conformably upon the Aldridge formation, these two series must have a similar structure, that is, the Creston has been folded into anticlines and synclines. The Creston quartzites are characterized at various horizons by shallow water features. Ripple marks are well shown in the rock cuts along the Upper Moyie lakes and along the road on Perry creek above Old Town.

## Kitchener Formation.

*Distribution.*—A small area of Kitchener calcareous argillites and quartzites occurs between Perry creek and the St. Mary river in the neighbourhood of Marysville. The strata rest conformably upon the Creston formation on the west and pass under the Quaternary deposits of the Kootenay valley on the east. The northern and southern boundaries are formed by faults which have a general east and west strike. On the north, the Kitchener is in contact with the Aldridge formation, while to the south, it is in contact with the Creston argillaceous quartzites.

In the vicinity of the headwaters of Whitefish or Meachen creek and the Goat river, an area of westerly dipping Kitchener rocks occurs. Its northeastern border is bounded by a fault which brings the Aldridge into contact with the Kitchener. This area extends to the west beyond the map-area where it was found that these rocks pass gradually into the Selkirk series. The southern boundary is formed by a fault which strikes in a northwesterly direction. This fault brings the Kitchener and Creston formations in contact.

Starting on Upper Moyie lake a linear-shaped area of Kitchener beds extends southeastwards to the International Boundary line and forms part of the easterly dipping limb of the Yahk anticline. On the north, it is cut off by the Moyie fault which places it in contact with the Aldridge formation. Its easterly and westerly limits are formed respectively by the conformable contacts of the overlying Siyeh and the underlying Creston formations.

Another area of the Kitchener rocks occurs between the two crossings of the Yahk river at the International Boundary line where it forms a synclinal basin capped by about 1,000 feet of the overlying Siyeh green and purple, mud-cracked shales.

*Thickness.*—The best section of the Kitchener formation for measurement, was found along the Canadian Pacific railway on Upper Moyie lake in the vicinity of Jerome. Exposures are fairly good and show evidences of only very little folding; hence the measured thickness, 4,500 feet, can be taken as correct.

*Lithology.*—In comparison with the underlying Creston and Aldridge formations, the most notable feature of the Kitchener formation is its content of lime. The formation consists of calcareous and argillaceous quartzites, quartzites, and limestones. The argillaceous limestones are well exposed in the railway tunnel at Jerome and occur in beds 6 inches to 1 foot in thickness. The general weathering colours are yellowish brown and grey. On the weathered surface, parallel to the bedding planes, are numerous linear depressions about one-eighth to one-quarter inch wide and one-half inch deep (Plate XVA), while on the planes perpendicular to the bedding, these depressions are irregular and some are vermicular (Plate XVB). Evidently these depressions are the result of the leaching out of the purer calcareous phases. This peculiar weathering effect is characteristic of these argillaceous limestones. Purer limestones also occur and were noted on the divide between the main river and the west fork of the Yahk. Argillaceous quartzites, darker on fresh fracture than the Creston quartzites, are quite abundant and weather to a yellowish brown or a light grey colour.

*Structure.*—The Kitchener formation rests conformably on the Creston formation. The contact exposed south of Jerome in the railway cut, shows that no sharp line can be drawn between the formations and that they grade into one another, the transition zone being about 500 feet thick. The Kitchener is overlain conformably by the Siyeh formation and this contact, which is gradational also, can be seen about one-half mile north of the Upper Moyie lake on the road which follows Peavine creek to Cranbrook.

## Siyeh Formation.

*Distribution.*—The most westerly exposure of the Siyeh formation occurs between the points where the West fork and the main Yahk river cross the International Boundary. Here it forms the axial portion of a small syncline. No limestone occurs in this section since the thickness exposed is only 1,500 feet. This exposure is surrounded in Canada by the Kitchener formation. The southern portion, since it lies in Idaho, was not explored.

A long linear area of the Siyeh formation begins on Moyie mountain where its northern continuation is cut by the Moyie fault which brings up an area of Aldridge argillaceous quartzites. The Siyeh formation from Moyie mountain, strikes in a southerly direction and crosses the International Boundary line. The strata form part of the western limb of a syncline which strikes in a north-south direction. The western boundary of the Siyeh area is formed by a conformable contact with the underlying Kitchener formation, while the eastern boundary is marked by the Purcell lava.

Another large area of the Siyeh formation forms, for the most part, the most easterly hills of the Purcell range. This area begins south of Cranbrook and with one interruption, continues to the International Boundary line. The central portion between the first gap in the hills south of Cranbrook, and Plumbob creek, is occupied partly by the Gateway formation and partly by Devonian-Carboniferous limestone. Fine exposures of the Siyeh formation showing its relation to the Purcell lava can be seen on Baker and Moyie mountains.

*Lithology.*—The lower part of the Siyeh formation is composed of thin-bedded, green and purple, mud-cracked metargillites and sandstones (Plate XVI, A and B). Some black metargillites are also present which weather to a rusty brown colour. About one mile north of Upper Moyie lake on Peavine creek is exposed a massive conglomerate about 200 feet thick which was seen in no other section of the Siyeh formation. It occurs about 200 feet above the determined base of the Siyeh. The lithology of the conglomerate is quite varied and consists of pebbles of greenish grey argillaceous quartzites, brownish red sandstones, white quartzites, and highly altered amygdaloidal and non-amygdaloidal basalt. Most of the pebbles are rounded; but some are angular and subangular. The origin of the pebbles cannot be definitely determined, although most of them strongly resemble the underlying formations. The terrane from which the pebbles of basalt were derived is unknown, as no lava flows were found in the underlying formations. Underneath the conglomerate with no unconformity, occur chocolate brown and purple, mud-cracked metargillites. The significance of this conglomerate could not be determined from the one isolated exposure. This conglomerate was succeeded by chocolate brown sandstone composed of small particles of the same materials as the conglomerate. The microscope shows that the sandstone is composed of angular and subangular grains of quartz, plagioclase, argillaceous quartzite, and altered basalt in a calcareous cement.

About 2,000 feet above the base of the Siyeh formation occur thin-bedded and massive, siliceous, concretionary limestones, grey on fresh fracture and weathering grey and buff. They reach a thickness of about 1,000 feet. These limestones are succeeded by purple and green, mud-cracked metargillites in thin beds and since the purple and green beds occur grouped alternately for a thickness of 10 to 15 feet they give a striped appearance to the mountain sides. This is especially well shown on the west side of Baker mountain. Towards the top of the Siyeh on Baker mountain, the following section, in descending order, was measured:

| | |
|---|---|
| Purple and green metargillites and sandy quartzites... | 20 feet |
| Porphyritic-amygdaloidal basalt .................... | 50 " |
| Purple and green metargillites and sandy quartzites... | 50 " |
| Non-amygdaloidal, non-porphyritic basalt ........... | 100 " |
| Purple and green metargillites...................... | 400 " |
| Amygdaloidal basalt................................. | 300 " |
| Purple and green metargillites and sandy quartzites... | 500+" |
| Remainder poorly exposed. | |

sediments which form the top of Baker mountain are succeeded on the east side of Baker mountain by another flow of amygdaloidal and porphyritic basalt. Frequently the lava flows are succeeded at the immediate contact by a sandstone composed of particles, generally angular, of the underlying basalt.

*Thickness.*—No complete section, with the definite top and bottom of the Siyeh formation was found, but a rough estimate of several sections gave a maximum thickness of 4,000 feet. This agrees well with Daly's thickness of 4,000 feet for the same formation at the International Boundary line.

*Structural Relations.*—The Siyeh formation rests conformably upon the Kitchener argillaceous quartzites and limestones with a transitional zone of 300 feet thickness. The top of the Siyeh formation, as defined by Daly, is the base of the Purcell lava. As seen from the above description of the Siyeh formation, several lava flows occur separated by important thicknesses of sediments. The top of the Siyeh is placed at the bottom of the last flow of lava since the sediments between the underlying flows of lava are identical with the remainder of the Siyeh metargillites. The Gateway formation which rests on the last Purcell lava bed, is in strong contrast both lithologically and in its colour scheme, to the Siyeh formation.

## Gateway Formation.

*Distribution.*—The Gateway formation is found only in the most easterly part of the Purcell range, the McGillivray range. The axis of this latter range is marked by a syncline of the Gateway formation striking a little west of north. The western boundary is limited by the Purcell lava, which also outcrops in places along its eastern boundary. The eastern contact for the most part, however, is formed by a fault striking north-northwest-south-southeast and roughly parallelling Gold creek. This fault brings the Siyeh into contact with the Gateway formation. Near the International Boundary the eastern limb of the syncline is exposed, the fault cutting across the succeeding anticline of Siyeh rocks to the east.

A smaller area of the Gateway formation, which dips to the east, occurs between the stream south of Baker creek and Plumbob creek. On the west, the Purcell lava forms the boundary, while on the east the Gateway is overlain unconformably by the Devonian-Carboniferous limestone.

Another area occurs in the Kootenay valley opposite the mouth of Elk river and this is also bounded on the west by the Purcell lava. It passes at its remaining boundaries under the Quaternary deposits of the Kootenay valley.

*Lithology.*—The base of the Gateway rests on the Purcell lava conformably and is formed of a fine-grained grit containing pebbles of the Purcell lava as well as a few pebbles of quartzite. This is succeeded by alternating beds of conglomerates and siliceous limestone. The conglomerates observed never exceeded 15 feet in thickness. The limestone weathers buff and is concretionary in habit, the siliceous parts projecting from the weathered surface. Some dolomites are also present. Interbanded with the dolomites are purple shales and grey sandstones. These are succeeded by greyish brown weathering, sandy argillites in beds 1 to 2 inches thick, containing abundant casts or salt crystals (Plate XVII), which were not found in any other formation in the district.

Interbanded in these sandy argillites are numerous heavy bedded buff weathered sandstones and quartzites.

*Thickness.*—A complete section of the Gateway was not found in the region examined. The thickness of 2,025 feet determined by Daly[1] is, therefore, taken.

*Structural Relations.*—The Gateway formation rests upon the Purcell lava conformably. In the Purcell range the Devonian limestone rests unconformably on the Gateway formation. Where this contact was examined no discordance of dip between the formations was noted; still the absence of the Phillips, Roosville, Burton, and Elko formations, present in the Rocky mountains, points to a great time interval between the Gateway and Jefferson limestone. The actual contact shows the sandy limestone brecciated and recemented. Many small patches a few feet to yards in diameter were noted on the hillside on Gold creek.

On the north side of Plumbob creek, the southern part of the hill is occupied by the green and siliceous mud-cracked metargillites of the Siyeh formation, while the eastern part is covered by the Devonian-Carboniferous limestone. Although the contact between these two formations is not well exposed, yet exposures are sufficient to show that the limestone rests upon the Siyeh formation and the Purcell lava. Thus the placing of an unconformity between the Carboniferous limestone and the Pre-Cambrian is warranted.

Willis[2] describe a similar break between the Carboniferous series and Pre-Cambrian in the Yakunkak valley, as follows: "On crossing the Flathead valley, however, to the Galton range.............a small area of limestone is encountered in Yakunkak valley. The rock is a light grey and dark blue limestone about 100 feet thick, distinctly bedded, commonly crystalline, occasionally oolitic.................it is without upper stratigraphic limit, but rests conformably on a quartzite, which is unconformable on Algonkian strata. The quartzite is 25 feet thick, and it and the limestone lies in a nearly horizontal position................The Yakunkak limestone contains numerous fossils of the Saint Louis horizon of the Mississippian series...................The absence of earlier Mississippian

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[1] Daly, R. A., Geol. Surv., Can., Mem. 38, 1913, p. 107.
[2] G.S.A., Vol. 13, 1902, p. 325.

strata is significant of an unusual overlap..................it is possible that it (Yakunkak limestone) rests on the Siyeh limestone, in which case the break between the two would not be readily recognized, as the rocks are very similar and the angular difference of dip is slight."

### Origin of the Purcell Series.

In the detailed description of the Purcell series, it was stated that the series consists of a great thickness of argillaceous quartzites, quartzites, argillites, and limestones. In general, the rocks are well bedded; the individual beds vary from 1 inch to 8 feet in thickness. The rocks consist of interlocking grains of quartz, striated feldspar, and argillaceous material. At various horizons in the series, occur ripple marks and mud-cracks which are especially abundant in the Siyeh formation. Casts of salt crystals are especially abundant only in the Gateway formation. Evidence of contemporaneous erosion occurs in the Aldridge formation.

The extreme fineness of grain and the almost perfect separation of the siliceous and aluminous material, lead to the conclusion that these sediments were derived from an older terrane probably composed of acid gneisses and schists, in a region in the stage of topographic late maturity.

The Aldridge argillaceous quartzites are dark grey on fresh fracture and weather to a rusty brown colour. Hence, the iron contained in these quartzites is in a ferrous condition. It is also probable that some carbonaceous material is present. This shows that the climate at the time of the deposition of the Aldridge sediments was humid.[1] The presence of the striated feldspar in the quartzites, supports the idea that mechanical disintegration of the source of supply was more rapid than decomposition or weathering. The evidence of contemporaneous erosion, as well as the conglomerates, found in the Aldridge formation on the Goat river suggests that the water in which these sediments were deposited was shallow and that subsidence and deposition proceeded approximately at the same rate.

[1]See page 39.

The quartzitic Creston formation is characterized by a greenish colour which, when wet, has a translucent olive green hue. Ripple marks are present at various horizons throughout the whole formation. Evidently the conditions of deposition of the Creston sediments were similar to those under which the Aldridge sediments were deposited.

The more calcareous portion of the Kitchener formation evidently accumulated in comparatively deep water, since no shallow water features were noted in it, although they were very prevalent in the more quartzitic phases.

The next succeeding formation, the Siyeh metargillite, is characterized by the presence of alternating greyish-green and purple to chocolate-brown argillites, the latter being especially distinguished by the presence of abundant sun cracks. Hence, the water in which these sediments were deposited was shallow, and even shallower than the Aldridge or Creston sea, since occasionally the water of the basin became shallow enough to allow the formation of mud-cracks. The climate at the beginning of Siyeh time must have been alternating humid and arid, since it is believed that such climatic conditions are necessary for the formation of alternating greenish-grey and purplish-red strata. Barrell[1] speaks of the significance of red coloured deposits as follows: "Turning to the climatic significance of red, it would therefore appear both from theoretical considerations and geological observations that the chief condition for the formation of red shales and sandstone is merely the alternation of seasons of warmth and dryness with seasons of flood, by means of which hydration, but especially oxidation, of the ferruginous material in the flood-plain deposits is accomplished. This supplements the decomposition at the source and that which takes place in the long transportation and great wear to which the larger rivers subject the detritus rolled along their beds. The annual wetting, drying, and oxidation not only decompose the original iron minerals but completely remove all traces of carbon. If this conclusion be correct, red shales and sandstones, as distinct from red mud and sand, may originate under intermittently rainy,

[1] Barrell, J., Jour. of Geol., 1908, p. 292.

subarid, or arid climates without any close relation to temperature and typically as fluvial and pluvial deposits upon the land, though to a limited extent as fluviatile sediments coming to rest upon the bottom of the shallow sea. The origin of such sediments is most favored by climates which are hot and alternately wet and dry as opposed to climates dry."

Continental deposition under arid conditions prevailed throughout the Gateway times, as shown by the presence of the casts of salt crystals and the abundance of ripple marks.

### Sources of the Sediments.

The Aldridge formation in the eastern part of the Purcell range contains no conglomerates; but in the western part, as in the vicinity of the Goat river, conglomerates are quite abundant. The Creston formation also is coarser in the western part of the range. Hence, it is concluded that the land from which these sediments were derived was situated to the west of the Purcell range, and probably as close as West Kootenay, for the Pre-Cambrian complex of gneisses and schists outcrops at various points in that region. Daly[1] in a study across the whole Rocky Mountain geosyncline, remarks on the decrease in the coarseness of the sediments from west to east.

### Purcell Sea.

The water in the Purcell continental basin, in which the Purcell sediments were deposited, was certainly shallow for the most part. Walcott[2] believes from the abrupt appearance of the Cambrian fauna in sediments of Rocky Mountain geosyncline, that the Purcell sea was not connected with the ocean and that the water in the sea was either fresh or brackish.

Bauerman[3] in his report on the Purcell range classes the rocks now known as the Purcell series as shallow water deposits and the presence of salt crystals he explains by the

[1] Daly, R. A., G.S.C., Summ. Rept., 1904, p. 97A.
[2] Smithsonian Coll., Vol. 57, 1910, p. 1.
[3] Bauerman, H., Geol. Surv., Can., Rep. of Progress, 1882, p. 25 B.

evaporation of a shallow sea which had no connexion with the ocean.

## Age and Correlation of the Purcell Series.

Dawson[1] first described the rocks of the Purcell range as Cambrian and McEvoy[2] followed him in this determination. Daly[3] working across the range along the International Boundary line considers the lower part of the series as Pre-Cambrian and the upper part Cambrian. The writer considers the Purcell series to be entirely of Pre-Cambrian age, the evidence for which is submitted in the following discussion.

Since the evidence collected in the Purcell range was insufficient to determine the age of the Purcell series with any degree of certainty, it was found necessary to examine in detail a section in the Rocky mountains where the contact of the Pre-Cambrian Galton series, which is correlated with the Purcell series and the older Palæozoic formations, is exposed. A fine section was found in the hill north of Elko, B.C.

A full discussion of the correlation of the Pre-Cambrain and Cambrian rocks of the Purcell and Rocky mountains has been given in the Museum Bulletin No. 2.[4]

The mountains to the north of the Elk River valley at Elko, form the most western part of the Rocky Mountain system. The structure of these mountains is of the nature of a syncline striking northwest-southeast. The eastern limb of the syncline is cut off by a northwest-southeast fault which brings the Devonian-Carboniferous limestone in contact with the Roosville formation. The strata forming the western limb of the syncline and incidentally the western face of Rocky mountains, dip on an average of 45 degrees to the northeast.

Elko, a station on the Crowsnest branch of the Canadian Pacific railway, is situated on the western slope of the Rocky Mountain system, at the Elk River portal to the Kootenay Valley

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[1] G. M. Dawson, Geol. Surv., Can., Ann. Rep., 1885, p. 148 B.
[2] Jas. McEvoy, Geol. Surv., Can., Summ. Rep., 1899, p. 87 A.
[3] R. A. Daly, Geol. Surv., Can., Mem. 38, 1913, pp. 119-138.
[4] L. D. Burling, Mus. Bull. No. 2, Geol. Surv., Can., 1914, pp. 93-129; S. J. Schofield, Mus. Bull. No. 2, Geol. Surv., Can., 1914, pp. 79-91.

or Rocky Mountain trench. The section exposed at Elko can be most easily expressed in a stratigraphical column.

| | | |
|---|---|---|
| Devonian | Jefferson limestone | 300+ feet |
| Cambrian | Elko formation | 90± " |
| Middle Cambrian | Burton formation | 80± " |
| | *Unconformity.* | |
| Beltian | Roosville formation | 1,000 " |
| | Phillips formation | 500 " |
| | Gateway formation | 1,000+ " |

The Gateway, Phillips, and Roosville belong to the Galton series of Daly.[1]

### *Gateway Formation.*

The lower part of the formation consists of alternating bands of massive, concretionary, siliceous dolomite and limestone weathering buff, and massive, light grey quartzites. These are succeeded by thin-bedded, sandy argillites and greenish grey, siliceous argillites. The sandy argillites weather a light buff and are characterized by the presence of abundant casts of salt crystals.

### *Phillips Formation.*

The Gateway formation passes gradually into the overlying Phillips formation which consists mainly of dark purplish and red metargillites, sandy argillites, and sandstones. At several horizons are intercalated thin laminæ of green siliceous argillite. These rocks are exposed in a rock cut on the Great Northern railway, 1½ miles east of Elko, from which point they rise to the east on the hill to the north of the track.

### *Roosville Formation.*

The Phillips is overlain conformably by the Roosville which is composed mostly of massive laminated, green, siliceous metargillites weathering greenish grey and rusty brown. Mud

[1] Daly, R. A., G.S.C., Memoir 38, p. 97.

cracks are abundant at all horizons. The Elk River canyon is carved in the horizontal strata of the Roosville formation. These rocks have been called the Elk River Bridge beds by Dawson[1].

*Burton Formation.*

The Burton formation, called after Burton creek near Elko, rests with no discordance of dip on the Roosville siliceous metargillites and consists in great part of greenish black, calcareous shales with interbedded siliceous limestone bands. A detailed section of the Burton formation at Elko is as follows:

| | | | |
|---|---|---|---|
| Elko formation. | | | |
| Burton formation | Greenish black shales with limestone interbands | 60 ± | feet |
| | Sandy limestone | 10 | " |
| | Greenish black shale | 4 | " |
| | Calcareous grit | 3 | " |
| | Hematitic conglomerate | 8–10 | inches |
| Roosville siliceous metargillites. | | | |

No structural unconformity could be detected between the Roosville and the Burton in this section. The hematite conglomerate, the base of the Burton, is composed of rounded to subangular pebbles of siliceous hematite, embedded in a cement consisting of quartz and hematite. The origin of this conglomerate might be attributed to the erosion of hematite deposits which occur quite abundantly in the underlying Pre-Cambrian formations. This conglomerate passes gradually into the overlying grit which is made up of angular and subangular grains of the Roosville siliceous metargillite and a great number of milky white and glassy quartz grains in a calcareous cement. This grit contains the oldest fossils found in the Burton series. Succeeding this grit are about 4 feet of calcareous, greenish black shales which readily weather to soft earth. They are brittle and break up in small rectangular shaped pieces. Above this shale comes 10 feet of sandy limestone, in beds from 1 to 2 feet in thickness, broken by vertical joints. The weathering colour of this limestone is brown. Above the limestone

[1] G. M. Dawson, Geol., Surv., Can. Vol. I, 1885, p. 78 B.

comes about 60 feet of greenish black, calcareous shale containing numerous bands of siliceous limestone. These interbands are especially rich in trilobite remains.

### *Age of the Burton Formation.*

The age of the Burton formation is discussed by L. D. Burling as follows:[1] "the Burton formation has been named and described by S. J. Schofield[2], who, together with the writer, measured the following section in the slope directly back of the Burton mine about 2 miles northwest of the town of Elko, British Columbia.

***Section of Burton Formation near Elko, British Columbia.***

| | Section. | Feet. | Fauna. |
|---|---|---|---|
| Elko limestone (Cambrian). | | | |
| Burton formation (early Middle Cambrian.) | 5. Greenish black shales with interbedded limestones, the limestone being in the form of lenses and layers 1 to 3 inches in thickness and more or less continuous but making up a very small proportion of the strata. | 60 | In interbedded limestones within 5 feet of the base: *Micromitra* (*Paterina*), *Micromitra* (*Iphidella*) *pannula*, *Obolus* sp., *Acrothele* sp., *Acrotreta* sp., *Agraulos* sp., *Ptychoparia* sp., *Albertella* sp., *Olenoides* sp., *Bathyuriscus* sp., *and Crepicephalus* 2 species. |
| | 4. Massive, dirty grey, sandy limestone. | 10 | Near top: *Micromitra* sp., *Micromitra* (*Iphidella*) *pannula*, *Agraulos* sp., Trilobite fragments 2 species. |
| | | | Near base: *Micromitra* (*Iphidella*) *pannula*, Trilobite fragments 2 species, one suggesting *Olenellus*. |
| | 3. Green micaceous shale, badly sheared. | 4 | One trilobitic fragment. |
| | 2. Rubbly weathering, calcareous grit, with annelid like borings in top layer. | 3 | Annelid borings, *Micromitra* (*Paterina*) sp., *Acrotreta* sp., Trilobite fragments 1 species. |
| | 1. Hematite conglomerate. | 1 | ... |
| unconformity | | | |
| Roosville siliceous metargillite (Pre-Cambrian). | | | |

[1] L. D. Burling, Geol. Surv., Can., Mus. Bulletin No. 2, 1914, p. 125.
[2] Geol. Surv., Can., Museum Bull. No. 2, 1914, p. 82.

So far as the writer is aware there are only three reported occurrences of the genus *Crepicephalus* in the beds below or immediately above the line separating the Lower from the Middle Cambrian. First, in the Pioche formation of Nevada, second, in a limestone with *Albertella* on Mount Stephen, British Columbia[1], and third in interbedded limestones in a Middle Cambrian shale immediately overlying a quartzite on an island east of Niang-Niang-Kung, Liau-tung, Manchuria.[2] The limits of this paper will hardly permit the inclusion of any further reference to the latter occurrence or to the relations between this shale series and the horizons under discussion. The Middle Cambrian aspect of the fauna of No. 5 of the Burton formation was evident at the time its study was undertaken, but the association in the same 1-inch layer of two species of *Crepicephalus* and a representative of the genus *Albertella* suggested the comparison of the Burton formation with the *Albertella* fauna and the Pioche formation, horizons which had both been referred to the Lower Cambrian.

Analysis of the *Albertella* fauna in the other regions from which it has been identified revealed the lack of any necessity for the assumption that its Lower Cambrian age was infallible and the writer turned his attention to the Pioche. This was shown to be divisible into Lower and Middle Cambrian zones respectively, and even to comprise faunas which, at the type locality of the *Albertella* fauna, are separated by 1,600 feet of limestone. At the type locality of the Pioche formation the range of faunas included in that unit does not appear to be so large and the Middle Cambrian horizon, to which the name *Crepicephalus* zone has been applied, is to be correlated, at least tentatively, with the Burton formation. The correlation of the Burton formation with the *Albertella* fauna is based largely upon the presence in the former of an *Albertella*, a genus which, according to our present information, is confined in the Cordilleran region to this one horizon. The weight of evidence so largely opposes the Lower Cambrian age of these formations and corroborates their reference to the overlying division of the Cambrian that the

[1] Walcott: Smithsonian Misc. Coll., vol. 53, No. 5, 1908, p. 213.
[2] Walcott: Research in China, vol. 3, 1913, p. 26, locality 35r.

*Correlation of Pioche Formation, Burton Shale, and Albertella Zone.*

| Pioche, Nevada | Big Cottonwood canyon, Utah | Elko, British Columbia | Mount Bosworth, British Columbia |
|---|---|---|---|
| *Zacanthoides typicalis* zone (2 of section, page 96) = No. 21 of Highland range. | *Bathyuriscus productus* zone ( = Spence shale horizon in northern Utah). | ........ | Stephen formation (*Ogygopsis* zone) = Titkana formation of Mount Robson region (in part). |
| Pioche formation: *Crepicephalus* zone ........ | Pioche formation. ........ | ....Burton formation. | Mount Whyte formation: *Albertella* zone ........ |
| Pioche formation: *Olenellus gilberti* zone .... | Pioche formation: *Olenellus gilberti* zone ........ | ........ | Mount Whyte formation: *Olenellus canadensis* zone. |

Burton formation is referred with some degree of certainty to the Middle Cambrian.

It is hard to resist the impression, however, that the clastic portion of the Burton formation may represent the Lower Cambrian, and while the few species occurring in these lower layers are either unrecognizable or referable to types hitherto unknown, the suggested definition of the Burton formation will not invalidate its future division into shale and sandstone members.

The Burton formation is, therefore, interpreted as a more or less heterogeneous formational unit unconformably overlying the Pre-Cambrian, referable to the early Middle Cambrian, and easily separable into upper and lower members if such a division should be warranted by future work upon the faunas of its basal portion."

### *Elko Formation.*

The Elko formation, called after the town of Elko, on the Crowsnest branch of the Canadian Pacific railway, rests upon the Burton formation. The exact contact between these two formations was not exposed in the sections studied, but no structural evidence of an unconformity was present, exposures on each side of the contact being very good.

The lower 30 feet of the Elko formation is composed of massive, grey, siliceous limestone, weathering grey, containing indistinct coral-like forms (Plate XVIII). The limestone by gradual transition, passes into a cream coloured siliceous dolomite in massive beds averaging about 6 feet in thickness.

### *Age of the Elko Formation.*

At Elko no determinable fossils were found in the Elko formation. The fossiliferous Jefferson limestone rests conformably upon the Elko formation, hence from the evidence at Elko, the Elko formation may include Cambrian, Ordovician, and Silurian strata. During the season of 1914 the writer, in company with C. W. Drysdale, found a Cambrian section at Canal flats situated on the east side of the Rocky Mountain trench about

65 miles northwest of Elko. Fossils were collected in the strata resting conformably on rocks, which strongly resemble the Elko formation in lithology and physical character. Mr. L. D. Burling, who examined the fossils, states, "I was unable to find the Albertella fauna, indeed most of the horizons appear to be much higher than the Albertella horizon, and represent the Middle or Upper Cambrian. If this interpretation is correct, you have obtained an upper limit for the Elko formation, placing it in the Cambrian instead of the interval between the Cambrian and the Devonian."

### *Jefferson Limestone.*

In the Rocky Mountain system, the Devonian limestone apparently rests conformably upon the underlying Cambrian series (at Elko, the Elko formation) while in the Purcell range to the west, an apparent unconformity exists between the Devonian limestone and the Gateway formation. The staple rock of the Devonian is a massive, dark grey limestone weathering a whitish-grey colour. The following fossils were found in the limestone and were identified by Dr. E. M. Kindle: *Atrypa reticularis*, *Spirifer pionensis*, *Orthothetes chemungensis var. arctostriatus.*

### *Unconformity at the Base of the Burton.*

Although no structural features emphasize the presence of an unconformity at the base of the Burton yet from other evidence such an unconformity is believed to exist.

(1) In harmony with the other sections throughout the Rocky Mountain geosynclinal, a marine Cambrian transgression is represented in the deposition of the Burton formations.

(2) The conglomerate at the base of the Burton is composed chiefly of hematite pebbles with minor quantities of pebbles of quartzite and quartz in a hematitic quartz cement. The hematite pebbles, although some have a concentric structure, represent the erosion and subsequent concentration of hematite layers which occur abundantly in the underlying Pre-Cambrian series. The quartzite (metamorphosed sandstone pebbles) are identical

with the quartzite of the underlying Phillips formation. The occurrence of these pebbles already metamorphosed before the deposition of the Burton, indicates that a time interval existed between the deposition of the Roosville and Burton formations.

(3) The grit which overlies the conglomerate is characterized by the abundance of milky white quartz particles evidently derived from the erosion of quartz veins which are known to be present in the underlying Roosville formation and other members of the Pre-Cambrian series. Green particles of the Roosville siliceous metargillites are also present and since they are identical with the underlying Roosville, it supports the idea that the Roosville formation was metamorphosed before the Burton was laid down, hence the idea of a time interval between the deposition of the Roosville and Burton formations is strengthened.

(4) The difference in degree of metamorphism of the Roosville and the Burton is very striking in the field. The laminæ of the Roosville siliceous metargillites are so throughly cemented together that they always form steep cliffs, in fact the perpendicular walls of the Elk River canyon are carved in the Roosville formation. In contrast to this the Burton formation weathers to a soft earth and is characterized by gentle slopes.

*Relation of Galton Series to the Purcell Series.*

The Purcell series of the Purcell range is regarded as the western or near shore equivalent of the Galton series. Daly's correlation of the two series is as follows.

*Correlation of the Purcell Series and Galton Series by Daly.*[1]

| Purcell Series, Purcell Range, 49° N. Lat. | Galton Series, Galton Range, 49° N. Lat. |
|---|---|
| Erosion surface. | Erosion surface. |
| Moyie. Thickness.....3,400+ feet | Roosville. Thickness.. 600+ feet<br>Phillips. Thickness.... 550 feet<br>Gateway. Thickness...1,850 feet |
| Kitchener. Thickness...6,000± feet | Gateway. Thickness.. 125 feet<br>Siyeh. Thickness.....4,000 feet |
| Kitchener. Thickness...1,400± feet<br>Creston. Thickness....3,000± feet | Wigwam. Thickness...1,200 feet<br>MacDonald. Thickness 2,350 feet<br>Hefty. Thickness..... 775 feet |
| Creston. Thickness....6,500± feet<br>Base concealed.<br>Total..............20,300+ feet | Altyn. Thickness..... 650 feet<br>Base concealed.<br>Total.............12,100 feet |

Daly, in his correlation, emphasizes the importance of the Purcell lava in the correlation of not only these two series but of all the equivalent series of the Rocky Mountain geosyncline.[2] This, however, must be used with care as the writer has found several lava flows separated by important bands of sediments.

*Correlation of the Purcell Series and Galton Series by Schofield.*

| Galton series of the Galton range of the Rocky Mountain system. | Purcell series of the Purcell range. |
|---|---|
| Roosville.<br>Phillips. | *absent.*<br>*absent.* |
| Gateway. | Gateway. |
| Purcell Lava. | Purcell Lava. |
| Siyeh. | Siyeh. |
| Wigwam.<br>MacDonald.<br>Hefty.<br>Altyn. | Kitchener.<br><br>Creston.<br>Aldridge. |

[1] Daly, R. A., Geol. Surv., Can., Mem. No. 38, 1913, table VIII, p. 178.
[2] Daly, R. A., Geol. Surv., Can., Mem. 38, 1913, p. 62.

A comparison of the above correlation tables shows marked differences. These differences primarily depend upon the position assigned to the Purcell Lava in the stratigraphy of the Purcell series. In a previous paragraph of this chapter (page 24) evidence is presented to show that the Purcell Lava occurs above the Moyie formation and not below it as Daly has postulated. The position of the Purcell Lava above the Moyie formation equates the Moyie and the Siyeh formations which are lithologically similar. The name Siyeh thus replaces Moyie in the stratigraphy of the Purcell series. The Kitchener is correlated with the formations between and including the Altyn and Wigwam because the Kitchener is correlated with the Wallace which is equivalent to the Newland. The Newland and the Altyn both contain *Beltena danai*.

*Correlation of Purcell Series with Coeur d'Alene Series.*

The correlation, as made by Walcott and Calkins, of the members of the Coeur d'Alene series with the Purcell series, was based upon Daly's subdivision of the Purcell series, which was subsequently found to be erroneous. The writer in 1911, carefully examined the formations in the Coeur d'Alene district and was able to identify in that region with some degree of certainty, the formations exposed in East Kootenay. The following table shows the writer's conception of this correlation.

| Coeur d'Alene Series. | | Purcell Series. | |
|---|---|---|---|
| Striped Peak. | 1000 | Siyeh (lower part). | 2000 |
| Wallace. | 4000 | Kitchener. | 4500 |
| St. Regis.<br>Revett.<br>Burke. | 1000<br>1200<br>2000 | Creston. | 5000 |
| Prichard. | 8000 | Aldridge. | 8000 |

The following correlation table is based on Walcott's original table,[1] with additions by the writer, on the results of

[1] Walcott, C. D., Bull., G.S.A., Vol. 17, 1906, p. 17.

field work in the Pre-Cambrian of Idaho and British Columbia. The controversy centres around the age of the Siyeh limestone which is one of the most important horizon markers in the Beltian.

The evidence for the determination of the Siyeh limestone as Middle Cambrian, by Daly, on stratigraphical and lithologic bases, is given in part by these words:

"Walcott recognizes the Cambrian-Ordovician equivalent of McConnell's Castle Mountain group as occurring near Belton, Montana, and Nyack creek, Montana. At these localities, massive bluish and greenish limestones, bearing a species of *Raphistoma* and *Stromatoporoid* form, were found in great development. As shown by Plate 6 of Walcott's paper, the field habit of these limestones is extremely similar to that of the Siyeh limestone at Mt. Siyeh, which is less than 15 miles distant from the Nyack Creek locality. It is difficult to avoid the suspicion that these Castle Mountain limestones are, in truth, identical with the Siyeh limestone in which, therefore, Middle Cambrian fossils may at some future time be discovered."[1]

The discovery of very early Middle Cambrian fossils in the Burton formation 3,535 feet above the Siyeh formation, points out that the Siyeh limestone cannot be Middle Cambrian and since the Siyeh formation occurs below the unconformity which exists between the Pre-Cambrian and the Cambrian in the Rocky Mountain geosynclinal, it is concluded that the Siyeh is Pre-Cambrian in age.

This conclusion is supported by Walcott in the following words:

"The series of limestones at the head of Nyack creek illustrated by Plate 6, are of Cambrian or Ordovician age, as indicated by fragments of fossils that I found in them. I do not think the Siyeh limestone is to be correlated with them nor with the Castle Mountain limestones of McConnell."[2]

---

[1] Daly, R. A., G.S.C., Memoir 38, 1913, p. 183.
[2] Walcott, C. D., G.S.C., Bull., Vol. 17, 1906, p. 19.

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*General Correlation Table by*

| Clark and Lewis range 49th Parallel. | Rocky mountains, B.C. | Purcell range, B.C. | Coeur d' |
|---|---|---|---|
| R. A. Daly, G.S.C. Mem. 38, 1913, p. 97. | The correlation of these two series by the author is based on sections described by Daly (G.S.C., Memoir 38, 1913) and subsequently modified by the author. | | F. C.<br>Prof. F |
| | Lowest Middle Cambrian | | |
| | Unconformity. | | |
| Erosion surface. | Roosville, 1,000 feet. | | |
| | Phillips, 500 feet. | Erosion surface. | |
| Kintla, 800 feet.<br>Sheppard, 600 feet. | Gateway, 2,025 feet. | Gateway, 1,000 feet. | |
| Purcell Lava. | Purcell Lava. | Purcell Lava. | Erosion s |
| Siyeh, 4,100 feet. | Siyeh, 4,000 feet. | Siyeh, 4,000 feet. | Striped p |
| Grinnell, 1,600 feet.<br>Appekunny, 2,600 feet. | Wigwam, 1,200 feet.<br>MacDonald, 2,350 feet.<br>Hefty, 775 feet. | Kitchener, 4,500 feet. | Wallace, |
| Altyn, 3,500 feet. | Altyn, 650 feet. | | |
| | | Creston, 5,000 feet. | St. Regis,<br>Revett, 1<br>Burke, 2, |
| | | Aldridge, 8,000 ± feet. | Prichard, |

*n Table by Schofield.*

| Coeur d'Alene district, Idaho. | Cabinet range, Montana. | |
|---|---|---|
| F. C. Calkins, U.S.G.S., Prof. Paper 62, 1908, p. 25. | F. C. Calkins, U.S.G.S., Bull. 384, 1909, p. 40 | |
| | | Cambrian. |
| | Erosion surface. | Pre-Cambrian. (Beltian). |
| Erosion surface. | Shales and sandstones 10,000 feet. | |
| Striped peak, 1.000 feet. | Striped peak, 2,000 feet. | |
| Wallace, 4,000 feet. | Blackfoot, 5,000 feet. | |
| St. Regis, 1,000 feet.<br>Revett, 1,200 feet.<br>Burke, 2,000 feet. | Ravalli, 8,000 feet. | |
| Prichard, 8,000 feet. | Prichard, 10,000 feet. | |

## *PALÆOZOIC FORMATIONS OF THE PURCELL RANGE.*

### General Statement.

The Palæozoic formations occurring in the Purcell range belong to the Devonian and Carboniferous horizons. On the geological map they are grouped together, as it was impossible to separate them in the field. In the text these two subdivisions are described separately; the Devonian is tentatively called the Jeffersc . limestone, and the Carboniferous the Wardner formatio

### Jefferson (?) Limestone.

*Distribution.*—The Jefferson (?) limestone probably includes all of the two areas of Palæozoic formations shown on the geological map as occurring on Gold creek. Only two areas of sufficient size to be mapped were found in this locality, although numerous smaller patches occur. It is also probable that the most westerly portion of the Palæozoic formations shown in the vicinity of Wardner belongs to the Jefferson (?) limestone. This determination is based purely on lithological and stratigraphical grounds.

*Thickness.*—The base and the top of the formation were not exposed in the area of reconnaissance, where the thickness was 150 feet.

*Lithology.*—The Jefferson (?) limestone consists mainly of massive to thin-bedded siliceous limestones weathering grey. The weathered surf : is also rough to the touch. The more sandy members are usually thin-bedded and weather a light chocolate brown. Near the contact with the underlying Gateway formation the Jefferson (?) limestone is composed of brecciated and recemented sandy limestone.

*Relation to Older Formations.*—The Jefferson (?) limestone in the Purcell range rests with concordance of dip and strike upon the Gateway, Purcell Lava, and Siyeh formations of Pre-Cambrian age. The contact with these formations was carefully examined in numerous localities and from the following observations a disconformity is believed to exist between the Jefferson (?) limestone and the Purcell series:

(1) The Jefferson (?) limestone rests in patches of from one foot to many thousands of feet in diameter upon different stratigraphic horizons.

(2) The base of the Jefferson (?) limestone consists of sandy limestone.

(3) The non-occurrence of the formations, Phillips, Roosville, Elko, and Burton between the Gateway formation, and the Jefferson (?) limestone suggests an erosion period between the Jefferson (?) limestone and the Purcell series.

The only other probable explanation of this occurrence of Jefferson (?) limestone with such contact relations with the Pre-Cambrian is that the limestone represents small masses of what once was a large and continuous overthrust fault block of Jefferson (?) limestone and younger formations.

The objections to the last interpretation of the phenomenon are as follows:

(1) There is an absence of crushing and shearing at the contact of the two formations.

(2) No rolling nor bending of the beds of the overthrust limestones were seen.

*Age and Correlation.*—The age and correlation of the Jefferson (?) limestone based on the fossil contents of the limestone were determined by Dr. Kindle as follows: "The collection comprises two lots. The lot marked No. 2 includes 2 species:

1. *Atrypa reticularis.*
2. *Spirifer piononensis.*

Lot Adg. is represented by the following species:

1. *Stropheodonta.* sp. undet
2. *Schizophoria.* cf. *striatula.*
3. *Orthothetes chemungensis* var *arctostriatus.*
4. *Spirifer piononensis.*

"The two lots represent the same fauna and are of Devonian age. It is probable that the formation from which this fauna came is an equivalent of the Jefferson limestone of Montana, but the present collection is not large enough to permit more than a tentative suggestion of this correlation. There is no question, however, regarding the Devonian age of the fauna."

## Wardner Formation.

*Distribution.*—The Wardner formation forms the eastern portion of that Palæozoic area which occurs on the eastern slope of the Purcell range between Rampart station on the Canadian Pacific railway and Plumbob creek, a tributary of the Kootenay river. As mentioned in describing the distribution of the Jefferson (?) limestone, the western part of this area may be Devonian in age. Good exposures of the Wardner formation are to be found in the rock cuts along the railway in the vicinity of Wardner. Limestone similar to that of the Wardner formation is reported by McEvoy as occurring in the Kootenay valley, east of Wardner.[1]

*Thickness.*—Since the Jefferson (?) limestone and the Wardner formation were not differentiated, the thickness of the Wardner formation cannot be given with any certainty. It is roughly estimated at 1,000 feet.

*Lithology.*—The staple rock of the Wardner formation consists of grey, crystalline limestone, weathering grey, in bdse from a fraction of a foot to 4 feet in thickness. Some of the limestones are bluish on fresh fracture and are characterized by chert nodules.

*Relation to Older Formations.*—The base of the Wardner formation was not determined in the Purcell range and all the limestones around Wardner have been grouped on the map under Devono-Carboniferous limestone. It is thought that the Devonian and Carboniferous are conformable, since no unconformity was noted in the limestone area around Wardner and since, also, the Carboniferous limestone and the Devonian limestone in the Rocky mountains to the east, form a conformable series.

*Relation to Younger Formations.*—The Wardner limestone is overlain unconformably by the unconsolidated gravels, clays, and sands of the Pleistocene within the area of reconnaissance.

[1] Jas. McEvoy, Geol. Surv., Can., Ann. Rept., Vol. XII, 1899, p. 84A.

*Age and Correlation.*—The following fossils collected from the immediate vicinity of Wardner were identified by Dr. P. E. Raymond:

*Camarophoria explanata* (McChesney).
*Camarotoechia* cf. *C. metallica* (White).
*Composita madisonensis* (Girty).
*Cleiothyrdina crassicardinalis* (White).
*Spirifer* cf. *S. centronatus* (Winchell).
*Productella cooperensis* (Swallow).

The above fossils point to a Mississippian age (Lower Carboniferous), for the Wardner formation.

## *THE PURCELL SILLS.*

### Distribution.

The name Purcell sills is given to that group of tabular intrusive bodies in the Purcell range, which were injected between the horizontal strata of the Purcell series and were later tilted into their present positions. These sills are present in greatest abundance in the Aldridge formation and occur occasionally in the Creston and Kitchener formations. The Purcell sills have a wide distribution in East Kootenay and Idaho since the Aldridge formation, and its equivalents in Idaho, occupy extensive areas. In East Kootenay, the sills can be seen to advantage in the valley walls which enclose St. Mary lake. In this locality, both normal gabbro, and differentiated sills are exposed. Along the Crowsnest branch of the Canadian Pacific railway, the Aldridge quartzites are crossed between Cranbrook and Curzon junction and in them many sills occur. At Wattsburg station, an easily accessible point, two normal gabbro sills show the method of intrusion and the relation of the sills to the enclosing sediments. On the same railway between Goatfell and Creston stations, many sills are exposed in the rock-cuts. About one mile west of Kitchener station, occurs a sill with basic upper and lower contact zones and an acid interior. Numerous large basic sills are found along the International Boundary line between the crossings of the Yahk and Moyie rivers. On the eastern slope of the first longitudinal valley west of Kingsgate on the International Boundary, outcrop the "Moyie sills." All the sills are not mapped owing to their number and sinuosity of outcrop and the limited time at the writer's disposal. They vary in thickness from 2 to 2,000 feet, and being more resistant to weathering agencies than the stratified rocks which enclose them, usually form steep cliffs which are conspicuous features in the topography of the country.

## Lithology.

The rocks which constitute the Purcell sills vary in composition from a hypersthene gabbro to a very acid granite or granophyre with intermediate members between these two extreme types. The texture of the sill rock varies from fine-grained to porphyritic. The granophyre is always associated with the gabbro and occurs at or near the upper contact of the sills. The thickness of the granophyre which grades downwards into a hornblende gabbro, bears no relationship to the thickness of the sill. In some cases, where the granophyre is not at the upper contact, it grades upwards into a quartz diorite and finally into a gabbro.

Before proceeding to the general discussion as to the origin and distribution of the granophyre in the sills, a description of the three main rock types will be given. It must be remembered, however, that all three types pass into each other by gradual transition.

### *Gabbro.*

The most basic type of gabbro, hypersthene gabbro, is a dark grey, crystalline rock of granitic texture, in which can be detected plagioclase and augite. The rock is quite fresh, the feldspars being clear and glassy, a feature very rare in the basic rocks of East Kootenay. Under the microscope, the essential constituents of the gabbro are seen to be labradorite and pyroxene. The labradorite occurs in lath-shaped individuals, which show carlsbad, pericline, and albite twinning. Filling the interstices between the labradorite crystals occurs the pyroxene, which is of two varieties, hypersthene and augite. The augite is colourless and without pleochroism. Uralitization is common in all stages in this rock; in many cases crystals of hornblende occur with a core of augite. When the secondary hornblende is in contact with the labradorite it has the characteristic pleochroism, greenish-blue parallel to **c**, strong green parallel to **b**, and pale yellowish-green parallel to **a**. This is worthy of notice as nearly all the hornblende in the hornblende gabbro is of this type and it also strongly supports the theory that all the hornblende is secondary in origin. An occurrence of similar nature has been described by C. H. Warren[1]. The hypersthene is about equal in amount to the augite and is characterized by a faint pleochroism parallel to **c**. It very frequently shows signs of alteration to hornblende. In one instance, the hypersthene appears to have changed to a fibrous hornblende, which in turn was changed to a compact hornblende.

The accessory constituents are small in amount and consist of magnetite in irregular grains and apatite in long, colourless, idiomorphic crystals. One allotriomorphic crystal of quartz was present in the slide examined. The secondary minerals consist chiefly of fibrous and non-fibrous hornblende. Sericite occurs as dust-like particles in the feldspars.

The structure of the rock is ophitic in which the femic constituents fill the interstices of the lath-shaped labradorite crystals.

A chemical analysis by M. F. Connor, of a typical specimen of hypersthene gabbro, is as follows:

| | | | |
|---|---|---|---|
| $SiO_2$ | 50·36 | $CaO$ | 11·50 |
| $TiO_2$ | 0·90 | $Na_2O$ | 2·54 |
| $Al_2O_3$ | 13·63 | $K_2O$ | 0·75 |
| $Fe_2O_3$ | 2·22 | $H_2O+$ | 0·05 |
| $FeO$ | 8·38 | $H_2O-$ | 0·71 |
| $MnO$ | 0·20 | $P_2O_5$ | 0·07 |
| $MgO$ | 8·67 | | |
| | | | 99·98 |

S. G. 2·970

[1] Warren, C. H., Am. Jour. Sci., Vol. 26, 1908, p. 469.

The norm calculated from this analysis is as follows:

| | |
|---|---|
| Orthoclase | 4·44 |
| Albite | 20·96 |
| Anorthite | 23·63 |
| Diopside | 26·97 |
| Hypersthene | 9·86 |
| Olivine | 8·16 |
| Magnetite | 3·24 |
| Ilmenite | 1·67 |
| | 98·93 |
| Water | 0·76 |
| | 99·69 |

Hence in the quantitative classification the rock is salfemic, perfelic, docalcic, presodic; and is, therefore, auvergnose.

The following table shows the chemical relationship of the hypersthene gabbro to other gabbros:—

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $SiO_2$ | 50·36 | 49·50 | 49·38 | 51·68 |
| $TiO_2$ | 0·90 | 0·84 | 1·19 | ....... |
| $Al_2O_3$ | 13·63 | 18·00 | 18·55 | 13·88 |
| $Fe_2O_3$ | 2·22 | 2·80 | 2·06 | 6·59 |
| FeO | 8·38 | 5·80 | 8·37 | 4·44 |
| MnO | 0·20 | 0·12 | 0·09 | ....... |
| MgO | 8·67 | 6·62 | 5·77 | 7·87 |
| CaO | 11·50 | 10·64 | 9·72 | 10·99 |
| $Na_2O$ | 2·54 | 2·82 | 2·59 | 2·93 |
| $K_2O$ | 0·75 | 0·98 | 0·68 | 0·81 |
| $H_2O+$ | 0·05 | ....... | ....... | 0·74 |
| $H_2O-$ | 0·71 | ....... | ....... | ....... |
| $P_2O_5$ | 0·07 | 0·28 | 0·16 | ....... |
| | 99·98 | 98·40 | 98·56 | 99·93 |
| S. G. | 2·970 | | | |

1 Hypersthene gabbro of Purcell sills.
2. Average analysis of all gabbros excluding olivine gabbro.[1]
3. Average analysis of all norites.[2]
4. An analysis of Karoo dolerite (olivine diabase).[3]

*Variations in the Gabbro.*—The most common variation in the gabbro is the occurrence of the hornblende gabbro, which is

[1] Daly, R. A., Proc. Am. Acad. of Arts and Sci., Vol. 45, 1900, p. 211.
[2] Daly, R. A., Proc. Am. Acad. of Arts and Sci., Vol. 45, 1900, p. 211.
[3] Hatch and Corstorphine, Geol. S. Africa, p. 232.

believed to be formed from the hypersthene gabbro by metamorphism. In this gabbro, the pyroxenes are entirely absent and as a femic constituent occurs a fibrous hornblende with the characteristic pleochroism bluish-green parallel to **c**, strong green parallel to **b**, and pale yellowish-green parallel to **a**. Also, these hornblendes contain inclusions of magnetite in irregular form. This hornblende is identical with that described above as being formed from augite and hypersthene and hence is considered secondary. In the hornblende gabbro, quartz is more abundant and with micropegmatite occasionally occurs as interstitial material. Epidote and calcite are present as products of deep-seated metamorphism of the feldspars. An analysis of this variety is given by Daly[1] who regards it as a primary hornblende gabbro.

| | | | |
|---|---|---|---|
| $SiO_2$ | 51·92 | $Na_2O$ | 1·38 |
| $TiO_2$ | 1·83 | $K_2O$ | 0·47 |
| $Al_2O_3$ | 14·13 | $H_2O+$ | 0·10 |
| $FeO_3$ | 2·97 | $H_2O-$ | 1·07 |
| FeO | 6·92 | $P_2O_5$ | 0·04 |
| MnO | 0·14 | $CO_2$ | 0·06 |
| MgO | 8·22 | | 100·78 |
| CaO | 11·53 | S. G. | 3·000 |

The norm of the hornblende gabbro is:—

| | |
|---|---|
| Quartz | 6·78 |
| Orthoclase | 2·78 |
| Albite | 11·53 |
| Anorthite | 30·86 |
| Diopside | 21·07 |
| Hypersthene | 19·44 |
| Ilmenite | 1·52 |
| Magnetite | 4·41 |
| Water, Carbon dioxide | 1·23 |

Hence, in the quantitative classification, the rock is salfemic, quadrofelic, percalcic, presodic.

Towards the centre of the thick sills, there are often conspicuous streaks of light coloured material in the gabbro, which generally approximates a position parallel to the upper and lower contacts of the sill. This variation—the differentiates of a later paragraph on the ore-deposits—strongly resembles the banding

[1] Daly, R. A., Am. Jour. Sci., 4th ser., vol. 20, 1905, p. 193.

in the gabbros of Skye, described by Harker.[1] The light coloured bands are pegmatitic in character and resemble segregation veins. They consist chiefly of quartz and the feldspars, orthoclase and oligoclase albite. The orthoclase occurs as intergrowths with quartz, forming micropegmatite. In this instance quartz holds the feldspar which is the reversal of the usual relations of the minerals in micropegmatite, in which the feldspars contain oriented inclusions of quartz. Masses of pure quartz are very abundant and in some cases hold needles of fibrous hornblende. This acid phase strongly resembles the composition of the granophyre described above, although it is coarser in texture, holds no biotite, and is richer in plagioclase. The similarity between the acid bands and the granophyre suggests the idea that they have the same origin.

A basic phase of the pegmatoid gabbro also occurs as schlieren. It consists of long needles of hornblende with some interstitial quartz and feldspar. Under the microscope it is seen that the apparent order of crystallization is the reverse of that holding in the case of the hypersthene gabbro which has an ophitic texture. In the basic pegmatoid variety, the hornblende, which is here compact and evidently primary, tends to idiomorphic outlines against the andesine. A little orthoclase and calcite are the accessory constituents, while the secondary minerals consist of epidote and calcite.

The contact between the two phases of the pegmatoid gabbro is generally gradational but has been observed to be quite sharp, like an igneous contact.

In one instance a dyke of aplite was found, which distinctly cut the basic gabbro, but was confined to the sill and apparently occurred near the upper contact of the sill. Microscopically, the essential constituents of the aplite are quartz and micropegmatite in which the quartz of the latter contains oriented inclusions of orthoclase. The latter mineral is usually clouded with a great number of sericite particles. The fibrous hornblende exhibits the pleochroism : **c**, bluish-green, **b**,

[1] Harker, A., Mem. Geol. Sur. of the United Kingdom, 1904, pp. 90–92, 117, 121.

strong green, a, yellowish-green, and thus resembles the secondary hornblende described above.

Again, in the interior of the basic sills there occurs a granitic phase, the acid differentiates, in irregular masses with gradational boundaries with the surrounding gabbro. This phase consists of long needles of hornblende enclosed in a groundmass of micropegmatite. The microscope shows that this hornblende is identical in optical properties with the secondary hornblende described above, but in this case, transformation of the augite into hornblende is complete. The hornblende has a distinctly shredded appearance and minute needles of it occur throughout the other mineral constituents. The micropegmatite, which forms the groundmass, consists of quartz containing oriented inclusions of orthoclase, charged with a great number of microscopic hornblende needles. Large masses of quartz occur which are usually, but not always, free from inclusions. Apatite in long needle-like crystals, and magnetite form the accessory constituents. This phase is believed to be a variation of the acid member of the banded gabbro.

Associated with the basic sills and sometimes with the banded gabbros, are small irregular dykes of aplite, which consist almost entirely of plagioclase and quartz in varying proportions, with minor amounts of calcite. With a decrease in calcite and plagioclase these dykes pass into quartz veins which represent the extreme differentiate of the gabbro magma. Associated with all these variations occur sulphides of iron and copper.

### *Quartz-Diorite or Transition Rock.*

With an increase in quartz and micropegmatite, the gabbro gradually passes into quartz-diorite which forms the transition type between the gabbro and the granite. The quartz-diorite is of a light greyish-green colour, and, in the hand specimen, shows quartz, feldspar, hornblende, and biotite. Under the microscope, the shredded hornblende is seen to have the same pleochroism occurring in the hypersthene gabbro as the secondary hornblende described as **c** bluish-green, **b** dark green, **a** yellowish-green, and is embedded in a groundmass of quartz and micropegmatite. In the latter, the quartz holds the feldspar which is clouded with a great number of dust-like inclusions. Plagioclase—andesine to labradorite—is rather plentiful, while biotite, in small plates, is present sporadically throughout the rock. Chlorite and zoisite occur as secondary minerals. The following analysis is given by Daly[1]:

| | |
|---|---|
| $SiO_2$ | 52·63 |
| $TiO_2$ | 0·62 |
| $Al_2O_3$ | 16·76 |
| $Fe_2O_3$ | 2·86 |
| $FeO$ | 10·74 |
| $MnO$ | 0·38 |
| $MgO$ | 4·33 |
| $CaO$ | 6·17 |
| $Na_2O$ | 1·41 |
| $K_2O$ | 2·29 |
| $H_2O+$ | 0·12 |
| $H_2O-$ | 1·17 |
| $P_2O_5$ | 0·33 |
| $CO_2$ | 0·10 |
| S. G. | 2·954 |

The norm of the quartz diorite is:

| | |
|---|---|
| Quartz | 9·72 |
| Orthoclase | 13·34 |
| Albite | 12·05 |
| Anorthite | 28·63 |
| Corundum | 1·53 |
| Hypersthene | 26·51 |
| Ilmenite | 1·23 |
| Magnetite | 4·18 |
| Apatite | 0·62 |
| Water } Carbon dioxide } | 1·39 |
| | 99·20 |

Hence, in the quantitative classification, the rock is dosalic, quadrofelic, docalcic, sodipotassic.

*Granite.*

The quartz diorite, with a decrease in hornblende and plagioclase and an increase in quartz and micropegmatite, gradually passes into granophyre, which occurs at or near the upper con-

[1] Daly, R. A., Festschrift zum siebzigsten Geburtstage von H. Rosenbush, 1906, p. 217.

tact of the sills, and in such sills the distribution of the materials resembles closely that of the laccoliths of Shonkinsag and Square butte[1]. The thickness of the granite bears no relation to the thickness of the sill, for cases will be cited below where sills 140 feet thick contain a large amount of granophyre, while other sills, in the same section, 900 feet in thickness, are entirely basic.

In the hand specimen, the granophyre is a fine-grained, holocrystalline to porphyritic rock of pinkish-grey colour, in which can be identified biotite, quartz, and feldspar. Under the microscope, are seen the essential constituents, quartz, biotite, and micropegmatite, with the accessory constituents, microperthite, and plagioclase, probably andesine. The rock is very quartzose, the quartz occurring in large irregular masses associated with micropegmatite, in which the quartz holds the orthoclase. The latter is filled with dust-like inclusions and is generally scattered evenly throughout the quartz in small round masses which extinguish simultaneously. Again, the orthoclase is only seen in the peripheral parts of the quartz, while the centre is quite free from such inclusions. Plagioclase, andesine to labradorite, is present in small amounts. Biotite is very plentiful and occurs in irregular plates having an average diameter of 0·25 mm. Muscovite is present very sparingly and has a rod-like form. Magnetite, titaniferous magnetite in irregular masses, apatite in idiomorphic crystals, together with very minute crystals of garnet, complete the mineralogy of the granophyre.

The analysis of the granophyre given in Column 1 is taken from Daly's paper,[2] "The Secondary Origin of Certain Granites." The analysis given in Column 2, is the average analysis of granites of all periods by Osann and Clarke, given by Daly.[3]

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[1] Pirsson, L. V., U.S.G.S., Bull. 237, p. 43.
[2] Daly, R. A., Am. Jour. Sci., 4th ser., vol. 20, 1905, p. 193.
[3] Daly, R. A., Proc. Am. Acad. of Arts and Sci., Vol. 45, 1910, p. 219.

| | 1 | 2 |
|---|---|---|
| $SiO_2$ | 71·69 | 69·92 |
| $TiO_2$ | 0·59 | 0·39 |
| $Al_2O_3$ | 13·29 | 14·78 |
| $Fe_2O_3$ | 0·83 | 1·62 |
| FeO | 4·23 | 1·67 |
| MnO | 0·09 | 0·13 |
| MgO | 1·28 | 0·97 |
| CaO | 1·66 | 2·15 |
| $Na_2O$ | 2·48 | 3·28 |
| $K_2O$ | 2·37 | 4·07 |
| $H_2O+$ | 0·14 | 0·78 |
| $H_2O-$ | 1·31 | |
| $P_2O_5$ | 0·07 | 0·24 |
| $CO_2$ | 0·13 | |
| | 100·16 | 100·10 |
| S. G. | 2·773 | 2·660 |

The calculation of the norm of the granite gives the following results:—

| | |
|---|---|
| Quartz | 39·90 |
| Orthoclase | 13·90 |
| Albite | 20·96 |
| Anorthite | 8·34 |
| Corundum | 4·59 |
| Hypersthene | 9·14 |
| Magnetite | 1·16 |
| Titanite | 1·22 |
| | 99·12 |

Hence, in the quantitative classification, the rock is of class persalane, order columbare, rang albachase, and subrang albachose.

## Internal Relations.

The folding and faulting, to which the sills have been subject, are evidenced by the attitude and the distribution of the sills now exposed in the Purcell range. As they were intruded when the strata were flat, they have suffered all the movements which have taken place in that range, so that now they form anticlines and synclines with all angles of dip from 0 to 90 degrees. The sills often end abruptly against strata which are older or younger than those holding the sills, and in some cases, the vertical displacement may be several thousand feet. Columnar jointing, perpendicular to the upper and lower contact, is especially prominent in the thick sills and is well shown in the escarpment to the north of St. Mary lake. The cross-section of the columns is a parallelogram with 2 acute and 2 obtuse angles.

The most striking phenomenon in the internal structure of the sills is a stratification of the material according to density. The stratification is of two kinds. In the example, studied with Daly on the International Boundary line, the distribution of material was: an upper gabbro zone 26 feet thick passing gradually downwards into a granitic phase 80 feet thick, which in turn gradually passed into a lower gabbro layer 30 feet thick. This type of differentiation is similar to that at Shonkinsag described by Pirsson.[1]

The other type was studied on St. Mary lake and consists of an upper granitic layer 70 feet thick passing gradually downwards into a gabbro zone also 70 feet thick. All gradations exist between the granite and the gabbro, and an arbitrarily chosen type, representing the intermediate rock between the two extremes, is called the quartz-diorite. The thick basic sills also show a rough stratification in the centre of their masses, where long schlieren of acid material are elongated parallel to the contacts of the sills. The gabbro at the contacts of these basic sills is usually fine-grained, while in the centre it is coarse-grained and pegmatitic.

## External Relations.

The exomorphic contact effects of the sills are very small, especially where the contact rock is a fine-grained argillaceous quartzite. In one case, the quartzite for an inch from the upper contact is thoroughly vitrified and charged with small needles of hornblende. Outside this narrow contact zone, the sediments are normal in character. A study of the contact under the

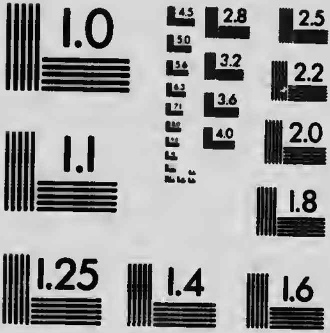
[1] Pirsson, L.V., U.S.G.S., Bull. 237, p. 43.

microscope revealed three distinct but gradational bands. The normal quartzite consists of interlocking grains of quartz 0·5 mm. in diameter. This zone passes gradually into the vitreous variety which shows no great signs of metamorphism, except a thorough cementing of the quartz grains whose contact with each other is very indistinct and whose individuality was only detected by their optical orientation. Hornblende with greenish-blue pleochroism parallel to **c** and identical with the hornblende in the gabbro, is present in this vitrified band. This zone, with a gradual increase in orthoclase and plagioclase, passes into micropegmatite in which the quartz holds the feldspar, the latter being filled with dust-like inclusions of sericite. Hornblende, similar to that described above, and biotite, are sparingly present in this micropegmatite zone. As the hornblende and plagioclase become greater in amount, with a concomitant decrease in the quartz and orthoclase, the micropegmatite variety passes into the hornblende-gabbro proper. All three zones were seen in one slide taken from a specimen at the contact.

The exomorphic contact action, exhibited at the lower contact, was studied in two localities. In the Pyramid basin, a sill 150 feet thick is intruded into grey weathering quartzite and argillaceous quartzite. The latter, at the lower contact of the sill, is impregnated at a distance of one foot with hornblende, similar to that found in the sill itself. This hornblende is shredded in appearance and sometines occurs in radiating groups embedded in a fine groundmass of quartz grains. Muscovite in small needle-shaped crystals is present in moderate amounts. A fine-grained variety of the quartzite occurred at a distance of 6 inches from the lower contact, and its metamorphism resulted only in the development of a few crystals of biotite. Under the microscope, the grains of quartz, whose average size is 0·08 mm., show a pitted structure as if acted upon by a solvent. Biotite is present in a large amount. These differences in degree and kind of metamorphism of these two laminæ suggest that the texture, as well as the composition, had some influence on the contact metamorphism induced by the sill on the enclosing sediments. In the Bootleg basin, where a sill 140 feet in thickness was intruded into fine-grained, argil-

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

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laceous quartzites, the contact effects are very slight and extend for a distance of 3 feet from the upper contact. The only result, visible in a hand specimen, is a slight baking of the sediments. Under the microscope, this baking is seen to consist of a slight coalescence of the quartz grains whose average diameter is 0·09 mm. Muscovite, which, in general, is restricted to the contact metamorphosed sediments, is present in rod-like individuals. Biotite, common to all the sediments of the Aldridge formation, occurs in irregular masses 0·49 mm. in diameter.

*Summary of the Contact Metamorphism.*—The sharp line of demarcation between the sill and the sediments is worthy of notice. The very small amount of contact metamorphism induced by the intrusion is perhaps what might be expected, when the intruded rock is a fine-grained quartzite. It consists of a baking of the sediments for a maximum distance of 3 feet from the contact, with the formation of muscovite and the transference of femic constituents from the gabbro into the quartzites for a distance of one foot.

## Age of the Purcell Sills.

### *Relations of Purcell Sills to Purcell Series.*

The age of the Purcell sills can be definitely fixed in relation to the Purcell series. A preliminary examination reveals the fact that the sills were injected when the strata were approximately horizontal, for they have been folded and faulted in the same manner and to the same degree as the quartzites which enclose them. An additional proof of this conclusion is supplied by the phenomenon of stratification described above, where sills have a granitic upper portion throughout the whole upper contact. For such a phenomenon to occur, the sill at the time of intrusion must have been horizontal. The earliest folding of the region is believed to have taken place at the close of the Jurassic. Hence, the sills are pre-Jurassic in age.

The youngest formation with which the Purcell sills was seen in contact, is the Kitchener calcareous quartzites. Daly[1]

[1] Daly, R. A., Geol. Surv., Can., Memoir 38, 1913, p. 218.

described dykes and sills cutting the Siyeh formation; and since no observation is recorded of the Purcell intrusives, either dykes or sills, cutting formations younger than the Siyeh and the Purcell lava, the conclusion, that the Purcell sills have the same age as the Purcell lava, is worthy of consideration.

### *Relation of Sills to Purcell Lava.*

No field facts, except similarity of composition, were noted in the study of the Purcell range, which would definitely correlate the Purcell sills and the Purcell lava. Daly summarizes his evidence for the association of these two igneous bodies[1] thus: "The Kintla Canyon sill and dykes crop out 12 miles or more west of the Oil Creek sill, while the Swift Current Pass locality is about 20 miles from either of the other two. Thus, at each of three widely distributed localities, we have a constant association of an extrusive basaltic lava resting on the top bed of the Siyeh formation and an intrusive gabbroid sill rock thrust into the Siyeh itself. Though the vertical dykes, either feeding the visible sills or apparently independent of them, are relatively numerous in the Siyeh, no dyke or sill has yet been observed in the admirably exposed Sheppard formation. These facts, of themselves, afford good presumptive evidence that the Purcell lava proper is genetically connected with the sills and dykes. This conclusion is amply corroborated by microscopic study, which, even in the face of the great alteration of all the rocks, goes to show an essential identity of the principal minerals respectively occurring in intrusion and extrusion."

### *Age of Purcell Lava.*

Since the Purcell Lava and Purcell sills are contemporaneous, and since arguments have been advanced for the Pre-Cambrian age of the Purcell series, the Purcell sills are considered to be of Pre-Cambrian age.

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[1] Daly, R. A., Geol. Surv., Can., Memoir 38, 1913, p. 218.

*Correlation.*

In a previous chapter the Prichard[1] formation of Idaho has been correlated with the Aldridge formation of East Kootenay; hence, the sills which occur in the Prichard formation are the same series of intrusives as occur in the Aldridge quartzites of East Kootenay. This idea is also supported by the lithology and the differentiation phenomena which are identical in the sills of the two regions.

## METAMORPHISM.

The changes which have taken place since the consolidation of the sills have been great. The basic facies, as might be expected, have been most susceptible to alteration. The augite and hypersthene of the original gabbro have been altered to both the fibrous and the compact hornblende, described above, and to such an extent that most of the gabbro is now of the hornblende variety. Zoisite is especially abundant in the hornblende gabbro. The granophyre is always relatively unaltered and whatever alteration has taken place is deep seated. Zoisite is present in small amounts and represents the decomposition of the plagioclase. The orthoclase in some cases shows a partial transformation to sericite. Dynamo-metamorphic changes were absent in the sills in the region examined.

## STRUCTURE OF THE SILLS.

### *The Moyie Sills.*

One of the finest, as well as one of the most easily accessible examples of differentiated and undifferentiated sills, is exposed on the western slope of the mountain west of Kingsgate, B.C., on the International Boundary line. This section was described in some detail by Daly.[2]

[1] Calkins, F. C., U.S.G.S., Bull. 384.
[2] R. A. Daly, Summary Report, Geol. Surv., Can., 1904, p. 98A.
R. A. Daly, Amer. Jour. Sci., 4th Series, vol. 20, 1905, p. 185.
R. A. Daly, Festschrift zum Siebzigsten Geburtstage von Harry Rosenbusch, 1906, p. 203.

At the time of his work in this area, through the paucity of rock outcrops, he failed to note two bands of sediment in his Moyie sills. So, instead of one sill as Daly described, there are three sills. This new field fact, which was found by the writer in 1910, materially affects the problem of petrogenesis. In 1911, the writer guided Daly to the several important exposures and the section was again carefully studied with the results given below. The exposures are not very satisfactory and other bands of sediment may be present in sill D.

The mountain to the west of Kingsgate consists of argillaceous quartzites, belonging to the oldest known member of the Purcell series, dipping 60 degrees to the east and intruded by sills of igneous material. Sections of these sills are given in Figures 2 and 3.

*Tabular Section of the Moyie Sills. (Measured at a locality 1½ miles distant from section illustrated in Figures 2 and 3.)*

| Sills, thickness in feet. | Rock zones, thickness in feet. | Character of rock. |
|---|---|---|
| | 100+ | Sediments. |
| A, 315± | 50+<br>100±<br>165± | Gabbro.<br>Granite.<br>Gabbro. |
| | 100 | Sediments. |
| B, 525 | 310<br>215 | Granite.<br>Gabbro. |
| | 45 | Sediments. |
| C, 30 | 30 | Gabbro. |
| | 250 | Sediments. |
| D, 438+ | 138<br>300+ | Granite.<br>Gabbro. |

Sill "A," (Figures 2 and 3) the highest in the series, consists of an upper gab[illegible]ase of specific gravity, 2·96, having a thickness of 26 feet and passing gradually downwards into a granite (micropegmatite) interior whose specific gravity is 2·76. This finally gives way to a lower gabbro zone of specific gravity 2·97, about 29 feet thick. Underlying this sill occur 80 feet of argillaceous quartzites. Sill "B," of specific gravity 2·93, 30 feet in thickness, now occurs and in turn is underlain by 670 feet of quartzitic sediments. At this point sill "C" makes its appearance and has a total thickness of 910 feet, containing an upper granitic (micropegmatic) zone, 310 feet thick, of specific gravity, 2·74, passing gradually downwards into hornblende gabbro approximately 590 feet in thickness. Intervening between sill "C" and sill "D" occurs 75 feet of argillaceous quartzites. Sill "D" is 1,500

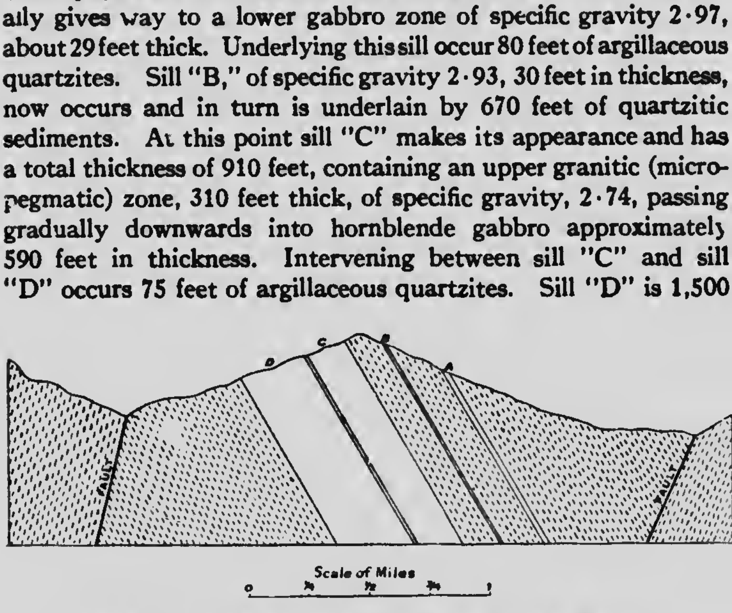


Figure 2. Natural section of Moyie sills. See also Figure 3.

feet thick, and was poorly exposed. It consists of hornblende gabbro of specific gravity, 2·99, no large mass of biotite granite (micropegmatite) being present in this sill. In the section at the Boundary line no further outcrops of gabbro were seen, but Daly, from his study of the region to the south, postulates another sill, "E", as the lowest sill in the Moyie group of sills. A summary description of the rock types mentioned above has been given under "lithological characters" and will not be repeated here. It will be noted in comparing Daly's columnar section of the Moyie sills with the one accompanying this paper, that there is a difference in the respective thicknesses of sills "C" and "D." Daly estimated his thickness in the field, while the writer obtained his results by calculation, taking into consideration the slope of the hill as well as the dip and strike of the sills.

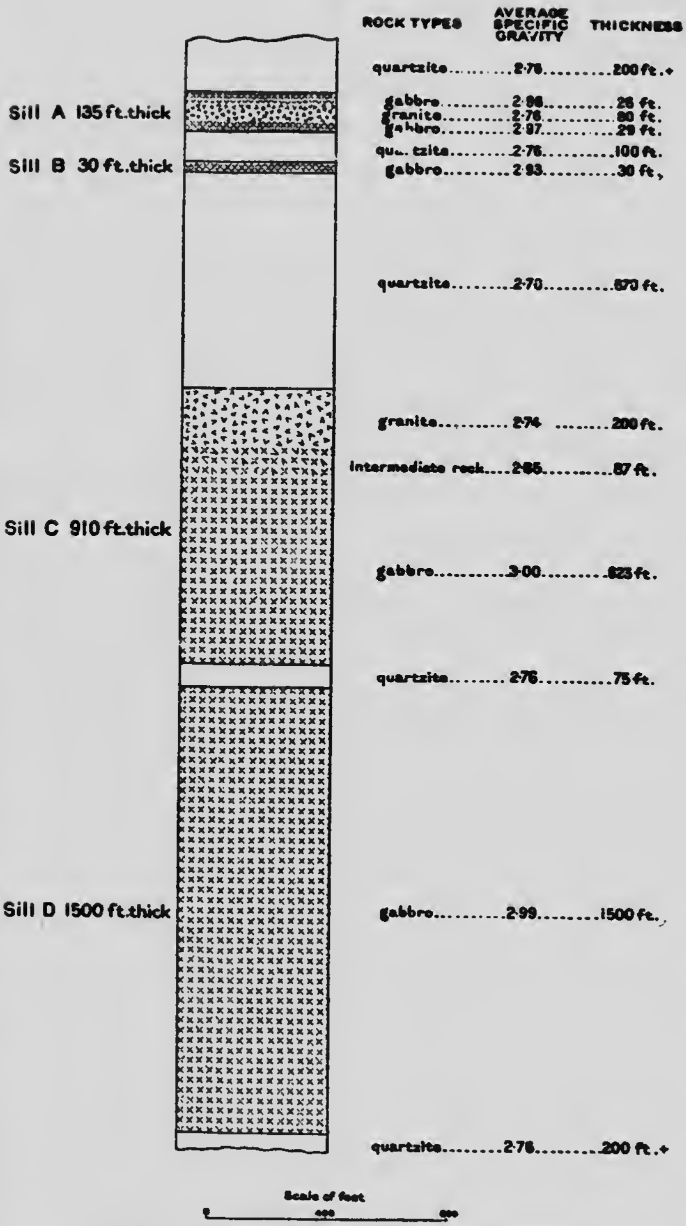


Figure 3. Columnar section of the Moyie sills.

*The St. Mary Sills.*

Intruded into the westerly dipping Aldridge quartzites, which form the mountains rising on both sides of St. Mary lake, is a series of gabbro sills which were studied in some detail. Sill "A" (See Figure 4), which apparently represents the highest one in the series, is 140 feet thick and contains an upper granite (micropegmatite) zone of specific gravity, 2·76, 70 feet in thickness, passing gradually downwards into a gabbro of specific gravity, 3·01, also 70 feet thick. Separating sill "A" from sill "B" occur 400 feet of argillaceous

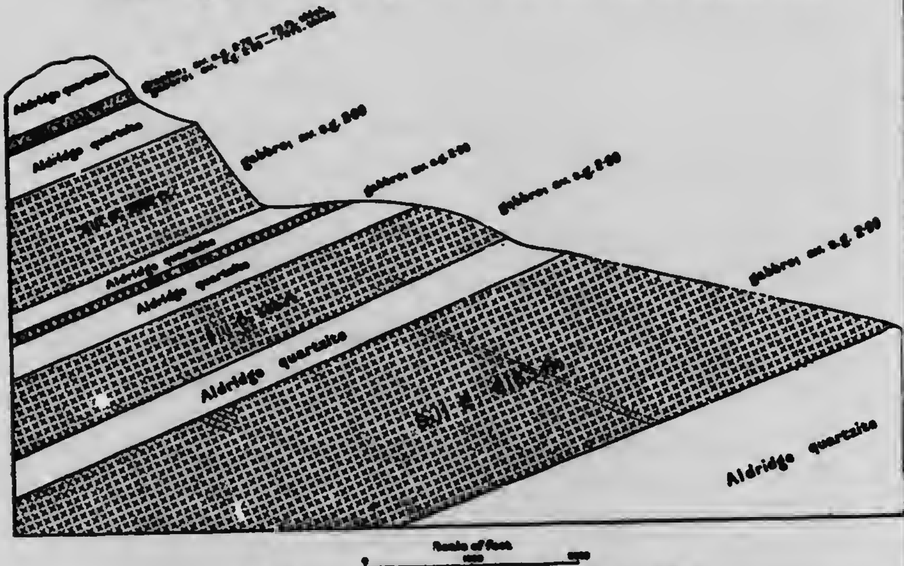


Figure 4. Natural section of the St. Mary sills.

quartzites. Sill "B", which is 985 feet thick, is composed almost entirely of hornblende gabbro. It is in this sill the hypersthene gabbro occurs which shows the transformation of augite and hypersthene into hornblende. No granitic (micropegmatitic) zone is present in this sill although here and there in the centre of the sill schlieren of acid material were observed. Sill "B" is separated from the underlying sill "C" by 200 feet of argillaceous quartzite. Sill "C" is 123 feet thick and consists entirely of hornblende gabbro. The two remaining sills observed in this section were respectively 565 and 2,165 feet in thickness, but as they were not well exposed, several bands of sediment may be contained in each of the two sills. No granite (micropegmatite) was found in these sills.

## Summary of Genesis.

The Purcell sills represent intrusions from a single intercrustal reservoir of a series of magmas—acid magmas—which gave rise to composite sills whose rock types vary in the same sill, from a granite (micropegmatite) to a gabbro; and of basic magmas which gave rise to simple sills of gabbro.

The reservoir may be assumed to have been stratified according to density, having a relatively acid portion collected in the irregularities and projections of the roof and grading downwards into more basic materials.

Crustal movements would furnish fissures which would tap this reservoir at various levels. In this way a separation of the acid and basic materials of the reservoir would occur, so that the acid and basic materials would rise through separate fissures and spread out between the strata as sills. Some exotic material was gathered up from the walls of the fissures through which they passed, and in part assimilated by the rising magmas. The magmas would also probably assimilate some of the enclosing Purcell sediments but not enough to materially affect their composition.

The simple sills solidified in the usual manner of such intrusions while the acid material differentiated under the influence of gravity giving rise to composite sills.

For a full discussion of the origin of the granite (micropegmatite) in the Purcell sills consult a paper entitled "The Origin of Granite (micropegmatite) in the Purcell sills, by S. J. Schofield."[1]

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[1] S. J. Schofield, G.S.C., Mus. Bull. No. 2, p. 1.

## *THE PURCELL LAVA.*

### Distribution.

The Purcell lava, although present in the Purcell and the Rocky Mountain systems, is restricted in its areal extent in the Purcell range to its eastern subdivision, the McGillivray range. It outcrops on Moyie mountain and the course of its outcrop is in a general southeasterly direction until it crosses the International Boundary line, forming the eastern boundary of a syncline of the Gateway formation. The Purcell lava forms also the eastern boundary of the syncline at the International Boundary line.

One of the finest sections occurs on the western slope of Baker mountain where three flows are exposed. The upper flow outcropping 50 feet from the summit, is a porphyritic-amygdaloidal basalt. Below this comes 50 feet of Siyeh, purple and green metargillites underlain by 100 feet of non-amygdaloidal, non-porphyritic basalt. The lowest flow noted consists of amygdaloidal basalt, 400 feet thick. The Purcell lava of Baker mountain extends along the eastern side of the valley of Gold creek until the transverse valley of Plumbob creek is reached where it evidently swings into the eastern part of the Kootenay valley, where it outcrops sporadically through the Glacial drift.

### Lithology.

The dominant rock of the Purcell lava is usually a highly altered amygdaloidal or porphyritic basalt. The flows are generally heterogeneous in character. The one exposed on Gold creek, about 10 miles south of Cranbrook, gave the following cross section:—

| | |
|---|---|
| Amygdaloidal basalt.................................... | 30 feet. |
| Amygdaloidal-porphyritic basalt.......................... | 25 feet approx. |
| Porphyritic basalt.......................................... | 50 " " |
| Breccia (basalt)............................................ | 25 " |

The amygdaloidal basalt is dark green to black in colour, shot through with numerous amygdules filled with quartz and, more rarely, hematite. The weathering colour is dark rusty brown. The porphyritic basalt has a greyish green colour and is remarkable for the size of the plagioclase phenocrysts (labradorite) embedded in a groundmass of labradorite and decomposed hornblende. The labradorite crystals vary in size from a fraction of an inch to 1½ inches in length and make up the greater part of the rock. All gradations exist between the amygdaloidal and porphyritic types. The lower part of the flow strongly resembles a volcanic breccia and is composed of angular and subangular masses of amygdaloidal and porphyritic basalt. Possibly, however, it is a flow breccia formed by the incorporation in the flow of solidified surface material. Very little is revealed by a microscopic examination of the lavas because they are so highly altered. The feldspar is probably labradorite and is embedded in needles of secondary hornblende, zoisite, and epidote. The amygdules are generally filled with quartz of fibrous nature with the fibres or crystals normal to the surface of the amygdules. Calcite and hematite also were noted filling the amygdules.

The following chemical analysis of the porphyritic type of the Purcell lava of the Purcell range, is given by Daly.[1]

| | | | |
|---|---|---|---|
| $SiO_2$ | 41·50 | $CaO$ | 0·97 |
| $TiO_2$ | 3·33 | $Na_2O$ | 2·84 |
| $Al_2O_3$ | 17·09 | $K_2O$ | 0·22 |
| $Fe_2O_3$ | 3·31 | $H_2O$ at 116°C. | 0·21 |
| $FeO$ | 10·08 | $H_2O$ above 110°C. | 6·99 |
| $MnO$ | trace | $CO_2$ | none |
| $MgO$ | 12·74 | $P_2O_5$ | 1·08 |
| | | | 100·36 |
| Sp. Gr. | | | 2·792 |

### Thickness.

The thickness of the flows varies from 50 to 300 feet in the Purcell range.

### External Relations.

The Purcell lava generally rests conformably on the underlying Siyeh formation, but in some cases, as in the Baker Moun-

[1] Daly, R. A., Geol. Surv., Can., Memoir 38, 1913, p. 209.

tain section, several flows occur interbedded in the Siyeh formation.

The Gateway formation rests conformably upon the Purcell lava. A detailed study on the eastern extension of the Yahk Mountain ridge exposed, gave the following section:

| | |
|---|---|
| Fine argillaceous quartzite | 10 feet |
| Fine conglomerate | 1 foot |
| Coarse conglomerate | 6 inches |
| Amygdaloidal basalt | ........ |

The upper surface of the lava is irregular, showing flow structure. Resting on this surface is a conglomerate composed of rounded fragments of fine-grained basalt in a sandy cement. The fine conglomerate also consists of volcanic material in an argillaceous cement.

### Age.

The Purcell lava was extruded on the surface of the Siyeh metargillites and since arguments have been advanced for the Pre-Cambrian age of the Siyeh formation, the Purcell lava is considered to be of Pre-Cambrian age.

## *GRANITES.*

### Distribution.

The rocks grouped under this name are very constant in mineralogical character. As shown by the accompanying map, they occupy only a very small portion of the map-area. The apparent distribution of nearly all the stocks along lines of faulting, cannot be accidental; rather it is believed that this faulting opened up the fissures through which the magma was given opportunity to rise and form the stock-like masses now exposed by erosion. The bodies are circular to elliptical in outline with flowing contacts. These stocks vary in size from 200 feet to 2 miles in diameter. An exposure of a hornblende variety of the granite is found on the road from Cherry creek to the St. Eugene Mission, about 4 miles north of the Mission. Here, it is somewhat porphyritic in character, the large phenocrysts of orthoclase being embedded in a groundmass of quartz and feldspar. At Bradfords quarry, 1 mile north of Wycliffe, a true porphyritic granite is exposed in a small cross-cutting mass, 200 feet in diameter. A micaceous variety of the granite is well exposed on the valley walls of Hall lake, where it has a surface exposure of 4

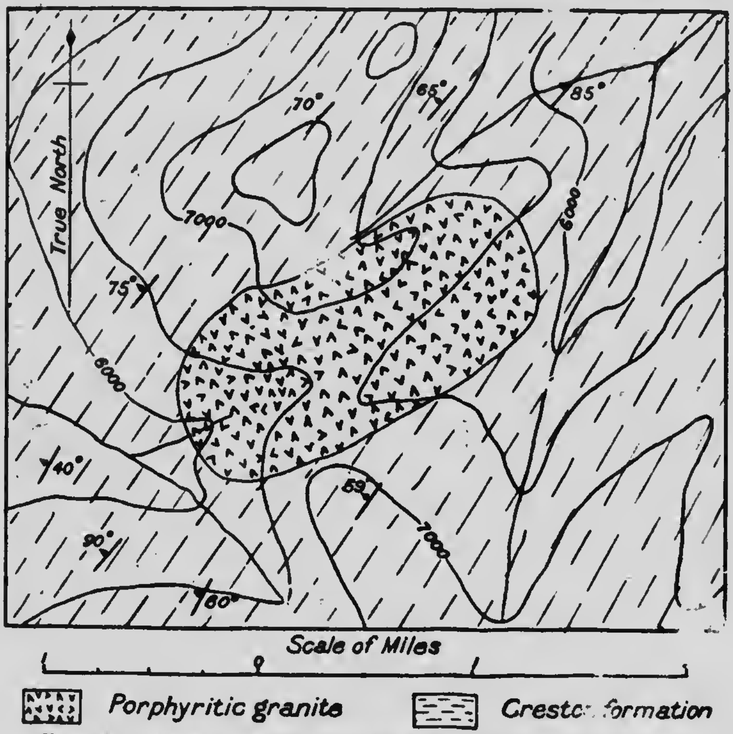


Figure 5. Granite intrusion on Hells Roaring creek. Detail showing intrusion methods.

square miles. In the ridge on the east side of the lake, the downward enlargement of the stock can be clearly seen. The methods of intrusion of these stocks were studied at the head-waters of Hells Roaring creek (Figure 5).

The apophyses related to the granite intrusion are not very numerous. They consist of the complementary rocks, aplite and lamprophyre, with a minor number of coarse pegmatites. Very frequently these dyke rocks are intruded along the bedding planes of the sediments and also cut the granite stocks themselves. The complementary dykes, which can be seen to advantage around the stock at Hall lake, are generally very narrow, having a maximum determined width of 15 feet, while some of the pegmatites are 200 feet wide and occur intruded along the bedding-planes of the quartzites. In the neighbourhood of Elko in the Elk River canyon a dyke of granite porphyry cuts the Roosville formation. The pegmatites are well exposed on the west slope of Hells Roaring creek at an elevation of 5,000 feet. The stocks increase in number and size towards the west, where the Nelson batholith occurs, with which these stocks in East Kootenay doubtless have satellitic relations.

## Lithology.

Megascopically, the granites are all light grey in colour. They are characterized by the presence of large phenocrysts of pink orthoclase feldspar. These phenocrysts are sometimes an inch in length, elongated parallel to the C axis, and in many cases show plainly the Carlsbad twinning. Quartz is very abundant and with the white coloured feldspar plagioclase, occurs in the groundmass. The femic constituents consist of either biotite or hornblende, or both in varying proportions. A more basic variety of the granite, a contact phase, in which hornblende is represented by augite, occurs in the granite at Bradfords quarry. Under the microscope the hornblende and biotite granites are seen to have a hypidiomorphic granular to a porphyritic texture. Orthoclase feldspar occurs in large amount and generally in idiomorphic crystals elongated parallel to 010. Twinning, according to the Carlsbad law, is very common in the orthoclase. The striated feldspar, which gives a maximum extinction angle of 15 degrees, by the statistical method of Michel Levy, and has a lower index of refraction than quartz, is oligoclase-albite. Zonal structure, with the more basic variety as the core, is characteristic of the plagioclases. The core is usually formed of basic oligoclase, gradually becoming more acidic towards the periphery, which is generally composed of albite. The basic core is very often decomposed. Quartz, filling the interstices of the other minerals, is abundant, especially in the biotite granite, which, by the Rosiwal method, contains 28·7 per cent quartz. Biotite, the coloured constituent of the biotite granite, occurs in plates which show strong absorption. In the hornblende granites, the hornblende occurs in hypidiomorphic crystals.

Microcline and perthite occur as accessory constituents in all the granites. Titanite is rather rare and shows its usual diamond-shaped cross-section. The following analysis of the Nelson granite, which is related to the granites of East Kootenay, is given by R. W. Brock.[1]

| $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | FeO | CaO | MgO | $Na_2O$ | $K_2O$ | $H_2O$ | $P_2O_5$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 66·46 | 0·27 | 15·34 | 1·68 | 1·83 | 3·43 | 1·11 | 4·86 | 4·58 | 0·29 | 0·08 | —99·93 |

Brock says, "The Nelson granite, which has been carefully studied, is a sort of granite representative of the monzonite group of rocks, intermediate between the alkali and the lime-soda series of rocks, and about on the boundary line between granite and diorite."

At Bradfords quarry, north of Wycliffe, the contact phase of the granite was found to be a quartz augite diorite which passes by gradual transition into the normal porphyritic granite. The orthoclase and the plagioclase, the latter with zonal growth, are in equal amounts. The femic constituent was originally augite, which has been changed to secondary hornblende. Some remnants of augite occur as cores in the hornblende crystals. The augite is non-pleochroic and has an extinction angle of 45 degrees. Titanite and apatite are quite abundant in idiomorphic crystals. Calcite, which is considered to be an original constituent, occurs filling the interstices of the other minerals. This basic phase of the granite was only noticed in contact with limestone. In contact with the quartzites, the contact phase was even more siliceous than the normal granite.

[1] Brock, R.W., G.S.C., Vol. 15, 101 A.

## Structural Features.

### *Internal.*

Brecciation and jointing are very prominent in many cases and in the granite stock at Hall lake, blocks 6 to 10 feet square cover the slope of the valley. The granite bodies, in general, are remarkable for their homogeneity. In the larger masses, which have been exposed by erosion to some depth in the magmatic chamber, no basic contact phase is present, although the contacts with the surrounding sediments are well exposed, especially at Hall lake and on Hells Roaring creek. In the case of the small intrusive mass, 200 feet in diameter, at Bradfords quarry, a well marked contact phase exists. As previously stated, the main mass consists of typical porphyritic granite, which, as the contact is approached, gives way to a quartz-augite diorite when in contact with limestone. When the granite cuts the quartzite, a fine-grained acid phase is present, which contains phenocrysts of feldspar, ranging from albite to basic oligoclase. These phenocrysts are common in the normal granite, embedded in a fine-grained groundmass of quartz and feldspar. Whether this phase is a fine-grained granite or quartzite impregnated with materials from the granite, could not be determined. The basic contact phase, described above, was coarse grained and contained calcite in such an amount and in such relations that it is believed to be either primary or to have been assimilated and recrystallized limestone from the surrounding sediment. This basic phase may be the normal condition at a horizon at this depth and may represent the original composition of, or is perhaps a little more basic than the intruding magma which cooled rather quickly along the contact. On the other hand the interior of the mass was differentiated by fractional crystallization, with the result that the alkalis and silica were concentrated in the upper part of the magmatic chamber, giving rise to the porphyritic granite, while the heavier femic constituents sank to a deeper part of the chamber.

*External.*

Granite intrusions cut the members of the Purcell series but its relation to the Mississippian limestone of the Kootenay valley is unknown. The contacts of the granite with the surrounding sediments are well exposed, and show that cross-cutting relations exist beyond doubt. Many apophyses of the granite penetrate the sediments near the contact. The contact metamorphism induced by the intrusive on the surrounding sediments is not of high order. There seems to be a gradation in metamorphism, decreasing in amount as we pass from the roof of the stock into the deeper parts of the body. Around the larger masses of granite, which in the region examined never exceed 2 miles in diameter, contact metamorphism is slight, the only visible effects on the quartzose sediments being the formation of knotted schist in an aureole around the intrusive for a distance of 500 feet. Under the microscope, it is seen that the sediments are very little affected and that the knots are composed of indeterminable collections of fine-grained dark material having no crystal outlines. In the small stocks, about 750 feet in diameter, the contact is peculiar. As mentioned above, in contact with the quartzites an aplitic phase is present, while against the limestone a basic phase, quartz-augite diorite, occurs. The limestone, in this vicinity, has been changed to a white crystalline marble, free from impurities except close to the contact, where it is charged with the contact metamorphic silicates, garnet and epidote, which at times form small veins or stringers in the marble. Associated with the garnet and epidote, are the sulphides, chalcopyrite and pyrite. The quartzites within 200 feet of the contact have been changed to a dense compact chert by infiltration of silica from the granite or by the rearrangement of the silica of the quartzites. Masses of granite smaller than 200 feet in diameter were not found, but the area of garnetiferous mica schist, described above, is believed to be the result of contact metamorphism of argillaceous quartzites by a granite intrusive, which has not been exposed by erosion or, in other words, the schist is the roof of a granite stock. From the above, it is seen that contact metamorphism has been greatest at the roof and gradually diminishes as we descend into the deeper contacts. Evidently the agents producing contact metamorphism must be in greater abundance near the roof. These agents are believed to be the volatile constituents of the magma which collect in the upper part of the magmatic chamber.

## Age and Correlation.

As the youngest sedimentary formation, with which the granites were found in contact, is Beltian (Pre-Cambrian), the age of this intrusive can only definitely be placed as Beltian or younger. In studying the relations which the granite bears to the folding and faulting, it is seen that it is younger than the chief orogenic movements which affected the region. Arguments have been advanced in a later chapter for a post-Jurassic age of these movements, hence the intrusion is probably post-Jurassic. Investigations by other workers, in adjacent districts, have thrown additional light on this complex problem. In West Kootenay, McConnell[1] found a granite similar to that of East Kootenay, cutting all the series in that region from the Shuswap crystalline complex to the Slocan slates; the latter are considered to be Pennsylvanian in age. In the Bitter-root and Clearwater mountains of Idaho, Lindgren[2] describes a porphyritic granite of a light grey colour, containing crystals of orthoclase 3 cm. in diameter, which he holds as certainly post-Carboniferous; and, as it cuts the sedimentary series on the south fork of the Clearwater river near Harpsler, which is very probably Triassic, the granite may be considered as of post-Triassic age. Again in the Silver City folio of Idaho[3], Lindgren and Drake correlate the granite intrusion in Idaho with the granites in the Blue mountains of Oregon and thus date it as post-Carboniferous and probably post-Triassic. From analogy with similar granite areas in Montana and California, this intrusion may very likely be assigned to the Cretaceous period. In his paper "The Gold Belt of the Blue Mountains of Oregon,"

[1] McConnell, R.G., G.S.C., Vol. 9, 1896, p. 19a.
[2] Lindgren, W., U.S.G.S., Prof. Paper, 27, p. 20.
[3] U.S.G.S., Geol. Atlas of U.S., Folio, No. 104, 1904.

Lindgren[1] places the date of the granite more specifically where he states "that the granite intrusion is certainly post-Triassic and pre-Neocene and is likely post-Jurassic and pre-Chico when it is compared with the intrusions in California."

## *SUPERFICIAL DEPOSITS.*

The greater part of the Cranbrook map-area is covered with drift, especially the Rocky Mountain trench and the valley of Gold creek. From their character and distribution, the records are interpreted as belonging to two glacial periods separated by a period of glacial retreat. The interglacial deposits are remarkable for their content of a flora whose modern representatives are indigenous to a climate warmer than that of the southern United States. The deposits, Pleistocene and Recent, can be subdivided as follows.

Recent.................*Post Glacial epoch.*
- Valley alluvium.
- Delta deposits.

Pleistocene..............*Wycliffe Glacial epoch.*
- Stage of glacial retreat.
  - Marysville sands.
- Stage of glacial occupation.
  - Wycliffe drift.

*St. Eugene interglacial (?) epoch.*
- St. Eugene silts.

## PLEISTOCENE DEPOSITS.

The Pleistocene deposits in the neighbourhood of the Rocky Mountain trench (Kootenay River valley) can be classified under two main heads, viz.: the Wycliffe drift named after the town of Wycliffe on the branch line of the Canadian Pacific railway from Cranbrook to Kimberley, and the St. Eugene silts named after the St. Eugene mission. A detailed section measured on the east bank of the St. Mary river about 3 miles east of Wycliffe gave the following results:

[1] Lindgren, W., 22nd Ann. Rept. U.S.G.S., Pt. 2, 1901, pp. 551-776.

**Erosion surface.**

| | | | | |
|---|---|---|---|---|
| **Recent** | **A.** | **Stratified sand** | **15 feet.** | **Marysville sands.** |

**Unconformity.**

| | | | | |
|---|---|---|---|---|
| **Pleistocene** | **B.** | **Till** | **30 "** | **Wycliffe drift.** |
| | **C.** | **Stratified silt** | **25 "** | **St. Eugene silts** |
| | **D.** | **" gravel** | **15 "** | |
| | **E.** | **" silt** | **5 "** | |
| | **F.** | **Unstratified coarse gravel (till ?)** | **25 "** | |
| | **G.** | **Stratified sandy clay fossil plants** | **60 "** | |
| | **H.** | **Stratified gravels, lignite Base unexposed** | **60 "** | |

Member A of the series consists of stratified sands deposited in quiet water which filled the depressions in the underlying glacial drift. The maximum thickness of this member is 15 feet.

Member B is true till and is unstratified. The most striking characteristic when a section is viewed at a distance, is its dark grey colour which is in marked contrast to the underlying creamy white silts and overlying slightly grey stratified sands. The boulders in the till, composed of gabbro and quartzite, are as large as 2½ feet in diameter. Member B rested with an irregular surface contact on the stratified silts.

Member C consists of creamy white silts very finely stratified and in general entirely free from pebbles.

Member D is composed of boulders of quartzite and diorite and is plainly stratified although very little sandy material is in evidence.

Member E very closely resembles member C as it consists of finely stratified creamy white silts.

Member F, 25 feet thick, consists of unstratified, very coarse gravel which strongly resembles till. The boulders which are as large as 2½ feet in diameter, consist of gabbro and quartzite. The structure, character of the pebbles, and composition of the material characterize it as true till; but, on the examination of sections of the same Pleistocene material 1½ miles east of this locality, this member was absent from the series. Whether or not this member represents a regional deposit of till, can only be decided by further work in the Kootenay River valley where the Pleistocene is well exposed in the river banks.

Member G consists mainly of finely stratified silts and clay with some gravel. The more clayey members near the base contain, between the laminæ, numerous well preserved plant remains of the Pleistocene.

Member H is composed mainly of stratified gravel consisting chiefly of quartzite and quartz pebbles with a minor quantity of diorite pebbles. The pebbles are on an average two-thirds of an inch in diameter and are well waterworn. The exposed surface of the gravels has a rusty appearance and they look older than the gravels in the upper part of the section. Small seams of lignite and pieces of lignitized wood occur in the gravels associated with lenses of sand. The lower part of these gravels is unexposed in this section, but 3½ miles west on the St. Mary river in the vicinity of Wycliffe these gravels rest upon the eroded surface of the bed-rock.

## Fossil Content of the St. Eugene Silts.

The plants collected in the St. Eugene silts were submitted for identification to Mr. Arthur Hollick, whose preliminary report is as follows:

"The matrix in which the plant remains are contained is a light grey friable, sandy clay, requiring considerable care in handling. The specimens are, for the most part, comparatively well preserved, although a majority are fragmentary. The species represented are few in number as compared with the number of specimens, even if the unidentifiable fragments are included as distinct species; and two genera, *Fagus* and *Platanus*, are so numerously represented that together, they constitute about a third of the entire collection.

A systematic arrangement of the material identified is as follows:

### *Angiospermae.*

#### *Monocotyledonae.*

Fragment of a large leaf, with obscure parallel nervatio (43L).

Fragment of a stem, with well-defined longitudinal striatio (43K).

Both of these fragments are evidently monocotyledonou but they are too indefinite for either generic or family identifica tion. The leaf is somewhat suggestive of a palm or a yucc and the other fragment has some resemblance to the petio of a palm, but the characters are too superficial to be of ar diagnostic value.

#### *Juglandaceae.*

*Hicoria.* n. sp. ? (43A, 43P in part).

This is a leaf which is hardly to be distinguished from tho of one or another of our living hickories, especially certain forn of *H. glabra* (Mill.) Britton. On general principles, howeve we should probably be better justified in considering it as repr senting an extinct species.

#### *Salicaceae.*

Fragment of the lower part of a large leaf with well defin lateral primaries, provisionally identified as belonging to t genus *Populus* (43 O).

#### *Betulaceae.*

*Alnus* n. sp. ? (43 G).

This leaf is suggestive of the more orbicular leaf forms *Alnus rugosa* (Du Roi) K. Koch.

#### *Fagaceae.*

*Fagus* n. sp. (43 F, 43R).

This species is represented in the collection by a number specimens. The leaves are of large size and are well preserve

*Fagus* n. sp. ? (43 P in part).

A much smaller leaf than the latter and hardly distinguishable from the living *Fagus Americana* Sweet.

*Artocarpaceae.*

*Ficus* n. sp. (leaf) (43 E).

*Ficus* n. sp. (fruit) (43 M).

The latter specimen is the most interesting and remarkable, in the entire collection. It consists of a long slender branch, on which the sessile fruit is arranged in pairs and larger clusters. Their reference to the genus *Ficus* can hardly be questioned, and the probability is that the fruiting branch and the leaf belong to a single species, but as they are not associated in the same piece of matrix it seems best to consider them as specifically different and, in the event of describing them, to give to each a distinct specific name.

*Ulmaceae.*

*Ulmus* n. sp. ? (43 Q).

A single fragment of the base of a leaf, evidently an *Ulmus*, which might be more or less satisfactorily compared with leaf forms of certain living and fossil species, but not enough of the leaf is preserved for accurate comparison.

*Menispermaceae.*

*Cebatha* (*Cocculus*) n. sp. (43 B, 43 C, 43 D).

These three specimens differ among themselves more or less in outline and nervation, and it is possible that more than one species may be represented by them; but, if the characteristic heterophylly of the genus be taken into consideration, they may well be regarded as all belonging to one and the same species.

*Cissampelos* ? (43 N).

Fragment of a leaf, which presents some of the features characteristic of the genus, but only enough for provisional determination.

### *Platanaceae.*

*Platanus* n. sp. (43 H, 43 J).

This species is very extensively represented in the collection. Many of the specimens are very large, approximately 9 inches in width by 7 or more in length and, except for their size, are hardly to be distinguished from the deeply lobed leaf forms of the living *Platanus occidentalis* L., or the extinct *P. aceroides* Goepp.

### *Vitaceae.*

*Vitis* n. sp. ? (43 I).

This leaf is hardly to be distinguished from certain leaf forms often seen on our living *Vitis labrusca* L., and *V. riparia* Michx.; but it is considerably larger than the normal leaves of either of these species.

An analysis of these identifications indicates that at least a warm temperate climate must have prevailed in the Kootenay valley at the time when this flora was living there. The presence of the genus *Ficus* alone is sufficient evidence on this point, inasmuch as this genus is tropical, for the most part, in its distribution, and only three species range as far north as the southern United States. The other genera are so widely distributed, north and south, that, regarded by themselves, they would have but little significance as climatic indices. The prevailingly large size of the leaves, however, indicates a luxuriant growth such as would probably obtain only in a climate milder than that of the middle United States, and is corroborative of the evidence furnished by the genus *Ficus* in this respect."

## AGE AND CORRELATION OF THE ST. EUGENE SILTS.

The St. Eugene silts occur over a large area in the Rocky Mountain trench and are exposed along the cut banks of the Kootenay river at an elevation of about 2,800 feet. In the determination of the age of these silts, the following facts are known:

1. The silts are horizontal.
2. They underlie unconformably a till sheet.
3. As far as known they are not underlain by a till sheet.
4. They are well stratified and were deposited in quiet waters.
5. They contain abundant plant remains of the Pleistocene.

From these facts the silts may be: (1) pre-Glacial and post-Tertiary; (2) interglacial, the underlying till sheet having been eroded away.

The age of these silts must at this stage remain an open question as the only fact which would prevent the silts from being post-Tertiary and pre-Glacial would be the presence of a till sheet older than the silts.

In composition and thickness these silts are similar to those described by Dawson[1] and Drysdale[2] who found them near Ashcroft underlain by an older boulder clay. If this correlation be correct, the St. Eugene silts are interglacial.

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[1] Dawson, G. M., G.S.C. Ann. Rep. 1894, p. 251B.
[2] Drysdale, C. W., G.S.C., Summ. Rep. 1912, p. 150.

# CHAPTER IV.

## STRUCTURAL GEOLOGY.

The southern part of the Purcell range is a region of structural complexity, since folds, faults, and minor structures, such as fissures and joints, are very abundant and of different ages. The folds have a general north and south trend. The faulting is probably of two ages, post-Jurassic and post-Cretaceous (Laramide).

### FOLDS.

The folds, which are so common in the East Kootenay district, are the result of the first recognized deformation in the region. This conforms to the general rule that compression is the first step in the production of a mountain range. In general they are simple in character and can be recognized in the field by the direction and distribution of the strikes and dips. These folds are the result of compressive forces acting in an east and west direction. Following this movement there was a period of tension whose results are expressed in the normal faulting which followed the folding.

The Moyie range, the most westerly subdivision of the Purcell Mountain system, in general is a simple, easterly dipping monocline composed of rocks of the Aldridge formation cut off to the east by the Moyie fault. To the east of this fault, occurs the Yahk anticline, the controlling structure of the Yahk range. Its marginal portion is composed of Creston argillaceous quartzites, while its axial portion is made up of the Aldridge argillaceous quartzites. The eastern limb of the Yahk anticline is modified by the formation of the Yahk syncline whose basement, as exposed in the field, consists of Creston argillaceous quartzites while its axial portion contains lower members of the Siyeh formation. The McGillivray range, the most easterly subdivision of the Purcell system, is dominantly a shallow syncline along whose axis are exposed the lower members of the Gateway formation, while its marginal portion shows successively older members of the Purcell series including the Kitchener, Creston, and Aldridge. This syncline is cut off on the east by the Cranbrook fault, to the east of which is a monocline underlying the Kootenay valley. The eastern side of this monocline is bounded by a normal fault. This fault block contains the Carboniferous limestone, the youngest sedimentary formation in the district.

The southern part of the valley of Goat river, north of Kitchener, approximately follows the axis of a northerly plunging anticline composed of Aldridge quartzites which disappear under the overlying Creston formation about 15 miles north of Kitchener. This anticline is succeeded on the west by a shallow syncline along whose axis the Creston quartzites are exposed in a long narrow belt. On the east, the same anticline passes into a flat syncline composed entirely of Aldridge quartzites. Another fold in the Aldridge formation occurs in the vicinity of Palmer Bay creek. It also strikes in a northerly direction.

The St. Mary river which flows in an easterly direction cuts across the axis of a huge anticline of Aldridge quartzites. The structure of this anticline is complex, as it is greatly modified by minor overturned anticlines smashed and faulted. It is really a geanticline (Plate V) with the axes of the minor folds (Plate XIV) appearing in Pyramid basin and in the vicinity of Matthew creek. The southwestern limb of the anticline is marked by a fault which brings the Kitchener formation into contact with the Aldridge quartzites. The northwestern limb of the anticline passes conformably under Creston formation. The northern boundary was not explored as it lies beyond the area of reconnaissance; but it evidently passes conformably under the Creston formation. The eastern limb of the anticline passes under the stratified sands and gravels of the Rocky Mountain trench or Kootenay River valley.

## FAULTS.

The second great movement which affected the Purcell range was normal faulting, a northeast-southwest system, including the Marysville and Moyie faults and several small faults of lesser importance; and a northwest-southeast system, the chief one being the Cranbrook fault.

The Marysville fault emerges from under the stratified gravels and sands of the Kootenay River valley about 2½ miles north of Wycliffe where the Kitchener and Aldridge formations are in contact. It strikes almost due west as far as Marysville, where the fault swings towards the southeast. The fault crosses both branches of Hells Roaring creek and reaches the watershed of the Goat river where it crosses the main river about 22 miles north of Kitchener. From this point the fault is not well defined; but it apparently swings to the northwest and passes beyond the limits of exploration.

The Moyie fault enters the eastern border of the sheet about 6 miles due south of Cranbrook, where it follows the depression occupied by Peavine creek. Here, the Aldridge and Siyeh formations are in contact. It then strikes in a southwesterly direction across the head of upper Moyie lake and swings in a gentle curve towards the south, crossing the Crowsnest branch of the Canadian Pacific railway about 2 miles east of Curzon junction. From here its course is south, crossing the International Boundary line in the valley of the Moyie river at Kingsgate.

In the western part of the region a normal fault striking in a northwesterly direction brings the Aldridge quartzites and the Kitchener formation in contact. At its southern extremity, it leaves the Marysville fault on the Goat River-Hells Roaring Creek summit and is well exposed on the hill above Hall lake, as shown in Plate VI. Its northern extremity was not seen, as it is cut off by an intrusion of granite.

The Cranbrook fault follows the valley of Gold creek. Daly first recognized it on the International Boundary line, from which it was traced by the writer with one minor break north of Plumbob creek to a point about 8 miles south of Cranbrook. Field conditions farther north were unfavourable for study of this fault. The structure around this fault has been worked out only in a general way and the results obtained are purely of a reconnaissance nature. The downthrow side is on the west where the

Siyeh formation, with the associated Purcell lava flows, outcrops for the most part north of Plumbob creek, while south of this stream the Gateway formation makes an appearance resting on the Purcell lava. On the east side of the fault, the upthrow side, the Siyeh formation and associated Purcell lava flows are repeated. The Purcell lava between Connell and Plumbob creek is covered with the younger Gateway formation and with patches of Palæozoic limestone.

## Age of Faulting.

The age of faulting in the Purcell range can only be determined as post-Carboniferous and pre-Pleistocene since the faults affect the Carboniferous limestone and do not affect the Pleistocene deposits. From other considerations the faults are considered as belonging to two different periods: Jurassic and early Tertiary (Laramide). All the faults are later than the folding, which is considered to be of Jurassic age. Also the faults (except the Cranbrook fault) are genetically associated with intrusions of granite which is correlated with the Nelson granite of West Kootenay. The age of the Nelson granite is considered to be Jurassic.

The Cranbrook fault is believed to be Early Tertiary (Laramide) from the following considerations:

1. It has the Rocky Mountain trend northwest-southeast.
2. It is associated genetically with the origin of the Rocky Mountain trench, whose age is believed to date from the Early Tertiary (Laramide). This point is more fully discussed under the chapter on "Physiography."

## Regional Structure.

The Rocky Mountain geosyncline, which includes the greater part of the Selkirk, Purcell, and Rocky Mountain ranges, consists of Pre-Cambrian, Palæozoic, and Mesozoic sediments. The western border of the geosyncline passes through Coeur d'Alene and Shuswap lakes, along whose shores is exposed the old crystalline complex from which part of the above sediments was derived.

In passing westwards from the almost horizontal Tertiary and Cretaceous strata which make up the elevated plateau of the prairie provinces, we meet first the folded region of the foothills; the latter contain the most easterly evidences of orogenic movements in the Rocky Mountain geosyncline. These folds trend in a northwest-southeast direction and represent the most easterly effects of the strong compressive forces which built the Rocky mountains proper lying to the west of the foothill area. The central or eastern part of the Rocky mountains, which are made up of Palæozoic and Mesozoic strata, consists of a series of overthrust fault blocks, striking in a northwest-southeast direction and dipping to the southwest; in the western part of the Rocky mountains, anticlines and synclines of Pre-Cambrian and Cambrian rocks make up the dominant structure. The age of the orogenic movements which built the Rocky Mountain system is early Tertiary.

In passing from the Rocky mountains on the east to the Purcell range on the west, the wide Kootenay-Columbia valley is crossed. This topographic feature, which is of first importance in the structure of the region, is called the Rocky Mountain trench. The rocks which form the greater part of the Purcell range are Pre-Cambrian in age and their structure is entirely different in character from that of the Rockies. As stated above, the Purcell sediments were first folded into a series of northerly plunging anticlines and synclines. Later, these folds were truncated by normal faults which strike for the most part in a northeast-southwest direction and hence trend in a direction at right angles to those of the Rocky mountains. These movements took place in the late Jurassic. Therefore, the Rocky Mountain geosyncline has suffered two orogenic movements: one at the close of the Jurassic, which built the Selkirk and the Purcell ranges, and the other at the beginning of the Tertiary which elevated the eroded Selkirk and Purcell ranges and imparted the Rocky Mountain structure to the sediments derived from the erosion of these Jurassic mountains.

G. M. Dawson[1] first recognized the possibility of a pre-

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[1] Dawson, G. M., Trans. Roy. Soc., Can., Vol. 7, Sec. 4, p. 7.

Laramie Mountain range in the Purcell range, as shown by the following extract: "The Triassic period was closed by one of those epochs of folding and dislocation of strata which are found to be recurrent in geological time, and which are generally attributed to contraction of the earth's crust. It is highly probable that some corrugation along the line of the Rocky mountains occurred at the same period, as, in the earlier Cretaceous strata next succeeding, without further evidence of disturbance, conglomerates are found composed of fragments of many varieties of older rocks which could scarcely otherwise have been rendered subject to denudation. Though much remains to be discovered respecting this post-Triassic epoch of disturbance, it was evidently an important one and its results are widespread in the Cordilleran region. It is quite possible that it was accompanied by or resulted in producing a general elevation of this entire region above sea-level, as no rocks certainly referable to the Jurassic or next succeeding period have yet been definitely recognized either in British Columbia or in its neighbouring region." Since the time that the above was written, marine Jurassic rocks have been found in the Rocky mountains to the east. These rocks consist of black shales which conformably underlie the Kootenay formation of the Lower Cretaceous consisting of conglomerates and shales. Hence the date of the orogenic movements, which built the range, from which these conglomerates were derived, occurred probably at the close of the Jurassic. This post-Jurassic mountain range was built along the Archæan land, which supplied the material now forming the Pre-Cambrian sediments of the Purcell range, which in its turn supplied the material for the Cretaceous strata now folded and faulted along with the Palæozoic sediments of the Rocky Mountain range. The Rocky Mountain range came into existence at the close of the Upper Cretaceous or in the early Tertiary, and in its turn supplied the sediments of the flat-lying Tertiary of the plains.

# CHAPTER V.

# GEOLOGICAL HISTORY.

## Introduction.

The data for the outlining of the geological history of the Purcell range must be taken from the surrounding region as well as from the Purcell range itself, since the Purcell range is composed almost entirely of Beltian rocks. The history, previous to the deposition of the Beltian, is recorded in the pre-Beltian gneisses and schists mostly of sedimentary origin which are exposed in the Selkirk Mountain system which lies to the west of the Purcell system. This metamorphosed complex in part formed the old land from which the Beltian rocks were derived. The pre-Beltian is not exposed in the Purcell range; but it may be concluded that it forms the basement complex of the Purcell range. The earliest record of the Beltian was not found in the Purcell range, and is represented in part by the Irene conglomerates which lie unconformably upon the pre-Beltian Priest River terrane in West Kootenay.[1]

## Beltian Sedimentation.

*Aldridge Epoch.*—The earliest record in the Purcell series is one of sedimentation—the deposition of the Aldridge argillaceous quartzites. No shallow water features were noticed in the Aldridge formation, except that, in the western part of the region in the neighbourhood of Goat river, conglomerates composed of pebbles as large as 3 inches in diameter, formed an important part of the formation. The main body of the Aldridge formation was laid down in rather a shallow sea with the shore-line to the west.

[1] Daly, R. A., Geol. Surv., Can., Memoir 30, 1913, p. 141.

*Creston Epoch.*—The Creston sediments are a little more siliceous than the underlying Aldridge and since ripple marks are abundant at various horizons the sea was shallow enough for mud flat conditions to prevail. In addition, contemporaneous erosion was identified in several localities.

*Kitchener Epoch.*—The sediments of the Kitchener formation, consisting of calcareous quartzites and limestones, suggest a deepening of the Beltian sea or a lowering of the land either by erosion or subsidence.

*Siyeh Epoch.*—Towards the close of the Kitchener time, mud flat conditions over a very wide area must have prevailed. This is evidenced by the great prevalence of mud cracks and ripple marks in the lower strata of the Siyeh formation. These muds, formed in shallow water, were for short intervals of time exposed to the dry atmosphere of an arid climate. The drying of these muds developed shrinkage cracks which were later filled with coarser material carried there either by wind or water. The relative thinness of the strata separating the mud-cracked surfaces indicates probably seasonal variations from arid to pluvial conditions. This is supported by the presence of a great number of green mud-cracked shales intercalated with the chocolate or maroon coloured argillites. Towards the middle of the Siyeh epoch, a deepening of the continental sea took place during which time the limestones of the Siyeh formation were laid down. This was followed during the closing stages of the epoch by a recurrence of mud flat conditions which produced the chocolate and green coloured mud-cracked argillites of late Siyeh time.

*Purcell Lava.*—Deposition of the Beltian sediments was interrupted by the outpouring of the Purcell lava consisting mainly of basalt and small amounts of rhyolite. These flows were accompanied by the intrusion of the Purcell sills injected along the bedding planes of the previously deposited sediments especially in those formed during the Aldridge epoch. Preparation for the injection of these sills may have been made by the region as a whole being subjected to compressional stresses which aided in the raising of the strata superjacent to the sills.

*Gateway Epoch.*—Sedimentation under continental arid conditions prevailed throughout the Gateway epoch with t formation of siliceous argillites characterized by the presence ripple marks, mud cracks, and abundant salt crystals. T hopper-shaped depressions of the cubic faces, so characteris of salt crystals, are still preserved.

*Phillips Epoch.*—Although sediments of this epoch are r present in the Purcell range, there is reason for supposing th they were deposited and subsequently removed by erosi They were examined in the Rocky Mountain system at Ell B.C., located on the western edge of the Rocky mountai Since the sediments consist of chocolate brown and green san argillites earing mud cracks and ripple marks they were pr ably deposited under continental conditions.

*Roosville Epoch.*—No sediments representing this epoch present in the Purcell range. In the Rocky mountains, they mainly greenish grey, laminated, siliceous argillites, contain abundant ripple marks and mud cracks, suggesting contine conditions of deposition.

## CAMBRIAN.

In the Rocky mountains to the east, an unconformity recorded between the Roosville of Pre-Cambrian age and Burton of Cambrian age. In the Purcell range, an unc formity exists between the Devonian limestone and the Gate formation of Pre-Cambrian age. As stated above, the Phil and the Roosville formations are lacking in the Purcell ra These rocks have been eroded during the interval between Roosville and the Burton and their detritus is represented the Burton and Elko formations of the Rocky mountains. in the Purcell range there is an interval of erosion between Gateway and the Devonian which has removed the Phi and the Roosville formations, with the result that the Devo rests upon the Gateway.

## DEVONIAN-CARBONIFEROUS EPOCH.

After this period of erosion, during which time about 3 feet of strata were removed from the horizontal Pre-Camb beds, the Devonian sea spread over the eastern part of the Purcell range. The western limits of this sea cannot be defined. Similar marine conditions evidently prevailed up to and including the Pennsylvanian period. The deposits of the Devonian-Carboniferous epoch are mainly limestones with minor amounts of argillaceous and quartzose limestones.

### JURASSIC.

No record of sedimentation is present in the Purcell range during this period; but to the east the Fernie shales form a conformable part of the Palæozoic-Mesozoic series. Regarding its deposition or non-deposition in the Purcell range, no evidence has come to hand.

### LATE JURASSIC OR EARLY CRETACEOUS.

The next event recorded in East Kootenay is the folding and faulting which affected the above-mentioned horizontal sediments. The first movement was one of compression which caused the region of the Purcell range to be raised above the sea and to form an area of erosion. At this time the dominant structure of northerly striking anticlines and synclines of the range was created. This period of compression was followed by one of tension and is evidenced by the occurrence of normal faults which truncate the anticlines and synclines. The strike of these fault lines is northeast-southwest. This folding and faulting were accompanied by an intrusion of granitic magma which apparently slowly replaced the overlying sediments by overhead stoping.[1] These granitic masses occur in the neighbourhood of the main faults of the region and probably have some genetic relations to them. The uprise of the magma may have been aided by the down sinking of fault blocks, similar to that described by Clough, Maufe, and Bailey in Scotland[2]; only,

[1] Daly, R. A., Am. Jour. Sci., Vol. 15, 1903, p. 269.
—— Am. Jour. Sci., Vol. 16, 1903, p. 107.

[2] Clough, C. T., Maufe, H. B., Bailey, E. B., Q.J.G.S., Vol. 65, 1909, p. 611.

the blocks in East Kootenay would be very much larger. The age of this deformation and intrusion is placed in the post-Jurassic, for reasons given under "Structure."

Following the intrusion of granite, with no great interval of time, came the intrusion of numerous dykes of aplite and pegmatite. During the cooling stages of the granitic magma occurred the deposition of the lead-silver ores of the St. Eugene and Sullivan mines.

## Cretaceous Erosion.

After the Jurassic uplift which formed the Purcell range no record of younger sedimentation other than the Pleistocene has been found. During the Cretaceous period, erosion was ver active in wearing down the Purcell range and in depositin most of the eroded material in the Cretaceous geosyncline, whicl covered the area now occupied by the Rocky Mountain systen and the Great Plains. Erosion had proceeded so far at the clos of the Cretaceous and early Tertiary that the Purcell rang was reduced to a land of low relief or to a peneplain, which migh be called the Purcell peneplain.

## Tertiary.

In early Tertiary times, the Cretaceous geosyncline to th east of the Purcells was mountain-built with the formatio of the Rocky Mountain system. At the same time the Purce range, characterized by a rolling monotonous landscape, wa uplifted without any deformation, thus rejuvenating the stream which proceeded to entrench themselves into the Cretaceou peneplain. The valleys, now seen in the Purcell range, a due to Tertiary river erosion. The course of Gold creek i early Tertiary times, differed widely from that of to-day. Co nell creek and the West Fork and South Fork of Gold cree flowed eastwards through the outer range of hills to join t Kootenay, independently. Later, the present Gold cre eroded along the present Gold Creek valley and captured t various branches of Gold creek, leaving "Wind gaps" throu the eastern range of hills.

## QUATERNARY.

The Quaternary history may be divided into four main divisions as follows:

1. First Glacial period.
2. Interglacial period.
3. Second Glacial period.
4. Post-Glacial and present period.

The records of the first Glacial period, if ever present in the Purcell range, have been removed during the erosion periods which followed this advance of the ice. The deposition of the St. Eugene silts of the interglacial period, took place in a lake which once occupied a great part of the present Kootenay valley. The climate after the first retreat of the ice, as indicated by the plant fossils found in the St. Mary silts, was, according to Mr. Arthur Hollick, milder than that of middle United States. This period of comparative warmth was followed by another refrigeration of the whole Cordillera, and during this time the Wycliffe drift was deposited. The southern part of the Cranbrook area was covered with ice, flowing, in general, southwards. A few monadnocks like Yahk mountain projected above the general ice-level. In the country north of Perry creek the glaciation was distinctly alpine. The main movement of the ice was governed by the direction of the main valleys, the two main valleys being the Rocky Mountain and the Purcell trenches, which received tributary ice streams from the mountains on each side of these valleys.

During the time of the disappearance of this ice-sheet, the clays which lie in the depressions in the Wycliffe drift, were deposited. Later, the streams cut down their channels into the deposits of clays, sands, and gravels, giving us the present topography of the valley floors.

# CHAPTER VI.

## ECONOMIC GEOLOGY.

The Cranbrook area contains varied deposits of econor
value and nearly all of these are in the first stages of develo
ment. For the last decade this territory has been the larg
lead producer in Canada, having within its confines the No
Star and St. Eugene mines, which are now almost exhaust
and the Sullivan mine now rapidly coming to the front as a la
producer. For facility of description, the ore deposits
classified according to the nature of their final product, whi
however, has in most cases a direct connexion with the ori
of the ores. The following economic deposits are found wit
the Cranbrook area.

I. Metallic.
  (a) Silver lead.
  (b) Gold-quartz.
  (c) Gold-copper.
  (d) Iron.
  (e) Placer gold.
II. Non-metallic.
  (a) Clay.

## *MINERAL PRODUCTION OF EAST KOOTENAY.*

*(Fort Steele Mining Division.)*

| | Total production. | Placer gold. | Lode gold. | Silver. | Lead. |
|---|---|---|---|---|---|
| | $ | $ | $ | $ | $ |
| 1874 | | 50,000 | | | |
| 1875 | | 41,890 | | | |
| 1876 | | 25,000 | | | |
| 1877 | | 37,000 | | | |
| 1878 | | 25,400 | | | |
| 1879 | | 19,000 | | | |
| 1880 | | 19,500 | | | |
| 1881 | | 25,000 | | | |
| 1882 | | 29,500 | | | |
| 1883 | | 28,100 | | | |
| 1884 | | 57,862 | | | |
| 1885 | | 55,250 | | | |
| 1886 | | 50,000 | | | |
| 1887 | | 29,350 | | | |
| 1888 | | 36,350 | | | |
| 1889 | | 36,300 | | | |
| 1890 | | 37,400 | | | |
| 1891 | | 28,550 | | | |
| 1892 | | 29,700 | | | |
| 1893 | | 19,700 | | | |
| 1894 | | 24,900 | | | |
| 1895 | 17,575 | 878 | | | |
| 1896 | 154,427 | 1,054 | | 49,443 | 83,908 |
| 1897 | 163,796 | 12,000 | | 69,760 | 82,0[illegible]6 |
| 1898 | 133,308 | [illegible],000 | | 38,623 | 77,745 |
| 1899 | 64,393 | 10,000 | | 18,970 | 35,423 |
| 1900 | 2,210,151 | 10,000 | | 560,305 | 1,639,848 |
| 1901 | 1,541,969 | 12,600 | | 402,333 | 1,127,036 |
| 1902 | 200,188 | 33,000 | | 56,738 | 110,450 |
| 1903 | 61,848 | 20,000 | | 14,491 | 27,357 |
| 1904 | 1,152,487 | 20,000 | | 314,923 | 817,564 |
| 1905 | 2,712,252 | 14,160 | | 652,342 | 2,045,750 |
| 1906 | 2,940,744 | 10,400 | | 665,931 | 2,264,413 |
| 1907 | 2,321,121 | 10,000 | 124 | 509,740 | 1,801,257 |
| 1908 | 1,467,481 | 3,400 | | 322,340 | 1,141,741 |
| 1909 | 1,340,585 | 3,000 | | 283,911 | 1,039,674 |
| 1910 | 1,217,792 | 3,000 | | 254,[illegible] | 954,983 |
| 1911 | 853,122 | 3,000 | | 167,231 | 682,891 |
| 1912 | 953,728 | 2,000 | | 217,821 | 733,907 |

## *SILVER-LEAD DEPOSITS.*

### DISTRIBUTION.

The silver-lead deposits at present are by far the most in portant economic deposits in the region. They occur, with fe exceptions, associated with the Aldridge formation and with th more quartzitic phases of this group of rocks. The ores ge erally consist of an intimate mixture of the sulphides pyrit pyrrhotite, and galena, either as fissure veins or replaceme deposits in argillaceous quartzites. The gangue, usually sm in amount, includes garnet, diopside, calcite, and quartz. Wit in the Cranbrook area, two districts include most of the importa mines, the Moyie and the Kimberly districts, the former co taining the St. Eugene, Society Girl, and Aurora, the latt the Sullivan, North Star, and Stemwinder mines. Several oth deposits of minor importance occur throughout the region.

### MINERALOGY.

Under this heading will be given the minerals occurri in the silver-lead deposits, arranged according to Dana's syst of classification.

#### NATIVE ELEMENTS.

*Silver.*—Native silver occurred in the oxidized zone in t North Star mine as arborescent and reticulated aggregates cavities in limonite. It is silver white when first exposed, b tarnishes to a greyish black on exposure. The presence native silver is probably due to the general rule formulated Cooke[1] that the "enrichment of a primary silver deposit brought about by reactions of silver or its sulphides with t sulphides of iron and their products of oxidation . . . Sulphu acid and ferric sulphate" (derived from the oxidation of pyri "exert a powerful solvent action both on silver sulphide and its companion sulphides, such as galena, chalcocite, orpime

[1] Cooke, H. C., Journal of Geol., Vol. 21, 1913, pp. 1-28.

and stibnite. Of these, silver sulphide is the least affected." And further he says: "A mixture of sulphuric acid and ferric sulphate has a powerful solvent action on metallic silver . . . . Equilibrium in silver-bearing solutions between ferric, ferrous, and silver sulphates is such that the reduction of ferric solutions to the ferrous condition by any means will rapidly precipitate the silver in metallic form."

## SULPHIDES.

The sulphides of iron, lead, and zinc comprise almost the entire ore content of the silver-lead deposits.

*Galena, PbS.*—Sulphide of lead is the most important mineral, as it contains not only the lead values but the silver values as well. In general, it is the fine grained, steely variety so well known in the Sullivan ore-deposit; but, it often occurs as the coarse cubic variety which constituted the ore-bodies of the North Star and St. Eugene. In general, the galena is silver-bearing, carrying from 3 to 4 ounces of silver to one per cent of lead.

*Zinc-blende, Sphalerite, ZnS, Sulphide of Zinc.*—Sphalerite is always present in greater or less quantities in all the silver-lead deposits. In the Sullivan it is intimately associated with the fine-grained galena and iron sulphides. In the St. Eugene and the Aurora the larger part of the sphalerite is coarse in texture and of a dark brown colour. The percentage of zinc-blende varies widely in the several deposits; to such a degree is this true, that the Aurora might be classified as a zinc mine.

*Pyrrhotite, Magnetic Sulphide of Iron.*—Pyrrhotite occurs abundantly in the Sullivan and Stemwinder intimately mixed with pyrite and zinc-blende. It occurs rarely in the St. Eugene and as far as known, is absent from the Aurora.

*Iron Pyrites,* $FeS_2$*, Disulphide of Iron.*—Pyrite is widely distributed throughout all the deposits, but is especially prominent in the Sullivan and Stemwinder.

*Arsenopyrite,* $FeS_2$*,* $FeAs_2$*, mispickel.*—Arsenopyrite is a rare mineral in the silver-lead deposits and was only noted in the

Sullivan mine, where it was in the form of crystals embedded in a mixture of pyrite, pyrrhotite, and zinc-blende.

*Chalcopyrite*, $CuFeS_2$ *Copper Pyrites.* — Chalcopyrite occurs sparingly in the Sullivan and the St. Eugene, associated with the sulphides of iron.

## Sulpho Salts.

*Jamesonite*, $2Pbs$, $Sb_2S_3$, *Sulpho-antimonite of Lead.*— Jamesonite was noted only in the Sullivan mine in small stringers of calcite, which were deposited later than the main ore-body In one case it was found in a water course and appeared to b forming at the present time, and, accordingly, it is believed to b secondary in origin. Its form is always fibrous. It has a stee grey colour and a metallic lustre.

## Oxides.

*Quartz*, $SiO_2$.—Quartz occurs in small amounts in the silve lead deposits as irregular grains of glassy appearance.

*Magnetite*, $FeO$ $Fe_2O_3$, *Magnetic Iron Ore.*—Magnetite wa noted only in the St. Eugene mine, where it was associated wit garnet and actinolite. Here, apparently, the magnetite precede all the other minerals, both gangue and sulphides, in the proce of final deposition.

*Limonite*, $2Fe_2O_3$ $3H_2O$.—Limonite is commonly known brown hematite, or hydrous oxide of iron. It is a common miner in the oxidized zone of the deposits and is especially promine in the North Star and Society Girl mines, as a product of th decomposition of the sulphides of iron. In the North Star occurs as brown earthy masses coating the decomposed count rocks. In the Society Girl it occurs as a dark, brown, compa mineral associated with cerussite and pyromorphite.

## Carbonates.

*Calcite*, $CaCO_3$, *Calcareous Spar.*—Calcite occurs sparing as a gangue mineral in all the silver-lead deposits, but mo abundantly in the St. Eugene. In the Sullivan, it is found in stringers cutting the ore-bodies and was evidently formed at a period later than that of the main ore deposition.

*Cerussite, $PbCO_3$, Lead Carbonate or White Lead Ore.*—Cerussite is white and colourless, and occurs in the oxidized zone of the North Star and Society Girl mines, mainly in the form of crystals and crystal aggregates, but often compact and massive, coating the surfaces along fissures. At the Society Girl, the cerussite is often embedded in dense masses of limonite.

## SILICATES.

*Diopside, $CaMg(SiO_3)_2$, $Ca(MgFe)\ (SiO_3)_2$.*—Diopside was noticed only in the Sullivan ore-body and towards the centre of that mass. It occurs as rare, transparent, light green crystals of imperfect outline and good cleavage. The presence of this silicate links the Sullivan deposit with the contact deposits. The diopside, as one of the silicates, is among the first formed minerals in the deposit.

*Actinolite, $(Mg\ Fe)SiO_3$, a Non-aluminous Variety of Amphibole.*—Actinolite is a gangue mineral in the Sullivan and St. Eugene ore-bodies. It occurs as radiating aggregates associated with the other gangue minerals.

*Garnet.*—Manganese-bearing garnet occurs in the Sullivan-St. Eugene ore-bodies. In the Sullivan, the garnet is found as idiomorphic crystals embedded in fine-grained galena. Its crystalline form is the ordinary rhombic dodecahedron, the faces of which show striations. The crystals are transparent and of a pink colour. In the exterior sulphide zone the garnets are quite numerous, but do not show the perfection in crystallographic development as do those occurring in the interior zone. They are transparent, almost colourless, strongly resembling, in the polished surfaces, irregular individuals of quartz. The ore minerals, galena, pyrite, and pyrrhotite fill cracks in the garnet, showing that the garnets have priority in formation.

*Almandite, $Fe_3\,Al_2\,(SiO_4)_3$, Iron Alumina Garnet.*—Almandite was only noticed twice in the examination of the silver-lead deposits. In both cases, it occurred in the rocks in close proxi mity to the ore-bodies. These two occurrences are exception to the general rule that garnets of any kind are restricted to th ore-bodies and do not occur in the country rocks.

*Biotite, Magnesium Iron Mica.*—Biotite occurs generall in the exterior sulphide zone of the ore-bodie . nd in the neigh bouring country rocks in small irregular plates.

PHOSPHATES.

*Pyromorphite, (PbCl) $Pb_4$ $(PO_4)_3$, Lead Phosphate.*—Pyro morphite was found only in the oxidized zone of the Society Gi mine, where it occurs in massive forms in barrel-shaped aggre gates, and in crystals with a high degree of crystal developmen There are two varieties distinguished by their colour, one yello and the other green. Bowles[1] made a complete chemical an crystallographic study of the pyromorphite. The forms ob served by him, are registered as follows:—

"*c* $(0001)$, *m* $(10\bar{1}0)$, *a* $(11\bar{2}0)$, *x* $(10\bar{1}1)$, *y* $(20\bar{2}1)$, *π* $(40\bar{4}1$ *ε* $(30\bar{3}4)$.

The basal pinacoid *c*$(0001)$ is very poorly developed. Th prism of the first order *m* $(10\bar{1}0)$ is the most prominent form o all crystals and is usually represented by well reflecting surfac from which satisfactory readings may be obtained. The faces commonly exhibit minute longitudinal striations. Th prism of the second order *a* $(11\bar{2}0)$ was observed on two crysta only, the faces being very narrow and in some instances curve The unit pyramid *x* $(10\bar{1}1)$ is the most prominent of all th pyramidal forms. The faces are in the most cases very di and on the goniometer give no distinct signals. The bipyram *y* $(20\bar{2}1)$ was found on three crystals only, and in each case th faces were very indistinct. They are proportionally very mu smaller than the faces of the unit bipyramid. On only o crystal, the bipyramid *π* $(40\bar{4}1)$ was observed to have ver narrow edges. The bipyramid *ε* $(30\bar{3}4)$ is a new form."

The chemical analyses of the yellow and green varieti of the pyromorphite are given thus:—

[1] Bowles, O., Am. Jour. Sci., 4th. Ser., Vol. 28, 1909, p. 40.

*Analyses of Pyromorphite.*

| | Yellow | Green |
|---|---|---|
| PbO | 80·20% | 80·13% |
| CaO | 0·59 | 0·56 |
| FeO | 0·86 | 0·46 |
| $P_2O_5$ | 16·12 | 15·65 |
| $As_2S_3$ | 0·41 | 0·90 |
| Cl | 2·52 | 2·59 |
| $CaF_2$ | trace | ...... |
| Insol | 0·08 | 0·05 |
| | 100·78 | 100·34 |
| Less Oxygen equivalent of Cl | 0·57 | 0·59 |
| | 100·21 | 99·75 |

## PARAGENESIS.

The age relations of garnet and diopside are unknown since they were not seen in contact.

The general order of formation may be summarized as follows:—

1. Magnetite.
2. Actinolite
3. Gar oside, idiomorphic crystals of pyrite and arsenopyrite.
4. Py otite, zinc-blende, and galena.
5. Cal
6. Ceru omorphite, native silver, limonite.
7. James ite.

A paragenetic study of the silver-lead ores is rather unsatisfactory on the whole. It shows that the gangue minerals, such as garnet and diopside, are in idiomorphic crystals and free from sulphides, as is the case in the Sullivan mine, where idiomorphic crystals of garnet occur embedded in a mixture of fine-grained galena and zinc-blende, as shown on Plate XIXA. Also the small crack the gangue minerals are filled with a mixture of pyrite, pyrrhotite, zinc-blende, and galena. In the St. Eugene ore deposits, magnetite was the first mineral deposited and this was followed by the gangue minerals. The garnet, with approximating idiomorphic outlines, is penetrated by numerous needles of actinolite, as shown on Plate XIXB. There is a possibility that some of the sulphides were contemporaneous with the gangue minerals, for idiomorphic crystals of pyrite and arsenopyrite were observed embedded in the fine-grained sulphides. The later second generation of the sulphides is represented by a fine-grained intimate mixture of galena, zinc-blende, pyrite, and pyrrhotite, so confused that they are believed to be contemporaneous. The sulpho-salt, jamesonite, is associated with the small calcite veins which are later than the main ore-bodies, and is probably a secondary mineral.

## GENESIS OF THE DEPOSITS.

The presence of the diagnostic minerals, garnet. diopside, actinolite, and muscovite, which are entirely restricted to the ore deposit and absent from the surrounding quartzites, suggests that the deposition of the ore took place in the deeper vein zone, under conditions of temperature and pressure comparable to those of contact metamorphic deposits. No igneous intrusion which could supply solutions of this kind outcrops within several miles of these deposits. However, in the neighbourhood of the Sullivan mine, small sills of gabbro, older than the ore deposit are exposed, and in the St. Eugene a dyke of diorite cuts the vein. The areal study of the East Kootenay district revealed numerous cross-cutting bodies of granite and granite porphyry, which are probably subordinate or "cupola" stocks of the West Kootenay granite batholith. In addition, the areas of sillimanite-garnetiferous-mica schist in East Kootenay are interpreted as argillaceous quartzites metamorphosed by an intrusion of granite not yet exposed by erosion. It is, therefore, concluded that the Purcell Series of East Kootenay, in part, rests upon an intrusive basement of granite which was the source of the ore solution, resulting in the formation of the Sullivan and St. Eugene ore masses.

The St. Eugene vein, described above, represents a fissure filled under conditions less extreme than those of the Sullivan, since garnets are less plentiful, galena is coarse-grained and more abundant and holds smaller quantities of zinc-blende and pyrrhotite. In addition carbonates are more abundant.

## Comparison with Coeur d'Alenes.

In comparing the deposits of East Kootenay with those of the Coeur d'Alenes, the genetic relationships become still more clear. In the two regions, the deposits occur under similar geological conditions, and as replacement deposits in fine-grained argillaceous and purer quartzites. The description of the various types will be given in an order corresponding to a decrease in conditions of temperature and pressure, starting with the most extreme, viz., those formed under contact metamorphic conditions. A rather full description of the Granite or Success mine is given, as in this deposit the relations to the intrusive is clearly shown. This deposit has been described by Ransome[1] in the following words:

"The ore of the Granite Mine is exclusively confined to the tongue like mass of slate and quartzite which . . . extends almost entirely across the large intrusive body of monzonite north of Gem. There is no vein, the ore occurring in masses of irregular form and various sizes, which are clearly, for the most part, replacements of the quartzites in places where the latter has been most thoroughly fissured. The ore masses in so far as they exhibit any regularity at all are suggestive of lenses standing on edge, the shortest diameter of nearly every mass being approximately horizontal. In the upper workings, the ore consisted chiefly of galena carrying about three-quarters of an ounce of silver to each unit of lead. It is said that almost all the ore bodies contained an increasing proportion of sphalerite in their outer portions and that where the ore finally graded into the country rock the principal constituent was pyrite. . . . The ore usually contains a little chalcopyrite and probably pyrrhotite, although none of the specimens collected show the latter mineral. There is very little gangue other than the mineralized quartzite. In places a little quartz is crystallized with the galena but siderite seems to be entirely absent. The ore is strictly confined to the sedimentary rock which probably belongs to the Prichard formation, although the quartzitic character shows that it is near the top of the formation. . . . The quartzite all

[1] Ransome, F. L., U.S.G.S., Prof. Paper 62, p. 184.

shows some metamorphism due to the intrusion of the monzonite . . . In consequence of it, the rock usually has a gree colour, due to the development of minute grains of pyroxene or in a few places a pink tint where garnet in microscopic crystal is the principal contact metamorphic mineral. The microscop shows that the quartzite is completely recrystallized to an aggre gate of interlocking quartz grains which enclose variable propor tions of the pale green monoclinic pyroxene, green brown biotite white mica (probably muscovite), and garnet. The associatio of the ore minerals with the metamorphic silicates is so clos that the conclusion of their contemporaneous genesis is unques tionable. . . . The microscope reveals the presence her and there of a little carbonate, apparently calcite. The fore going characteristics indicate that the ore of the Granite min was deposited shortly after the intrusion of monzonite and is phase of contact metamorphism."

A comparison of the description of the Granite or Succes mine of Idaho with that of the Sullivan of British Columbi given above shows a striking similarity. Both deposits ar replacements of argillaceous quartzites by an intimate mixtur of zinc-blende, galena, and iron sulphides, the latter increasing towards the periphery of the ore-bodies. The gangue mineral are almost identical in the two cases; but, in the Sullivan, th contact metamorphic silicates are restricted entirely to the or masses, while in the Granite or Success mine, the enclosing quartz ites are heavily charged with these minerals. Therefore, it is concluded that the Sullivan ore masses were deposited unde conditions of temperature and pressure less extreme than thos under which the Granite or Success ore-bodies were formed. Als the fact which is especially worthy of emphasis is the presence o an intrusive monzonite genetically related to the ore deposit in the Granite or Success mine, while in the Sullivan no such intrusion is known; but, from the similarity of the deposit in mineralogy and relationships, such a mass is doubtless present, although probably too deep to be exposed in the future workings of the mine.

With a further decrease in temperature and pressure the conditions, under which the St. Eugene of East Kootenay, the

Eight, and B.B. ore-bodies of Idaho[1] were deposited, are reached. In these deposits pyrite, pyrrhotite, and the contact metamorphic silicates are less abundant and calcite more plentiful than the Sullivan and Granite ore-bodies.

With the entire disappearance of the above silicates and a notable increase of carbonates, which point to conditions of deposition less extreme than those of the St. Eugene, we have the Tiger-Poorman Lode[2] described by Ransome as follows:

"In the Tiger-Poorman and Standard-Mammouth mines siderite is only moderately abundant and the ores contain notable quantities of sphalerite and pyrrhotite. Pyrite and chalcopyrite are comparatively abundant in both mines."

The Wardner mines represent ore-bodies deposited under the least extreme of any either in East Kootenay or the Coeur d'Alenes. Concerning these deposits[3] Ransome summarizes as follows:

"In the Wardner mines siderite is more abundant than elsewhere in the district. Sphalerite is rare, pyrite subordinate and pyrrhotite unknown. Garnet, biotite, pyroxene, and magnetite are entirely absent from these deposits."

Thus the evidence regarding genesis brought to light in the study of the silver-lead deposits of East Kootenay supports the view advanced by Ransome in 1908 concerning the origin of the silver-lead deposits of the Coeur d' Alenes.

The following table is a summary of the relations existing between the deposits of East Kootenay and the Coeur d' Alenes and showing their probable relations to decreasing temperature and pressure.

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[1] MacDonald, D. F., U.S.G.S. Bull. 334, p. 99.
[2] U.S.G.S. Prof. Paper 62, p. 136.
[3] U.S.G.S. Prof. Paper 62, p. 136.

## Correlation of Ore Deposits.

| Mine. | Country rock. | Metamorphism of country rock. | Ores. | Gangue. | Structural relations. | Intrusive. |
|---|---|---|---|---|---|---|
| Granite or Success, Idaho. | Prichard slate (upper part). | Recrystallized to an aggregate of interlocking quartz grains which enclose pyroxene, mica, and garnet. | Galena and zinc-blende with abundant pyrite; some chalcopyrite and pyrrhotite present. | Mineralized quartzite, garnet, pyroxene, biotite, muscovite, quartz, very little calcite. | Replacement deposit in fissured quartzite, not a true vein. | Monzonite. |
| Sullivan, East Kootenay. | Aldridge formation (upper part) lithologically same as Prichard. | Recrystallized and altered to chert in close vicinity of ore-bodies. | Galena and zinc-blende, with abundant pyrite and pyrrhotite; some chalcopyrite present. | Mineralized quartzite, garnet, pyroxene, biotite, and muscovite quartz, very little calcite. | Replacement deposit in well-bedded quartzites, not a true vein. | None known. |
| St. Eugene, East Kootenay. | Aldridge formation (upper part) lithologically same as Prichard. | Some recrystallization of wall rock shown. | Galena and zinc-blende, some pyrite, pyrrhotite, chalcopyrite, and magnetite. | Mineralized quartzite, garnet, actinolite, biotite, and quartz, some calcite. | Replacement deposit in fissured quartzites, true vein. | None known. |
| Tiger Poorman, Idaho. | Burke formation. | | Galena, some zinc-blende, pyrite, pyrrhotite, and chalcopyrite. | Quartz and siderite abundant. | Replacement deposit in fissured quartzite, true vein. | None known. |
| Wardner mines, Idaho. | Revett formation. | | Mostly galena, small amounts of sphalerite and pyrite. | Siderite in great abundance, small amount of quartz. | Replacement deposit in fissured quartzite, true vein. | None known. |

## AGE OF THE DEPOSITS.

Since the silver-lead deposits are thought to be genetically associated with the granite intrusions of East Kootenay, and since these intrusions are correlated with the Jurassic (?) Nelson granite of West Kootenay, their age is provisionally placed in late Jurassic (?) time.

## FUTURE OF THE SILVER-LEAD DEPOSITS.

The mineralized silver-lead zones are generally associated with the Aldridge argillaceous quartzites, as if these quartzites were favourable for the deposition of silver-lead ores. If this be true, the Cranbrook area, being underlain for most part by the Aldridge formation, offers a wide field for prospecting work.

In case the problem of the successful separation of the high content of zinc in the silver-lead ores is solved, renewed activity will be seen in several deposits now in a state of quiescence.

# Description of Mines and Prospects.

## THE MOYIE AREA.

The Moyie area embraces the area around Lower Moyie lake and includes the Society Girl, St. Eugene, the Cambrian and Mabelle claims, the Aurora, and the Guindon group of claims.

### Geology.

The Moyie area is underlain by the Aldridge and Creston formations of the Purcell series. These formations are folded into a northerly dipping anticline, the axis of which roughly coincides with the depression occupied by the Moyie lakes and river. The Aldridge formation occupies the axial portion of the anticlines and consists of dark grey argillaceous quartzites in beds up to 1 foot in thickness, and dark grey siliceous argillites generally not exceeding 2 inches in thickness. The weathering colour of these rocks is a dark rusty brown, which is the most valuable field characteristic in its determination. On the east side of the lake, in the vicinity of Moyie, the rocks strike east west with a dip of 30 degrees to the north and are close to axis of the anticline, while in proceeding eastward up the towards the Society Girl the formation gradually changes strikes to a northwest-southeast strike with a dip of 25 deg to the northeast, as would be expected in going from the of the anticline to its eastern limb. On the hill to the wes the lake, where the Aurora and Guindon group of claims are cated, the strike is northeast-southwest with a dip of 20 deg to the northwest. The axial portion of the anticline is occup by the Creston argillaceous quartzites, purer quartzites, dolomites which are well exposed on each side of the Up Moyie lake.

## Fissure System.

All the ore deposits in the Moyie area are connected with main parallel fissures striking a little north of west and dipp on an average 70 degrees to the south. They cross the of the anticline composed of the Aldridge formation. Tl two fissures occur on both the east and west side of the l and it is probable that they occur in the rock formation un the lake (Figure 6). The walls bounding the fissures sl very little evidence of relative displacement, the greatest mo ment observed being 18 inches; however, in such a homogene series of quartzites the detection of such a movement might impossible.

## St. Eugene Mine.

### *Location.*

The St. Eugene mine (Plate XX) is owned by the C solidated Mining and Smelting Company of Canada, and property consists of 1,050 acres situated on the east side Moyie lake near Moyie, B.C.

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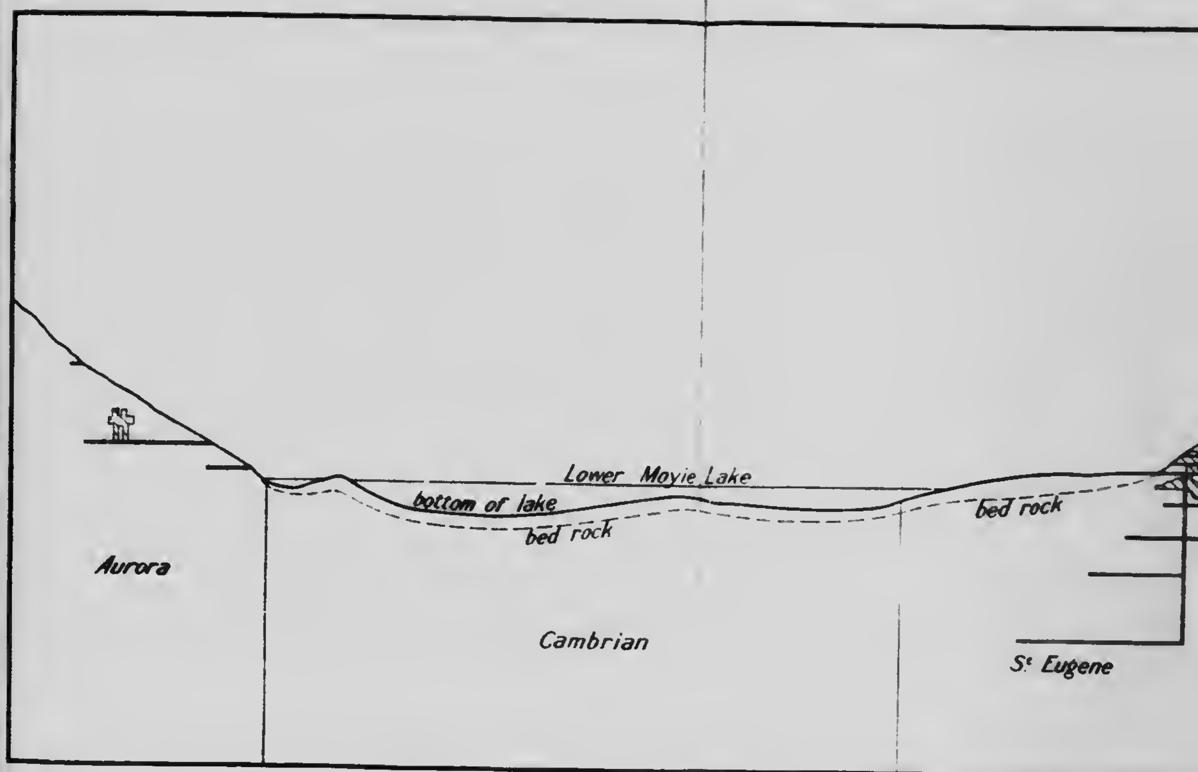
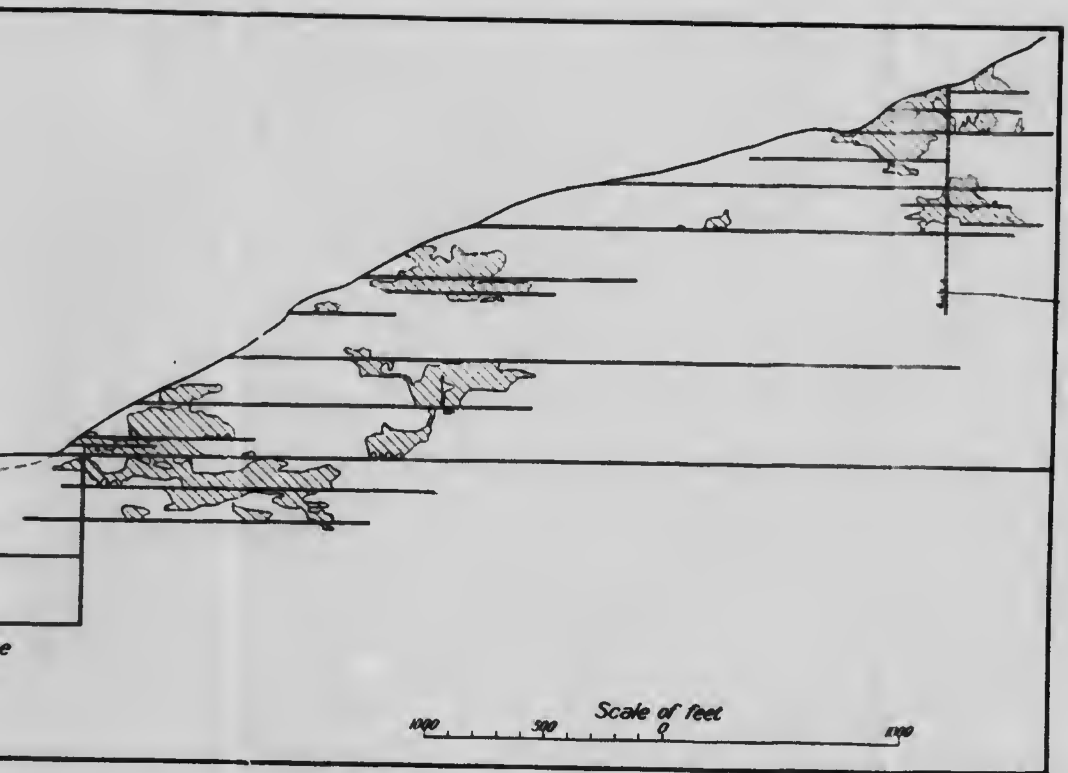



Figure 6. Cross-section along the vein of St. Eugene, Camb




gene, Cambrian, and Aurora mining claims.

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*History.*

Father Coccola, Roman Catholic priest at the St. Eugene Mission, by showing the Kootenay Indians specimens of the different ores of the valuable metals, impressed upon their primitive minds, the importance of discovering deposits of these minerals. Peter, one of the Kootenay Indians now resident at the Mission, on a hunting trip around the Moyie lakes, brought back a specimen of clean galena ore from the hill on the east side of Lower Moyie lake.

James Cronin, a mining engineer, while on his way to Fort Steele, visited the St. Eugene Mission, and was told the story of the discovery of rich silver-lead ore. In company with Father Coccola and the Indian, he journeyed to Moyie and located the Peter and the St. Eugene claims in 1893.

On the advent of the Canadian Pacific railway, John Finch of Spokane, Washington, purchased the holdings of the Father for $12,000 and this money was used in building the beautiful church now to be seen at the St. Eugene mission.

The development of the St. Eugene mine now progressed rapidly under the management of Mr. Cronin. Later, the Moyie and the Lake Shore group of claims, which lie between the St. Eugene and Moyie lake, were purchased and the St. Eugene Consolidated Mining Company formed. In 1905, the properties of this company were taken over by the Consolidated Mining and Smelting Company. The total amount of development work under ground to September 30, 1913, is 19·79 miles.

*Production.*

From July 1, 1912, to September 30, 1913, the St. Eugene produced 1,826 tons of ore containing 46,082 ounces of silver and 16,098,885 pounds of lead with a total value of $98,623. The total production of the St. Eugene mine since its discovery to September 30, 1913, has been 1,017,106 tons of ore containing 5,365,232 ounces of silver and 229,305,721 pounds of lead, having a given value of $10,626,608.

*Methods of Mining.*

In the ground above the level of Moyie lake, the veins are mined by a series of adits driven along the main veins. The ore from the higher levels is transported by an aërial tramway to the ore bins. Below the level of the lake a 3-compartment shaft has been sunk to a depth of 800 feet.

*Fissure System.*

The deposit of the St. Eugene mine occurs on a zone of fissuring which has a general east and west strike. In this zone two fissures are the most important, both of which strike east and west with an average dip of 70 degrees to the south. On the 1000-foot level, which is 1,000 feet above the level of Moyie lake, these two fissures are 600 feet apart and converge downwards and to the west. Joining these two main fissures is an important system of connecting fissure at various distances apart, which usually meet the main fissure at a small angle (Figure 7). At the junction or close to it, occurred most of the important ore-bodies. Very little displacement was noted along the veins as a whole.

*Character of Ore-bodies.*

The ore-bodies (Figure 8) are replacement deposits in the heavy bedded purer quartzites and are restricted to the fractured area between the two main fissures. Where the fissures cross the more argillaceous quartzites, the veins are narrow and usually filled with quartz containing small quantities of sulphides.

The ore consists mainly of coarse-grained galena with subordinate amounts of zinc-blende, pyrite, pyrrhotite, magnetite, and a little chalcopyrite. It is also reported by the officials of the mine, that the sulphides—pyrite, pyrrhotite, and zinc-blende—were slightly more abundant near the periphery of the ore-bodies and that the zinc-blende showed no increase with depth. The gangue, which is small in amount, consists of pink garnet, actinolite, quartz, and some calcite. The garnet, actino-

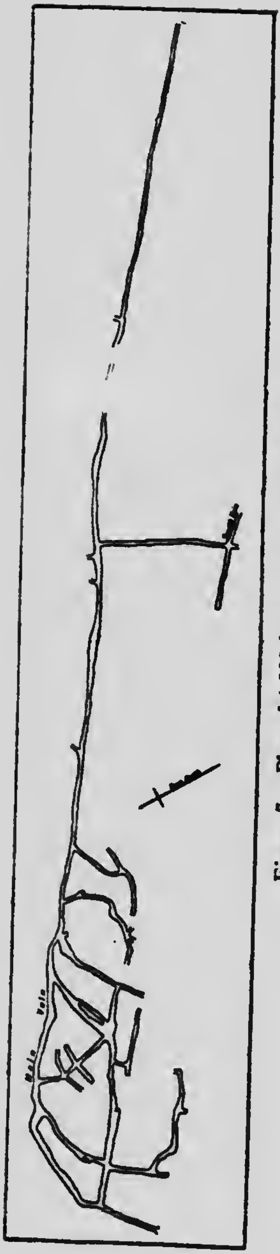



Figure 7. Plan of 1,800-foot level, St. Eugene mine.

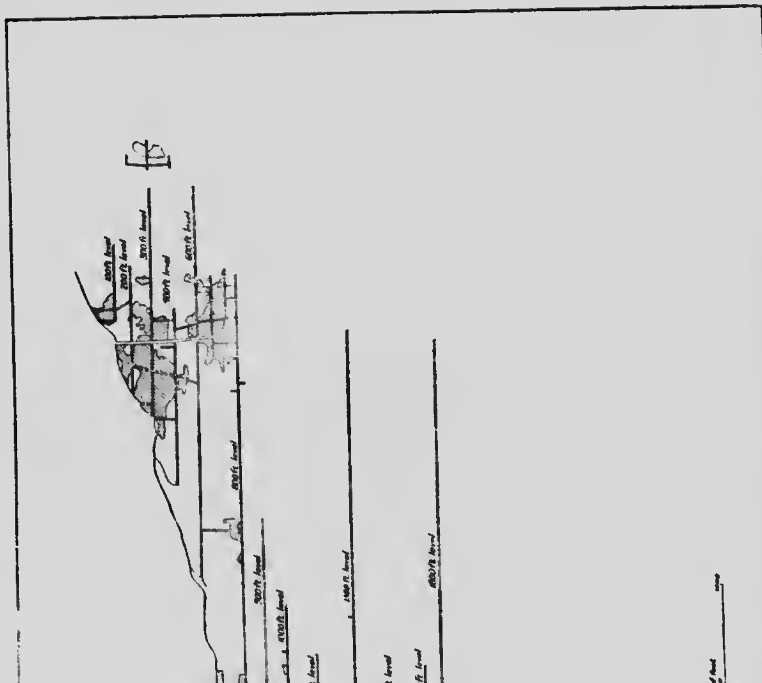


Figure 8. Longitudinal section along north or main vein of St. Eugene mine.

Figure 8. Longitudinal section along north or main vein of St. Eugene mine.



lite, and quartz are more abundant in the transition zone of the ore and country rock and at times the fissured quartzites near the vein are heavily charged with these minerals. In some cases the quartzites show evidence of silicification, although no true chert, as found in the Sullivan deposit, was identified in the St. Eugene.

A study of the paragenesis of the ores of the St. Eugene shows that magnetite was the first mineral deposited and was followed by the gangue minerals. The garnet approximating idiomorphic outlines, is penetrated by numerous needles of actinolite. The sulphides were deposited last and fill the cracks and interstices of the other minerals. The above relations are shown in Plate XIXB.

## Aurora Group of Claims.

The Aurora group operated by the Aurora Mining and Milling Company of Moyie, B.C., consists of five crown-granted claims, the Aurora, Horse Shoe, Durang, Etna, and Portland, situated on the west side of Lower Moyie lake opposite Moyie, B.C. (Plate XXI). The vein occurs on the east and west system of fissuring described in the general description of the district, and possibly on the southern of the main fissures which here has a general strike east and west, but varies as much as 15 degrees from this direction. The dip of the vein is 60 degrees to the south (Figure 9). The vein cuts across the Aldridge formation, the oldest subdivision of the Purcell series, which here strikes northeast with a dip of 50 degrees to the northwest.

The formation is made up of thin-bedded argillaceous quartzites (locally called slates) and massive purer quartzites which here form the western limb of the northerly plunging anticline described above. The vein has a maximum observed width of 6 feet and consists of zinc-blende and galena with very little gangue. Occasionally fragments of the wall rocks are enclosed by the ore. In the report on the Zinc Resources of British Columbia, the following assay of the ore is quoted: gold 0·02 ounces, silver 7·3 ounces, lead 31·5 per cent, zinc 33 per cent. The ore represented in the Aurora is also considered by the same

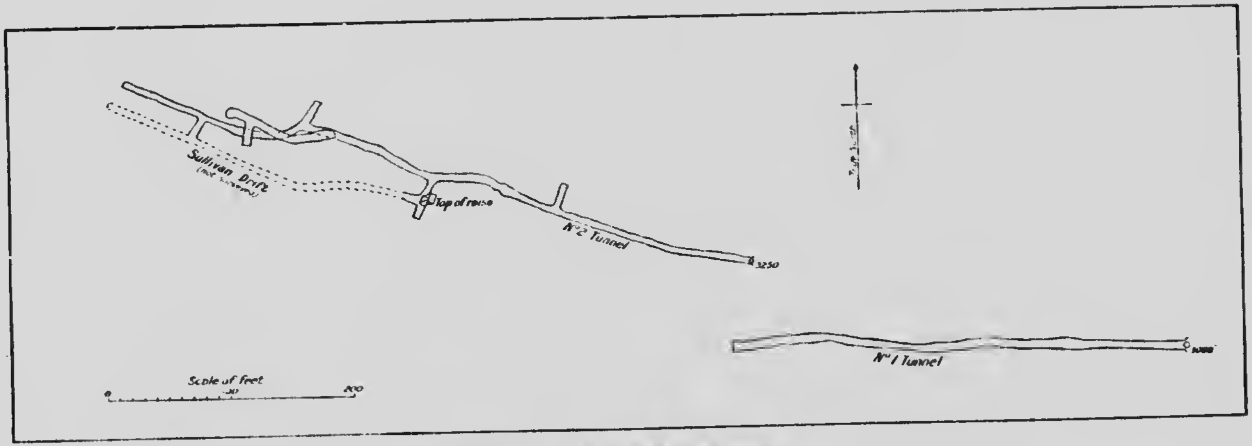



Figure 9. Plan of Aurora mine.

commission to be the simplest to treat of any of the ores examined in their series of experiments. Development on the property consists of about 1,500 feet of workings, mostly in the form of tunnels (Figure 10). Operations on this property are suspended, for at present there is no demand for zinc ore in British Columbia.

### Guindon Group of Claims.

This group, consisting of the Guindon, Fereole, the Alice and the St. Joseph fractions, is located in the territory adjoining the Aurora group to the north. The vein on which these claims are located is about 700 feet north of the Aurora vein and has an east and west strike with a dip of 60 degrees to the south. The formation which the vein traverses is the Aldridge formation, which here strikes northeast and dips 20 degrees to the northwest. The vein is from 4 to 5 feet wide and in one tunnel the ore was 18 inches in width. It consisted of galena, zinc-blende and some pyrite. Development work consisted of a few short tunnels.

### Cambrian and Mabelle Claims.

The Cambrian and Mabelle crown-granted claims operated by the Cambrian Mining Company, Limited, of Moyie, B.C., embraces the territory between the St. Eugene Consolidated and the Aurora and thus lies for the most part under the waters of Lower Moyie lake. The extensive zone of fissuring, described in the general statement and which occurs on both sides of the lake, is to be expected to occur in the intervening territory. As the veins are mineralized in the St. Eugene Consolidated and in the Aurora it is logical to expect that the Cambrian and Mabelle claims will also be productive. The sounding of the lake on the Cambrian and Mabelle claims revealed the maximum depth of water to be 140 feet and in addition 90 feet of blue clay and hard pan cover the bottom of the lake (Figure 11). This last information was supplied by Chas. A. MacKay of Moyie, B.C., one of the directors of the company.

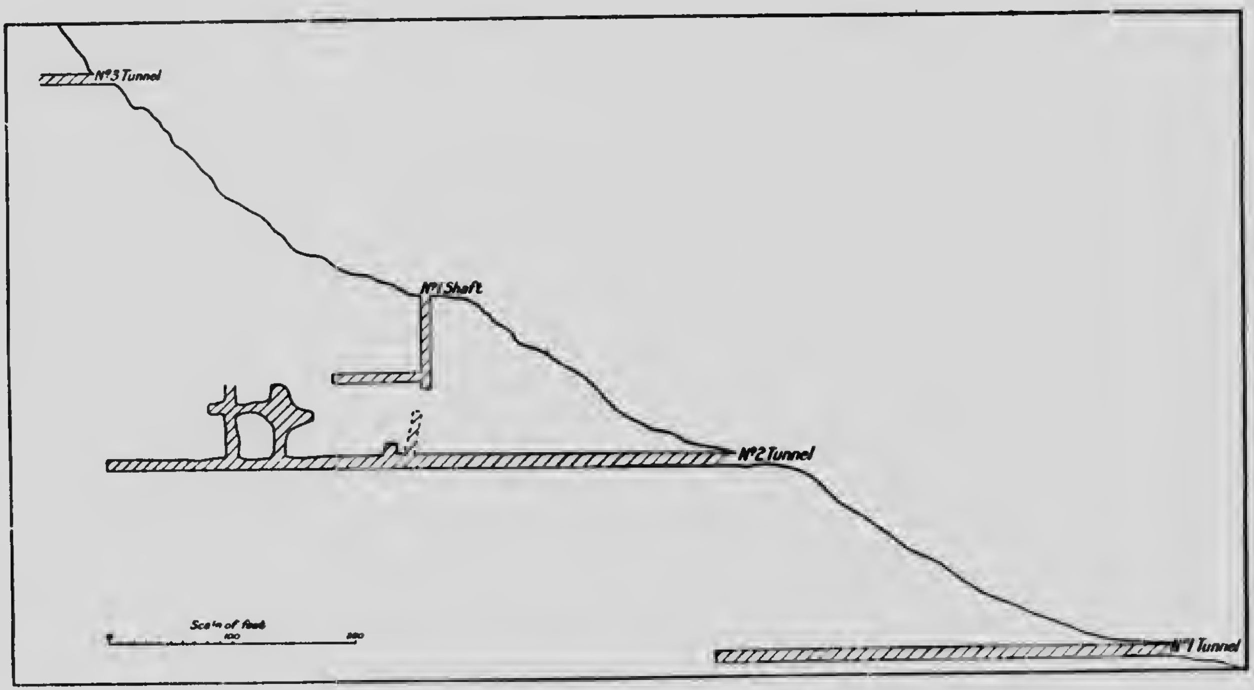



Figure 10. Longitudinal section of the Aurora mine

## Society Girl.

This group comprises seven crown-granted claims operated by the Society Girl Mining Company, Limited. They are situated about 2 miles east of Moyie at an elevation of about 5,000 feet and adjoin the eastern boundary of the St. Eugene Consolidated. The formation in which the deposits occur, is the oldest subdivision of the Purcell series called the Aldridge formation, which here strikes north and south with a dip of 25 degrees to the east and forms the eastern limb of the anticline described above. The vein, where examined, strikes N.60° W. with a dip of 60 degrees to the south and appears to be in the great zone of fissuring which traverses the Moyie area. The vein is narrow where it traverses the thin-bedded argillaceous quartzites and widens out in the heavier-bedded quartzites.

The upper workings expose an oxidized ore-body consisting of cerussite and pyromorphite, both massive, and in beautiful crystals.

The cerussite is white to colourless and occurs in tabular orthorhombic crystals either singly or as penetration twins. Massive cerussite is also present. The cerussite is often embedded in dense masses of limonite. The oxidized ore zone is a rare occurrence in East Kootenay. The unoxidized or primary ore, consisting of galena and zinc-blende with little or no gangue, is exposed in the lower tunnel which penetrates the ore-body 250 feet below the surface. At present the ore is hand-sorted and then sent to the smelter at Trail for treatment. For the year 1911 up to the end of September, the total output of the mine amounted to about 400 tons. The galena carries 1 ounce of silver to 4 per cent of lead while the oxidized ores carry 1 ounce of silver to 5½ per cent of lead.

# THE KIMBERLEY AREA.

## Location.

This area is situated near Kimberley, the terminus of the Canadian Pacific branch line from Cranbrook to Kimberley, and includes the Sullivan, Stemwinder, North Star, and several minor properties.

## GEOLOGY.

The Kimberley area is underlain by the argillaceous quartzites and argillites of the Aldridge formation. These rocks are intruded by several Purcell sills composed of gabbro, which are well exposed on Mark creek above Kimberley. The Aldridge quartzites of the Kimberley area form the eastern limb of the large anticline the axis of which is located in the vicinity of Matthew creek. It has been described in detail in the chapter on "Structural Geology." In general, the strike of the rocks near Kimberley is nearly north and south, with the most prevalent dip to the east; but minor folds modify this simple structure, as can be well seen in the vicinity of the North Star mine, where a number of anticlines and synclines are impressed on the eastern limb of the main anticline mentioned above.

## CHARACTER OF THE DEPOSITS.

In contrast to the deposits of the Moyie area, which are true fissure veins, the deposits of the Kimberley area are replacement deposits in argillaceous quartzites. The ore-bodies in general conform to the dip and strike of the quartzites. This relationship is not proved in the case of the Stemwinder. The hanging-walls and foot-walls are not usually well defined; but the ore gradually passes into the normal country rocks so that the distinction between rocks and ore is commercial rather than structural. Exceptions to this occur where the walls consist of the thin-bedded slaty quartzites which are evidently difficult to replace. The deposits are arranged in distinct zones. The centre of each body is occupied by a fine-grained mixture of galena and zinc-blende in which masses of purer galena occur as lenses. This inner portion gradually passes exteriorly into a fine-grained intimate mixture of pyrite, pyrrhotite, and zinc-blende. The sulphides gradually diminish in amount and finally give way to a fine-grained chert which is present where the country rock is a heavy-bedded, purer quartzite, and especially on the foot-wall of the ore-bodies. The chert passes exteriorly into the normal argillaceous quartzites.

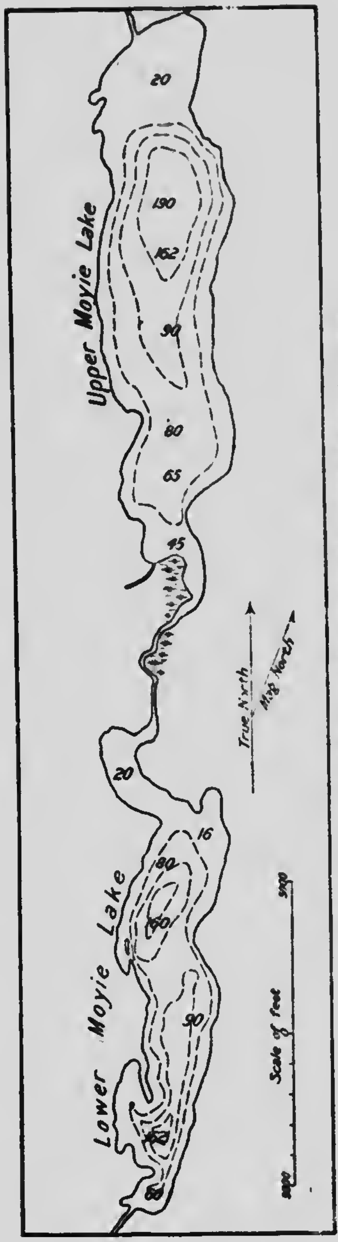



**Figure 11. Plan of Moyie lakes showing contour of lake bottoms.**

## SULLIVAN MINE.

*Location.*—The Sullivan mine is located on the southern slope of the Sullivan hill about 2½ miles by road north of Kimberley, at an elevation of 4,600 feet above sea-level.

*History.*—The Sullivan, discovered in 1895 by Pat Sullivan, Jno. Cleaver, E. C. Smith, and W. C. Burchett, was bonded to Col. Redpath and Judge Turner of Spokane, Washington, in 1896 and probably constituted the Sullivan Group Mining Company of Spokane. In 19[illegible], this company commenced the building of the Marysville smelter at Marysville, B.C., at the junction of the St. Mary river and Mark creek. It was completed in 1903, but remodelled in 1904 and was finally closed down for good in 1908. In 1910, the Consolidated Mining and Smelting Company acquired the claims of the Sullivan Group Mining Company, as well as many of the surrounding claims. The ore is being shipped to the company's smelter at Trail. The smelter at Marysville is now dismantled and a thing of the past.

*Production.*—The production of the Sullivan from 1894 to September 30, 1913, was 188,648 tons of ore containing 1,694,402 ounces of silver, and 86,821,629 pounds of lead with a gross value of $4,364,805. The production from July 1, 1912, to September 30, 1913, was 41,284 tons of ore containing 448,379 ounces of silver and 23,411,667 pounds of lead having a gross value of $1,281,150.

*Equipment.*—The mine was originally opened by a vertical shaft with levels at various intervals of 5 or 10 feet along the strike of the ore-body. On acquisition by the Consolidated Mining and Smelting Company, the 100-foot level was continued to the surface and this tunnel is now the portal to the mine. At the mouth of this tunnel, a large ore-sorting house is located. An aërial tram from the ore-sorting house connects the mine with the Canadian Pacific railway which carries the ore to the smelter at Trail. There is a hydro-electric power plant, deriving its power from the falls on Mark creek by means of three 6-foot Pelton wheels—two connected to a 40-drill compressor and one to a 120 kw. generator. Compressed air is conveyed to the mine through an 8-inch pipe 5,100 feet long.

### *Character of the Ore-Bodies.*

The deposit occurs in the Aldridge formation which here strikes about north and south with a dip of 10 degrees to 60 degrees to the east. This formation consists of thin-bedded argillaceous quartzites and heavy-bedded, purer quartzites. The ore-body conforms in dip and strike with the quartzites and cannot be called a true fissure vein, but a replacement deposit in which the sulphides replaced the fine-grained quartzites (Figure 12). The hanging-wall and foot-wall are not well defined and the ore grades gradually into the country rock,

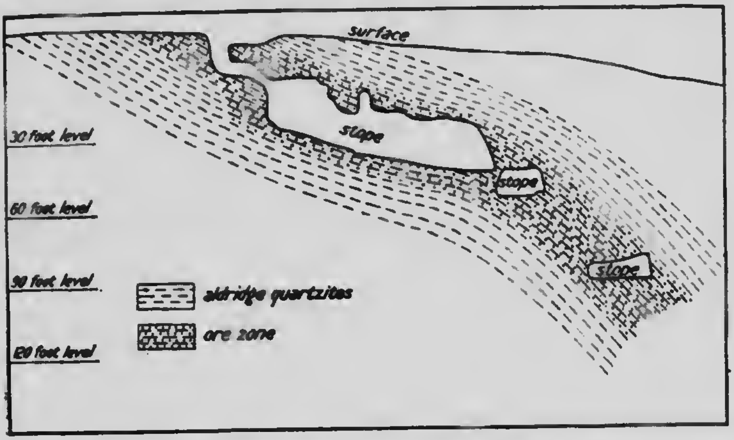



Figure 12. Diagrammatic cross-section of Sullivan mine.

except when the country rock consists of thin-bedded slaty quartzites which are evidently difficult to replace. In the upper workings close folding later than the ore deposition increases the real width of the ore. This was well shown in the glory hole at the time of the writer's visit. On the 60-foot level the dip of the ore-body in places approximates 25 degrees and on the 100-foot level the dip increases to 70 degrees, which is also the dip of the surrounding quartzites. As far as exploited, the maximum stope width is 120 feet and the maximum stope length, 325 feet.

There are 10 levels, the north level being 100 feet below the surface and forming the entrance to the mine.

The ore-body is arranged in distinct zones which grade imperceptibly into each other (Figure 13). The centre of the lode is occupied by a fine-grained mixture of galena and zinc-blende in which masses of purer galena occur as large lenses. It is these lenses that constitute the valuable ore shoots in the mine. They occur either singly or as two parallel shoots separated by one of poorer grade. The gangue in this inner zone is absent except

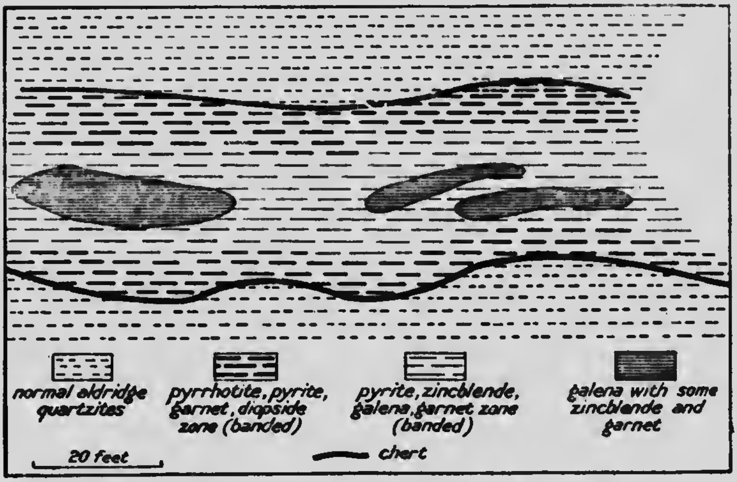



Figure 13. Diagrammatic longitudinal section of Sullivan ore-body.

for a few idiomorphic crystals of a pink manganese-bearing garnet (Plate XIXA). This inner zone gradually passes exteriorly into a fine-grained mixture of pyrite, pyrrhotite, and zinc-blende, which contains as a gangue numerous crystals of an almost colourless garnet with some grains of actinolite or possibly diopside (Plate XXIIB). The sulphides gradually diminish in amount and finally give way especially on the foot-wall to a fine-grained chert which is present when the country rock is a heavy-bedded purer quartzite, and is absent when a more argillaceous slaty member constitutes the wallrock. No garnets or other gangue minerals were noted in this cherty zone. The chert gradually passes into the normal quartzite in which, with one exception, all contact minerals such as garnet, diopside, and actinolite, are absent.

As mentioned, the ore deposit as a whole is a conformable replacement of fine-grained argillaceous quartzites by fine-grained galena, zinc-blende, and iron sulphides. Replacement is very well shown in most parts of the deposit since alternate banding of ore and quartzite is seen near the periphery of the ore masses where the relative susceptibility to replacement of the laminæ of the quartzite is different. Joining these favourable bands are numerous interlacing veinlets of sulphides which, as shown in Plate XXIIIA represent an intermediate stage in the complete replacement of the quartzite. Examined microscopically, the sulphides appear to have entered between the quartz grains of the quartzite and then to have attacked the quartz itself. The sulphides, entering along the favourable laminæ, replace the muscovite also, as shown in Plate XXIIIB. Evidently muscovite has been formed previous to the introduction of the sulphides.

## North Star Mine.

*Location.*—The North Star mine is located on the east slope of the North Star hill at an elevation of 5,260 feet above sea-level or about 1,500 feet above Kimberley, which lies at the foot of the North Star hill on Mark creek.

*History.*—The North Star was discovered in September, 1912, by Bourgeois and Langill who bonded the claims to Woods Bros. of Quebec; the latter transferred four-fifths of their interest to D. P. Mann of Montreal in 1893. Subsequently, a company under the name of the North Star Mining Company was organized. In 1895, 62 tons of ore, valued at $68.70 a ton, were shipped to the United States. In 1900, the railway from Cranbrook to Kimberley was completed and the mine was joined with the railway by an aërial tramway. During the year, 16,000 tons, averaging 50 to 55 per cent lead and 20 to 25 ounces of silver, were shipped. In 1904, the mine was reported to be worked out; but the cleaning up of the deposit lasted until 1908, in which year 3,000 tons were shipped. The property is now closed down.

*Geology.*—At the time of the writer's visit, the mine was abandoned and all the ore removed, so the following description is based mainly on the reports of the British Columbia Bureau of Mines, and a paper written by Mr. Corless[1] with additional notes on the structure by the writer. The country rocks are argillaceous quartzites of the Aldridge formation forming part of the eastern limb of the anticline described in the general description of the Kimberley area. In the vicinity of the mine, small anticlines and synclines modify this general structure. On the whole the quartzites strike north and south and dip at various angles to the east. In the immediate contact with the ore-bodies, the quartzites are bleached to a greyish white colour and were known locally as "porphyry."

*Ore.*—(a) The ore was primarily a very clean solid argentiferous galena rather fine grained with only a small amount of zinc-blende. The assay value from smelter return was, silver 23·50 to 45·3 ounces per ton, lead 53 to 68 per cent.

(b) The upper part of the ore shoot was composed of a reddish brown, black and yellow mixture of oxides and carbonates of iron and lead, with beautiful specimens of wire silver, crystals of cerussite formed by the oxidation of galena, and sulphides of iron. There was a large amount of this ore which carried a higher silver value than the crude galena. The values from smelter returns of this "carbonate" ore are as follows: silver 52 to 60 ounces per ton, lead 49 to 57 per cent.

*Ore-Bodies.*—The main ore-bodies are the west and the east ore-bodies, 400 feet long, 70 feet wide, and 50 feet deep, and 180 feet long by 40 feet deep respectively. The longer axes of these are parallel, both striking a little east of north. These bodies apparently occur in synclinal basins formed of argillaceous quartzites. These two basins are separated by an anticline. The ore-bodies probably represent remnants of a once continuous ore-body, the larger part of which has been removed by erosion (Figure 14).

[1] Corless, F.V., Bull. Can. Min. Inst., Vol. 5, 1902, p. 512.

## Stemwinder.

The Stemwinder is situated about one mile northwest of Kimberley on Mark creek and hence between the Sullivan group on the east and the North Star on the west.

The country rock consists of argillaceous quartzites of the Aldridge formation intruded by several sills of hornblende gabbro. The ore-body is entirely enclosed by the quartzites and closely resembles the Sullivan in its occurrence and mineralogy. The interior of the ore-body consists of a fine-grained

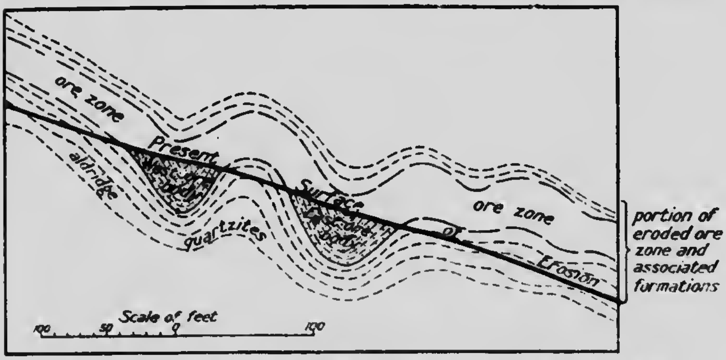



Figure 14. Diagrammatic cross-section of North Star ore-bodies.

mixture of galena and zinc-blende passing exteriorly into a fine-grained mixture of pyrrhotite, pyrite, and zinc-blende. This is succeeded by a cherty layer which in turn passes into the normal quartzite. The amount of development consisting of a few short tunnels was not sufficient to expose the relations of the ore-body, but it is evidently of large size.

## Mascot and Eclipse.

These claims are situated on the east branch of Hells Roaring creek, at an elevation of 5,800 feet. The vein occurs in the argillaceous quartzites of the Creston formation; it is well defined and conforms in dip and strike with the sediments, which near the vein strike almost east and west with a dip of 69 degrees to the north. The ore, consisting of galena, with a small amount of chalcopyrite in a quartz gangue, favours the hanging-wall, and is associated with a band of gouge about 1 foot wide. At the bottom of a shaft 56 feet deep, which opens up the deposit, the vein is somewhat broken, but is still in evidence. About 200 feet down the hill from the outcrop of the vein, the sediments are intruded by a granite porphyry which contains large idiomorphic crystals of orthoclase in an isometric groundmass of plagioclase, quartz, and hornblende. The following assays were supplied by the owners, Messrs. Tarrant and Angus:—

| Sample | Gold | Silver | Lead | Copper |
|---|---|---|---|---|
| | Ozs. | Ozs. | % | % |
| 1 | 0·04 | 2·2 | 10·3 | ...... |
| 2 | 0·16 | 0·6 | ...... | ...... |
| 3 | 0·10 | 6·1 | 57·8 | ...... |
| 4 | 0·24 | 3·4 | ...... | 1·2 |
| 5 | 0·11 | 6·8 | 49·4 | ...... |
| 6 | 2·00 | 4·17 | 39·50 | ...... |
| 7 (Dump) | 4·80 | 2·34 | ...... | 4·12 |
| 8 | 2·20 | 4·69 | 32·11 | ...... |

## *GOLD QUARTZ VEINS.*

### Distribution.

The gold quartz veins occur for the most part on Perry creek. A great many claims were located on these deposits on the north side of Perry creek in 1896 by prospectors in search of the source of the placer gold which had been worked with much success on the same creek.

### Geology.

The deposits occur in the argillaceous quartzites of the Creston formation, which is well exposed on Perry creek. The quartzites are well-bedded in beds 2 inches to 2 feet in thickness, the latter separated by thin beds of metargillites averaging one inch in thickness. The massive quartzites weather a light grey while the metargillites weather dark grey or rusty brown. The strata of this formation are so well cemented together that they appear massive and form steep cliffs.

## Character of Deposits.

The deposits occur as true fissure veins. Their width averages about 8 feet, but some are as wide as 20 feet. They can be traced for long distances along the strike.

## Mineralogy.

The mineralogy of the gold quartz veins is very simple and consists of free gold, pyrite, and quartz.

### *Native Elements.*

*Gold, Au.*—Gold is reported as occurring native in the outcrops of the veins, but in depth is evidently associated with the pyrite.

### *Sulphides.*

*Pyrite, $FeS_2$.*—Sulphide of iron occurs sparingly throughout the quartz gangue.

### *Oxides.*

*Quartz, $SiO_2$.*—Quartz is the only gangue mineral noted in the deposits.

## Persistency.

From the width of the veins and their great extension along the strike, it is almost certain that they persist in depth, although no workings have as yet proved this point.

## Values.

The values in these deposits are reported to be unequally distributed. A report of a mill test on these ores given by the Provincial Mineralogist of British Columbia in the report of 1898, p. 1016, is as follows:—

"Recognizing the futility of trusting to small samples, and that a satisfactory test of the various properties could only be determined by a practical test, Mr. J. E. Hardman, mining engineer, of Montreal, had a small stamp mill erected during 1897, at the mouth of Saw Mill Creek, for the purpose of making mill tests of the ore from the various properties he had under bond. The mill is a small 5-stamp battery, so constructed as to be easily portable, manufactured in Nova Scotia, and is driven by a small upright engine supplied with steam from a vertical water-tube boiler. It is provided with the usual amalgamating plates, etc., for the collection of any "free gold," and is, as a whole, a very complete and well-constructed little plant. This mill was set up under the roof of the old saw-mill.

"Test runs were made on ore from several of the claims on the creek, in lots of 5 to 10 tons each. The results obtained were not commercially satisfactory, for, notwithstanding the fact that some gold was saved, in no instance were the values obtained sufficiently high to warrant serious work on the claims. The tests, however, do not seem to have satisfied the claim owners, as the results obtained did not tally with their private assays. I heard several complaints about the matter, regret being expressed that the running of the mill had been left to inexperienced men, and the values allowed to escape in the tailings. Of this I know nothing further than was told me by men who might be considered 'interested parties.'

"It was, of course, impossible for me to form any opinion as to how the mill had been run, except by testing the tailings, which I did in the presence of a well-known engineer and mill man, Mr. Farrell, of San Francisco, who likewise made several independent tests for his own information. The tailings from the mill had run down to the creek bottom, some 100 feet, over gravel, and had been subjected to a winter's snow and rain. I panned the mixed gravel and tailings over all of this distance, and in each pan I found I could save, besides the iron sulphides to be expected, a globule of mercury as large as the head of a match, and a string of amalgam in the bottom of the pan from a quarter to half an inch long. On driving off the mercury on a hot iron I found I left a very fair sized particle of gold. I collected some of the mercury and amalgam, which I turned over to the Provincial Assayer, who reports to me that the mercury carries over 2% of gold, while the 'black sand' contains $20.00 in gold and a trace of silver. Samples which I took of the tailings gave me on assay as high as $4.00 in gold.

"As the result of my investigation, I am satisfied that the mill did not save such free gold as may have been in the ores, and that the tests made were not conclusive as to the values

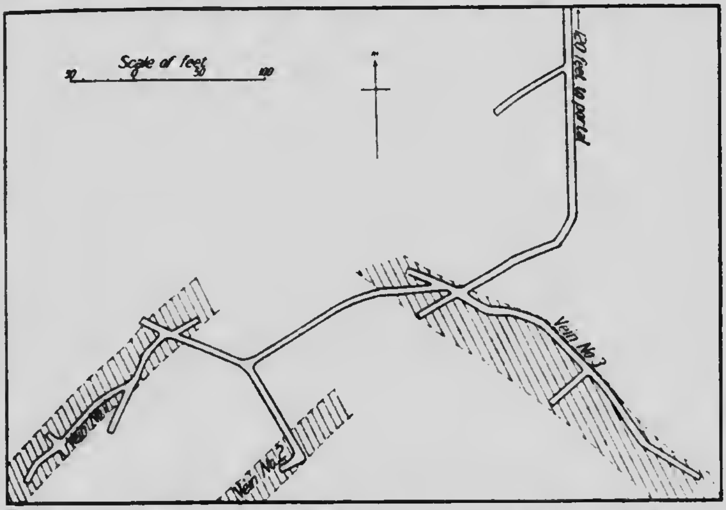



Figure 15. Plan of Running Wolf mine, Perry creek, Kootenay, B.C.

of these properties. I am further satisfied that only a portion of the gold is 'free,' and that some method of concentration would have to be adopted to save the gold occurring in the iron sulphides."

## Detailed Description of Properties.

### *The Running Wolf.*

The only property in operation at the time of the writer's visit was the Running Wolf on which considerable work had been done. It is located on French creek, a southern tributary of Perry creek, at an elevation of 5,000 feet above sea-level.

The claim owned by the Perry Creek Mining Company contains two parallel veins, 100 feet apart, and each 20 feet wide, vertical and striking S. 50° W.; and a single vein about 30 feet wide vertical and striking S. 50° E. (Figure 15).

## *COPPER-GOLD DEPOSITS.*

### Introduction.

The copper-gold deposits of the Cranbrook area are widespread and at present somewhat neglected, since they are overshadowed so greatly in importance by the deposits of silver-lead. Nevertheless, from their extent and character, a moderate amount of success is possible in these deposits if carefully worked.

### Distribution.

Since the copper-gold deposits are always associated with the Purcell sills, the distribution of these deposits is governed by the distribution of the Purcell sills, which occur almost exclusively in the Aldridge formation; the sills in the younger formations are thin and unimportant. The copper deposits which have received most attention, occur on the several branches of the St. Mary river, where sufficient work has been done to expose their geological relationships.

### Geology.

The Purcell sills, with which these deposits are associated, have been described at some length in a previous chapter and only a short description here is necessary. These tabular intrusive bodies are injected along the bedding planes of the quartzites and vary in thickness from 2 to 2,000 feet. They consist mainly of hornblende gabbro with large irregular masses or differentiates of a peculiar hornblende granite. It is with these irregular masses that some of the copper deposits are associated.

## Character of the Deposits.

The deposits are of two varieties.

(1.) Large irregular masses or differentiates.

(2.) Veins.

The differentiates occur usually in the interior of the sills and are of varied shape and size. No single body has as yet been outlined, but they are believed to be at least 200 to 300 feet in diameter. The boundaries of these bodies with the surrounding rocks are always gradational. The differentiates consist generally of a peculiar hornblende granite containing as a prominent feature, opalescent quartz. The hornblende is usually fibrous and in some cases makes up 75 per cent of the rock. The other constituent of the rock is an intergrowth of quartz and orthoclase. The ore minerals chalcopyrite, pyrite, and pyrrhotite occur sporadically throughout the differentiates.

The true veins, 2 to 4 feet wide, occur on shear zones in the sills. The hornblende gabbro, which forms the wallrock, shows the effect of shearing at the time of the formation of the shear zone by the occurrence of an alignment of the feldspar constituents of the gabbro parallel to the vein. The filling of the shear zone consists most frequently of quartz impregnated with chalcopyrite, pyrite, and pyrrhotite. The presence of a sulphide of cobalt is indicated by the occurrence on the weathered outcrop of the vein, of erythrite, a hydrated arsenate of cobalt. Native copper sometimes occurs in the quartz. In several cases coarsely crystalline calcite formed part of the veins and from its relationships to the other constituents, was the latest filling.

## Mineralogy.

### *Native Elements.*

*Copper Cu.*—Native copper was noted in a vein on the Evans property on Whitefish creek. It occurred as small plates in quartz. Native copper is also reported from the differentiated ore-body on Alki creek.

*Sulphides.*

*Galena, Pbs., Sulphide of Lead.*—Galena occurs sparingly in the copper deposits and was found only in the Howe's claim on the south side of St. Mary lake in a vein on the contact of a gabbro sill with the underlying quartzites.

*Pyrrhotite, $Fe_{11}S_{12}$.*—Magnetic pyrites is the most abundant sulphide in the copper deposits. It occurs as small masses of irregular outline associated with pyrite and copper-bearing pyrite in both the differentiates and the true vein.

*Chalcopyrite, $CuFeS_2$, Copper Pyrites.*—Chalcopyrite occurs in the copper deposits as small irregular masses associated with pyrite and pyrrhotite.

*Pyrite, $FeS_2$, Iron Pyrites.*—Pyrite occurs abundantly in both the differentiates and in the true veins. In most cases, it apparently approaches chalcopyrite in appearance.

*Oxides.*

*Quartz, $SiO_2$, Oxide of Silicon.*—Quartz is the most abundant gangue mineral in the copper-bearing veins. It occurs massive and contains the sulphide as impregnations. The quartz carrying the sulphides of iron and copper, is evidently the first vein filling. Later, a reopening of the vein occurred, as is well shown in the vein on the Evans group, allowing a later deposition of coarsely crystallized calcite, which as far as known, does not carry any sulphides. In the differentiates, quartz occurs as an opalescent variety and as an intergrowth with orthoclase in the micropegmatite.

*Carbonates.*

*Calcite, $CaCO_3$.*—Carbonate of calcium is a prominent gangue mineral of the copper deposits of the vein type. In the vein on the Park claim on the St. Mary prairie, it forms almost the entire gangue. It is generally white and coarsely crystallized.

*Malachite, $CuCO_3$ $Cu(OH)_2$, Basic Copper Carbonate.*—Malachite occurs as green incrustations on the outcrop of the copper-bearing veins as a result of the decomposition of chalcopyrite and cupriferous pyrite.

*Azurite, $2CuCO_3$, $Cu(OH)_2$.*—Azurite occurs as a blue incrustation on the weathered outcrops of the copper-bearing deposits.

## *Silicates.*

*Pyroxene.*—Pyroxene was found only in a vein on Pollens group of claims on Whitefish creek. It occurred as short prismatic crystals of green colour.

*Hornblende.*—Hornblende is the most common mineral in the differentiates, occurring as black lustrous crystals associated with micropegmatite and the sulphides of copper and iron.

## *Arsenates.*

*Erythrite, $Co_3As_2O_8$ $8H_2O$, Hydrated Arsenate of Cobalt, commonly known as Cobalt Bloom.*—Erythrite occurs as a crimson red incrustation on the oxidized outcrop of the copper-bearing veins. Although no cobalt sulphides were identified in the copper deposits it is very probable that they exist in small quantities associated with the other sulphides.

## PERSISTENCY.

From the very nature of the differentiates, they cannot extend beyond the limits of the sills. In the case of the veins, the following facts tend to show that they also are either restricted to the sills or to the quartzites in the immediate neighbourhood of the sills.

1. With very few exceptions, the veins occur within the sills themselves.

2. All gradations exist between the differentiates and the true veins showing that the deposits originated from the sills.

3. In one case, on Mackay's claims, the vein which was 8 feet wide in the sill pinched out in the quartzites within a few feet of the lower contact.

4. No veins have been located in the quartzites.

### Origin.

The origin of the copper deposits may be safely associated with the cooling stages of the Purcell sills, since all gradations exist from the normal gabbro through the differentiates to the true veins and all gradations carry sulphides of copper and iron. Also, the occurrence of the copper deposits always in association with the sills and the fact that the veins pinch out when passing from the sills to the quartzite support this idea.

### Age.

The Purcell sills represent the intrusive phase of the Purcell lava, which was poured out at the close of the Siyeh times. Arguments have been advanced in a previous chapter, for a Pre-Cambrian age of the Siyeh formation; hence the Purcell lava and Purcell sills are Pre-Cambrian in age. From this, the conclusion is justified that the copper deposits are Pre-Cambrian in age.

## DETAILED DESCRIPTION OF COPPER PROPERTIES.

### Evans Group of Claims.

The Evans group of claims, owned by C. and W. Evans, of Marysville, is situated on the western slope of Evans mountain, at an elevation of about 6,000 feet. The mountain is composed of easterly dipping Aldridge quartzites intruded by three diorite sills, the upper one forming the summit of Evans mountain.

The lower claims contain a tunnel 200 feet long driven into a low grade ore-body of the differentiate type contained in a gabbro sill about 400 feet thick and forming the lowest of the three sills. The ore consists of pyrrhotite and cupriferous pyrite impregnating a coarse-grained hornblende granite. The upper claim contains a fissure vein about 4 feet wide, striking N. 45° E. in a sill of normal hornblende gabbro, which forms the middle of the three sills. The ore consists of chalcopyrite, pyrite, and some pyrrhotite and native copper in a quartz calcite gangue.

Work is being pursued on both groups of claims with a view to determine the size and relation of the two types of deposits.

## McKay Claims.

The McKay claims are situated on the northern slope of Whitefish creek and about 7 miles from where it joins the St. Mary river. The country rocks consist of Aldridge quartzites intruded by hornblende gabbro sills, all dipping at an angle of 65 degrees to the northeast.

The vein, 8 feet wide, which occupies a shear zone in the hornblende gabbro, strikes S. 85° W. and dips 79 degrees to the south. That the fissure is a shear zone is supported by the alignment of the feldspars in the hornblende gabbro parallel to and in close proximity to the surface of the fissure. In tracing the continuation of the vein into the underlying quartzites, it was seen to pinch out within 8 feet.

## Sylvia Claim.

The Sylvia claim is situated 2 miles east of Marysville. The country rock consists of a hornblende gabbro whose form and relationships are concealed by a covering of superficial deposits, but from a study of the surrounding district the hornblende gabbro is believed to be in the form of a sill intruded into the Aldridge formation.

The vein, 7 feet wide, strikes N. 63° E. and dips 85 degrees to the southeast. The vein filling consists of pyrite in a quartz gangue. The reopening of the fissure gave opportunity for deposition of calcite which, occurring in two distinct zones, gives the vein a banded appearance.

### Blue Dragon Claim.

The Blue Dragon claim is situated 1 mile east of the Sylvia and occurs under the same geological conditions. The vein which traverses hornblende gabbro consists of a number of vertical shear zones containing chalcopyrite and pyrite in a quartz calcite gangue. The vein strikes N. 60° E. The workable width of the vein is 4½ feet.

### Black Hills Claim.

The Black Hills claim adjoins the Blue Dragon and contains three main veins traversing hornblende gabbro. Two intersecting veins 6-8 feet wide, composed of quartz, containing chalcopyrite and pyrite, strike N. 20° W. and N. 30° W. respectively. The weathered outcrop of the vein shows azurite and malachite. The other vein strikes S. 75° W. and dips 65 degrees to the southwest. The ore consists of chalcopyrite, pyrite, and some galena in a gangue of quartz and calcite. A shaft 45 feet deep opens up the deposit.

### Yankee Girl Claim.

The Yankee Girl property contains a quartz vein 6 feet wide striking S. 65° E. and dipping 66 degrees to the southwest, traversing hornblende diorite. The ore consists of pyrite and chalcopyrite in a gangue of quartz and calcite. Cobalt bloom occurs as one of the products of oxidation. The following assays were supplied by Messrs. Angus and Tarrant:—

| Sample | Gold | Silver | Copper |
|---|---|---|---|
| 1 open cut............................ | 0·80 oz. | 1·44 oz. | 6·90% |
| 2 open cut............................ | 0·44 | 4·20 | 2·05 |
| 3 shaft................................ | trace | 2·80 | 32·50 |

A shaft 25 feet deep and an open-cut expose the ore-body.

### Omineca Claim.

The Omineca claim is situated 1 mile west of Marysville at an elevation of 3,100 feet. The vein which is 7 to 8 feet wide, traverses hornblende gabbro and contains chalcopyrite and pyrite in a quartz calcite gangue.

## *PLACER GOLD.*

Placer deposits have been an important source of gold in East Kootenay district; but during the last few years the only activity has been on Perry creek. Gold has been obtained out of several creeks, the most important being Perry creek, Palmer Bar, Moyie river, and Weaver creek. From an examination of the tables given in the introduction to the chapter on economic geology, some idea of the importance and history of the production can be determined.

The gold in the placer deposits is evidently derived from the gold quartz veins which occur in the Aldridge, but more particularly in the Creston formation. Free gold has been found in the weathered outcrops of these veins on Perry creek, where they reach a width of 20 feet. It might be recorded that the valley walls of Perry creek, the richest placer gold creek within the Cranbrook map-area, contain the greatest number of gold quartz veins.

## DETAILED DESCRIPTION OF PROFERTIES.

As only one property was in operation at the time of the writer's visit and very little information could be obtained at that time, the following description is quoted from the Annual Report of the Minister of Mines for British Columbia, 1903.

### "Perry Creek Hydraulic Mining Company."

"The 'Falls' occur in a canyon which cuts through a bluff of rock, the old channel of the stream apparently having passed on one side of this, and certainly on the right bank of the creek there is an old gravel channel on which, at the level of the creek, below the Falls, a tunnel (the old Montezuma tunnel) was driven in for from 1,000 to 2,000 feet, with certain workings in connection therewith of which no plan is known to exist. Whatever the course of this old channel may have been, it apparently emptied into the present creek below the Falls, as the old drifting proposition mentioned proved, and this work also proved that there is a paystreak which, according to 'old time miners,' was not down to bed or even rimrock, as bedrock was never reached by the tunnel. While there is unquestionably gold in such old channel, the paystreak was either not sufficiently defined or not rich enough to pay as a drifting proposition after it reached such considerable distance from the surface. That the gold in this old channel is not confined to bedrock, was demonstrated by the old tunnel workings in the first place, while later prospecting work has revealed two or three paystreaks in the overlying bank, not rich enough for drifting but sufficiently so to induce a company to attempt to hydraulic the whole bank. This company is the Perry Creek Hydraulic Mining Co., a syndicate formed of United States capital, and of which A. S. Trow, H. A. Bright, E. G. Brayton, and D. Halliway, of Merrillan, Wis., are the largest holders. Mr. Wm. Trow is local manager or agent, and Robert Jennings, superintendent in charge of the work. The company has secured water rights on Perry creek, taking water from the stream about 4 miles above the Falls, and having under construction a wooden flume, 4 feet wide by 3 feet high, built of 1 1-4 inch lumber. To cut this lumber the company had erected a saw-mill at Saw-mill creek, and had let a contract for 300 M. feet of logs at $4 per M.

"The clearing of the surveyed flume line was well under way at the time the property was visited, as was also the flume construction, with every probability of being completed during 1903. The flume leads along the right or south side-hill, attaining a height above the creek of about 300 feet. At the lower end of the flume, a 'siphon' of rivetted iron pipe was to be constructed over a draw, narrow but having a depth of 175 feet. The siphon was to deliver its water to a short ditch, leading to a pressure box situated on the top of the hill, from which a pipe-line was to run down the face of the bank to the mouth of the Montezuma tunnel, where it should deliver water under a head of about 400 feet. The stream, from the tunnel down, is confined by steep banks and has a fall of about 3 per cent; this is not enough to carry off hydraulic tailings and, consequently, they will have to be sluiced away in boxes for about half a mile below the Falls. This will necessitate the bottom of the hydraulic pit being some 50 or 60 feet above the creek at the mouth of the Montezuma tunnel. Consequently, while the upper part of the bank can be run off by straight sluicing methods, the lower 60 feet will have to be raised by an elevator of some sort.

"The bank representing the face of this old channel has been cleared of timber to its summit. This bank is about 400 feet high and is composed of fine gravel, silt and some clay, which will wash cheaply and quickly, but will have to be handled very carefully as it has a tendency to 'slide,' a thing which, if it occurs, will choke the canyon and interrupt operations for some time. Hydraulicing operations should begin in the spring of 1904 and with judicious handling the property has a good chance of becoming a producing mine this next season.

"Above the Falls the old channel is deep and several attempts have been made to test and work it by means of shafts sunk in the early 90's; but, while gold has been found, these operations have not been commercial successes. In the stream bed there is a clay or 'false' bedrock, on which gold in paying quantities has been obtained at several points."

### "THE EAST KOOTENAY PLACER MINING COMPANY."

"The East Kootenay Placer Mining company, a local company, in which Dr. Bonnell, W. Ross and J. McDonnell, of Fernie and others, are interested, has secured leases about 4½ miles above the Falls, and has established a steam shovel for lifting the gravel into the sluice boxes. At the point selected for operations the creek bed has a grade of about 2 to 3 per cent, and at a depth varying from 3 to 10 feet there occurs a 'false bedrock,' consisting of a sandy clay, on and above which gold in considerable quantities has been found. The true bedrock is believed to be at a depth of approximately 50 feet lower, since at this depth it was struck in both the old Ridgeway and Baker shafts, a short distance away. From the former of these shafts drifts were made, so its is reported, down stream for 150 feet and up for 25 feet. In the shaft $90 was said to have been found, and the drifts were stated to have paid $7 per day to the man for a time. The Baker shaft was also drifted from for some 100 feet, but was not profitable.

The original intention at the installation of the plant was to work the gravel on and above the false bedrock, and of this a patch 64 yards long, 8 yards wide and 2 yards deep, equal to about 1,000 cubic yards, has been taken and dumped into the rough sluice-boxes. From this small patch gold amounting to $260, as reported by the management, was obtained, being equivalent to 26 cents per cubic yard.

"The shovel is a regular railway steam shovel (built by the Vulcan Iron Works, of Toledo, Ohio), mounted on a standard gauge car running on rails; it is self-propelling and has a bucket of 1½ cubic yards capacity. The motive power is supplied by steam from a vertical boiler forming a part of the equipment. The shovel, which weighs about 45 tons, was brought up from the railway as it stands and under its own steam, over the waggon road, on moveable sections of track, an exceedingly difficult undertaking considering the road travelled over. The shovel has a rigid bucket arm long enough to load railway cars from a gravel pit, a lift of say 10 to 12 feet, and at first worked very well; but as the cuts worked upstream the bedrock ran very flat, and the height therefrom to the sluice-boxes increased, so that eventually the dipper arm was found to be too short. Operations were accordingly stopped and the superintendent, Mr. Banks, was then sent East to have a longer arm prepared to enable the shovel to take a wider cut and to lift higher.

"Some difficulty has also been found in disposing of the tailings, as the stream had not sufficient grade to carry them off and it was, therefore, found to be necessary to 'stack' them, an appliance for which was also being arranged for by Mr. Banks. These additions to the plant will not be ready until the season of 1904.

"If the ground worked may be taken as a sample of the values to be found above the false bedrock, and there is no reason why it should not be, there is on the lease a large tonnage of material which, with the plant modified as proposed to suit the conditions, can be handled to a good profit. The plant, as it stands at present, is realised to have too small a range to be effective, and operations had been suspended until the requisite alterations were made. In the meantime the bucket arm had been unshipped and the winding engine of the shovel was employed to hoist the dirt from a shaft, which was being sunk to the bedrock proper to test it at this point. It is expected that, as work proceeds upstream, true bedrock will rise nearer the surface, and that towards the upper part of the leases it may be possible to reach it from the level.

"Water for sluices is taken out of the creek about half a mile above the shovel, and is brought down in a board sluice-box 32 inches wide and 15 inches deep.

"These were the only two placer mining enterprises in actual operation on the creek in August last. Some little placer prospecting was being done with a view of locating ground suitable for shovels, dredges, or other mechanical arrangements; this work, as yet, has not been developed into mining propositions. About half a mile below the Falls, on the right bank of the stream, a partnership of the old-time placer miners has sunk a shaft and is drifting for bedrock. This work is only carried on in the winter when water is not troublesome. The results obtained are said to be satisfactory, yielding good wages to those employed.

"Of the mineral claims located on Perry creek there is little to be said that is new; a general description of these will be found in the report for 1898, and, with the exception of a certain amount of additional development work, nothing of importance has transpired. A large number of the claims then mentioned have been allowed to lapse, though some new ones have been located. Sherwood's claims, there noted, are still held by him in good standing, and he has done considerable development work on them, proving the continuity of the ledges, with what results as to values has not been learned. It is understood, however, that the claims had this past summer been bonded to eastern parties, after an examination by their representative."

## *CLAY.*

The following extract from a report by H. Ries[1] summarizes the information concerning the clay deposits of East Kootenay:

### CRANBROOK, B.C., AND VICINITY.

"The calcareous silts in the valley of St. Mary river at Cranbrook, have been referred to in last year's report, and their similarity to the silts of the Columbia valley commented on. These materials were very calcareous, cream burning, and yielded a highly porous brick.

In the year 1913 another yard was established about 2 miles west of Cranbrook by Mr. Hanson. The deposit worked here, lies not in the main valley but behind a ridge, and slightly above the terrace level in the valley proper. It seems to be a separate basin or small lake deposit, of very different character from the valley silts, as it is much more plastic and of better working quality. The clay is stratified, in layers one-half to 1 inch thick, separated by thin laminæ of sand, and there are only a few inches of soil overlying it. A thickness of 5 feet had been exposed. Like the valley silts it is calcareous, but not enough so to make a cream-coloured product.

It is sufficiently plastic to flow through a tile die. The clay (Lab. No. 1935) worked up with 20 per cent of water, and had an average air shrinkage of 5·4 per cent, and an average tensile strength of 87 pounds per square inch. Both wet-moulded and dry-press bricklets were made with satifactory results. The wet-moulded bricklets burned to a pink colour at low cones and then red if well burned, but were not steel hard unless fired to cone 05, although they had a good ring even at cone 010. The burning tests of the wet-moulded bricklets are as follows:

[1]Ries, H., Geol. Surv., Can., Mem. 65, 1915, p. 33.

*Laboratory Sample No. 1935.*

| Cone | Fire shrinkage % | Absorption % |
|---|---|---|
| 010 | 0 | 26·43 |
| 05 | 1·0 | 20·80 |
| 1 | 10·7 | 0·10 |
| 3 | Fused | |

It will be seen from these tests that although the clay is not sufficiently calcareous to burn buff, it nevertheless shows some of the characteristics of a calcareous clay, in its rapid shrinkage and vitrification between cone 05 and cone 1. It should be burned at cone 05 if possible.

The burning tests of the dry-press bricklets were as follows:

*Laboratory Sample No. 1935.*

| Cone | Fire shrinkage % | Absorption % |
|---|---|---|
| 010 | Too soft for use | |
| 05 | 0·3 | 31·64 |
| 1 | 11·00 | 0·97 |

The dry-press bricklets at cone 05 were pink in colour fine grained, and had a good ring, but the absorption was too high. At cone 1 the shrinkage was excessive and the colour dark brown. If dry-press brick were made of this clay they would probably have to be burned about cone 03 for the dual purpose of getting less absorption than at cone 05 and of avoiding the high shrinkage developed when burned at cone 1.

As to the uses of this clay, it could be and is manufactured into common brick. It would, I believe also, make drain tile. It lends itself to dry pressing. Lastly the smoother portions of the deposit could, I think, be moulded into earthenware such as flower pots. Mr. Hanson showed me some interesting and very creditable pieces of rustic pottery that had been modelled by hand from the material in his clay pit. At the time of my visit the product consisted wholly of common brick. The plant was equipped with pug mill, rolls, and side-cut-stiff-mud machine. Drying was done on pallet racks, and burning in scove kilns.

Along the railway track at Wycliffe station 6 miles northwest of Cranbrook, there is a strong outcrop of Pre-Cambrian metargillite. The material is a very hard schistose rock, which in some beds contains considerably more quartz than in others. A tunnel has been driven along one of the less quartzose beds, and at this point a sample for testing was taken. The material is not at all promising looking, and the only reason it was tested was because it was said to have been used for making brick, to line the smelter at Marysville, B. C. Even when finely ground, the material (Lab. No. 1941) had no plasticity so that it could not be wet-moulded. Some of it was then ground up very fine, moistened slightly with water and dry-pressed. These tests yielded the following results:

Cone 010. No ring to brick, body soft, colour red, absorption 12·58 per cent.

Cone 05. Little ring absorption 12·28 per cent.

Cone 1. Fire shrinkage 1 per cent, bricklet barely steel hard, absorption 9 per cent.

The material is not recommended for brick manufacture, for it can barely be moulded even by the dry-press process, and even then has to be very finely ground.

In looking for good clays in this region, Mr. S. J. Schofield of the Geological Survey, pointed out to the writer a bed of dark grey clay located along the north bank of St. Mary river, about 4 miles above the St. Eugene mission. The bed outcrops at the base of a high bank, and has a thickness of about 5 feet. As the overburden is considerable it could not be worked as an open pit, and could only be extracted by means of drifts. Neither is there evidence of a large quantity of the material.

There would, however, be enough to supply a small pottery, the idea being that the material might be used for earthenware.

The clay was plastic, although it contained much very fine grit, and took 29 per cent of water for mixing. It had an average tensile strength when air dried of 57 pounds per square inch, and an air shrinkage of 4·2 per cent. It burns to a pink colour and does not become steel hard until cone 1. The fire shrinkage is not high up to cone 05, and while the absorption appears to be it is often so in common earthenware made from some clays. The clay could probably be improved by washing, so as to remove fine grit.

The following are the fire tests on the bricklets:

*Laboratory Sample No. 1946—Wet-moulded bricklets.*

| Cone | Fire shrinkage % | Absorption % |
|---|---|---|
| 010 | 2 | 27·60 |
| 05 | 5 | 25·00 |
| 1 | 11 | 8·80 |
| 3 | 13 | 0·00 |

*Laboratory Sample No. 1946—Dry-press bricklets.*

| Cone | Fire shrinkage % | Absorption % | Colour |
|---|---|---|---|
| 010 | Soft, no ring when struck | | |
| 05 | Fairly hard | 26·88 | pink |
| 1 | Not steel hard | 16·82 | |

It would hardly be worth while to attempt making any dry-press forms of the clay.

CRESTON, B.C.

Goat river, a tributary of Kootenay river, joins the latter near Creston, and the Canadian Pacific railway follows the narrow valley of this stream from Goatfell to Creston. Along the line of the railway there are in this distance a number of clay cuts, which have given considerable trouble by sliding. These cuts, which are mostly of silty, laminated clay, are especially numerous between Kitchener and Erickson. Some of the cuts show stony or boulder clay, and in these there may be lenses of the laminated clays. All of these laminated clays are very silty and somewhat calcareous.

The deposits are not in all cases large enough to be worked, nor where they outcrop along the railway track, it might not in all cases be practicable to work them. They represent, however, a common type of clay in this region, and since they are best exposed along the railway, our samples were taken from these points.

A sample (Lab. No. 1930) was taken from along the railway about one mile northeast of Canyon station. It is a fine-grained silty material of fair plasticity, but at the same time exhibits the resistance to pressure, so characteristic of silty clays. It worked up with 23·8 per cent of water, had an average air shrinkage of 3·1 per cent, and an average tensile strength of 25 pounds per square inch. On account of its silty character the clay did not give results when moulded dry-press, but it did lend itself to the plastic method of working, and the test bricklets were formed in this manner. They burned to a pink colour, but did not become steel hard until cone 1, and in fact did not give a brick with real good ring unless burned to cone 05.

The other details of the burning tests are as follows:

*Laboratory Sample No. 1930.*

| Cone | Fire shrinkage % | Absorption % |
|---|---|---|
| 010 | 0 | 18·60 |
| 05 | 1 | 16·20 |
| 1 | 9·4 | 4·76 |
| 3 | 9·5 | 4·7 |
| 7 | nearly viscous | |

It will be seen from these tests that the clay does not become very dense until above cone 05 and that the great decrease in absorption at cone 1 is accompanied by a strong increase in shrinkage.

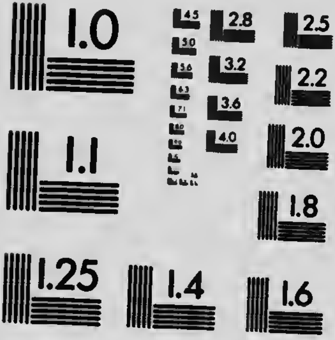
The clay is not plastic enough to flow through a die, and the only use suggested is for making common brick by the soft-mud process.

The best clay bank exposed along the railway track in the stretch mentioned is in the large cut at Goat canyon. It is a typical silty clay, which bakes to a hard mass in dry weather, and runs easily in wet weather. The clay (Lab. No. 1924) is of greyish-yellow colour, somewhat calcareous, and of fair plasticity, but not enough to flow through a tile die. It required 30·8 per cent of water to work the clay up to a plastic mass, which had an average air shrinkage of 4·9 per cent. The average tensile strength when air dried was 45 pounds per square inch. The clay like many other silty ones swelled slightly at cone 010, and its fire shrinkage was practically zero up to cone 05· By cone 1 the shrinkage had increased to 10·3 per cent. The absorption was high in every case except cone 1, and ran as follows—cone 010, 25·80 per cent; cone 05, 24·00 per cent; cone 1, 0 per cent. This peculiar behaviour is due in part to its silty nature, and in part to its lime carbonate contents. The clay burns pink, but is not steel hard until fired above cone 05.

It is at best only a common brick clay.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Along the road from Creston to Goat canyon, and opposite the site of Lisk and Slater's old saw mill, there is a long outcrop of reddish brown clay, with very little stony material. The deposit, as nearly as could be determined without boring, is probably 15 or 20 feet thick. There is room here for a brick plant, and the locality is about 1,000 feet by an air line from the railway. Similar clay outcrops at other points near by.

This material (Lab. No. 1920) is quite different in its nature from that in the railway cuts mentioned above, being less sandy to the feel and denser, but like the others is somewhat calcareous. It took considerable water to work it up, viz., 35 per cent, but yielded a mass that was sufficiently plastic to flow through a tile die. The average air shrinkage was 7 per cent, and the average tensile strength when air-dried, 90 pounds per square inch. This was almost double that of the Goat Canyon clay. The clay burned to a red colour, and the bricklets had a good ring even at cone 010. The fire tests were as below:

*Laboratory Sample No. 1920.*

| Cone | Fire shrinkage % | Absorption % | Colour |
|---|---|---|---|
| 010 | 0 | 26·40 | salmon |
| 05 | 1·5 | 23·50 | |
| 1 | 1·7 | 16·87 | red |
| 3 | Fused | | |

The clay could be used for common brick as it is plastic enough to work. It burns hard at a low heat, and the only objection to it is the somewhat high absorption. However, the latter is not necessarily an indication of low durability. The clay could, moreover, be utilized in making drain tile, provided these did not have to be vitrified, but if they were burned to cone 1, the absorption would not be excessive. Even though the absorption of the brick made from this clay is somewhat high, the clay is better than several others which are used for brick in southern British Columbia. If the project of lowering the level of Kootenay lake is carried out, so as to unwater the delta lands south of Kootenay Landing, the drain tile which could be made from this clay should prove of value for draining these reclaimed lands.

Along the Erickson road, about 2½ miles from Creston, this same kind of clay again occurs, and here is not far from the railway track."

# CHAPTER VII.

## PHYSIOGRAPHY.

### Tabular Physiographic History.

The Cordillera in the vicinity of the Forty-ninth Parallel has been subdivided from east to west by Daly into the following physiographic provinces.[1]

| *Ranges.* | *Physiographic Provinces.* |
| --- | --- |
| Rocky Mountain system...... | Front Range syncline.<br>Galton MacDonald horst. |
| Purcell Mountain system..... | The Purcell range. |
| Selkirk Mountain system..... | The Selkirk monocline. |
| Columbia Mountain system... | The Rossland Phoenix volcanic cap.<br>The Midway volcanic cap. |
| Belt of Interior Plateau....... | The Anarchist old mountain plateau. |
| Okanagan range............. | The Okanagan composite batholith. |
| Hozomeen range............. | The Pasayten monocline.<br>The Hozomeen horst. |
| Skagit range................. | The Skagit volcanic cap.<br>The Skagit composite batholith.<br>The Chilliwack province of folded Palæozoic sediments.<br>The Gulf of Georgia down-warp. |
| Vancouver range................ | The Vancouver complex. |

### The Purcell Range.

The Purcell range, separated from the Selkirk range on the west by the Purcell trench and from the Rocky Mountain system on the east by the Rocky Mountain trench, is composed mainly of sedimentary rocks of varying hardness. The western part of the range is mainly made up of tough argillaceous quartzites with intruded gabbro sills, while the eastern part consists of younger, well-bedded siliceous and sandy argillites. On the whole, the materials are homogeneous from east to west.

[1] Daly, R. A., Geol. Surv., Can., Memoir 38, 1913, p. 601.

As mentioned in a previous chapter the structure is characterized principally by open folding in which the rocks form broad anticlines and synclines (see chapter on "Structural Geology") broken by a few normal faults.

## Tabular Geological History.

The complete physiographic history of the Purcell range, now that the materials and structure have been briefly described, can be entered upon. Since the rocks which form the range are Pre-Cambrian in age, the processes, which have produced its present surface, have extended over nearly the whole geological time scale; hence a brief geological history is here tabulated in which the periods of sedimentation, mountain building, and erosion, are expressed.

| *Period.* | *Processes.* |
|---|---|
| Present | Erosion, entrenching of streams, subaërial erosion. |
| Pleistocene | Erosion and deposition, glacial, interglacial, subaërial. |
| Tertiary | Erosion, entrenching of valleys in the Cretaceous peneplain, river capture, uplift, and faulting in east. |
| Late Mesozoic (Cretaceous). | Erosion, peneplanation. |
| Early Mesozoic | Mountain building, folded mountains, igneous intrusion. |
| Late Palæozoic | Deposition in east, erosion in west. |
| Mid-Palæozoic | Erosion. |
| Early Palæozoic | Plateau uplift and erosion. |
| Beltian | Deposition of Purcell series. |

## Relation of Drainage to Structure.

In an examination of the geological and topographical map of East Kootenay, it will be noticed in the western part of the range that the drainage lines are impressed upon the land surface discordant with the underlying geological structures, while in the eastern part, in the vicinity of Gold creek, the two are concordant. The St. Mary river rising on the summit of the r[illegible] cuts across an anticline of Aldridge quartzites before [illegible]ng the Kootenay river. A glance at the course of the

Moyie river shows that in the vicinity of the Moyie lakes it occupies the axes of an anticline then swings on to the eastern limb of the same anticline until it reaches the International Boundary line, where it occupies a fault zone. In the eastern part of the range, the drainage of Gold creek is worthy of attention. Connell creek, the West and South Forks of Gold creek flow eastward from their sources until the main Gold Creek valley is reached when they turn almost at right angles, flow southward and join the Kootenay river near the International Bounda line. The continuations of these tributary valleys, through which the streams at one time found exit to the Kootenay valley, are now for the most part devoid of drainage and are represented by three "wind gaps."

## General Description of the Upland Surface.

In a view from one of the higher peaks in the western part of the range, the most striking feature is the accordance of mountain summits giving the impression of a deeply dissected upland surface out of which projects numerous peaks of greater elevation and into which great trough-like valleys have been eroded. On close examination of details this imaginary reconstructed surface would appear to slope gently towards the Rocky Mountain trench and to be modified by recent glacial action. Three types of topography can be recognized. In the neighbourhood of the watershed of the range, the region is alpine in character, many peaks exceeding 9,000 feet in elevation (Plate XXXIII). Towards the east and southeast, the mountains are more subdued in character, having rounded wooded summits and finally ceasing altogether, when the prairie land of the Kootenay valley is reached (Plate IV). This valley in the neighbourhood of the St. Mary river is 16 miles wide. In the background the Rocky Mountain system rises wall-like to a height of 9,000 feet out of the valley, which here has a general elevation of 3,000 feet.

## Genesis.

The origin of the present physiography of the Purcell range has been stated by Daly[1] in the following summary.

[1] Daly, R. A., Memoir 38, 1913, Vol. 2, p. 612.

"In summary it may be said that the existing drainage of the Purcell has the relations of a set of dominant consequent streams and that there is little evidence of stream adjustment in this mountain system."

"Each of the three constituent ranges shows the accordance of summit levels in a very notable way. In no case, however, is there any known remnant plateau of an old, uplifted peneplain. The problem of explaining the accordance of summit levels is the same as in the Galton range and, in fact, throughout the majority of the ranges crossed by the Forty-ninth Parallel, we have the same phenomenon. The problem's solution in terms of one erosion-cycle has already been partly indicated and will be discussed more fully on later pages." This interpretation is based upon the idea that the Purcell range as well as the Rockies was built at the time of the Laramie revolution. Facts have been advanced in the preceding pages to show that the Purcell range was built at the close of the Jurassic and also that the streams now active in the Purcell range are not consqeuent and bear no relation to the structural features of the range.

The problem of the erosion of the Purcell type of mountain structure has been thoroughly worked out in the Jura mountains of Europe and in the Appalachians of eastern United States. In the study of the erosion of anticlines and synclines, it has been shown that structural features entirely govern the drainage. Erosion begins along the axes of the anticline, the weakest point in the structure, and as erosion proceeds, the streams in the anticlines sink below the level of those in the synclines and readjustments of the drainage lines occur in which the streams in the anticlines capture those in the synclines, thus producing the well-known Appalachian structure of synclinal mountains and anticlinal valleys. When old age is reached the hill tops and valley floors are graded and the adjustments of drainage to structure is thoroughly established. In late maturity and old age a state of peneplanation is reached when the streams bear no relation to structure. At this stage suppose an uplift occurs, the streams are rejuvenated in their non-structural positions and begin to cut down into this old peneplained surface. Finally, in maturity again we have an old upland or peneplain deeply entrenched by valleys which bear no relation to the underlyin geological structures.

Such has been in part the history of the Purcell range. Th anticlines and synclines, which were formed in late Jurassic o very early Cretaceous (Kootenay) were eroded as describe above in Cretaceous times until a state approximating pene planation was reached. The time necessary for this enormou amount of erosion—15,000 to 20,000 feet of sediments from th anticlines—is supplied by the whole of the Cretaceous an possibly some of the early Tertiary periods. That this perio of time is sufficient for so vast a piece of work is supported b comparison of the peneplanation of the Appalachians during th Cretaceous period. Hence at the close of the Cretaceous o early Tertiary, the Purcell range was one approximating a plai and hence of low relief. Over the monotonous landscape, th rivers meandered sluggishly.

## Evidence from the Rocky Mountains of a Cretaceou Peneplain.

The stratigraphic succession in the Rocky mountains, whicl lie to the east of the Purcell range, is conformable from th Cambrian to the close of the Cretaceous. The sediments in thi prism serve for an index to the conditions of unrest which pre vailed in the source of this material at the time of deposition This information can best be shown in tabular form.

| Period. | Formation. | Condition of deposition. | Character of sediments. |
|---|---|---|---|
| Cretaceous | Edmonton | brackish | clays and sandstone. |
| | Foxhills | marine | sandstone. |
| | Pierre | marine | shales. |
| | Niobrara | marine | highly calcareous shales. |
| | Benton | marine | shales. |
| | Dakota | continental | sandstone. |
| | Kootenay | delta | conglomerates sandstone and shale. |
| Jurassic | Fernie shales | marine | shales. |
| Carboniferous | | marine | limestone. |
| Lower Palæozoic | | marine | limestone and shales. |

From an examination of the above section it will be noticed that the only horizon in which conglomerates form a prominent portion of the succession is in the Kootenay formation. In a section of the Cretaceous near Fernie, B.C., the most western exposure of these rocks, McEvoy[1] has shown moreover that the conglomerates are almost confined to the upper part of the Kootenay and the lower part of the Dakota. From this it would seem logical that the Purcell range at this time reached its maximum elevation. The preparation for this period of erosion is shown in the shaly character of the Fernie shales of Jurassic age which are conformably underlain by the Carboniferous limestones. The upper Cretaceous is represented by the deposition of calcareous shales which show that the Purcell range was at that time reaching maturity or old age.

## Tertiary Physiographic History.

At the close of the Cretaceous or in early Tertiary the Laramide revolution took place, causing an uplift to occur in the Purcell range and probably throughout the whole Cordillera. At this time, the Rocky mountains were built. One Rocky Mountain structure is represented in the eastern part of the Purcell range; that of the fault running parallel with Gold creek. The huge block to the east of this fault settled with the greater throw on the eastern edge of the block. This gave rise to the Kootenay valley in this region.

The effect of this uplift was to slowly raise the old land surface described above, to almost its present height with the natural r[illegible] streams which meandered over the old sufrace were [illegible] and sank their valleys into this old peneplain. As t[illegible] bear no relation to the underlying structure, their re[illegible]d descendants, the present main valleys of the range, bear no relation to structure. The St. Mary river and Moyie rivers are hence comparable to the Shenandoah and Susquehanna of the Appalachians. While erosion was thus opening up the present valleys in the western part, let us see what

[1] McEvoy, J., G.S., Can., Summary Rept., 1900, p. 87.

was happening in the eastern belt. The Gold Creek fault, whi occurs to the west of the Kootenay graben, caused a line of wea ness to occur throughout its length and hence streams worked this favourable line. The most northerly fork of Gold cree the West Fork and South Fork evidently flowed eastwa through their respective gaps into the Kootenay. The ma Gold creek working on more favourable ground, gradually erod headwards and captured the above three streams, and now all t waters from the area south of Cranbrook drain down this ma valley. Thus, the wind gaps were formed in the eastern range hills.

## Quaternary Physiographical History.

On this maturely eroded land surface, the ice of the glaci period gradually collected and moved in a southerly directio Two types of glaciation show their effects in the district. Nor of Perry creek, alpine glaciation (Plate XXIV) was the rul while south of the same river, continental glaciation predom nated. In the northern region the rounded (pre-glacial) summi were greatly affected by glacial sculpturing. Numerous horn arêtes, cirques, etc. (Plates XXV and XXVI) are present in a stages of development and are well preserved in the dense har quartzites of the Purcell series. In the southern part, the ran is at present covered in drift which greatly impedes geologic investigation. On some of the highest summits (7,300 fee glacial erratics were seen. As might be expected from th type of glaciation, the summits are rounded and monotonou The valleys of the district show the effects of glaciation i presence of facetted spurs (Plate XXVII) and hanging valle The over deepening of the main valleys causes a break in th grade of the side streams which have canyons in their low stretches. The great volume of waters which occupied the va leys as the ice retreated, were overloaded with gravel, sand, an particles of rock, deposited as a great thickness of rudely stratifie gravels and sands. In the Purcell range two advances of th ice, separated by an interglacial period of milder temperatur are indicated if the age of lignite beds with the associated plan remains in the gravels of the Kootenay valley are interglacial. Since the final retreat of the ice, the streams have sunk their channels into the gravels and sand, leaving protected terraces along their courses.

## ORIGIN OF THE TRENCHES.

### PURCELL TRENCH.

The Purcell trench, a longitudinal valley, separates the Purcell range on the east from the Selkirk range on the west. On an average, the valley is 2 to 4 miles wide and is occupied in great part by Kootenay lake. The valley in the northern United States and Canada contains the north-flowing Kootenay river which empties into Kootenay lake in Canada about 15 miles north of the International Boundary line. Kootenay lake, which is 70 miles long, has an average width of 2½ miles. It is 1,760 feet above sea-level and as far as known, has a maximum depth of 450 feet. The mountains, which are very precipitous on each side of the lake, rise abruptly to a height of 7,000 to 8,000 feet above sea-level. The tribuary streams occupy hanging valleys and enter the lake by a series of cascades and falls. At the mouths of all tributary streams occur deltas which are occupied either by townsites like Kaslo, or by fruit farms. The drainage of Kootenay lake is effected by the Kootenay river which drains its waters westward into the Columbia river.

#### *Geological Features.*

The Purcell trench has been eroded into a complex of ancient sedimentary rocks which have been intruded by granites of Jurassic age. The strike of the sedimentary rocks in the neighbourhood of the lake little east of north, thus cutting at a small angle across the lake whose bearing is a little west of north.

#### *Origin of the Purcell Trench.*

Since it has been shown that the Purcell range was built in the late Jurassic or early Cretaceous times and peneplained

during the Cretaceous, and since the Selkirk range in the vi
of the Purcell trench has the same history and structure, it
be concluded that the Selkirk range has a history similar to
of the Purcell range.

The wall of the trench in the neighbourhood of the I
national Boundary line is composed of the Aldridge forma
the oldest known member of the Purcell series and from D
correlations mentioned in this report, it can be deduced tha
western side of the trench also has patches of Aldridge form
exposed on its slopes. The valley is floored with recent
deposits, but the underlying rocks, which Daly called Kitch
exposed in the cuts on the Bedlington and Nelson railway
also Aldridge, hence the fault postulated by Daly on the
side of the valley on stratigraphical grounds, is not prese
at least there is no field evidence for it. The fault on the wes
side of the valley which, according to Daly, has a throw of 30
feet, although not examined in the field, is not postulated
very firm evidence. The Kitchener rocks mapped on the w
ern side of the trench are really Aldridge, the oldest memb
the Purcell series, and low down in the formation, hence the th
of the fault, if present, would certainly not be 30,000 feet. He
the Purcell trench in this locality, cannot be a "graben."

Daly[1] has put forward the idea that the Purcell trench
"graben" because a block of Kitchener quartzite has been do
faulted, on the east side, with the Creston formation, and
the west side with the Priest River terrane of pre-Beltian ag

### *Summary of Origin.*

The region now traversed by the Purcell trench was pe
plained in the Cretaceous, uplifted in the early Tertiary and
Purcell trench was eroded by one of the rejuvenated Cretace
rivers during Tertiary times. No uplift is recorded in Terti
or recent times. The Tertiary valley was glaciated in Pleis
cene times, giving rise to the facetted spurs and hanging vall
so prominent in the architecture of the Purcell trench.

[1] Daly, R. ..., B.C., Memoir 38, p. 600, 1913.

## Rocky Mountain Trench.

The Rocky Mountain trench lies between the Purcell and Rocky mountains. It extends in Canada from the International Boundary in a northwesterly direction as far north as Alaska and perhaps to the Arctic ocean. The average width of its floor is about 5 miles, but in the neighbourhood of the St. Mary river it is 16 miles wide. It is occupied in its southern part by the south-flowing Kootenay river.

### *Geology.*

The eastern face of the Rocky Mountain trench, in the neighbourhood of Wardner, B.C., is composed of easterly dipping rocks of the Galton series of Pre-Cambrian age. The range of hills on the western side of the trench, are made up of the Purcell series, also of Pre-Cambrian age while the floor is covered with Devonian limestone. The fault on the east side of the trench was first determined by Dawson.[1]

The fault on the western side of the trench occurs in the valley of Gold creek, which lies within the first range of low rounded hills. The throw of the fault varies greatly and on the whole, is not large. The complexity of the structure of this down faulted block is greatly enhanced in that in the Rocky mountains, the Devonian limestone rests conformably on the lower Palæozoic formation, while in the Purcell range the Devonian limestone rests unconformably on the Pre-Cambrian formation.

### *Physiographic History.*

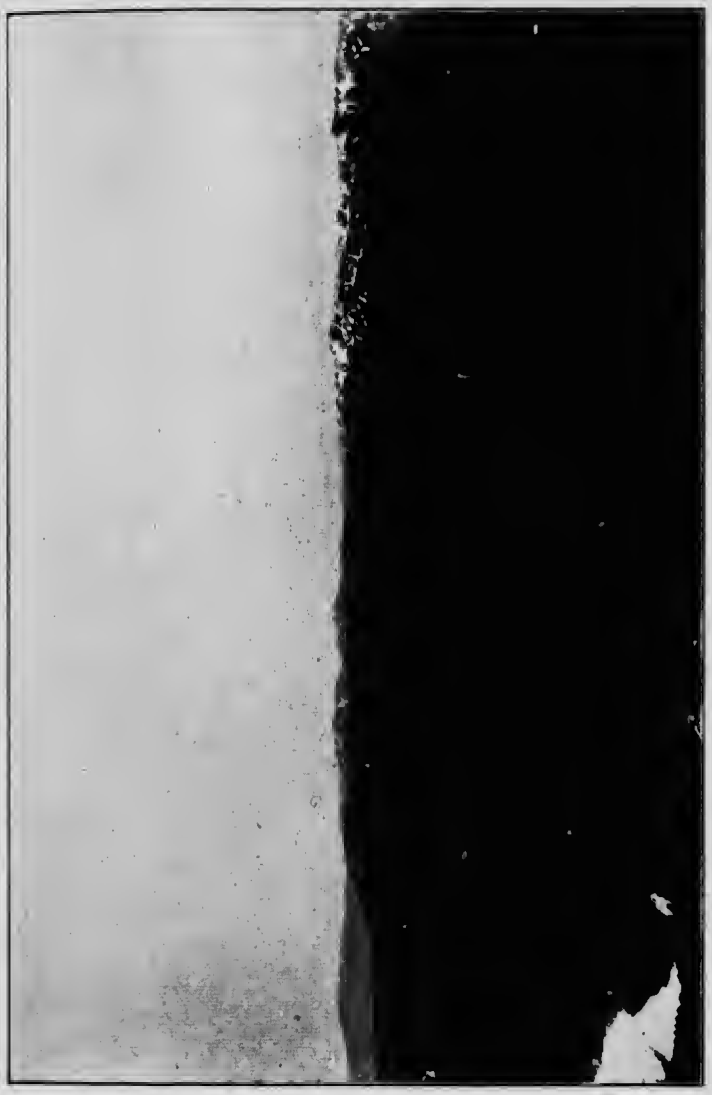
Since the Rocky mountains were built in early Tertiary and the faults on both sides of the Rocky Mountain trench are referred to this period of orogenic movements, it follows that the valley was initiated in early Tertiary times. Since then, it has been in greater part an area of erosion. During the early Pleistocene it was an area of deposition, giving rise to the St. Mary's silts. The shape of the Rocky Mountain trench has been somewhat modified by glacial action.

[1] Dawson, G.M., G.S.C., Ann. Rept., 1885, p. 150 B.

EXPLANATION OF PLATE II.

The contact of the fretted and non-fretted upland surface. Note the fla
areas on the upland surface in the non-fretted area. (See page 9.)

PLATE II.



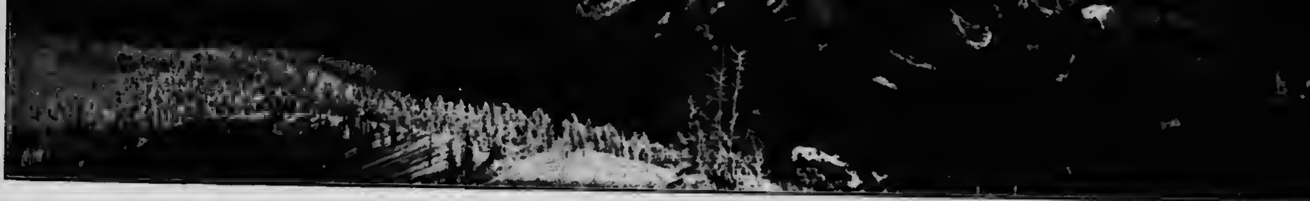
EXPLANATION OF PLATE III.

Farming land in neighbourhood of Wycliffe; Mt. Baker, and foothill
Purcell range in background. (See pages 9 and 10.)

EXPLANATION OF PLATE IV.

Rocky Mountain trench from the west. South flowing Kootenay river be seen in middle ground. (See pages 9, 10, and 162.)

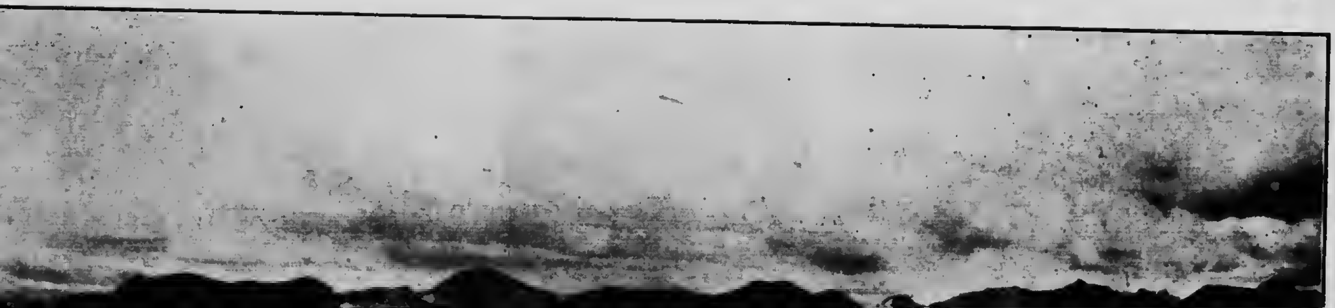
PLATE IV.



Cross section of Marysville anticline looking

ne looking south along its axis. (See pages 9 and 93.)

PLATE V.



EXPLANATION OF PLATE VI.

Fault crossing r' _. at head of Hall creek; brings Aldridge formation (on
in contact with Kitchener formation (on right). Foregr
granite intruded in the vicinity of fault. (See pages 10 and 94.

PLATE VI.

EXPLANATION OF PLATE VII.

Type of non-alpine topography. Placer gold camp on Perry creek. (See page 10.)

Plate VII.

(See

EXPLANATION OF PLATE VIII.

Continental glaciated area in neighbourhood of Perry creek. Note the eve sky-line and the continuity of the interstream divides. Compar with areas of alpine topography. (See page 10.)

PLATE VIII.

EXPLANATION OF PLATE IX.

Continental glaciated area in neighbourhood of Perry creek. Note the sky-line and the continuity of the interstream divides. Com with areas of alpine topography. (See page 10.)

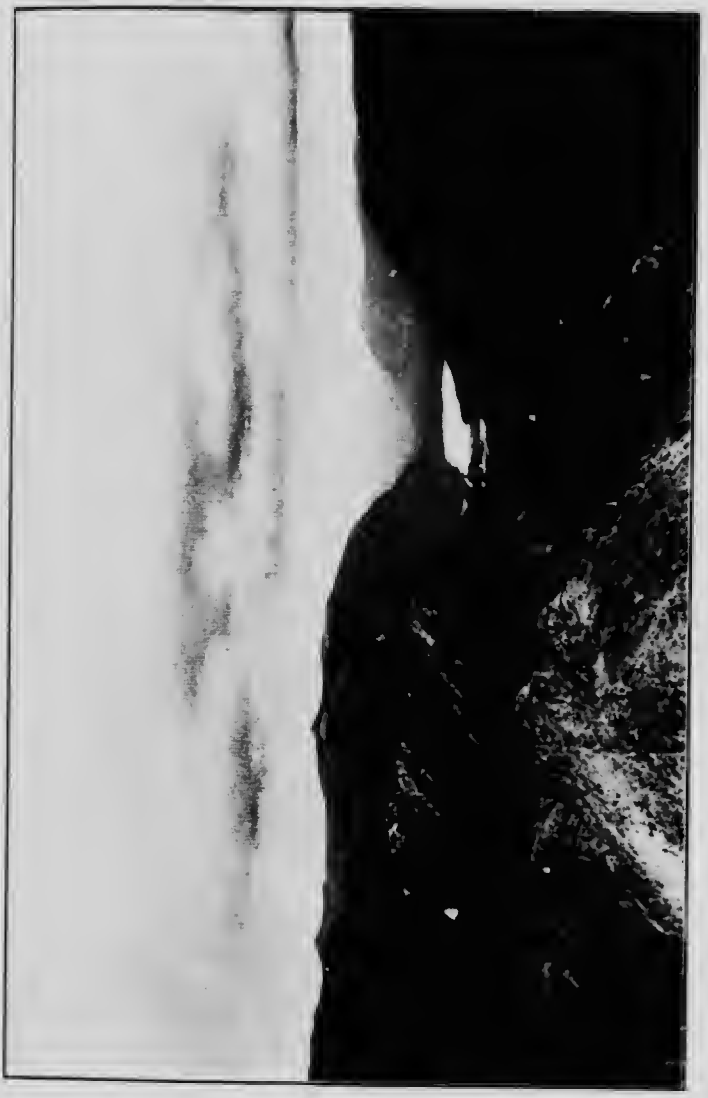
EXPLANATION OF PLATE X.

Valley of St. Mary river above St. Mary lake, looking west. Note ha valleys, facetted spurs, and flat valley floor. (See pages 10 anc

EXPLANATION OF PLATE XI.

St. Mary lake from the west. Shows the entrenched valleys and up
or Cretaceous erosion surface. (See pages 10 and 11.)

PLATE XI.



### Explanation of Plate XII.

St. Mary prairie looking north; shows contact of Purcell range and the prairi
land. St. Mary river in foreground. (See page 12.)

PLATE XII.

EXPLANATION OF PLATE XIII.

Upper and Lower Moyie lakes, looking north from St. Eugene mine. (S
page 13.)

PLATE XIII.

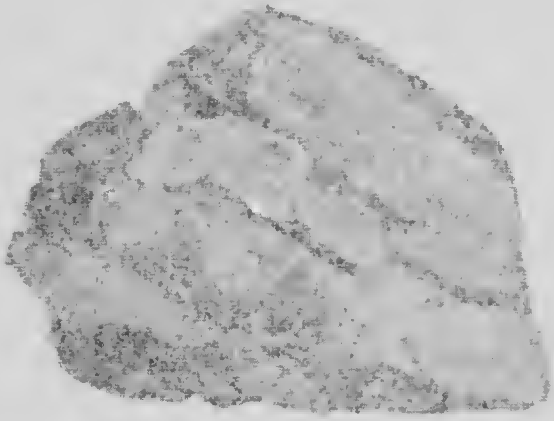
EXPLANATION OF PLATE XIV

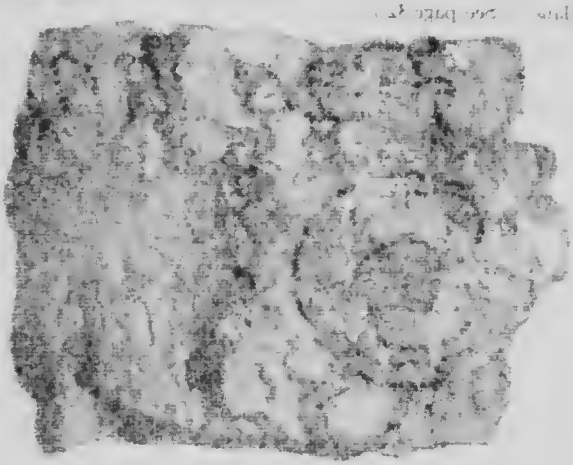
Anticline of Aldridge quartzites in Pyramid Creek drainage area. (See pages 26 and 93.)

EXPLANATION OF PLATE XIV.

Anticline of Aldridge quartzites in Pyramid Creek drainage area. (See pages 26 and 93.)

PLATE XIV.





## Explanation of Plate XV.

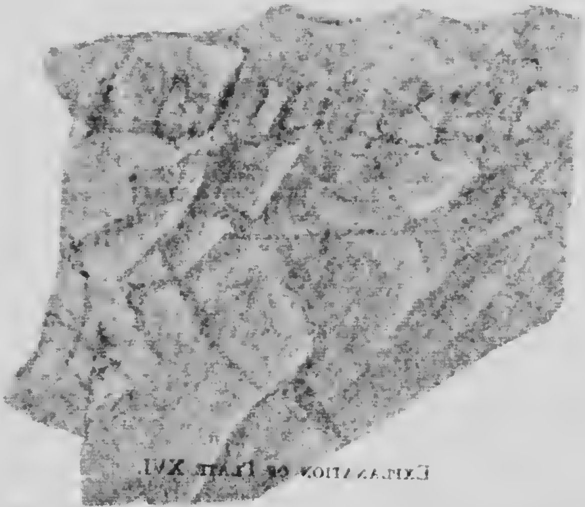
**A.** Limestone of Kitchener formation showing peculiar weathering on the bedding plane. (See page 32.)

**B.** Weathered surface of Kitchener limestones at right angles to bedding plane. (See page 32.)

Plate XV.

A.

B.



EXPLANATION OF PLATE XVI.

A. Mud cracks, Siyeh formation, one-half natural size (See page 34.)

B. Mud cracks, Siyeh formation, one-half natural size (See page 34.)

B.

### Explanation of Plate XVI.

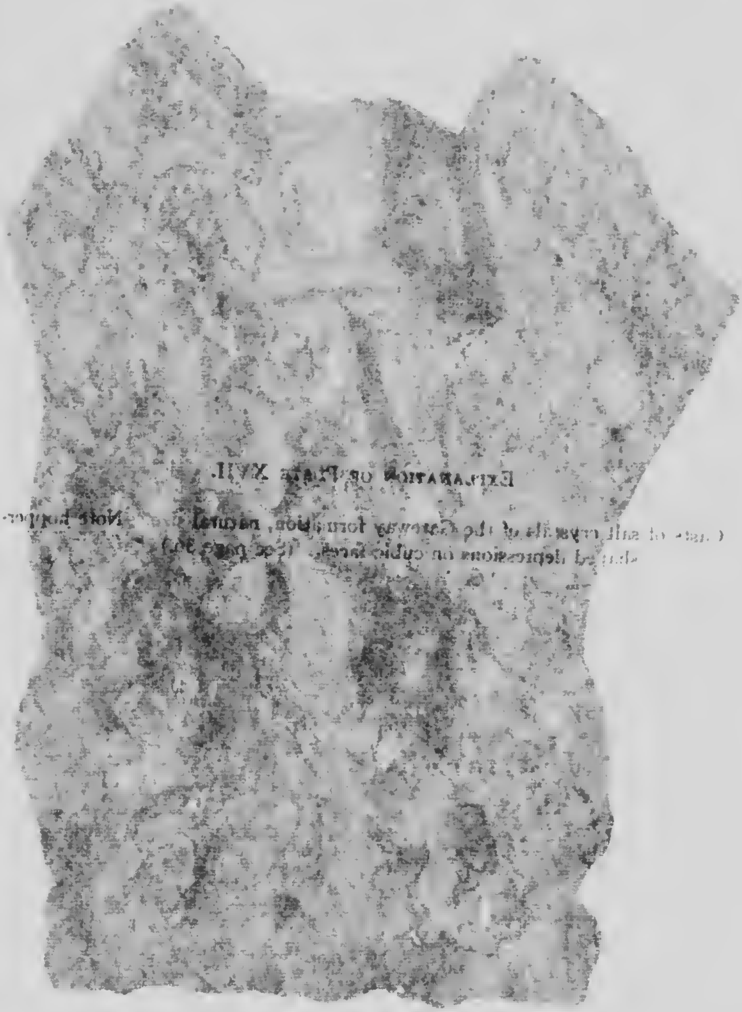
A. Mud cracks, Siyeh formation, one-half natural size. (See page 34.)

B. Mud cracks, Siyeh formation, one-half natural size. (See page 34.)

PLATE XVI.

A.

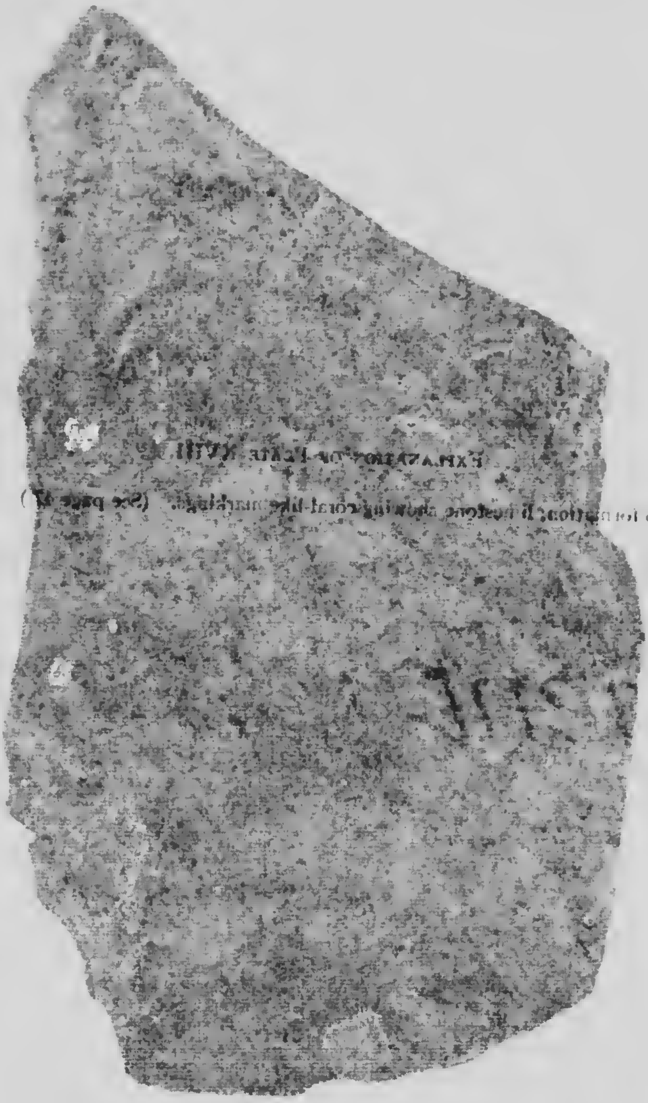
B.



EXPLANATION OF PLATE XVII.

Casts of salt crystals of the Gateway formation, natural size. Note hopper-shaped depressions on cubic faces. (See page 36.)

PLATE XVII.



EXPLANATION OF PLATE XVIII.

Elko formation; limestone showing coral-like markings. (See page 47.)

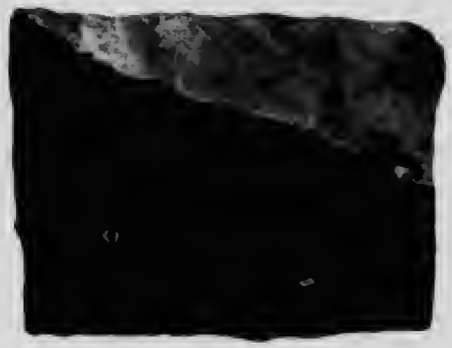
PLATE XVIII.

EXPLANATION OF PLATE XIX.

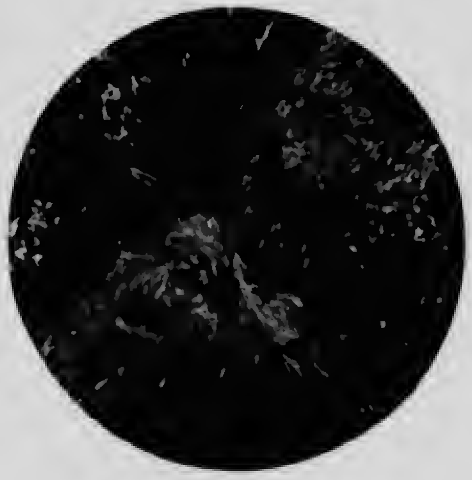
A. Idiomorphic crystal of garnet embedded in fine-grained galena of Sullivan mine. (See pages 111 and 132.)

B. Photomicrograph of St. Eugene ore. Black areas, magnetite; greyish black, garnet; fibrous mineral, actinolite; X16, cross nicols. (See pages 112 and 123.)

Plate XIX.



A.

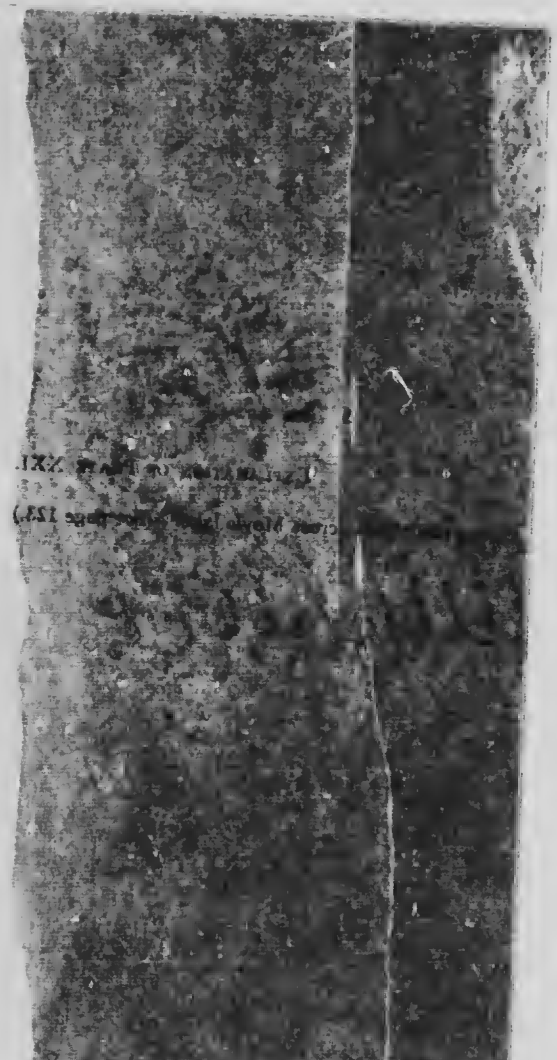


B.

### Explanation of Plate XX.

Moyie city and St. Eugene mine from across Moyie lake. (See page 118.)

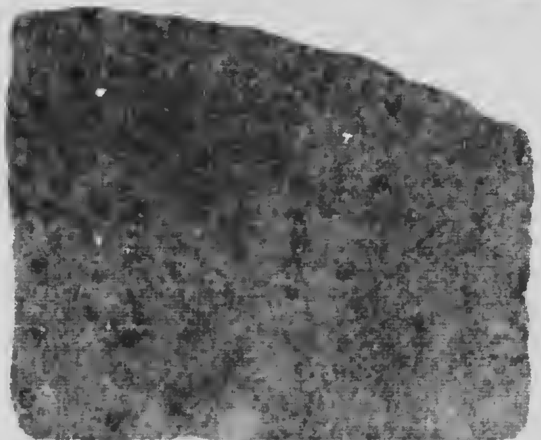
PLATE XX.



EXPLANATION OF PLATE XXI.

Aurora mine from across Moyie lake. (See page 123.)

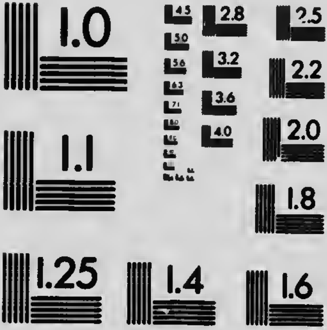
PLATE XXI.



B.

**MICROCOPY RESOLUTION TEST CHART**

(ANSI and ISO TEST CHART No. 2)



### EXPLANATION OF PLATE XXII.

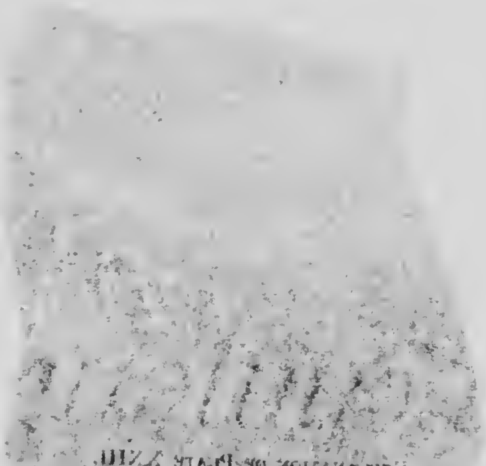
A. Photomicrograph of Sullivan ore. White areas, garnet, black areas, sulphides.

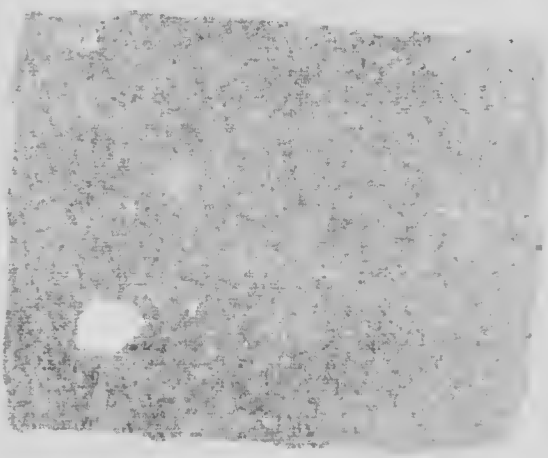
B. Pyritic zone of Sullivan ore; shows numerous round dark patches colourless crystals of garnet. Idiomorphic crystals of arsenopyrite are present but do not show in photograph. The fine-grained matrix consists of an intimate mixture of pyrite, pyrrhotite, and zinc blende. (See page 132.)

PLATE XXII.

A.

B.





### Explanation of Plate XXIII.

A. Polished surface of Sullivan ore, showing methods of replacement. (See page 133.)

B. Polished surface of Sullivan ore. The needle-like forms are pyrite pseudomorph after muscovite, dark background is quartzite. (See page 133.)

t. (See

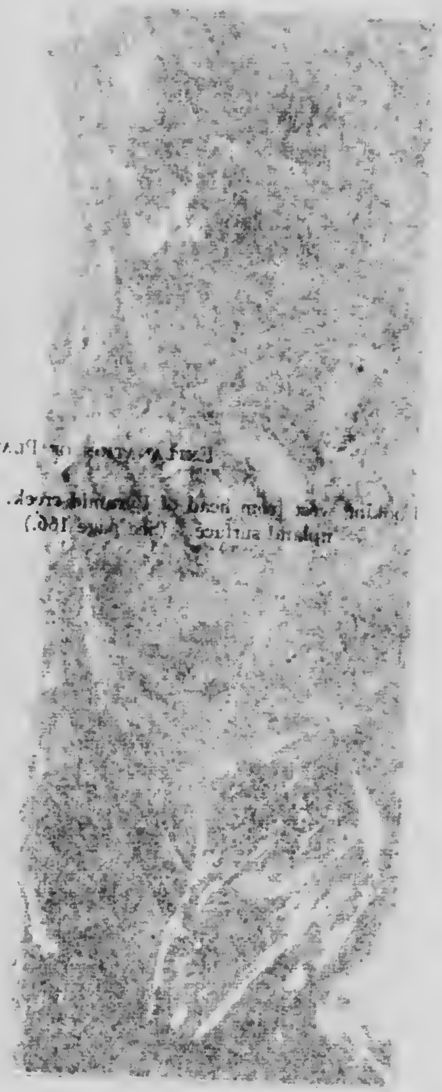
pseudo-
age 133.)



PLATE XXIII.

A.

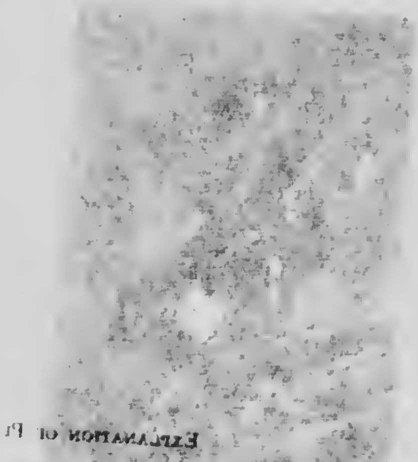
B.



EXPLANATION OF PLATE XXIV.

Looking west from head of Pyramid creek. Alpine topography and fretted upland surface. (See page 166.)

Plate XXIV.



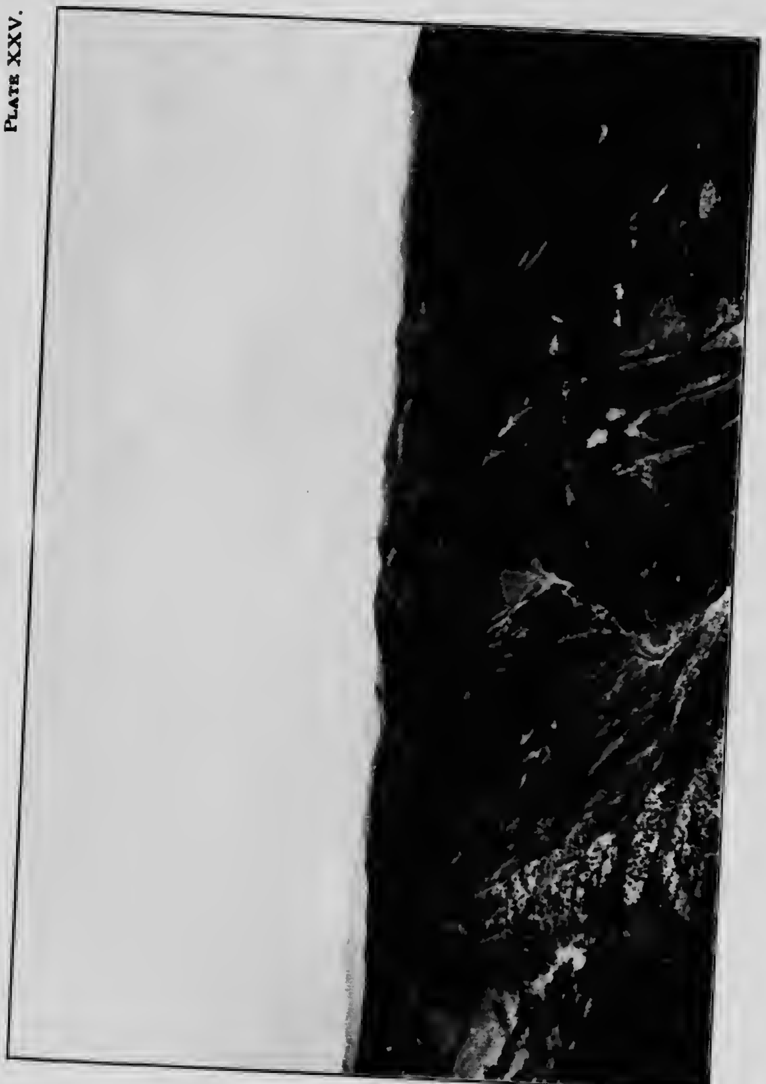
Explanation of Plate XXI.

Glacial cirque on border between the alpine and continental glaciated upland surface. (See page 156.)

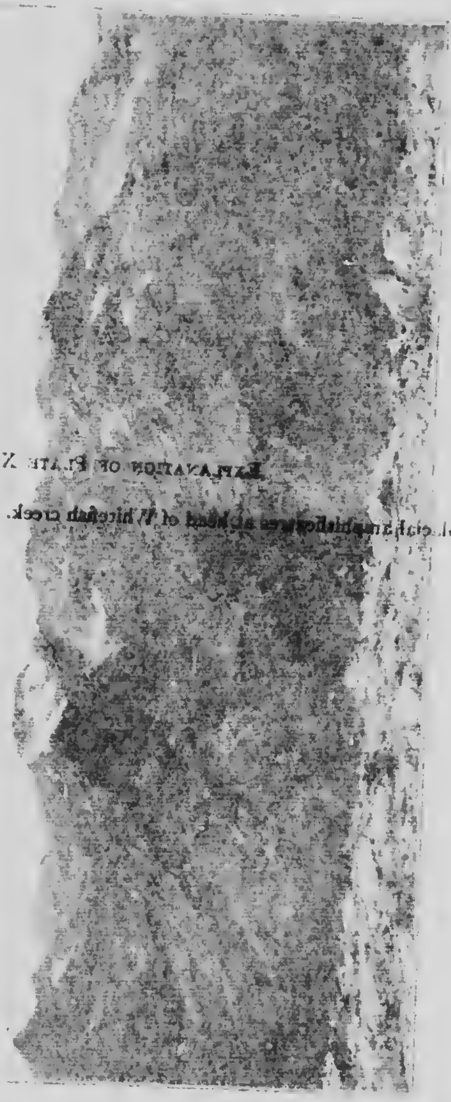
EXPLANATION OF PLATE XXV.

Glacial cirque on border between the alpine and continental glaciated upland surface. (See page 166)

PLATE XXV.



l upland



### Explanation of Plate XXVI.

Glacial amphitheatres at head of Whitefish creek. (See page 166.)

Plate XXVI.

EXPLANATION OF PLATE XXVII.

Hanging valley and facetted spur, in the main valley of St. Mary river. (See pages 11 and 166.)

PLATE XXVII.

16

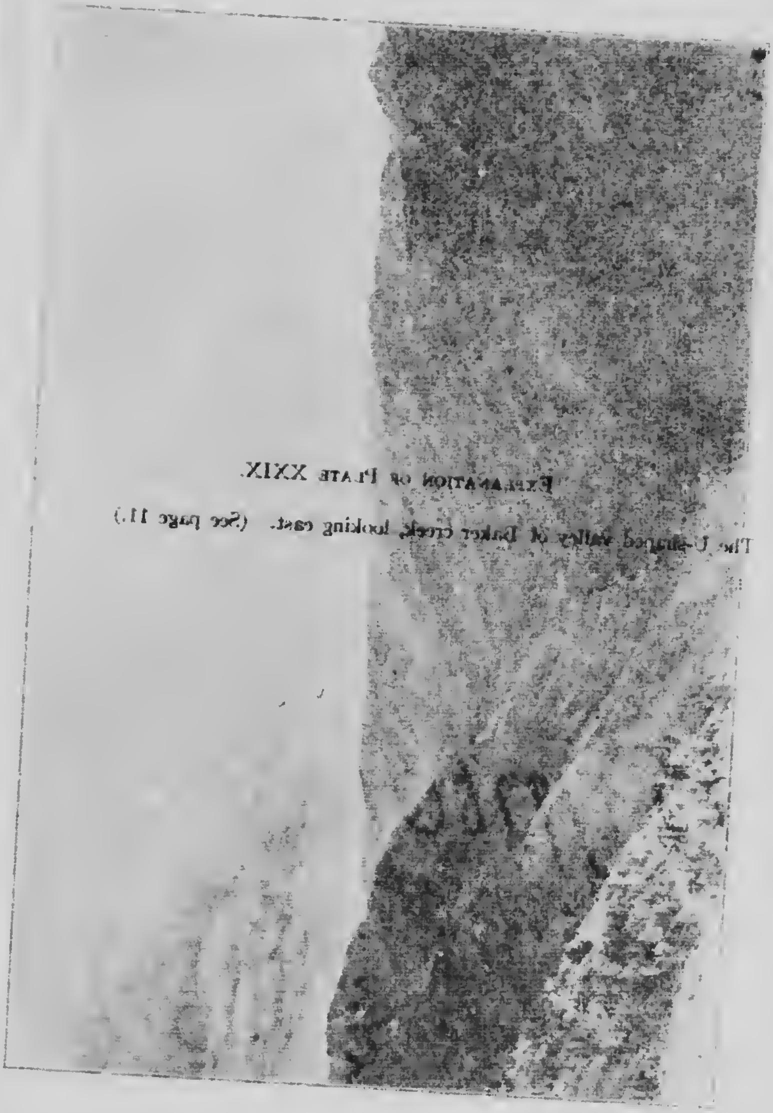
river.

[illegible]

Plate XXVIII.

Panorama of vicinity of Cra

ity of Cranbrook. (See page 3.)



EXPLANATION OF PLATE XXIX.

The U-shaped valley of Baker creek, looking east. (See page 11.)

### Explanation of Plate XXIX.

The U-shaped valley of Baker creek, looking east. (See page 11.)

PLATE XXIX.

EXPLANATION OF PLATE XXX.

Trough-shaped valley of Matthew creek, looking west. (See page 11.)

Plate XXX.

EXPLANATION OF PLATE XXXI.

Detailed view of a cirque. (See page 9.)

PLATE XXXI.

EXPLANATION OF PLATE XXXII.

Looking west up the St. Mary valley in the neighbourhood of Marysville. (See page 10.)

PLATE XXXII.

### Explanation of Plate XXXIII.

Alpine topography, looking northeast from head of Hells Roaring creek, Evans mountain on right. Note fretted surface. (See page 162.)

PLATE XXXIII.

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## A.

## B.



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## M.

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## T.

## U.



## V.



## W.



## Y.



## Z.

## LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

## Memoirs and Reports Published During 1910.

### REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

### MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario —by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Le..s and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and lfred E. Barlow.

MEMOIR 7 *No. 6, Geological Series.* Geology of St. Bruno mountain, province of Quebec—by John A. Dresser.

### MEMOIRS—TOPOGRAPHICAL SERIES.

MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

## Memoirs and Reports Published During 1911.

### REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of LakeTimiskaming—by Morley E. Wilson. No. 1064.

Summary Report for the calendar year 1910. No. 1170.

### MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

Memoir 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

Memoir 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

Memoir 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

Memoir 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

Memoir 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

Memoir 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

Memoir 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

## Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

Memoir 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

Memoir 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

Memoir 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

Memoir 28. *No. 18, Geological Series.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

## Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways: parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel, Parts I and II—by Reginald Aldworth Daly.

## Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 23. *No. 23, Geological Series.* Geology of the Coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 25. *No. 21, Geological Series.* Report on the clay and shale deposits of the western provinces (Part II)—by Heinrich Ries and Joseph Keele.

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

MEMOIR 52. *No. 42, Geological Series.* Geological notes to accompany map of Sheep River gas and oil field, Alberta—by D. B. Dowling.

MEMOIR 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neill.

MEMOIR 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.

MEMOIR 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks, in southern Quebec—by J. A. Dresser.

MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.

MEMOIR 47. *No. 39, Geological Series.* Clay and shale deposits of the western provinces, Part III—by Heinrich Ries.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.

MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.

MEMOIR 39. *No. 35, Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.

MEMOIR 51. *No. 43, Geological Series.* Geology of the Nanaimo map-area—by C. H. Clapp.

MEMOIR 61. *No. 45, Geological Series.* Moose Mountain district, southern Alberta (second edition)—by D. D. Cairnes.

MEMOIR 41. *No. 38, Geological Series.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick—by Marie C. Stopes.

MEMOIR 53. *No. 44, Geological Series.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition)—by D. B. Dowling.

MEMOIR 55. *No. 46, Geological Series.* Geology of Field map-area, Alberta and British Columbia—by John A. Allan.

## MEMOIRS—ANTHROPOLOGICAL SERIES.

MEMOIR 48. *No. 2, Anthropological Series.* Some myths and tales of the Ojibwa of southeastern Ontario—collected by Paul Radin.

MEMOIR 45. *No. 3, Anthropological Series.* The inviting-in feast of the Alaska Eskimo—by E. W. Hawkes.

MEMOIR 49. *No. 4, Anthropological Series.* Malecite tales—by W. H. Mechling.

MEMOIR 42. *No. 1, Anthropological Series.* The double curve motive in northeastern Algonkian art—by Frank G. Speck.

## MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 54. *No. 2, Biological Series.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts—by C. K. Dodge.

## Memoirs and Reports Published During 1915.

### REPORTS, ETC.

Summary Report for the calendar year 1913, No. 1359.

Report from Anthropological Division. Separate from Summary Report 1913.

Report from Topographical Division. Separate from Summary Report 1913.

Museum Bulletin No. [illegible]: No. 3, *Anthropological Series.* Pre-historic and present commerce among the Arctic Coast Eskimo—N. Stefansson.

Museum Bulletin No. [illegible]: No. 4, *Anthropological Series.* The glenoid fossa in the skull of the Eskimo—F. H. S. Knowles.

Museum Bulletin No. 13: No. 5, *Biological Series.* The double crested cormorant (*Phalacrocorax auritus*). Its relation to the salmon industries on the Gulf of St. Lawrence—P. A. Taverner.

### MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 58. *No. 48, Geological Series.* Texada island—by R. G. McConnell

MEMOIR 60. *No. 47, Geological Series.* Arisaig-Antigonish district—by M. Y. Williams.

MEMOIR 67. *No. 49, Geological Series.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers—by D. D. Cairnes.

MEMOIR 59. *No. 55, Geological Series.* Coal fields and coal resources of Canada—by D. B. Dowling.

MEMOIR 50. *No. 51, Geological Series.* Upper White River District, Yukon—by D. D. Cairnes.

MEMOIR 66. *No. 54, Geological Series.* Clay and shale deposits of the western provinces, Part V—by J. Keele.

MEMOIR 65. *No. 53, Geological Series.* Clay and shale deposits of the western provinces, Part IV—by H. Ries.

MEMOIR 56. *No. 56, Geological Series.* Geology of Franklin mining camp, B. C.—by Chas. W. Drysdale.

MEMOIR 64. *No. 52, Geological Series.* Preliminary report on the clay and shale deposits of the Province of Quebec—by J. Keele.

MEMOIR 57. *No. 50, Geological Series.* Corundum, its occurrence, distribution, exploitation, and uses—by A. E. Barlow.

## Memoirs and Reports in Press, May 8, 1915.

MEMOIR 62. *No. 5, Anthropological Series.* Abnormal types of speech in Nootka—by E. Sapir.

MEMOIR 63. *No. 6, Anthropological Series.* Noun reduplication in Comox, a Salish language of Vancouver island—by E. Sapir.

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MEMOIR 71. *No. 9, Anthropological Series.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa—by F. G. Speck.

MEMOIR 69. *No. 57, Geological Series.* Coal fields of British Columbia—by D. B. Dowling.

Memoir 34. *No. 63, Geological Series.* The Devonian of southwestern Ontario—by C. R. Stauffer.

Memoir 73. *No. 58, Geological Series.* The Pleistocene and Recent deposits of the island of Montreal—by J. Stansfield.

Memoir 68. *No. 59, Geological Series.* A geological reconnaissance between Golden and Kamloops, B.C., along the line of the Canadian Pacific railway—by R. A. Daly.

Memoir 72. *No. 60, Geological Series.* The artesian wells of Montreal—by C. L. Cumming.

Memoir 74. *No. 61, Geological Series.* A list of Canadian mineral occurrences—by R. A. A. Johnston.

Memoir 75. *No. 10, Anthropological Series.* Decorative art of Indian tribes of Connecticut—Frank G. Speck.

Memoir 76. *No. 62, Geological Series.* Geology of the Cranbrook map-area—by S. J. Schofield.

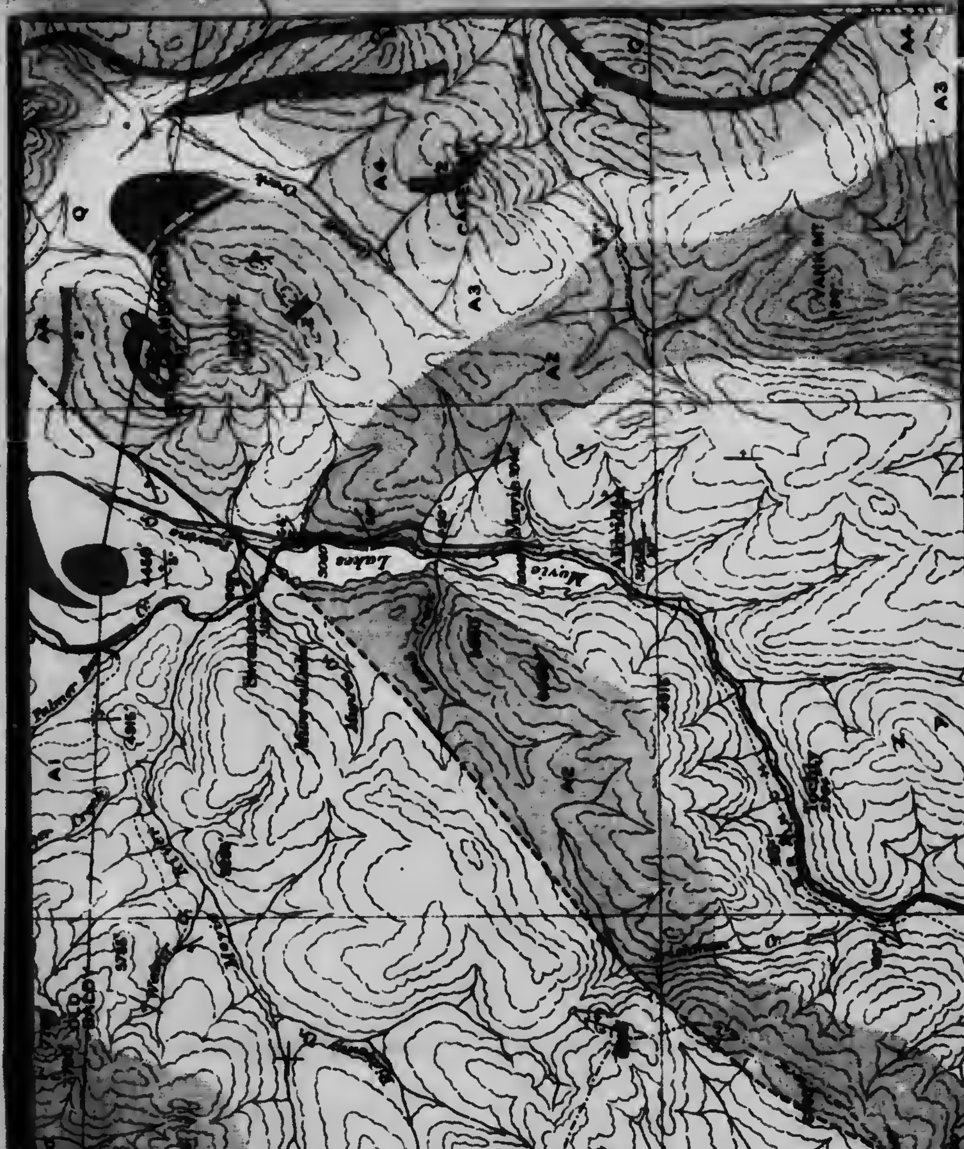
Summary Report for the calendar year 1914.

Museum Bulletin No. 10. *No. 5, Anthropological Series.* The social organization of the Winnebago Indians—by P. Radin.

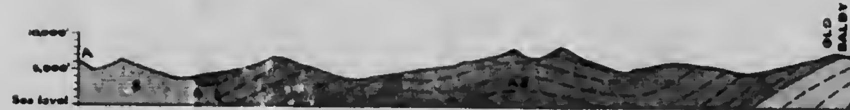
Museum Bulletin No. 11. *No. 23, Geological Series.* Physiography of the Beaverdell map-area and the southern part of the Interior plateaus, B.C.—by Leopold Reinecke.

Museum Bulletin No. 12. *No. 24, Geological Series.* On Eoceratops canadensis, gen. nov., with remarks on other genera of Cretaceous horned dinosaurs—by L. M. Lambe.

Museum Bulletin No. 14. *No. 25, Geological Series.* The occurrence of Glacial drift on the Magdalen islands—by J. W. Goldthwait.


Moyie
Lakes
A1
A2
A3
A4

HON. L. COD






**LEGEND**

QUATERNARY — Q — Stratified clay and sand

JURASSIC(?) — 3 — Granite and porphyritic granite

DEVONIAN AND CARBONIFEROUS — Limestone

PRE-CAMBRIAN —

- A5 — Gateway formation
- Purcell lava
- Purcell sills
- A4 — Siyeh formation
- A3 — Kitchener formation
- A2 — Creston formation
- A1 — Aldridge formation

**Symbols**

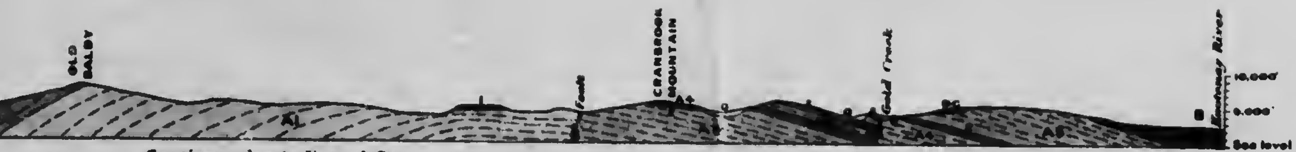
Geological boundary

Geological boundary

# Canada
# Department of Mines

Hon. L. Coderre, Minister; R.G. McConnell, Deputy Minister.

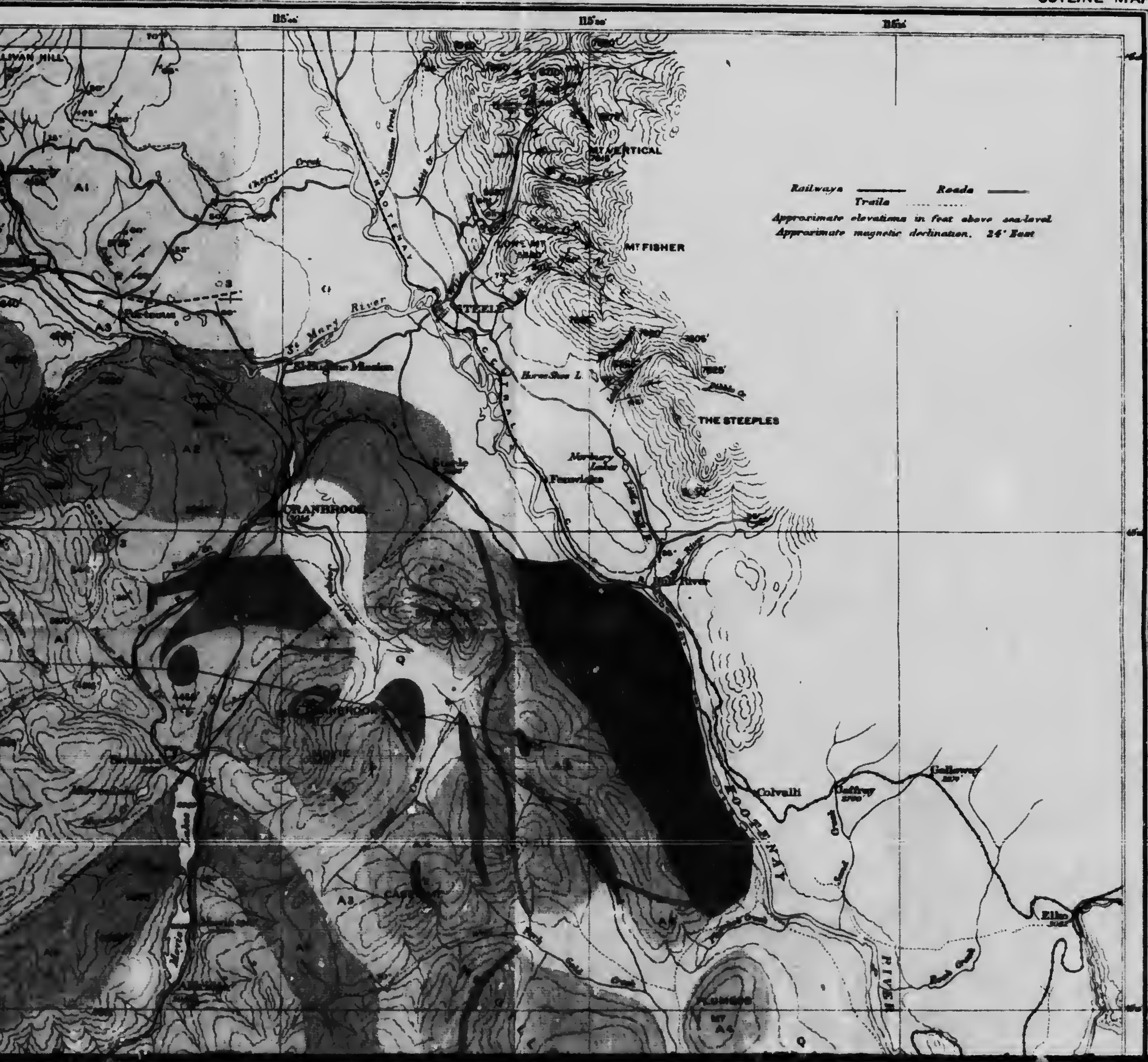
## GEOLOGICAL SURVEY




Section along line A-B


Section along International Boundary

OUTLINE MAP



PRE CAMBRIAN

Purcell sills
(all gradations from gabbro to granite intrusive equivalents of Purcell lava)

A4
Siyeh formation
(argillites, some siliceous limestones)

A3
Kitchener formation
(calcareous quartzite, limestone)

A2
Creston formation
(greyish weathering argillaceous quartzite and quartzite)

A1
Aldridge formation
(rusty weathering argillaceous quartzite and quartzite)

## Symbols

Geological boundary
(position observed)

Geological boundary
(position inferred)

Fault
(position observed)

Fault
(position inferred)

Dip and strike

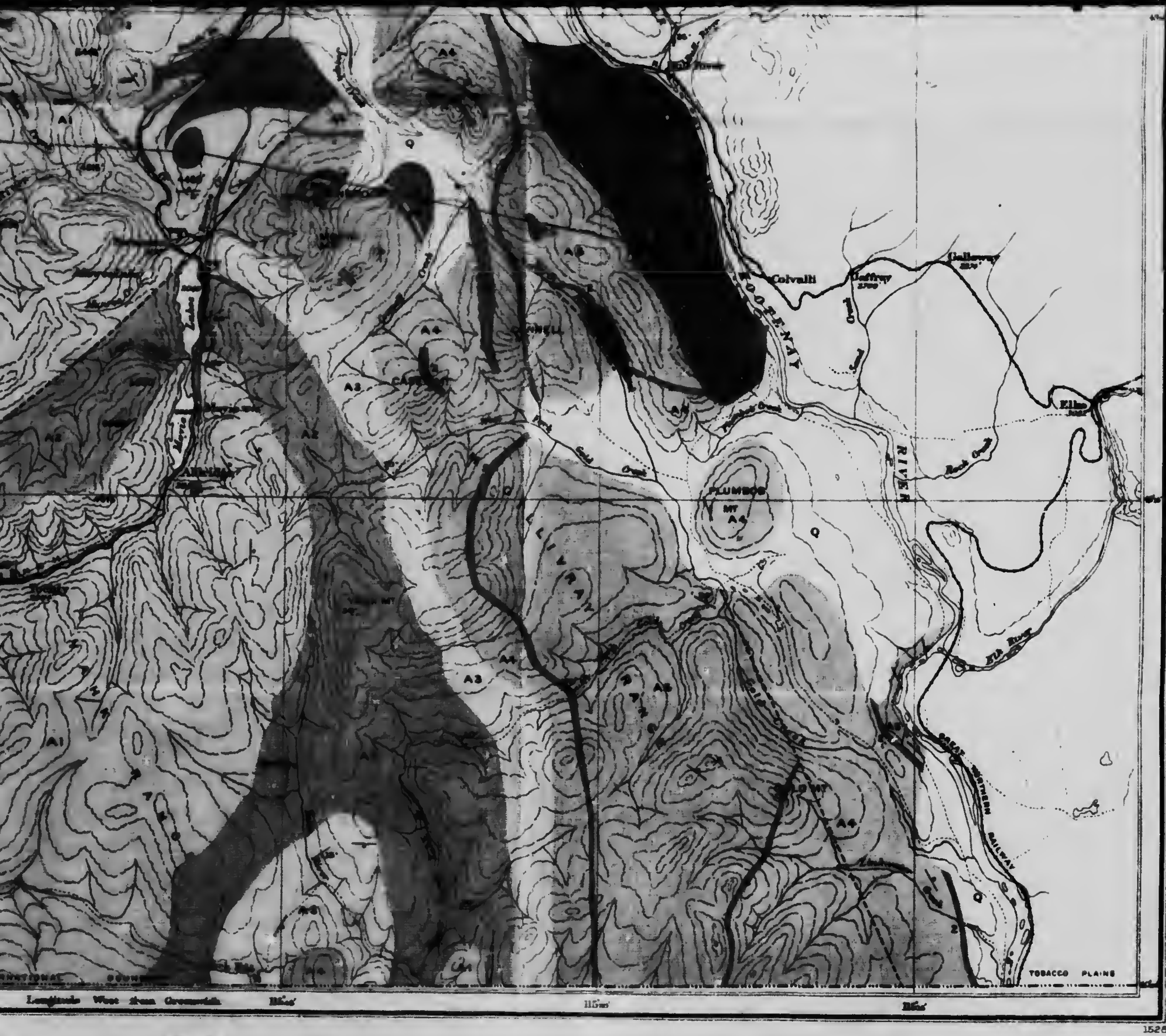
Vertical strata

Horizontal strata


C.O. Senécal, Geographer and Chief Draughtsman
A. Joanes and A. Braidwood, Draughtsmen

CRANBROOK, KOO

to accompany Memoir by S.J. Schofield.




MAP 147A

K, KOOTENAY DISTRICT, BRITISH COLUMBIA.

Scale of Miles