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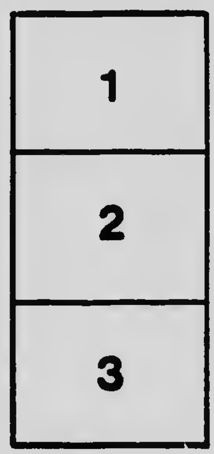
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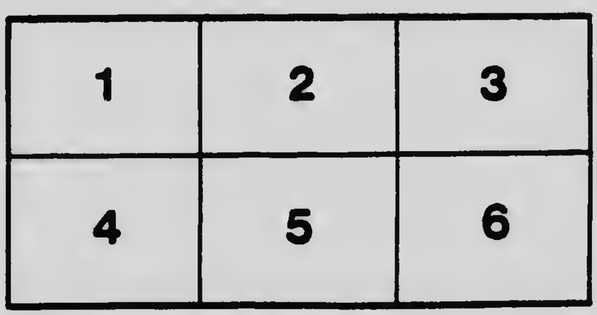
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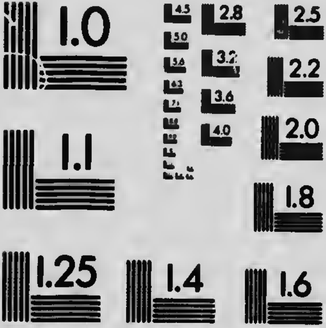

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GEOLOGICAL SURVEY

MEMOIR 77

No. 64, GEOLOGICAL SERIES

Geology and Ore Deposits of Rossland, British Columbia

BY

Charles Wales Drysdale

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

No. 1520

PLATE I

EXPLANATION OF PLATE I.

Typical gold-copper ore of Rossland, B.C. Shows banded structure of chalcopyrite (golden yellow) and pyrrhotite (neutral grey). Specimen from No. 501J contact ore-shoot, LeRoi mine.

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CONTENTS.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

Part II.

CHAPTER I.

CHAPTER II.

CHAPTER III.

ILLUSTRATIONS.

PREFACE.

In this memoir is embodied the results of geological field work carried on at Rossland during the seasons of 1905 and 1906 by Professor R. W. Brock and Dr. G. A. Young. The writer had the free use of all field notes, micro-slides, plans, and data collected by them, and their many helpful suggestions and advice, both in field and office, have greatly facilitated the progress of the work. The chapter on "General Geology" (Part II, Chapter II) of this memoir is taken in large part directly from Dr. Young's unpublished manuscript. The writer spent the field season of 1913 and a part of 1914 at Rossland, continuing Professor Brock's investigation of the ore deposits and bringing the work up to date.

The memoir is divided into two parts: the first part (including six chapters) is intended primarily for those whose interests are centred chiefly in the mining geology of Rossland or in descriptions of individual mines and properties; while the second part (which includes three chapters) is written more for those interested mainly in the general geology and physiography of the region. The first part includes, however a brief summary account of the essential geology (Chapter II) necessary to a comprehensive understanding of the occurrence and possible origin of the Rossland ore deposits. For further details and a more specialized discussion of the local geology and related subjects the reader is referred to the second part.

PART I.

Geology and Ore Deposits of Rossland, British Columbia.

PART I.

CHAPTER I.

INTRODUCTION.

The geology of the Rossland mining camp merits especial attention on account of the magnitude of the ore deposits and their richness and persistence in depth. Since its discovery in 1890, the district has produced 4,655,388 tons of ore containing 2,293,255 ounces of gold, 2,875,440 ounces of silver, and 93,455,188 pounds of copper. The gross value is placed at $62,347,682[1], a total in value greater than that of any other lode mining camp in British Columbia.

Field Work and Acknowledgments.

Geological field work at Rossland began with reconnaissance surveys by R. G. McConnell in 1894 and 1896. This was followed by detailed work from June, 1905, to October, 1906, by R. W. Brock and G. A. Young, Brock doing the economic, and Young, the areal geology. Mr. Brock visited the camp during subsequent field seasons. The results of the above work were published in the Summary Reports for the years 1894, 1895, 1896, 1906, 1907, 1908, and 1909, and in a "Preliminary Report on the Rossland, B.C. Mining District[2]" published in 1906.

During 1905 and 1906, topographic surveys were made by W. H. Boyd. One of the resulting maps which accompany

[1] Figures kindly furnished by Provincial Bureau of Mines. See p. 12.
[2] Geological Survey, Canada, 1906, No. 939.

this memoir consists of a sheet on the scale of 1,200 feet to one inch, with 40-foot contour intervals, and includes an area of approximately 140 square miles. The other is a special map of Rossland, including the main mineralized belt, on a scale of 400 feet to one inch, with 20-foot contour intervals.

Owing to pressure of duties as Director of the Geological Survey, Mr. Brock was unable to continue the Rossland field work and write the final report. He instructed the writer to continue his detailed investigation of the ore deposits during the field season of 1913, in order to bring the work up to date, and to prepare the final report for publication. In this report is incorporated, therefore, the material previously collected by Mr. Brock and Dr. Young, as well as additional data obtained by the writer during the field season of 1913 and part of 1914.

Much indebtedness is due the officials of the operating companies, mine superintendents, engineers, and people of Rossland for many courtesies extended and for information freely given throughout the whole period of field work. Thanks are especially due to Mr. R. H. Stewart, general manager of the Consolidated Mining and Smelting Company of Canada, Superintendent M. E. Purcell and assistant superintendent E. G. Montgomery, of the Centre Star-War Eagle group of mines, Superintendent F. S. Peters and G. H. Kilburn of the LeRoi mine, and Messrs. Ernest Levy and Lionel Hill of the LeRoi No. 2 mines, for kind aid and interest in the work. Able assistance in the field work of 1913 was rendered by E. L. Bruce from June until September, and by Bruce Rose during October and November.

Geography.

Location and Means of Communication.

Rossland is situated in the Trail Creek mining division of the West Kootenay district, British Columbia, about 6 miles west of the Columbia river, and 5 miles north of the International Boundary line (Figure 1).

Both the Canadian Pacific and the Great Northern Railway Companies have branch lines into Rossland; the former from Nelson via Castlegar and Trail, and the latter from Spokane, Washington, via Marcus and Northport. Good wagon roads, some of which are suitable for automobiles, connect Rossland with Trail, Grand Forks, and other points in British Columbia, as well as with towns and cities in the state of Washington.

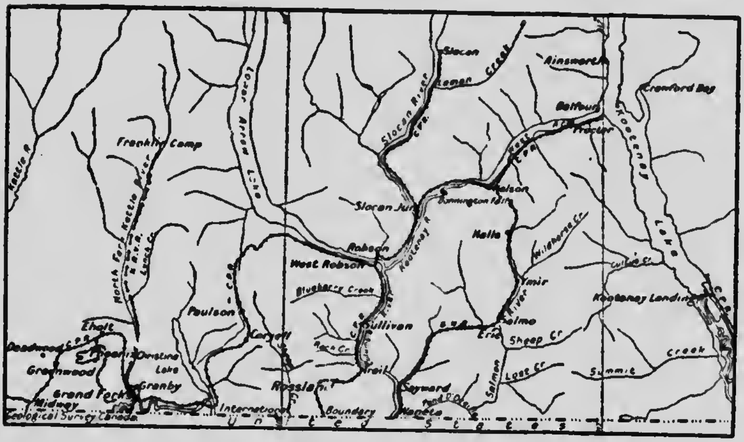

Figure 1. Index map showing position of Rossland, B.C.

Physical Features.

Rossland lies within the well watered and wooded Columbia range of mountains, a range characterized by summits less lofty and alpine than those of the Selkirks to the east. The two ranges are separated by the deep, longitudinal Selkirk valley, through the bottom lands of which meanders the swift flowing Columbia river.

A summit view in the Columbia range reveals the presence of a gently flowing though mountainous upland landscape surmounted here and there by more rugged peaks and crest lines, which rise several hundred feet above the general level of this old surface of erosion. Beneath this rolling highland topography the present steep-walled glaciated valleys appear to be entrenched. The latter head in broad basin-like tracts or glacial amphitheatres, and have lower valley stretches which bear evidence of intense glacial action. In the central portion of the range may be seen relatively flat-topped interstream areas with intervening steep-sided valleys (Plate III).

The mining town of Rossland is picturesquely situated on the lowest and broadest of a series of rock benches which gradually lead up to a group of round-topped hills known as Monte Christo and Columbia-Kootenay mountains (Plate II). These hills rise from 800 to 1,500 feet above the town and lie below the general level of the upland surface of erosion. The elevation of the main street, Columbia avenue, is about 3,410 feet above the level of the sea. The town overlooks to the south, a broad glacial amphitheatre forming the headwaters of Trail creek which empties into the Columbia river about 6 miles distant at the smelter town of Trail. The amphitheatre is bounded on the south by a high ridge culminating in Lake mountain (5,410 feet A. T.); on the west by Deer Park mountain; and on the north by Red (5,150 feet A.T.) and Monte Christo mountains. Red and Deer Park mountains are separated by a low saddle-like pass or "col" which leads into the deep valley of the east fork of Sheep creek, known as Little Sheep Creek valley. Little Sheep creek has its source in Jumbo gulch between Red mountain to the east and Granite mountain (6,500 feet) and Mount Roberts (6,450 feet) to the west. It flows southward to unite with Big Sheep creek whose waters empty, 18 miles distant, into the Columbia river near the town of Northport, Washington.

Climate and Agriculture.

The summers are temperate and dry, with moderately warm days and cool nights; the winters are equable and not extremely cold, the temperature remaining for long periods only a few degrees below freezing. The snowfall is heavy, but the clear air and sunshine and the absence of wind, make the winters very pleasant and afford ideal conditions for Rossland's annual carnival of winter sports. The following table of mean temperatures, rainfall, and snowfall has been compiled by the Director of the Meteorological Service, Toronto.

Monthly Mean T

Year.	Jan.	Feb.	Mar.	Apr.	May	June
	°	°	°	°	°	°
1900	28·6	23·2	39·2	48·4	52·7	60·2
1905	24·9	23·4	38·7	44·4	49·0	55·4
1906	25·9	28·4	31·3	48·0	49·3	53·8
1907	13·7	28·2	31·3	39·3	51·9	56·1
1908	24·5	25·7	32·4	42·3	48·2	55·9
1909	14·7	27·5	33·1	38·9	48·2	61·7
1910	22·3	20·5	38·3	47·1	54·6	56·3
1911	20·5	24·5	36·7	42·1	48·1	58·3
1912	21·0	31·0	31·0	43·1	52·4	61·4
1913	19·3	19·9	29·7	41·8	50·3	57·4

Monthly Rai

1900	0·92	0·42	1·10	1·19	1·75	1·41
1905	0·67	0·97	2·32	0·85	2·94	2·71
1906	0·88	1·10	0·85	0·77	4·75	2·57
1907	0·00	0·67	0·17	0·59	3·58	2·87
1908	0·00	0·10	0·58	2·76	3·62	2·21
1909	0·40	0·58	0·98	0·19	3·75	1·55
1910	1·10	0·00	1·57	1·26	2·56	2·02
1911	0·00	0·00	0·64	0·48	5·64	2·68
1912	0·40	0·25	0·00	2·84	2·54	1·74
1913	0·00	0·00	1·15	0·31	3·32	4·15

Monthly Snow

1900	31·0	36·9	23·1	5·2	
1905	32·8	8·2	15·2	6·2	......
1906	24·0	26·7	4·3	0·1	......
1907	37·8	10·7	25·9	15·8	......
1908	28·0	26·5	15·6	0·4	......
1909	31·8	44·7	7·8	1·0	1·0
1910	23·8	18·6	5·5	0·0	......
1911	35·5	18·0	7·6	6·5	......
1912	32·1	15·2	8·5	0·2	......
1913	40·9	26·0	10·2	4·0	......

Temperature data referring to growing season—Yearly mean tem of growing season—181 days from April 15 to October 13. Total hea weeks—62·2 degrees.

Mean Temperature.

ay	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	°	°	°	°	°	°	°	°
7	60·2	62·9	58·5	54·6	41·7	30·3	32·0	44·4
0	55·4	63·7	61·7	53·6	37·4	31·5	26·3	42·5
3	53·8	68·4	61·7	54·1	44·8	29·6	27·1	43·5
9	56·1	62·3	55·7	51·6	47·4	34·1	26·6	41·5
2	55·9	63·8	10·5	53·4	42·6	37·0	22·3	42·4
2	61·7	59·5	59·5	55·1	42·9	32·9	19·6	41·2
5	56·3	65·8	59·3	54·5	44·1	32·8	29·0	43·7
1	58·3	64·1	60·4	50·8	41·9	27·4	23·8	41·2
4	61·4	60·3	58·0	50·2	38·6	32·9	26·5	42·2
8	57·4	61·2	62·6	53·5	39·1	32·5		41·1

thly Rainfall.

75	1·41	1·38	1·24	2·56	3·45	1·48	2·22	19·12
94	2·71	1·63	0·46	2·64	2·89	0·11	0·15	18·34
75	2·57	0·48	0·71	1·41	1·59	2·56	0·53	18·20
68	2·87	0·88	5·89	4·28	1·37	1·54	0·00	21·84
62	2·21	1·19	1·08	0·13	3·23	1·62	0·00	16·52
75	1·55	3·35	0·14	2·82	2·53	1·15	0·19	17·63
66	2·02	0·30	1·09	1·25	3·04	2·95	0·00	17·14
64	2·68	1·10	1·33	2·20	0·61	0·62	0·00	15·30
54	1·74	2·84	3·14	1·96	1·67	0·48	0·00	17·86
32	4·15	1·24	0·71	1·19	1·06	0·24	0·00	13·37

hly Snowfall.

					26·4	3·3	37·7	163·6
......	......	......	......	......	8·6	29·2	26·7	126·9
......	......	......	......	......	0·0	24·8	39·6	119·5
......	......	......	......	......	0·0	17·0	38·1	145·3
......	......	......	......	......	2·4	3·3	28·9	105·1
......	......	......	......	......	5·8	34·5	26·4	153·0
......	......	......	......	......	0·0	23·7	34·7	106·3
......	......	......	......	......	0·0	26·5	43·9	138·0
......	......	......	......	......	14·0	30·6	26·8	127·4
......	......	......	......	......	5·0	37·4	13·7	137·2

mean temperature for period of eight years—42·1 degrees. Length
Total heat units—9,898. Mean average temperature of six hottest

Considerable attention has been paid to horticulture in the district with the result that the community raises practically all its own vegetables. The people pride themselves on their gardens and at the annual fruit and flower show the local exhibits compare most favourably with those from outside points.[1]

History and Development.

The following historical outline is taken in large part from the "Preliminary Report on the Rossland, B. C., Mining District" by R. W. Brock, but the statement has been amplified here and there by material from other sources and brought up to date.

Although lead was discovered on Kootenay lake (Bluebell mine) in the early twenties of the last century and was used as a source of lead for bullets by the Hudson's Bay Company, mining in West Kootenay district is of recent growth. In the early sixties, a few hardy prospectors came northward, attracted by the rich placers of the Cariboo, and tested and worked some of the local streams for gold. In 1865 the Dewdney trail was completed, from Hope on the Fraser river, to the placers of Wild Horse and other East Kootenay creeks, passing close by the site of Rossland, down Trail creek. In the eighties, some claims were staked in the Boundary district; in 1883, at Ainsworth on Kootenay lake, and in 1886, rich ore was discovered on Toad mountain, near Nelson. In 1887, the news of the discovery had attracted prospectors, and a trading post was established at Nelson. These discoveries started prospectors along the Dewdney trail, on the lookout for lode ores. The first claim located was the Lily May, on the trail itself. It was discovered in 1887 and relocated in 1889 by Oliver Bordeau and Newlin Hoover as the Tip Top claim. They relocated it as the Lily May the following year and recorded their location in Nelson.

Although the gossan of Red mountain had attracted the attention of the earlier travellers along the Dewdney trail, some of whom, including Nelson Demers, had done a little work

[1] For useful agricultural information covering this district see the report of the Royal Commission on Agriculture published by the British Columbian Government.

on it, the values were too low to warrant lode mining in a wilderness, with its high cost for transportation and development; placer mining, consequently, absorbed their interest. It was not until 1890 that claims were located on the lodes which were to create the city of Rossland and to bring southern British Columbia prominently before the mining and commercial world.

In the summer of 1890, Bourgeois and Morris, who were working on the Lily May, crossed over to Red mountain and located in one day the LeRoi (then the Louis claim), Centre Star, War Eagle, Idaho, and Virginia. These claims were recorded at Nelson, the LeRoi being given to Col. E. S. Topping, deputy mining recorder, for paying the $12.50 recording fees.[1] He secured specimens and went to Spokane, interesting some business men of that town, headed by Oliver Durant, in the LeRoi, and the development of the camp began. The Spokane Syndicate acquired a bond on a sixteen-thirtieths interest for six months in the LeRoi for $16,000 and under the management of Durant proceeded to prospect the claim during the winter of 1890-1. The news of the strike brought prospectors, and the Josie and most of the other claims whose names became so familiar, were located shortly after the first discovery—many in the same month. A mining recorder's office was established in Rossland and about 50 men wintered that year (1890) in the camp.

Ross Thompson was the founder of the town of Rossland. While working as a miner in 1890 at the Centre Star mine under Oliver Durant, he located a pre-emption claim of 160 acres. Two years later he obtained a title to his claim; plotted it as a townsite and proceeded to erect buildings. Lots were sold at first for $30, but as building proceeded, they advanced a little in price. The town was first called Thompson, but there being another town of the same name in British Columbia, the present name of Rossland was finally adopted.

The first ore sent out of the camp was a small lot (10 tons) in 1891 from the bottom of the LeRoi 35-foot shaft. This ore was packed by mule to the Columbia river and thence shipped to a smelter in Butte, Montana. The returns showed values

[1] The old British Columbia mining law forbade the prospector staking more than one claim on the same vein.

amounting to $84.60 to the ton; 3 ounces of silver, 5·21 per cent of copper, and about 4 ounces of gold to the ton. The bond was then taken up and Mr. Topping's remaining interest acquired, by George Turner, Col. Isaac Peyton, W. W. Turner, W. M. Ridpath, all of Spokane, and Alexander Tarbet of Butte. Durant and Tarbet sold their interest about the same time and bonded the Centre Star and Idaho from the original owners. In the spring of 1892, sixty-seven mining claims, including the Josie, Jumbo, Monte Christo, and Columbia-Kootenay, were recorded and a wagon road was cut to Northport. Durant and his partner Tarbet in 1892 spent $25,000 on work in the Centre Star mine which for the time being was the mainstay of the camp. The LeRoi Company succeeded in selling $25,000 worth of treasury stock in Danville, Ill., for development purposes. During the same year, the Spokane Falls and Northern railway was completed from Spokane to Northport. Through the efforts of Oliver Durant, a trail, which was afterwards improved to a road, was built from Northport to the camp. Early in 1893, private individuals started and the government completed 12 miles of wagon road from the landing at Trail on the Columbia river to the mines. During the same year, the War Eagle was bonded, but the bond was dropped. It was again bonded, but, on account of the workings being off the ore, was again dropped. It was finally bonded by Wakefield Corbin and others who in 1894 took in P. Clark and associates. During this period the fortunes of the little camp were at a low ebb. Lack of transportation facilities and the financial panic of 1893, were the chief deterrent factors that nearly wrecked the fortunes of the camp. Durant, who had overcome many obstacles and disappointments in developing and demonstrating the worth of his properties, was forced to give up for the time being. Fortunately the new wagon road to Trail enabled the LeRoi to ship some ore (700 tons) that had accumulated on the dumps, and the returns from this made it possible to resume operations, and put new heart into the camp. In 1894, the Josie was purchased and P. Clark having discovered the ore shoot, paid up his bond on the War Eagle ($23,000). The shipments for the year amounted to 1,856 tons of ore, which returned $75,510, freight and treatment costing $22 per ton. During the summer R. G. McConnell of the Geological Survey, made a reconnaissance survey ot the camp. Several of the more important properties were bonded for considerable sums and development was begun in earnest. The population grew to about 300 in the summer of 1894 and it was not until December of that year, when the great ore shoot in the War Eagle mine was struck, that the people made up their minds that the camp would live.

The following year, 1895, was a year of great activity and the young camp received marked attention (Plates IV and V). The population rose from 300 to 3,000, railway and smelting facilities were projected, and from that time forward, development was rapid. Dividends were declared by the LeRoi and War Eagle, the latter mine paying its first dividend of $32,500 in February 1895. In seven months the War Eagle paid $132,000 in dividends. The most important event in 1895, however, was the contract made by the LeRoi mine with the late Augustus Heinze of Butte, for 37,500 tons of ore at a freight and treatment rate of $11 per ton, and also for 37,500 tons on which the treatment charges should be the lowest obtainable in the open market. With this contract, a land grant from the Provincial government, and a bonus of $1 per ton from the Dominion government, Heinze built the Trail smelter, and a tramway from the smelter to the mine. Work was commenced in October and in the following February the first furnace was blown in. By June, the tramway was in operation.

Writing of the development of Rossland this season, McConnell in the Geological Survey Report for 1895, states: "The number of working mines has been largely increased, the known area of the mineral belt extended in all directions, a well built town of 2,000 or more inhabitants has sprung up near the mines, and a second town is being built near the mouth of Trail creek ....The shaft on the LeRoi is now down 380 feet, and the lode followed appears to be strengthening with depth. At the 350-feet level, the ore shoot has a length of 168 feet and a width at one point, of over 40 feet. The result of the workings on the LeRoi, the pioneer mine of the camp, has inspired confidence in the permanency of the numerous other less developed lodes in the district."

It was reported that in November of the same year the Cliff was sold for $150,000 and the St. Elmo for $75,000. The population increased faster than buildings could be erected and by 1896 it had grown to about 4,000. The construction of the Columbia and Western railway to Trail was completed in May 1895, making large regular shipments possible. The cost of freight and treatment in 1896 was about $10 to $14 per ton. At that time 95 per cent of the assay value of the gold and silver was paid for and the percentage of copper carried by the ore, less 1·3 per cent. The coke for use at the smelter cost $17 per ton and was brought from Union Mines, Vancouver island.

In 1896, the Red Mountain railway, connecting Rossland with the Spokane Falls and Northern railway at Northport, was completed, giving standard gauge connexions with three transcontinental lines at Spokane. The shipping mines at this time were the LeRoi, War Eagle, Josie, Iron Mask, and Columbia-Kootenay.

"Then came the inevitable wild boom. The evil effects of a boom are not confined solely to the thousands of dollars squandered in worthless property, the losses sustained by the innocents, and the damaged reputation of the district, but they are manifest in careless work on deserving claims, in a rash expenditure that may for some time survive the boom; in a loss of interest in properties of merit; and in a tendency to maintain prohibitive prices on promising prospects by owners who have purchased during the period of inflation and are not prepared to accept a serious loss, or by owners who, once having experienced the sensation of being millionaires, are loth to accept present conditions, but prefer to speculate on the improbabilities of the future. Rossland has been called on to pay in full all the penalties attaching to a boom. The phenomenal rise in the value of LeRoi stock, the dividends declared by this company and the War Eagle, and the sale of the latter to Toronto capitalists, for the reported sum of $700,000, produced a feeling of buoyancy that afforded every opportunity to the unprincipled boomster and the amateur mining magnate, the public for the time being cheerfully swallowing whatever was offered. The inevitable slump followed."

In 1897, Rossland had an estimated population of 6,000 and was incorporated as a city. A broad gauge railway was built from Trail to Robson, giving better connexion with the Canadian Pacific railway than was afforded by the Columbia river which is very rapid along this portion of its course. Stronger companies were formed to take over and develop promising prospects. In particular, the British American Corporation purchased the Josie, Nickel Plate, Great Western, Poorman, West Le Roi, No. 1, and Columbia-Kootenay mines. Development work had yielded most promising results. The LeRoi Company, having completed its contract for 75,000 tons with the Trail smelter, erected its own smelter at Northport with a capacity of 250 tons per day. In 1898, the Canadian Pacific railway purchased the Trail smelter and railway line from Heinze, and immediately reduced the smelting charges to $7.50 per ton. The British American Corporation secured the LeRoi mine and smelter by purchasing the stock at a price which was said to represent nearly $4,000,000 for the property. The LeRoi had realized from its operations before the sale in 1898, $975,000 in dividends. The Centre Star was purchased by Messrs. Gooderham, Blackstock, Struss and Company of Toronto in the autumn of 1898 for the reported sum of $2,000,000 cash.

The construction of the Crowsnest branch of the Canadian Pacific, built through the Crowsnest coal-fields to Kootenay lake, was an important event for the camp. It meant cheaper and better fuel and coke, and a consequent reduction in cost of ore production and treatment. These reductions brought about a large increase in ore tonnage with a corresponding diminution in the grade of ore mined. Large plants with the most approved machinery for the economical working of the mines, were installed or planned, and operations on a large scale were projected. The construction of the West Kootenay Power Company's plant at Bonnington Falls, 32 miles distant, was another important event, making electric power available for the Trail smelter and the Rossland mines.

At the close of 1899, the reputation of Rossland suffered from the sudden collapse in the price of War Eagle stock. This stock had been run up to a wholly unwarranted point, and was held in the hope that new machinery would permit an increased output, with a resultant advance in the stock. Unfortunately the machinery proved a failure and the stock dropped. A general desire to realize followed and brought about a collapse, with a consequent loss of faith in the camp. In 1900 the LeRoi No. 2 Company was formed to acquire the Josie, Poorman, Annie, and other claims. In 1901, Rossland again received a set-back, this time in the form of labour troubles, which closed up the mines for a part of the year. These difficulties were amicably adjusted, but the evil effects of such troubles in discouraging investments are not quickly effaced. By 1902 the mines had resumed their normal operations and on a more business-like basis than before. Experiments in concentration were commenced in 1903 and are still being made, and serious efforts are being made to obtain the greatest possible profit per ton of ore.

In 1906, the Centre Star Mining Company and War Eagle Consolidated Mining and Development Company were amalgamated by the Consolidated Mining and Smelting Company of Canada, which company in 1911 acquired the LeRoi, Black Bear, and LeRoi Star fraction claims. The latter properties were for many years owned and operated by the LeRoi Mining Company.

During t[illegible]x months of 1912 a coal strike in the Crowsnest pass and [illegible]sequent high price of coke imported from Pennsylvania increased by about $120,000 the operating expenses of the Trail smelter. At the close of the strike the cost of electric power was increased to an extent which increased expenses approximately $40,000 annually. The improvement in the grade of the Rossland ore, however, and new developments in the War Eagle and LeRoi mines have more than offset this extra expense. The Consolidated Company in 1912 acquired the Monte Chr[illegible]to, Iron Horse, Abe Lincoln, and Virginia claims. Threatene[illegible]gation between the LeRoi No. 2 Company and the Consolidated was settled in 1913 by mutual agreement and concessions. Operations at Rossland in 1913 and 1914 have been extensive and the pay roll the largest the camp has ever had. New machinery has been installed at the Centre Star, War Eagle, and LeRoi mines and shipments now aggregate 1,000 tons daily. The present cost of mining, freight, and treatment amounts to about $7 per ton. In 1914 the Consolidated Company purchased the Mabel, Paul Boy, Eddie J., and the Annie E. claims, one-fifth interest in the Pilgrim claim, and the property of the Canadian Goldfields Syndicate in Rossland, chief of which were the Sunset No. 2, Alabama, Gold Hunter, and Jennie mineral claims.

The development and progress of mining from 1894 until 1914, are shown in the following table of production and diagrams (Figure 2) compiled from the reports of the provincial mineralogist.

Production Table for Rossland, B.C.

Year.	Tonnage (2000 lbs.)	Gold ozs.	Silver ozs.	Copper lbs.	Values $
1894.............	1,856*	3,723	5,357	106,229	75,510
1895.............	19,693*	31,497	46,702	840,420	702,459
1896.............	38,075*	55,275	89,285	1,580,635	1,243,360
1897.............	68,804*	97,024	110,068	1,819,586	2,097,280
1898.............	111,282	87,343	170,804	5,232,011	2,470,811
1899.............	172,665	102,976	185,818	5,693,889	3,229,086
1900.............	217,636	111,625	167,378	2,071,865	2,739,300
1901.............	283,360	132,333	216,574	8,333,446	4,631,299
1902.............	329,534	162,146	373,101	11,667,807	4,893,395
1903.............	360,786	145,353	209,537	8,652,127	4,255,958
1904.............	312,991	133,095	181,830	7,119,876	3,760,866
1905.............	330,618	129,843	147,753	5,800,294	3,672,828
1906.............	279,527	105,356	126,174	4,750,110	3,173,587
1907.............	285,923	94,573	126,661	5,080,275	3,049,702
1908.............	302,419	142,314	129,558	5,042,244	3,693,392
1909.............	237,656	115,153	80,026	3,509,909	2,875,084
1910.............	253,471	119,277	87,833	3,577,745	2,966,096
1911.............	254,062	116,683	88,076	3,429,702	2,881,366
1912.............	243,870	132,073	87,530	2,539,900	3,196,037
1913.............	253,870	137,004	109,585	2,538,661	3,249,200
1914.............	297,290	138,589	135,790	4,068,457	3,491,066
Totals...........	4,655,388	2,293,255	2,875,440	93,455,188	62,347,682

* Smelter returns.

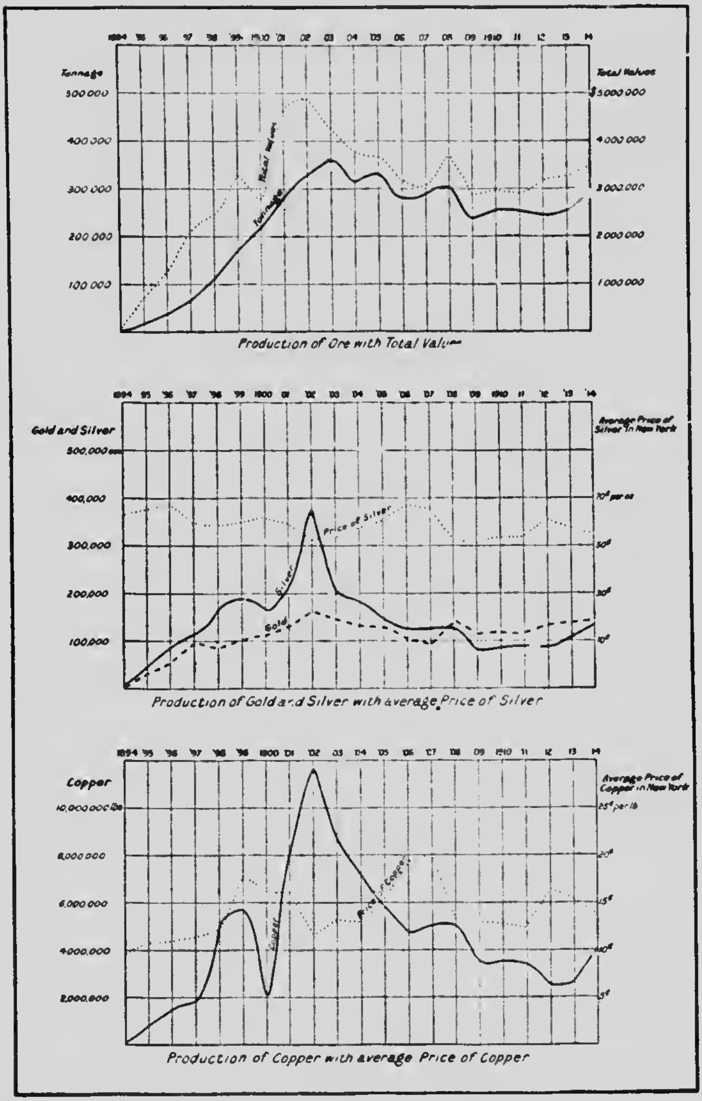

Figure 2. Production of ore and metals · Rossland from 1894 to 1914.

Mining, Milling, and Metallurgy.

The ores are mined[1] from the Rossland veins by the overhead stoping system in which gravity facilitates all operations of breaking down the ore and rock. The narrow ore shoots are stoped on stulls or by the "shrinkage" system and in the wide shoots the square set timbering system is adopted. The ore-zone ground is traversed in many places by lime seams and cut by slip planes which render the walls of the stopes difficult to support. Local red fir, and tamarack with some spruce and cedar are used in timbering.[2]

The ore is drawn from the stopes through chutes on the different levels and conveyed to ore pockets at the shaft stations by means of electric haulage. It is then hoisted up the inclined shaft to the shaft house where from grizzlies it passes through crushers and is transferred by belt conveyers to the sorting and sampling plants. From the sampling mill the ore is fed into various ore bins by means of bucket conveyers. From the bins it is loaded into railway cars and shipped to the Trail smelter.[3]

The LeRoi No. 2 Company has a concentrating mill at the Josie mine, driven by motors using about 80 horse-power, and treating 60 tons of ore per day. From Blake crushers the ore is fed to two 6-foot Chilian mills and ground approximately to 20 or 30 mesh; the pulp is classified in three Jencke sizers and fed to three Wilfley tables; the concentrates are shipped; the middlings rewashed on an ordinary Wilfley table; and the tailing waste washed into the creek. This company was the first to install an Elmore oil concentrator at Rossland. The plant was completed in 1903 proving a technical but not a commercial success and was superseded by Wilfley tables.

In 1904 the Consolidated White Bear Mining Company constructed an Elmore plant of larger dimensions than that of the LeRoi No. 2 Company. This plant included many labour

[1] For details refer to "Mining Practice at Rossland" by R. B. Brinsmade, Mines and Minerals, March 1901, p. 363.

[2] Four species of destructive fungi belonging to the genera *Trametes* and *Polyporus* were noted in the mines by John Macoun of the Geological Survey. To keep the algoid spores of the fungus out of the timbers and thus prevent rot it has been suggested to treat them with salt solution or creosote; Summary Report Geol. Surv., Can., 1908, pp. 187-188.

[3] For details refer to extract on p. 97 of this report taken from a paper by Mr. M. E. Purcell and presented before the Western branch of the Canadian Mining Institute at Rossland, May, 1913.

saving devices. The Consolidated Mining and Smelting Company have for several years been carrying on milling experiments at their LeRoi mill.

The Rossland ore is shipped to the Trail smelter 9 miles distant by railway from the mines. The smelter is situated on a river terrace overlooking the town of Trail and on the west bank of the Columbia river where Trail creek empties into it.

The following flow sheets indicate the manner in which the Rossland ores are treated at the Trail smelter:[1] (Figures 3 and 4).

[1] Since writing this section a report on the Copper Industries of Canada by A. W. G. Wilson has been published by the Mines Branch, and the reader is referred to this publicatinn fnr an illustrated description nf the smelting works at Trail: Nn. 209 Mines Branch, Dept. of Mines, 1913, pp. 78-94. For further descriptive articles nn the Trail smelter see the Mineral Industry during 1909, Vol. XVIII, pp. 209-212; Bull. Can. Min. Inst., July, 1909; The Mineral Industry, Vol. XI, p. 196.

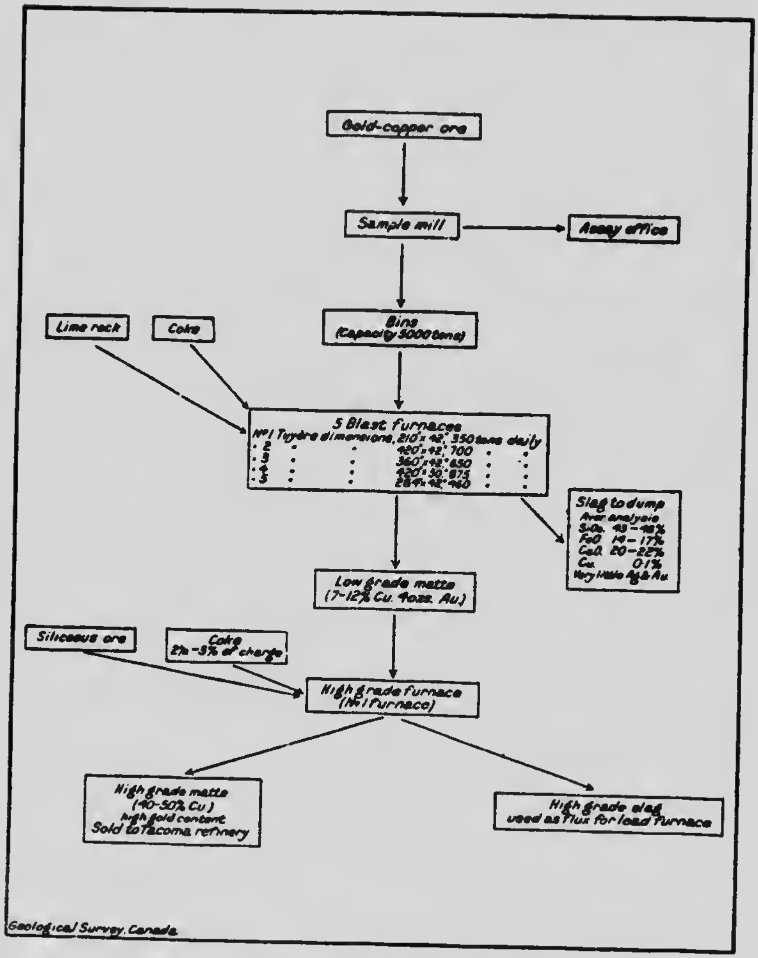

Figure 3. Flow sheet for Rossland gold-copper ore, Trail smelter, B.C.

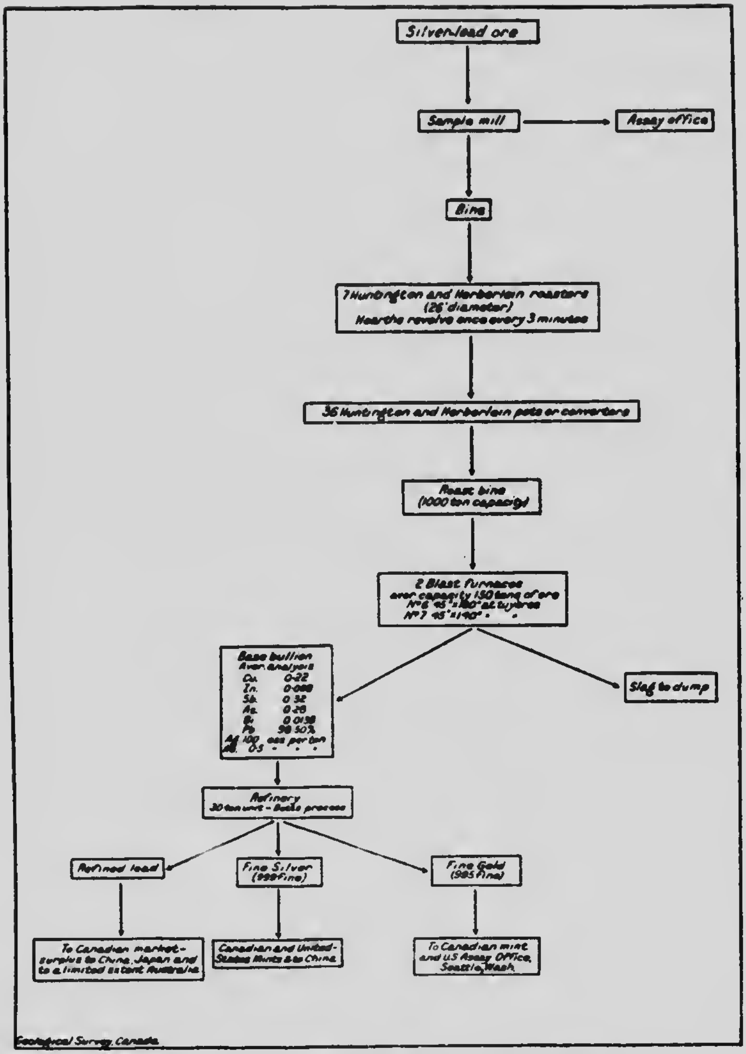

Figure 4. Flow sheet for silver-lead ore, Trail smelter, B.C.

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CHAPTER II.

GENERAL GEOLOGY.

Age and Succession of Formations.

The accompanying geological time table indicates the age and succession of the different formational units.

As may be seen from the table the majority of the rock formations are of igneous origin and like so many Cordilleran mining camps the structural and age relations of the various igneous members are complex and difficult in places to interpret.

Formational Units.

Mount Roberts Formation.

The oldest formation in the district is known as the Mount Roberts, a broad band of which is well exposed on the western half of Red mountain and on the lower eastern slopes of Mount Roberts. A smaller remnant of this old formation (Palæozoic complex) outcrops on the northwestern slope of Monte Christo mountain. Between these two main belts occur stray inclusions or "horses" of the Mount Roberts formation within the igneous formations of the intervening ore-producing ground.

The formation consists essentially of highly silicified slates, in part carbonaceous, with arenaceous and calcareous varieties. There are included also some metamorphic tuff beds, the whole series having a minimum thickness of 1,200 feet. The sedimentaries are much metamorphosed, but where bedding planes are determinable they strike in a general north and south direction and dip to the west at angles varying from a few degrees to 60 degrees. There are many local and, in a few places, abrupt variations of dip and strike. Cross bedding is also present in a few localities (Plate X A).

Geological Time Table.

Estimate of years.[1]	Eras.	Ages.	Periods.		Character of deposits and formation names.
30,000	Psychozoic	Age of man	Human		
3,000,000	Cenozoic	Age of mammals	Quaternary	Recent	Soil, subsoil.
				Pleistocene	Boulder clay, alluvium.
			Tertiary	Pliocene	*Erosion interval.*
				Miocene	Sheppard granite porphyry dykes and lamprophyres. Coryell batholith and pulaskite intrusions.
				Oligocene (?)	Porphyritic monzonite and lamprophyre dykes.
				Eocene (?)	Sophie and Lake Mountain conglomerate.
9,000,000	Mesozoic	Age of reptiles	Cretaceous		*Erosion interval.*
			Jurassic		Trail batholith of granodiorite and monzonite chonolith, injection tongues of diorite porphyrite; lava flows of andesite and latite and tuff beds.
			Triassic (?)		Augite porphyrite and agglomerate.
36,000,000	Palæozoic	Age of amphibians Age of fishes Age of invertebrates	Upper Palæozoic		Mount Roberts formation.
			Lower Palæozoic		*Erosion interval.*
?	Proterozoic				
?	Archeozoic				

[1] Estimate of length of time after J. D. Dana.

The fossils found by Brock in calcareous beds on O. K. mountain, indicate a Carboniferous age[1] for the formation, and it may for the present be correlated with LeRoy's Knobhill and Brooklyn formations at Phoenix,[2] and Dawson's Câche Creek group in the Kamloops district.[3]

Augite Porphyrite.

Younger than and intrusive into the Mount Roberts formation are extensive sill-like intrusions of a dark greyish to greenish black augite porphyrite, studded with numerous dark crystals of augite. This rock forms one of the main wall rocks [illegible]e veins. Many different areas of augite porphyrite [illegible] on the map, but the most important area is on the eastern slope of Red mountain where the porphyrite is bounded on the south and east by an area of monzonite and on the west by the bedded Mount Roberts formation. There are many different varieties of augite porphyrite and the common type, with large phenocrysts of augite in a dense groundmass, in many places passes rapidly into a variety without any visible phenocrysts (Plate VI C). Such types when highly silicified are difficult to distinguish from some metamorphic members of the Mount Roberts formation.

Under the microscope the typical augite porphyrite appears to be composed of phenocrysts of augite, hornblende, and plagioclase feldspar lying in a fine groundmass chiefly of plagioclase feldspar and hornblende. The hornblende has a green colour, low pleochroism, and in the case of some of the larger individuals the core is of colourless augite indicating that much of the hornblende is of secondary origin. The plagioclase feldspar is chiefly labradorite.

The augite porphyrite assumes in places a brecciated or agglomeratic structure, that is, the mass appears to be made up of rounded and angular fragments up to several inches in diameter, of a porphyrite slightly different in colour or texture from

[1] For a preliminary report on the above fossils by Dr. H. M. Ami refer to p. 199 this memoir.

[2] Geol. and Ore Deposits of Phoenix, B. C., Geol. Surv., Can., Memoir 21, 1912, pp. 30-34.

[3] Report on Area of Kamloops Map Sheet, Geol. Surv., Can., Ann. Rept., Vol. VII (1894), p. 37 B., also Summary Report, Geol. Surv., Can., for 1912, pp. 130-132.

the material in which they lie. Young states[1] that "the general appearance and distribution of the fragments suggest that they represent the remains of an older body which while still in a fluid condition, was injected by a second volume of the same molten rock or magma and in which part of the first irrupted matter resisted any thorough mixing with the matter of the second period." The following facts support this explanation. (1) "The embedded fragments differ apparently only in texture from their host." (2) "The outlines of the fragments are irregularly rounded or oval." (3) "The absence of vesicular or scoriaceous structures and other related phenomena, seems to preclude the possibility of the agglomeratic habit having resulted mechanically through movements in a cooling lava flow."

"If such an explanation as the above, of the origin of the agglomeratic structure be adopted then it would appear that the mass of augite porphyrite of Red mountain represents a sill or intrusive sheet and not a lava flow for the conditions under which a flow forms would scarcely permit of the action of the above supposed phenomena."

The age of the augite porphyrite is in doubt. It is tentatively placed in the Triassic and correlated with the augite porphyrites of Dawson's Nicola group.[2]

Volcanic Agglomerate.

A volcanic agglomerate composed of fragments of quartz, slates, and altered volcanics overlies the Mount Roberts formation on the lower slopes of Mount Roberts, and is interbedded with finer grained, tufaceous beds. The fragments are as a rule oval in outline, elongated parallel to the strike, and appear to be roughly assorted according to size which varies from 5 to 6 inches in diameter down to small grains.

The agglomerate formation has a north and south strike and the beds are vertical, in contrast to the lava flows on the summit which are almost horizontal. This formation may represent the surface equivalents of the augite porphyrite intrusives and

[1] Unpublished manuscript.
[2] Ann. Rept. Geol. Surv., Can., 1894, pp. 49B-62B. Summary Rept. Geol. Surv., Can. 1912, pp. 133-135.

is probably of Triassic age, corresponding to the volcanic agglomerates of the Nicola group.[1]

Granodiorite Batholith and Cupola Stocks (Trail).

Underlying the district and outcropping in a few isolated areas is a large mass of granodiorite. The granodiorite is a medium-grained light-grey crystalline rock composed of feldspars, (orthoclase, andesine, and microcline), quartz, hornblende, and biotite. The masses of granodiorite, which are in the general form of stocks (*cupola stocks*[2]), probably represent the upward extensions of what Daly has referred to as the Trail batholith.[3] The granodiorite batholith underlies the district and is intimately connected with the ore deposits.[4] Large areas of it outcrop near the headwaters of Little Sheep creek and to the northeast of the Rossland map-area. It also outcrops in a few isolated areas on Red mountain and has been exposed in the lower workings of some of the mines (See stereograms Map 1496 in pocket). The batholith has a great areal extent throughout the West Kootenay district and is known also as the Nelson granite. The age of the batholithic intrusion has been tentatively placed as late [illegible]urassic and correlated with similar granitic intrusives fo[illegible]tting lower Jurassic rocks in the Kamloops district farthe[illegible] and north.[5]

Diorite Porphyrite Tongues.

A border and dyke facies of the granodiorite is a light grey to dark greenish diorite porphyrite composed of numerous dark, slender prisms of hornblende and many lath-like feldspars (both plagioclase and orthoclase), lying in a fine crystalline greyish groundmass (Plate VI A and B). The hornblende and feldspars occur as distinct phenocrysts in the diorite porphyrite and there are two distinct gradational phases, a horn-

[1] Summary Report Geol. Surv., Can., 1912, p. 133.
[2] An intrusive body with highly inclined contacts, irregular shape, and bearing cupola relations to the underlying main mass of granodiorite.
[3] *Batholith* means the largest kind of intrusion of molten rock, generally granitic and characteristically found in great mountain ranges.
[4] See pp. 51 and 88.
[5] Summary Report Geol. Surv., Can., 1912, p. 136.

blende phase and a feldspar phase. In the hornblende phase the tabular phenocrysts of feldspar are not very noticeable, whereas in the feldspar phase they are very abundant and give the rock a decidedly spotted appearance. With an increase in the number of feldspars the rock passes gradually from a porphyrite into a fine granular granodiorite.

The chemical compositions of diorite porphyrite and granodiorite may be compared in the following analyses made by the Mines Branch.

	1	2
SiO_2	55·62	56·62
Al_2O_3	15·64	16·66
Fe_2O_3	1·85	3·86
FeO	5·63	3·55
MgO	3·68	3·08
CaO	5·92	6·34
Na_2O	1·37	4·05
K_2O	8·56	4·46
H_2O	0·35	0·60
TiO_2	0·88	0·60
P_2O_5	0·29	0·14
MnO	0·03	0·02
BaO	0·11	0·09
SrO	0·14	0·24
S[1]	0·30	0·31
Cl	0·02	0·11
	100·58	100·63

[1]Sulphur present in the form of sulphide-pyrite or pyrrhotite.

1. Diorite porphyrite from the hanging wall of No. 895 stope, LeRoi mine N. L. Turner, Analyst.
2. Granodiorite from the 1100-foot level west. Centre Star mine. N. L. Turner, Analyst.

The diorite porphyrite occurs in very irregular forms, the commonest form being that of long tongues (apophyses) which pinch and swell and send off branches (Map 1518 in pocket). The strikes and dips of such tongues correspond to those of the vein fissures which in many places follow the borders of the tongues, thus indicating close genetic relations between the veins and the diorite porphyrite. In some localities the diorite porphyrite bodies have spread out along horizontal planes and in such cases conditions have apparently not been so favourable for ore deposition.

Andesite and Augite Latite Lavas and Tuff Beds.

On the summit and upper slopes of Mount Roberts and Record Mountain ridge are exposed a conformable series of lavas and tuff beds, having low dips to the west. The main type of lava is an andesite with a mineralogical composition approaching closely to that of the diorite porphyrite and granodiorite. The uppermost flow is an augite latite corresponding in mineralogical composition to the slightly younger monzonite. These lavas probably represent the surface equivalents of the granodiorite and monzonite intrusions which have since been largely removed by erosion.

Monzonite Chonolith.

The monzonite is commonly a granular to semi-porphyritic rock of a greenish grey to black colour. The coarser types consist of black prisms of pyroxene or secondary hornblende, flakes of brown biotite, and a light coloured plagioclase feldspar often labradorite. The microscope discloses in addition alkalic feldspar, magnetite, and apatite.

An analysis of the monzonite from the 700-foot level of the LeRoi mine made by the Mines Branch, is as follows:—

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O
54·49	0·70	16·51	2·79	5·20	0·10	3·55	7·06	4·36	3·50

H_2O-	H_2O+	P_2O_5	S	CO_2
0·07	1·18	0·20	0·23	0·24

The monzonite occurs in an irregularly shaped intrusive mass (chonolith) bounded in some places by flatly dipping contacts and elsewhere by steeply dipping contacts. The main mass outcrops on the lower eastern slopes of Red mountain extending as far east as Columbia-Kootenay mountain. The main productive belt of the camp surrounds this mass of monzonite.

Porphyritic Monzo 'e Stocks.

The porphyritic monzonite, used locally for building stones, is a coarse-grained rock with large stout prisms of pyroxene, secondary hornblende, countless small rounded hexagonal flakes of brown biotite and abundant andesine feldspar with some alkalic feldspar and acid labradorite (Plate VII A). It displays pronounced spheroidal weathering where exposed to the atmosphere. The porphyritic monzonite occurs as irregular, generally oval-shaped stocks and dyke-like bodies of younger age than the normal monzonite, having been intruded possibly at the time of crustal movements in the Oligocene and genetically related to the alkalic syenite intrusions.[1] The Centre Star dyke in the lower levels of the mines is coarsely granular and resembles both in appearance and mineralogical composition the porphyritic monzonite (Plate VII A, B).

Lamprophyric Dykes.

The granodiorite and monzonite intrusions were followed by fissuring and dyking on an extensive scale. Many varieties of lamprophyre dykes are present which for convenience in underground mapping have been divided into mica and non-mica dykes. Many of these dykes, in depth, resemble and may be of the same age as the porphyritic monzonite. The principal types are minettes (Tramway and Black dykes), kersantites (Josie and Nickel Plate dykes), vogesites (Upper Centre Star dykes), spessartites (Spokane and White dykes), and odonites, but there are also intermediate forms ranging from those rich in plagioclase to those rich in orthoclase and from biotite-bearing types to those in which pyroxene with hornblende is the predominant coloured constituent. These relationships are made clear in the following table:

	Orthoclase dominant	Plagioclase dominant
Biotite dominant	Minette	Kersantite
Hornblende dominant	Vogesite	Spessartite

[1]See footnote on p. 236.

The dykes have a general northerly trend although they cross, branch, and coalesce in a very intricate manner (See stereograms Map 1496 in pocket).

"Conglomerate" or "White" Dyke. An interesting dyke known in the Josie mine as the "White dyke" outcrops in a Great Northern railway cut about 400 feet west of the LeRoi mill (Plate VIII). The dyke is from 5 to 8 feet wide striking north-south and dipping to the east at an angle of 80 degrees. The dyke is seen in the photograph to be intrusive into a porphyritic monzonite stock (locally known as "the plug") but farther north in the Josie mine the White dyke is found cutting all the country rock formations as well as the veins. It has been opened up down to the 900-foot level of the mine and displays in depth the same appearance as at the surface. The dyke is composed of a heterogeneous mixture of large and small fragments of different rocks which are foreign to the district. They are included in a lamprophyric matrix (spessartite). The most common types of rock included are quartzite, gneiss, syenite, quartz, and aplite with here and there large crystals of hornblende in the matrix similar to those found in the spessartite dykes of the mines. The fragments in the outcrop have weathered out and show smooth, rounded to subangular forms which resemble water-worn or ice-worn pebbles. Many of the pebbles are tabular in shape and longer than they are broad. They lie with their greatest diameters parallel to the walls and in the direction of flow of the dyke. One of the largest fragments near the centre of the dyke measures 21 inches in length. In the mine workings angular fragments and large crystals of hornblende appear to be more prominent than on the surface.

A similar dyke was found in the Columbia and Kootenay mine. There it was more agglomerate-like with smaller fragments composed chiefly of a siliceous, gneissic rock almost identical in appearance with the vein rock on that level of the mine.

Several hypotheses have been advanced to account for the origin of this puzzling conglomerate dyke, but not one of them is entirely satisfactory. It might be considered a true agglomerate dyke in which the inclusions represent fragments ripped from the sides of the fissure, and rounded both by the corrosive action of the molten rock and by rubbing against the walls of the fissure during their upward course. However, the sharp contacts between the matrix and the inclusions, the lack of pronounced reaction rims about the inclusions, the ready manner in which the inclusions separate from their lamprophyric matrix, and the heterogeneous character of the included fragments are all adverse to such a hypothesis of origi:.

An alternative hypothesis is that the dyke cut through a buried conglomerate, possibly the basal member of the Mount Roberts formation, and carried up with it the water-worn pebbles derived from the conglomerate. No coarse conglomerate formation, however, containing pebbl·s similar to those included in the dyke, has, as yet, been recorded from this part of British Columbia.[1]

Pulaskite Cupola Stocks and Dykes (Coryell).

An alkalic syenite of the mineralogical composition, predominantly, of pulaskite[2] occurs in irregular boss-like and dyke-like intrusions cutting all the preceding formations. Good exposures of it may be seen on Earl street, at the Jumbo mine, and on the Trail wagon road. The normal rock is coarse in grain and pale pink in colour although the dyke intrusives have a porphyritic texture. The pulaskite is composed essentially of long rectangular feldspars (intergrowths of orthocla·. and albite) with a little biotite and hornblende. The follow·· analysis was made by Dr. F. Dittrich of Heidelberg:—

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O
62·59	0·54	17·23	1·51	2·02	tr.	1·30	1·99	6·74

Na_2O	P_2O_5	H_2O	CO_2	Cl	SO	
5·50	0·11	0·30	tr.	tr.	tr.—99·83	

[1] Since writing this an article by Sidney Powers, in the Journal of Geology, on the "Origin of the Inclusions in Dykes," has appeared which discusses the "White dyke" at Rossland. Jour. of Geol., Vol. XXIII, No. 2. pp. 174-177, 1915.

[2] *Pulaskite* may be defined as a type of .lkalic syenite between a normal syenite and a nepheline syenite with biotite as chief ferromagnesian constituent. *Nordmarkite* is a quartz-bearing pulaskite.

The pulaskite intrusives have been correlated with Daly's Coryell batholith[1] in Big Sheep Creek valley and with similar intrusions in the Boundary district[2], which are of Miocene age.

Granite Porphyry (Sheppard) and Lamprophyre Dykes.

Younger than the pulaskite are certain granite porphyry and lamprophyre dykes which are found cutting it in several places. The granite porphyry is a pinkish to grey, medium to fine-grained fresh rock composed of quartz, microperthite, orthoclase and oligoclase, hornblende, and a little biotite (Plate XIX B). It occurs as dykes in the LeRoi mine and on Deer Park hill, cutting all the preceding formations; and may represent an aplitic phase of the Coryell batholith. It is correlated lithologically with Daly's Sheppard granite[3] outcropping on Lake mountain where it is intrusive into early Tertiary conglomerate.

For purposes of comparison the following chemical analyses made by the Mines Branch of specimens of granite porphyry from the LeRoi mine and of Sheppard granite from Lake mountain over 5 miles distant are given:

	1	2
SiO_2	62·73	58·47
Al_2O_3	16·17	16·60
Fe_2O_3	0·28	1·57
FeO	3·58	3·45
MgO	1·76	2·41
CaO	3·03	5·64
Na_2O	5·74	4·60
K_2O	5·11	5·73
H_2O	0·45	0·45
TiO_2	0·60	0·60
P_2O_5	0·14	0·29
MnO	0·06	0·05
BaO	0·19	0·19
SrO	0·25	0·05
S[1]	0·08	0·24
Cl	0·13	0·02
	100·50	100·54

[1]Sulphur present in the form of sulphide-pyrite or pyrrhotite.

1. Granite porphyry from the foot-wall of the Black Bear ore shoot, 700-foot level, LeRoi mine, N. L. Turner, Analyst.
2. Sheppard granite from Triangulation station on summit of Lake mountain. N. L. Turner, Analyst.

[1] Geol. of the North American Cordillera at the 49th Parallel. Geol. Surv., Can., Memoir 38, 1912, pp. 358-366.

[2] Geol. and Ore Deposits of Phoenix, by O. E. LeRoy, Geol. Surv., Can., Memoir 21, pp. 49-52.

[3] Geol. of North American Cordillera 49th Parallel; Geol. Surv., Can., 1912, pp. 354-356.

There are a few lamprophyre dykes in the region younger than those already mentioned. They belong to the non-mica class and approach camptonite in composition—a rock in which the predominant feldspar is plagioclase while hornblende or augite forms the chief ferromagnesian mineral. Such dykes are found cutting pulaskite on the Trail road (Plate IX), and elsewhere.

Surficial Deposits and Vein Outcrops.

The recent unconsolidated formations consist of glacial till, gravel, sand, clay and silt. The vein outcrops present extensive 'gossans' or iron cappings where the ore has oxidized to a reddish brown sintery mass. The LeRoi iron cap was from 6 to 14 feet wide and outcropped for 200 to 300 feet in a north-east-southwest direction (Plate XXII). At the west end the oxidized vein seemed to branch into two or even three smaller diverging veins.

GEOLOGICAL STRUCTURE.

The structures may be divided into (*a*) primary, such as sedimentary and igneous structures and (*b*) secondary, such as folding and fracturing (joints, faults, and fissures).

Primary Structures.

Most of the structures have to do either directly or indirectly with igneous activity. Sedimentary structures are of minor importance and restricted to the Mount Roberts formation. The sedimentaries of this formation are as a rule remarkably evenly bedded indicating a lack of strong currents at the time of their deposition. In some places, however, marked cross bedding was noticed as, for instance, in the California tunnel (Plate X A).

The primary structures of the different igneous formations have to be inferred from rather meagre field data. The structure of the augite prophyrite is that of an irregular sill-like mass;

the structure of the granodiorite is that of a batholith with stock and tongue-like protuberances (cupola-stocks[1]) penetrating the roof rocks. Such stocks of granodiorite and injection tongues of diorite porphyrite can be traced to the underlying batholith and probably represent in part conduits through which the gases and magma reached the surface to form the tuff beds and andesite lava flows of Mount Roberts. Both the form of the diorite porphyrite tongues and the fact that "horses" or inclusions of Mount Roberts formation are found within them afford evidence of the intense nature of this injection which ripped off portions of the intruded rocks and transported them long distances upward.

The structure of the monzonite is that of an irregularly shaped intrusive (chonolith), in part flat-lying, which has been intruded slightly later than the granodiorite and probably had access to the surface to form lava flows of augite latite now exposed on the Record Mountain ridge. Younger lamprophyre rocks were intruded in the form of long persistent dykes which pinch and swell, branch, and coalesce in a most irregular manner.

Secondary Structures.

Folding. Evidence regarding the nature of folding in the Mount Roberts formation is very fragmental. Erosion has spared only a few isolated belts of the Palæozoic complex and where bedding planes are discernible the strikes and dips are found to vary a great deal from place to place. The prevailing dips are from a few degrees to 60 degrees west. The fact, however, that the granodiorite truncates the highly tilted and folded Mount Roberts sedimentaries suggests that the period of folding was prior to igneous intrusion.

Fracturing. All fractures are accompanied by some displacements and when molten rocks or magmas cool and solidify tensile stresses result which form fissures and joints. Such contraction joints and fissures are well developed in the igneous and adjoining rock formations of this district. The planes of jointing vary considerably from place to place and with the

[1] See p. 27 for definition.

different formations. Two main systems were noted, traversing the porphyrite and monzonite alike. One set appeared to be in a general north and south direction with nearly vertical dip corresponding to the trend of the lamprophyre dykes. The other system is at right angles to the latter and has flatter dips. Locally, the joint fractures take curved or broadly concentric forms about what were probably loci of cooling. The lamprophyre dykes where narrow, display pronounced columnar jointing; particularly is this true for the non-mica dykes. Where the lamprophyre dykes are very wide, columnar jointing gives place to diagonal jointing. The joint planes have pyrite and biotite in some places developed along them.

Faulting. Concerning the faults, Young states: "The district is traversed by innumerable faults and though on an average, the amount of relative movement (slip) due to any one fault is small, yet in the bulk, their results likely are considerable. But because of their great number it was practically impossible to map individual faults or to determine the combined effects of their throws."

Evidence of a fault traversing the low pass between Red and Granite mountains at present occupied by a dyke of pulaskite was noted by Young in 1906. The evidence is structural in that "the beds of Mount Roberts group . . . . . occupying the western portion of Red mountain strike usually to the west of north and the value of the angle of westerly dip commonly varies between 10 and 30 degrees. Throughout the band of these rocks to the west of the above and from which it is separated by a comparatively narrow zone of igneous rocks, the direction of the strike is the same, nearly north and south, but the beds are highly inclined and usually in an approximately vertical position. This sudden change in the value of the angle of dip seems almost certainly to be due to a fault along which afterwards has appeared the dyke of pulaskite intervening between the two areas of bedded rocks. This fault apparently had formed before the intrusion of the majority of the dykes, since they have the same general vertical attitude both east and west of the supposed fault; but whether the dislocation occurred before or after the intrusion of the large body of granodiorite of Mesozoic age now found in the valley of Sheep creek, is not so evident. The small amount of evidence collected would, however, indicate that this fault had appeared before the granodiorite invasion."

In the mines where fault surfaces are visible, marked by slickensides, gouge, and fault breccia, the *slip*[1] or relative displacement of formerly adjacent points on opposite sides of the fault measured along the fault surface, is commonly determined. On the surface, in dealing with the structures in a broader sense the *shift* which indicates the relative displacement of regions on opposite sides of the fault and outside of the dislocated zone would more often be determined.

Faulting has commonly taken place in and along the borders of the "mica" and "non-mica dykes," particularly along the mica dykes. A good example of faulting along a mica dyke may be seen in the LeRoi and Josie mines where the main and south veins of the LeRoi mine west of the Josie dyke have been faulted along the Josie dyke to the south about 300 feet and downward an undetermined distance (Maps 1518 and 1496 in pocket). Ore bodies in the veins such as the Tregear and the Black Bear (the former on the north border of a granodiorite stock and the latter on the south border of the same stock in contact with augite porphyrite), have been faulted approximately that amount. The No. 1 vein west of the Josie dyke is in all probability the faulted end of the War Eagle vein (See stereograms Map 1496 in pocket). Another fault has taken place along the Nickel Plate dyke resulting in the dropping of the ground east of the fault to the south. Thus the ore-bearing ground between the Josie and Nickel Plate dykes is a fault block thrust upward and northward with respect to the bordering blocks or in other words is a '*horst*.' The planes of movement have irregularities resembling a warped surface and the rocks are in places polished, grooved, and striated along such planes. It was not demonstrated, however, that there had been in the majority of cases extensive movement.

In such a region of igneous rocks, where the faults run in nearly all directions, intersect at all angles, change their direc-

[1] Lindgren, W., Mineral Deposits, 1913, pp. 119, 121.

tions, are cut off suddenly and in fact show all the irregularities to be expected from interior strains of intrusion and cooling, it is unsafe and unwarranted to extend and correlate the faults. It was possible, however, to correlate some of the most important faults in the mines such as faults K, E, Q, F, L, etc. (Stereograms Map 1496 in pocket). Faults of different ages are present, for instance, fault K (which is mineralized for considerable distances) probably shortly succeeded the main period of sulphide mineralization, which is considered to have taken place at the time of or shortly following the Jurassic revolution. The vast majority of the faults and secondary structures, however, are of comparatively recent date and directly due to crustal movements connected with the younger Tertiary periods of igneous activity.

The shear zone and compression fissures will be dealt with in the chapter on "Economic Geology."

Geological History.

A brief outline of the main events in the geological history of Rossland so far as understood will here be given illustrated by hypothetical structure sections of the district at different periods (Figure 5).

Palæozoic History—Mount Roberts Formation.

During at least a part of the Carboniferous period the district was covered by the ocean in whose waters abode shell fish, corals, and other invertebrate forms. From the islands and shores of this sea, or from volcanic vents rising above the sea-level, volcanoes burst forth at intervals and deposited vast amounts of volcanic dust or tuff in beds along with the normal clays and sands. The sedimentary materials represented by the Mount Roberts formation are all fine-grained and indicate deposition in waters without strong currents.

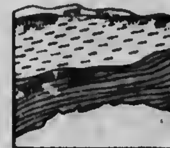
This long period of relative quiet was brought to a close by a series of great disturbances when the region was uplifted above the sea and the rocks were deformed. The Palæozoic era closed with the beginning of continental conditions of erosion

During the Carboniferous (Mount Roberts formation)

During the Triassic (Agglomerate, tuff, and augite porphyrite)

Rossland 'Rockies' of the Late Jurassic - Red Mountain Volcano (Andesite and latite)

Close of the Cretaceous (Prior to Laramide Revolution)



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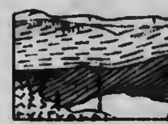


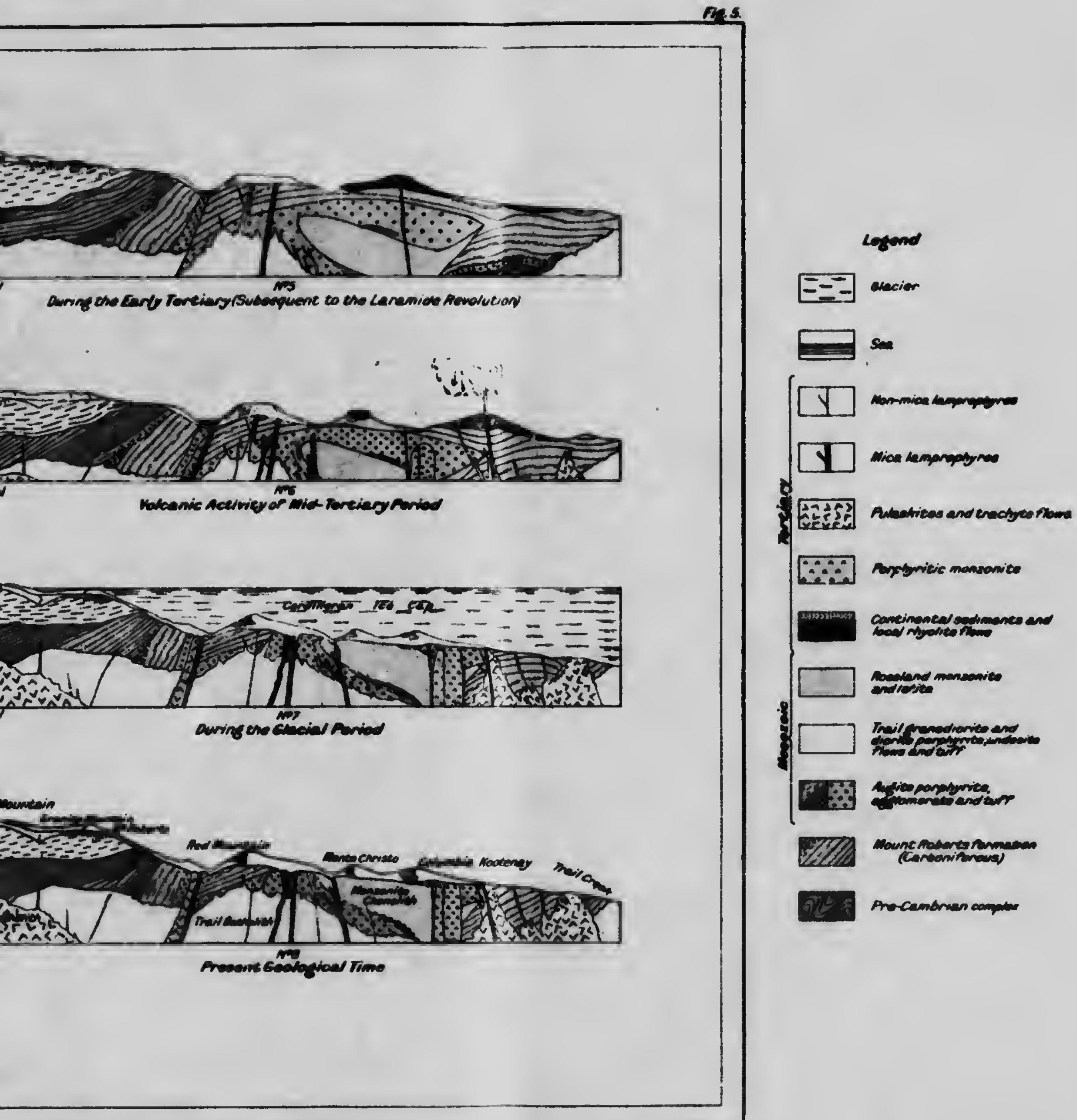
Geological Survey, Canada

Hypothetical Sections illustrating the **Progressive Development** of the **Geolog**

(Line of Section East-West 400 feet north of War Eagle Sha

Vertical and Horizontal Scale of Feet

To accompany Memoir by C.W. Drysdale



...e Geological Structure at Rossland, B.C.

...r Eagle Shaft)

and sedimentation, which have lasted until the present time. There is no evidence in the vicinity of Rossland to indicate that any marine transgression since the Carboniferous has taken place, although the district was probably very near sea-level toward the close of the Cretaceous.

Mesozoic History.

During the Triassic period an intrusion of augite porphyrite took place, in the form of sills and irregularly shaped masses, which spread out between the bedding planes of the older formations and probably reached the surface to form agglomerates, tuffs, and lava flows.

Jurassic Revolution—First Main Period of Mineralization. A most important geological event from the economic standpoint took place toward the close of the Jurassic period, known throughout the Cordilleran region as the Jurassic mountain-making revolution. It gave birth to the Sierra Nevada mountains in the United States and the Coast range as well as other ranges in British Columbia, and was accompanied by much igneous activity and accompanying mineralization. The rock formations of Rossland were at this time invaded by the Trail granodiorite batholith from which stocks and tongues were actively injected upward under great pressure into the roof rocks. Some of these injected tongues reached the surface to form the tuff beds and lava flows (andesites) so well exposed to-day on Mount Roberts. Mount Roberts may then be considered as a portion of the old rim to the Rossland volcano, whose crater was probably where Red mountain now stands. Such extinct volcanoes may be seen throughout many districts in British Columbia in every stage of decay.[1] The youngest still show their craters with the streams of lava that escaped from them. Those of less recent date are worn down into rounded hills, or the whole cone has been cleared away and there remains only the hard core of material that solidified in the funnel of the volcano below the surface. The lava flows from the

[1] Geology of Franklin Mining Camp, B.C., Geol. Surv., Can., Memoir 56, 1914, pp. 86-88, Fig. 13.

Rossland volcano have been cut through by streams and now remain in scattered remnants capping hills.

At Trail, the Columbia valley has been cut deep into the Trail batholith whereas at Rossland only isolated patches outcrop amidst the highly silicified roof rocks of this underlying granodiorite formation. Many of the stocks of granodiorite and injected tongues of diorite porphyrite from it, however, are visible both on the surface and in the mines. They have been influential in many cases in the control of the fissuring system, and mineralization zones, as shown by their correspondence in strike and dip with the latter and the number of rich ore shoots that are found on their contacts.

A slightly younger intrusion but one closely related to the Trail granodiorite took the form of an irregular, in places flat-lying, monzonite mass (monzonite chonolith) one narrow embayment of which was important in controlling the trend of the main Centre Star-LeRoi vein. From the north border of this monzonite embayment a great quantity of ore has been shipped. The shear zone fissures were formed chiefly in the cover rocks, following batholithic and chonolithic intrusion and consolidation. The mineralizing solutions circulated and replaced the country rock along such zones of fissuring. The principal channels appear to have been in the proximity of the diorite porphyrite and monzonite and along their contacts with the older augite porphyrite formation. In many places, however, the fissures broke away from the contacts and penetrated both monzonite and augite porphyrite for great distances. In such cases the distribution of copper and gold values varies with the kind of rock replaced.

Following the main period of mineralization, came a long period of erosion, lasting throughout Cretaceous time. The mountains were slowly worn down and the land brought nearly to a base level. The Cretaceous erosion cycle removed in many places the entire cover overlying the Trail batholith, and in certain localities removed with it many rich ore deposits. The removal of the cover was accomplished during Cretaceous time, for Eocene river and lake deposits are found lying directly upon the late Jurassic granodiorite.

Laramide Revolution. At the end of the Cretaceous the whole Cordillera was uplifted and the present ranges became outlined. The Columbia Mountain system in which Rossland lies, formed one of the axes of maximum uplift and the vein fissures of the mines were probably further shattered and sheared to form channels, possibly, for more mineralizing solutions. Such were the conditions of mountain growth that left the Cordillera with a rugged and youthful relief at the close of the Mesozoic era. While, during the Cretaceous, sandstones, lignites, clays, and such products were deposited, coarse mechanical sediments accumulated following this mountain-making period.

Tertiary History.

Eocene. The Laramide uplift and deformation brought about a change in climate for this section of the Cordillera, from the subtropical of the Cretaceous to one of coolness and humidity in the Eocene. This is evinced by the thoroughly leached light-coloured sediments. The coarse heterogeneous conglomerates, containing in places scratched and facetted boulders and pebbles, point towards rugged alpine conditions in the surrounding Columbian highlands with probably local glaciers supplying their quota of material to the conglomerates which were being deposited in alluvial cones at the base of the ranges. At that time, probably, a river flowed westward from the Selkirks toward the Pacific, a few miles south of Rossland. The boulders and sands laid down in its valley bottom may still be seen on the summits of Sophie and Lake mountains. The old valley bottom of Eocene time is at present the mountain summit.

Oligocene. Following the erosion and continental sedimentation of the Eocene, deformative movements took place accompanied by the intrusion at Rossland of the porphyritic monzonite and closely related "mica" and "non-mica" dykes. The old Eocene river deposits were deformed and local displacements of some of the veins probably took place at this time.

Once more a period of crustal stability ensued and a new erosion interval commenced which was largely responsible for the stripping of vast thicknesses of early Tertiary sedimentary and volcanic records.

Miocene—Second Main Period of Mineralization. During the mid Tertiary, the district was again invaded by a batholith, but instead of being composed of granodiorite and related types of rocks this one was composed of the much rarer alkalic types (dominantly pulaskite). The southern border of the batholith outcrops a few miles north of Rossland on Granite mountain, and arms from it penetrate the rocks in the heart of the town, as for instance, on Earl street. Another arm from it may be seen at the Jumbo mine and dykes occur elsewhere throughout the district. At this time the vein fissures were probably further fractured and the sulphide deposits locally enriched by gold brought in by the alkaline mineralizing solutions connected with the Coryell batholith.

The youngest intrusions we have record of in Rossland are certain granite porphyry (Sheppard alkalic granite) and lamprophyre dykes found cutting pulaskite. Good exposures of these dykes may be seen on Deer Park hill and on the Trail road, a few miles below the town of Rossland.

Pliocene. Following the great epoch of igneous activity and crustal movements of the Miocene, came quiet, stable conditions, with a long period of erosion.

Rossland owes, in part, its present gentler, though still mountainous, upland topography with broad flaring valleys to this Pliocene erosion cycle. The presence of Pliocene gold-bearing quartz drift in certain parts of British Columbia would imply long subaërial decay and stability of level at this time, somewhat analogous to conditions during the Cretaceous erosion at the end of the Mesozoic. Thus it is considered that both the Mesozoic and Tertiary eras in this region ended with the land reduced to a surface of relatively low relief and near the level of the sea.

Quaternary History.

Pleistocene. The crustal movement which closed the Tertiary was in the nature of a broad differential uplift of the land which permitted the invigorated drainage to incise itself deeply within the older upland surface and produce the present steep-walled valleys, since rounded and modified by glacial ice.

Glacial Period. During the Pleistocene a change to a cooler climate took place and snow accumulated in the Cassiar highlands on account of winter precipitation exceeding summer melting. Ice fields slowly gathered, deepened, and crept southward to form the Cordilleran ice cap, which covered the whole region with the possible exception of a few high peaks outside the area in question which stood as islands (nunataks) above the ice surface. The Cordilleran ice cap modified only slightly the upland topography. It produced striæ and scourings in places, and on retreating left morainic drift and erratics stranded high on the upland. The ice cap gave place to alpine valley and cirque glaciers which slowly retreated until possibly the time of the maximum extension of the Keewatin ice sheet to the east, when a refrigeration brought on a second advance of valley ice (the Vashon period of Pacific coast). It is to this second period of valley glaciation that the strongly glaciated valley forms, such as U-shaped valleys and lateral moraines, are due and at this time too the valley trains of outwash material were deposited. A glacial lake existed at the confluence of the Trail Creek valley with the major Columbia valley, formed by the damming of the waters from Trail creek against the Columbia Valley glacier. In this lake a great thickness of sand and silt accumulated.

Recent. With the retreat of the valley glaciers, the streams, unburdened of the morainic material they were carrying, began to cut into their valley fills. A series of terrace steps mark successive stages in the down-cutting process of the meandering Columbia river.

The last events are connected with the slow, normal weathering agencies of frost, ice, snow, rain, and humus which are facilitating the disintegration and decomposition of the rock formations into subsoil and soil.

CHAPTER III.

ECONOMIC GEOLOGY.

This chapter includes a general account of the most important facts and reasonable inferences concerning the occurrence, structure, and character of the ore deposits followed by the main conclusions regarding their origin and age[1].

ORE OCCURRENCE AND STRUCTURE.

The Rossland ore consists mainly of pyrrhotite and chalcopyrite, associated with a gangue of altered country rock containing some quartz and locally a little calcite (Plate I). The sulphides form from 50 to 70 per cent of the mass. The values are largely in gold (0·4 to 1·2 ounces), with some copper (0·7 to 3·6 per cent), and a little silver (0·3 to 2·3 ounces). There are all transitions from typical ore to solid sulphides or to rock matter, or to gangue with little apparent mineralization but carrying values.

It has been concluded from a study of the field facts shortly to follow that the ore deposits of the producing belt at least, are replacement veins along fissures and sheeted or shear zones.[2] In other words the veins represent the channels into which the alkaline aqueous solutions and gases containing the metals were forced to penetrate under conditions of high temperature and pressure. In time these solutions and gases transformed the fractured and brecciated country rock into ore through practically simultaneous solution and precipitation. Furthermore, it has been concluded that the fissures and shear zones have been controlled in their development by the formational contacts and that the ore shoots are chiefly contact shoots.

[1] For detailed description of properties the reader is referred to the succeeding chapters.

[2] A *shear* or *sheeted* zone consists of a number of planes of fissuring situated at a distance apart varying from a few inches to a few feet and formed through compressive stresses in the crust of the earth.

TYPES OF DEPOSIT AND DISTRIBUTION.

Five main types of deposit have been recognized in the district, which may be enumerated as follows:

(1) Ore deposits in true replacement vein fissures with fairly definite hanging and foot-walls. Such veins display in contrast to the other types great uniformity in width and value of ore. The best examples of this type are the fissure veins traversing augite porphyrite country rock, as for instance the Hamilton vein in the Josie mine, the vein fissure in the upper workings of the War Eagle mine, the No. 1 vein, portions of the Peyton vein, and others throughout the region.

(2) Ore deposits occurring along sheeted fissure or shear zones, in irregular, generally lens or tabular shaped shoots with intervening stretches of barren vein characterized by crushed country rock and fault gouge. The shoots as a rule, though not invariably, lie along the portion of the shear zone traversing a formational contact. In many cases only one definite wall is present, the other boundary being a commercial rather than a structural one, although there is generally a certain parallelism of lines of fracture for short distances which may be mistaken for walls. The great majority of the ore deposits in the district belong to this type as for instance the main Centre Star-LeRoi vein, North and South veins, War Eagle veins of lower workings, Annie vein in Josie mine, and others.

(3) Ore deposits in cross fractures or fault fissure veins which are of very local occurrence and of not very great economic importance. In some cases, however, the intersections of such cross fractures with main vein fractures show enrichment, whereas in other cases they show impoverishment. Such cross fractures are often misleading in diamond-drill operations. This type of vein is most common in the upper workings of the mines, and particularly in the wedge-shaped remnant of augite porphyrite intervening between the monzonite of the War Eagle and that of the Centre Star and Iron Mask mines, which is traversed by a great number of such veins.

(4) Ore deposits as irregular impregnations of country rock; in part somewhat resembling stockworks. This type

of deposit occurs in areas underlain by the Mount Roberts formation and the deposits are of an erratic nature and difficult to mine. The impregnations, however, in places occur in and around small pegmatitic and aplitic alkalic syenite dykes as at the Giant and Jumbo mines, and from these occurrences considerable good ore has been mined. Many of the South Belt deposits belong to this type.

(5) Gold bearing quartz fissure veins carrying iron, copper, and lead sulphides as well as gold. This type of deposit is more in the nature of cavity fillings than replacement veins. The best example of the type is at the I.X.L. and O.K. properties in Little Sheep Creek valley (page 151).

Over ninety per cent of the ore shipped from Rossland was mined from deposits belonging to the first three types, all of which may be included and described as fissure veins.

Fissure Vein Systems.

The accompanying geological maps (Maps 1518 and 1496 in pocket) show in plan and elevation the multiple and somewhat complicated primary ore bearing fractures or fissure vein systems as exposed in mine workings, their direction and spacing.

Direction of Vein Fissures.

The LeRoi-Centre Star vein and South vein and the Poorman vein have a direction averaging about north 60 degrees east. The LeRoi North vein, Peyton vein, War Eagle and Centre Star North vein have a trend of about north 70 degrees west. The veins of the LeRoi No. 2, vary in direction from about that of the War Eagle to that of the LeRoi Main vein. The St. Elmo-Cliff-Monte Christo vein has an almost easterly direction. The dips are uniformly north usually at an angle of from 60 degrees to 70 degrees, although in some places flattening, as on the War Eagle 8th level, to an angle of 10 degrees[1]. The strikes of the principal vein fissures are indicated in the accompanying diagram (Figure 6).

[1]See Map 1518 in pocket, also Figure 7, p. 49. The ore on such flatly dipping stretches of the vein is, as a rule, lower in grade than where the vein is steeply dipping.

Spacing of Vein Fissures.

The vein fissures are quite closely spaced in the LeRoi ground and the so-called Main and South veins might be considered as one composite vein or lode with hanging-wall and foot-wall sections. In the lower workings of the Josie and War Eagle mines also, the veins are closely spaced so that it might

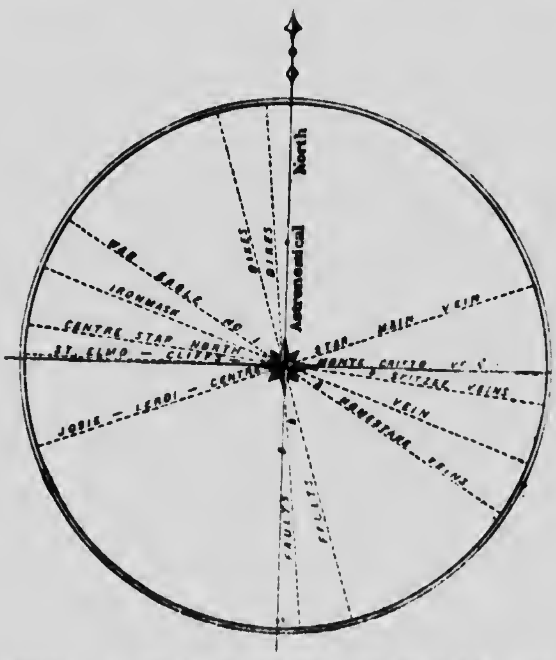


Figure 6. Strikes of the principal veins, faults, and dykes.

be stated that the great productive vein fissures on the whole are closely spaced. Although in some cases several smooth walls occur in the shear zone veins and faulting has taken place along the vein fissures either before or after vein filling, the amount of differential movement has been slight. This is evinced by the absence of original open spaces or cavities, slickensides, and friction breccias. In this respect these primary ore bearing fractures stand in contrast with the secondary fractures, which have strong gouge zones and cavities lined with crystals of calcite and zeolites. Parallel veins containing ore shoots are in places separated by sheets of barren country rock, generally of a different rock formation.

Linking, Forking, and Reticulating Systems of Vein Fissures.

The veins fork and reticulate in an intricate manner in some parts of the workings as illustrated on a small scale in the accompanying photograph taken on the 10th intermediate level of the War Eagle mine (Plate X B). The veins in places split or branch both on strike and dip to form linked[1] systems (Map 1518 in pocket). In the War Eagle mine the forking and branching of the veins appear to be connected with the main trunk and limbs of a tree-like mass (in cross section) of diorite porphyrite which is intrusive into augite porphyrite. In the case of the main shear zone vein the branch fissures traverse the hanging-wall territory, following the branching tongues of diorite porphyrite.

Relations of Vein Fissures to Country Rock Formations.

The vein fissures correspond in strike and dip with the diorite porphyrite tongues and for long distances follow their contacts with the older formations. They are, however, younger than the tongues, since the tongues are found cut by the fissures in many places. The Centre Star-LeRoi main vein fissure is also younger than the monzonite and follows for a long distance the north border of the monzonite embayment, the ore having a prominent foot-wall of monzonite but no structural hanging-wall (Plate XXII). The ore passes transitionally into unmineralized augite porphyrite, thus forming a commercial hanging-wall. The vein fissure, however, breaks away entirely from the contact farther east and traverses monzonite alone.

[1] Linked veins are veins which are linked together by direct continuations of divergent strike or by small stringers intersecting the country rock which intervenes between them.

Long productive stretches of the Main and South veins in which the Mulligan, Tregear, and Black Bear ore shoots occur follow the borders of granodiorite stocks (Figure 7).

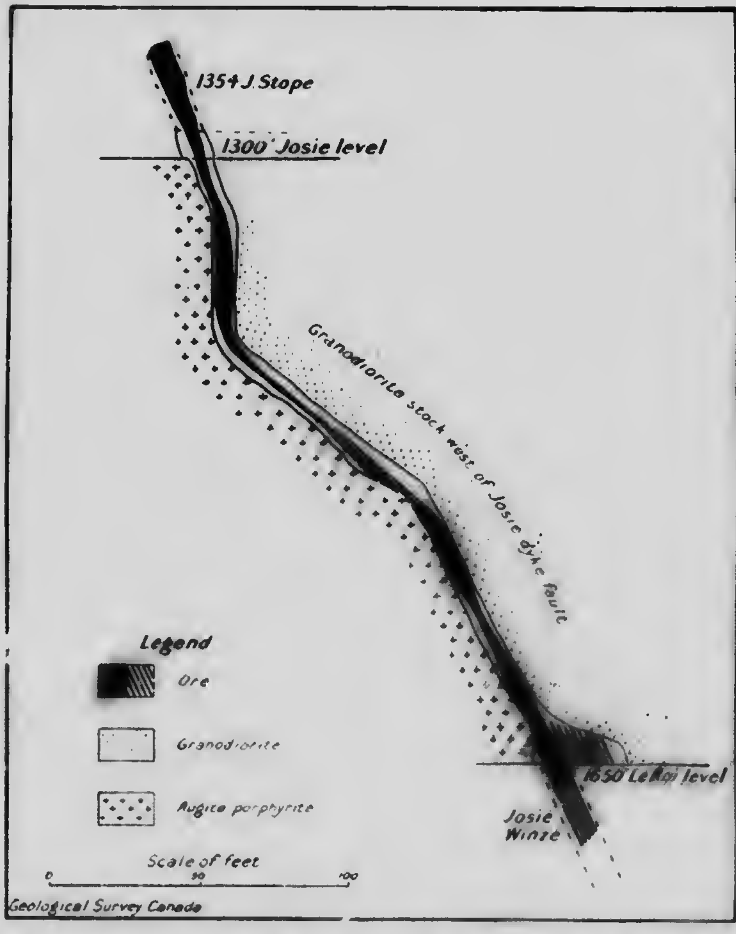


Figure 7. Transverse vertical section through No. 1687 raise, LeRoi mine, Rossland, B.C.

The vein fissures in many cases fray out, flatten, or terminate against the stratified rocks of the Mount Roberts formation as for instance in the War Eagle vein below the 11th level (1195*b*[1] stope) and again above the 8th level (Map 1518 in pocket). The Mount Roberts formation, which occurs as isolated blocks or inclusions within the igneous rocks of the productive area, seldom carries ore.

A schistose type of porphyrite, not so favourable to vein permanence and ore shoots as the less altered massive types, occurs throughout the ore bearing rock belt (Plate VI D). This porphyrite schist type forms indefinitely shaped zones which cut off or deflect the vein and ore in certain localities. One such schist zone appears to follow the lower border of the War Eagle monzonite chonolith (Map 1518 in pocket). Elsewhere it forms narrow zones appearing to trend with the diorite porphyrite tongues but dipping in a reverse direction to them.

Such zones of porphyrite schist may represent, like the shear zone veins themselves, the metamorphic work of compressional stresses which acted, however, in the case of the schist zones more in the nature of regional mashing[2] than shearing. The mineralizing solutions favoured the shear zones rather than the less persistent and less intimately fractured zones of mashing (schist zones). The latter zones, however, were locally silicified and pyritized.

Persistence of Vein Fissures.

Some of the vein fissures have great persistence[3] and this persistence of ore in depth appears to be, as Maclaren has stated,[4] a function not of depth but of geological structure. Some of the veins are 4,000 feet and more in length and from a few

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[1] The following system of numbering the working places in the mines is used by the Consolidated Mining and Smelting Company: The levels are numbered consecutively from the collar of the shaft down, thus: 1, 2, 3, 4, etc. In the numeration the numeral indicating the level is placed first; the numerals following indicate the precise position. Positions east of the shaft and on a sill floor are indicated by the numerals 01 to 50, if above the sill floor by 51 to 70; positions west of the shaft and on a sill floor are indicated by the numerals 71 to 85, if above the sill floor by 86 to 99. For instance No. 1195 stope denotes a working place on the 11th level, west of the shaft and above the sill floor, and No. 839 denotes a working place on the 8th level, east of the shaft and on the sill floor.

[2] *Mashing* takes place in planes normal to the greatest pressure. *Shearing*, on the other hand, takes place along definite planes (planes of scission or simple shear) which are inclined to the greatest pressure.

[3] Rickard, T. A.; The Persistence of Ore in Depth. Min. and Scien. Press, Vol. CV, p. 264.

[4] Maclaren, Malcolm: The Persistence of Ore in Depth. Compte Rendu XIIe Congres Geol. Internat. pp. 295-304.

inches to 130 feet in width. The main LeRoi-Centre Star vein can be followed from the porphyrite monzonite "plug" west of the Josie dyke fault eastward through the LeRoi, Centre Star, and Idaho claims; and it possibly extends through to the Kootenay claim (Figure 13, page 94.)

The fissures have greatest persistence in the augite porphyrite, particularly where it is in contact with the steeply dipping tongues of diorite porphyrite, with steep-walled cupola stocks of granodiorite, or with the north border of the Centre Star monzonite mass. The firm and homogeneous younger granitic intrusives have apparently reinforced with strong rock ribs, the older augite porphyrite of the batholithic roof, and formed ground which would fracture under crustal stresses in such a way as to be traversed by remarkably persistent fissures.[1] Furthermore, as Brock has pointed out, the fissuring and shearing of the rock, were such that the mineralizing solutions were restricted within a zone of moderate width, and had free movement within that zone. The rock within that zone was thoroughly fractured, while the wall rock as a whole was characterized by solidity. In such cases conditions were favourable for persistent ore producing veins.

The stratified rocks of the Mount Roberts formation, on the other hand, have been completely shattered and minutely fractured by the great dynamic stresses to which the rocks of this district were subjected. In this way, they did not to the same extent, confine the mineralizing solutions to particular channels, but allowed them to circulate over wide areas. The minerals deposited in the stratified rocks, therefore, while occasionally in small veins or bodies, are usually found diffused over great stretches of the formation. The chemical as well as the physical character of the stratified rocks as a whole may have been less favourable, so that replacement and precipitation of the ores occurred only at small isolated points. In the White Bear mine, for instance, the workings to the 500-foot level are in the stratified rocks, and it was not until the underlying crystalline rocks were reached that a well defined vein was found.

[1] For a somewhat similar case refer to Figure 196 Star-Old Abe section, Homestake Mine (Emmons) in "Gold" by Malcolm Maclaren, p. 580, and cf. map 1518 in pocket of this memoir.

The shear zone fissures persist and are wide for great distances in both the monzonite and the underlying granodiorite, but the ore-shoots become smaller and of a sporadic character. In the lower levels of the Centre Star mine the main shear zone fissure is strongly developed and contains a broad band of silicified granodiorite containing calcite, chlorite, biotite, epidote, and pyrite but without important ore shoots. The quartz, biotite, and epidote develop in more or less distinct alternating layers, producing a light or reddish banded material that closely simulates a stratified rock.

In addition to the well defined fissure veins which may be traced for considerable distances there are in most of the mines a number of less important co-ordinate fractures that are mineralized, as for example, the cross fracture followed by "839 working"[1] of the War Eagle mine. This cross fracture is traceable down to at least the 10th level. The ore producing ground at Rossland, however, was of too heterogeneous a character to readily form any definitely co-ordinated system of fracturing, when it was submitted to orogenic pressure. The force instead of being resolved into two components (as would be the case in a homogeneous mass where the strongest and most persistent veins would be the resultant of the two directions) in the case of Rossland was resolved into many components which had little influence upon the direction and persistence of the main vein fissures.

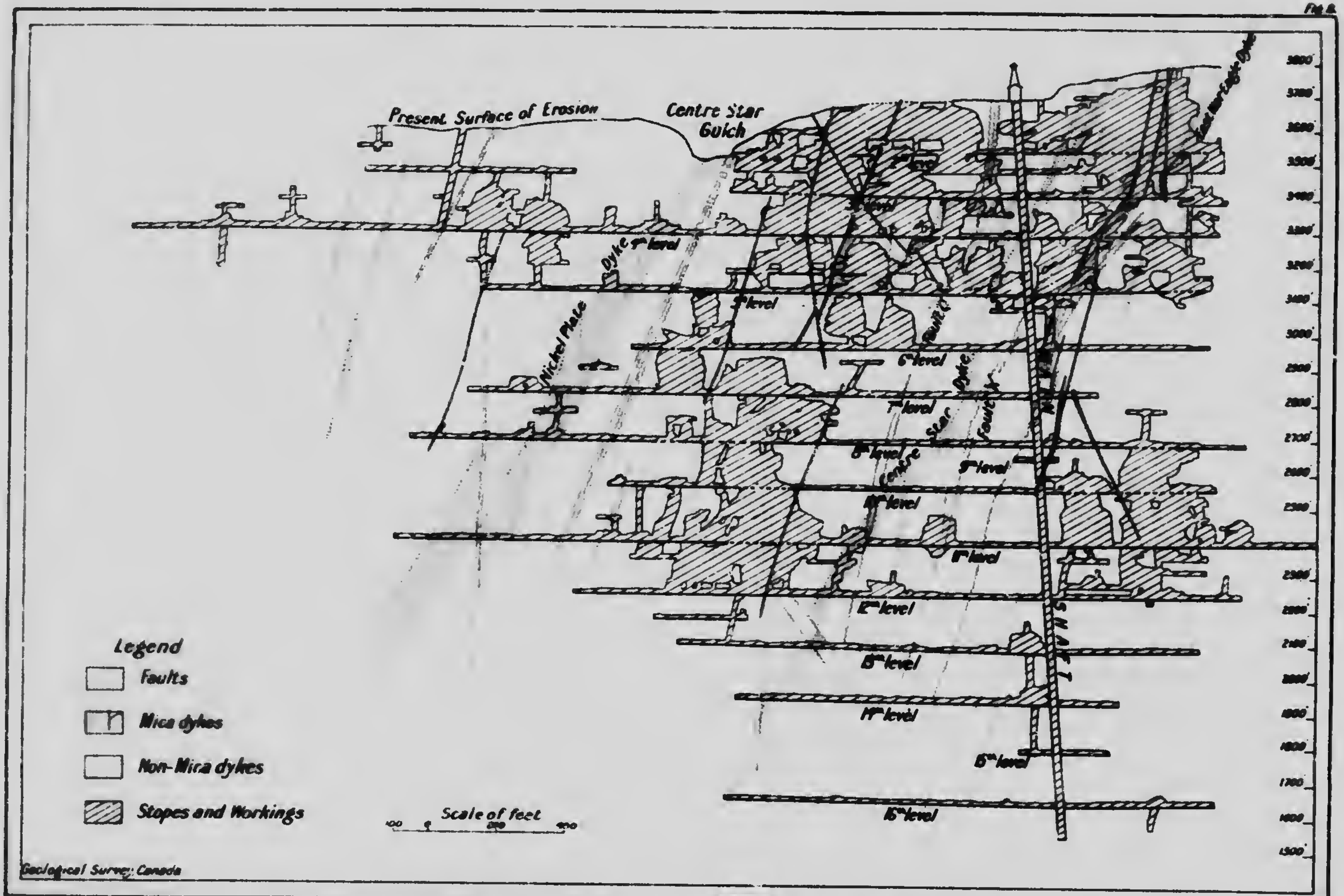
In ground that is so heterogeneous and altered as that of the War Eagle mine, it is difficult to correlate the numerous sections of veins that are to be found and to determine the number and direction of these subordinate veins.

Origin and Age of Vein Fissures.

From the foregoing discussion it follows that the vein fissures have originated from a common cause which operated through various periods; and that they were due to compressional stresses set up in the upper portions of the Trail batholith and cover formations contemporaneous with mountain making.

[1] See footnote on p. 50.

Fig. 8.



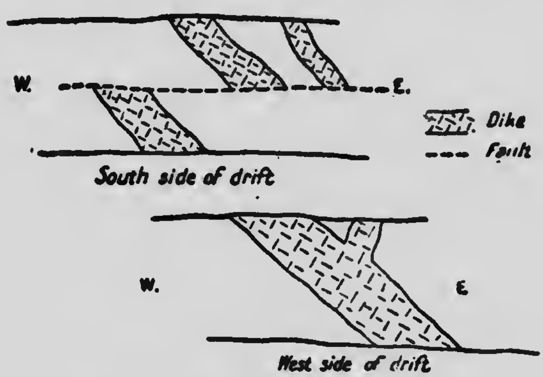
Longitudinal projection of Centre Star Mine, Rossland, B.C.

To Accompany memoir by C. W. Drysdale

The main period of mountain-building was probably during the early Cretaceous or Comanchic following the Jurassic revolution. The stresses found relief in the fissures, which were controlled in their development largely by formational contacts. The fissures formed passages through which the mineralizing solutions ascended from the same deep-lying molten rock or magma reservoir that gave rise to the diorite porphyrite tongues with which the vein fissures are very probably genetically connected.

DYKING.

The vein fissures are cut by a series of very persistent lamprophyre dykes which have a general north and south trend corresponding to the master-joint planes of the district (Figure 8). The dykes do not disturb the trend of the veins. They are found branching and faulted in many places (Figure 9) and elsewhere they are together forming mixed or composite dykes (Figure 10).



BRANCHING AND FAULTING IN DIKE
(Monte Cristo Mine)

Figure 9.

They are most numerous on the lower eastern slopes of Red mountain and eastward, averaging in certain belts about one in every 25 feet. Some of the lamprophyres are older than the vein fissures and are found both cut off by the veins and as inclusions in the ore (Plate XI). In some places the older dykes are slightly mineralized. In a few cases, they have followed for short distances the vein fissures, the ore occurring on the underside of the dyke which forms the hanging-wall of the vein, as for instance on the War Eagle 5th level where the hanging-wall to the ore shoot is a mica lamprophyre. Elsewhere the vein is found constricted where it cuts the dyke (Figure 11). Such pre-ore dykes have played an important rôle in the locali-

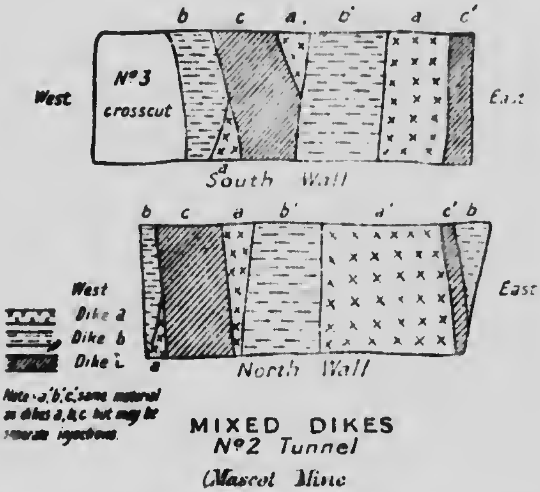


Figure 10. Composite dyke No. 2 tunnel, Mascot mine.

zation of some of the ore shoots and enrichments in the veins. In the Josie mine west of the Josie dyke there is a persistent feldspar-porphyry dyke (Map 1518 in pocket) which cuts the ore but does not fault it, nor is the ore bunched against it as is common in the case of the mica dykes. The vast majority of the lamprophyre dykes, however, are of Tertiary age and were formed after the ore deposits. The younger dykes do not appear to bear any genetic relations to the veins as do the more important tongue injections of the Mesozoic period. It is important for location and diamond-drill purposes, however, to have the position, strike, and dip of all such dykes carefully mapped and correlated. In some localities they are so plentiful that it hardly pays to mine the intervening blocks of ore.

VEIN CUTTING DIKE BUT CONSTRICTED BY IT.
6th Level. 30 feet East of Sta. 168.
(War Eagle Mine)

Figure 11.

Origin and Age of Dyking.

The lamprophyres probably owe their origin to the intrusion of molten rock into deep-seated fissures produced through east and west tensional stresses set up in the crust at a time following the maximum period of mountain-building when the stresses were dominantly compressional. The main north and south dykes are of Tertiary age although the older pre-ore set may date back to the late Jurassic or early Cretaceous (Comanchic). The deformation of the earth's crust then was probably widespread in its effects, but here it manifested itself by local and sudden deformations like that accompanying an earthquake or an eruption of igneous rock. The highly fluid basic-dyke material was injected suddenly and travelled long distances from its parent source.

FAULTING.

Secondary fracturing or faulting of the fissures is common and in many cases has taken place along the lamprophyre

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 2.8 2.5 4.5 5.0 3.2 2.2 5.6 6.3 3.6 7.1 2.0 8.0 4.0 9.0 1.1 1.8 1.25 1.4 1.6

dykes. In some instances it was possibly contemporaneous with dyke intrusion. The amount of movement has been greater in the secondary than in the primary or ore-bearing fractures as evidenced by wide (from a few inches to 2 feet) gouge or attrition clay zones, friction breccias and cavities lined with zeolites and calcite crystals. Some of the secondary fractures dip at low angles, are very persistent, and form water courses ("mud seams"). The striations on the secondary fracture or fault planes have as a rule lower angles of dip than have the striations on vein-fissure walls. Two sets of striations are often present, one set vertical and the other at low angles: as for instance on the War Eagle 3rd level, where one set of striations had a dip of 10 degrees to the south (on the slip plane) and the other set was vertical.

The absence of sedimentary strata and the extreme complexity of the fracture systems render it difficult to determine definitely the amount of throw, heave, or offset that has taken place. The faults are chiefly dip or cross faults which have horizontal displacements or heaves varying from a few feet to as much as 300 feet in one case. They are of different ages; some, as for instance the ore-bearing fault "K" of the War Eagle and Centre Star mines (Map 1518 in pocket) were formed within the period of ore deposition, whereas others are of more recent age. North and south-striking ore shoots, as the Centre Star No. 284 shoot and certain shoots in the War Eagle mine, were deposited in fault "K" and stand in strong contrast to the normal east-west and northwest-southeast striking ore shoots.

There is good evidence of faulting along the Josie dyke to a maximum extent of about 300 feet horizontally. The amount of vertical displacement has not as yet been determined although it is known that the ground west of the fault has been dropped down with respect to that east of the fault (normal fault). It is difficult to correlate the veins east of the Josie dyke with those west of it owing to this faulting and the unfavourable north and south strike of a diorite porphyrite tongue west of the dyke and in line with the Main and South veins of the LeRoi mine (Map 1518 in pocket). The Black Bear ore shoot in the South vein of the LeRoi mine is located on the south border of a steeply dipping granodiorite stock and the Tregear shoot on the Main vein is located on the north border of the same stock. The Black Bear ore shoot has a dyke of Sheppard granite porphyry in the foot-wall. On the 1050-foot level of the LeRoi mine, the Black Bear ore appeared to cease at the Josie dyke, but on drilling through the dyke, some ore was encountered west of it which was thought at the time to be the extension of the South vein and Black Bear ore. This ore is in reality Tregear ore from the Main vein as evidenced by its presence on the north border of the granodiorite stock, the same stock present east of the dyke. Diamond drilling west of the Josie dyke, during the autumn of 1913, disclosed an ore body about 300 feet south on the south border of the same stock which has proved to be the faulted end of the Black Bear shoot with the same Sheppard granite porphyry dyke in its foot-wall (Plate XVIB). If this faulting hypothesis is correct, and the evidence seems conclusive in its support, the No. 1 vein represents the faulted end of the War Eagle vein, the Annie vein represents the faulted Poorman or Josie vein, and the Hamilton and Clover or 501J vein the faulted Peyton vein. A similar fault has taken place along the Nickel Plate dyke, but one in which the horizontal displacement or '*heave*' has not exceeded 30 feet. The amount of vertical displacement is not known. The dyke dips eastward and assuming that it, too, is a normal fault the most developed belt of ore-bearing ground bounded on the east by this fault and on the west by the Josie dyke fault represents a *horst* or fault block thrust upward and northward with respect to the bordering blocks.

Age of Faulting.

The main periods of faulting are tentatively referred to crustal deformation at the time of the Laramide and Tertiary mountain making revolutions particularly the former. The older set of lamprophyre dykes (pre-ore dykes) have been much more faulted and disturbed than the younger Tertiary dykes which were not subjected to the faulting of the Laramide revolution. The younger dykes, however, are faulted locally (Plate IX) and this second period of faulting is referred to crustal disturbances of middle and late Tertiary time.

ORE SHOOTS.

Shape and Size of Ore Shoots.

The ore occurs in irregular replacement ore shoots along both the main fissures or shear zones and the various branches composing them. The form of the replacement shoots varies, but in general is governed by the character of the vein, being determined (a) by the facility of access to the solution afforded by the fissures, (b) by the presence or absence of impermeable rocks, and (c) by the varying susceptibility to replacement of the original rocks in which the fissures occurred. In the majority of cases the shoots are either lenticular masses with gradational boundaries or tabular blocks terminating against faults or dykes. The ore shoots vary in width from a few feet up to, in exceptional cases, 130 feet, and in stope or horizontal length from 50 to 500 feet and more.[1] On an average the vertical dimension is greater than the lateral. The main stope of the LeRoi mine had a stope length of 600 feet and persisted to the 900-foot level. The main ore shoot of the upper levels of the War Eagle mine had a stope length of from 300 to 450 feet, a pitch length of 750 feet, with an average width of 8 feet. From this shoot was extracted 10,000 tons of ore running higher than $40 per ton in gold and the rest from $40 ore down to the pay limit (about $8 then). The No. 251A east and No. 255A stopes, near the portal of the Centre Star No. 2 tunnel, are high-grade shoots, the former having a stope length of 55 feet and a pitch length of 110 feet. The ore averages $20 in gold, 0·8 per cent copper, and runs as high as $28 per ton. It is sometimes difficult to trace the vein from shoot to shoot, particularly where its continuity is interrupted by faults and dykes.

Pitch[2] of Ore Shoots.

The pitch of the Rossland ore shoots varies from nearly vertical to pronouncedly easterly or westerly and seems dependent upon purely local conditions. In a general way the pitches

[1] The total length of the ore-body developed on the 13th level of the War Eagle mir about 530 feet of high average value.

[2] The *pitch* is the angle which the pitch-length, or linear distance between the extreme ends of a shoot, makes with the strike of the vein and is measured in the plane of the vein.

correspond closely to the dip of the lamprophyre dykes. The main War Eagle shoot in the upper levels is from 300 to 450 feet long and has a perpendicular pitch. The Centre Star main shoot is 300 to 500 feet long with steep pitch to the east; the Centre Star eastern shoot several hundred feet east of the shaft, varies from a pitch steeply to the east to nearly perpendicular. The LeRoi and Josie ore shoots as a rule pitch steeply to the west.

Both the eastward pitch of the Centre Star shoots and dykes as well as the northeastward offsetting and dip of the War Eagle ore-bodies are facts which suggest that the ore bearing solutions circulated upward from a source to the northeast and probably from the same parent magma that gave rise to the monzonite intrusion which also dips in the War Eagle mine at low angles to the northeast. Furthermore the fact that the LeRoi and Josie ore shoots pitch steeply to the west with the younger lamprophyre dykes suggests a westward source for the mineralizing solutions of these latter veins. This possible convergence and mixing of the ore solutions from two main channels of circulation is one factor in many which may account for the great extent and richness of the Rossland ore-bodies.

Distribution of Values in Ore Shoots.

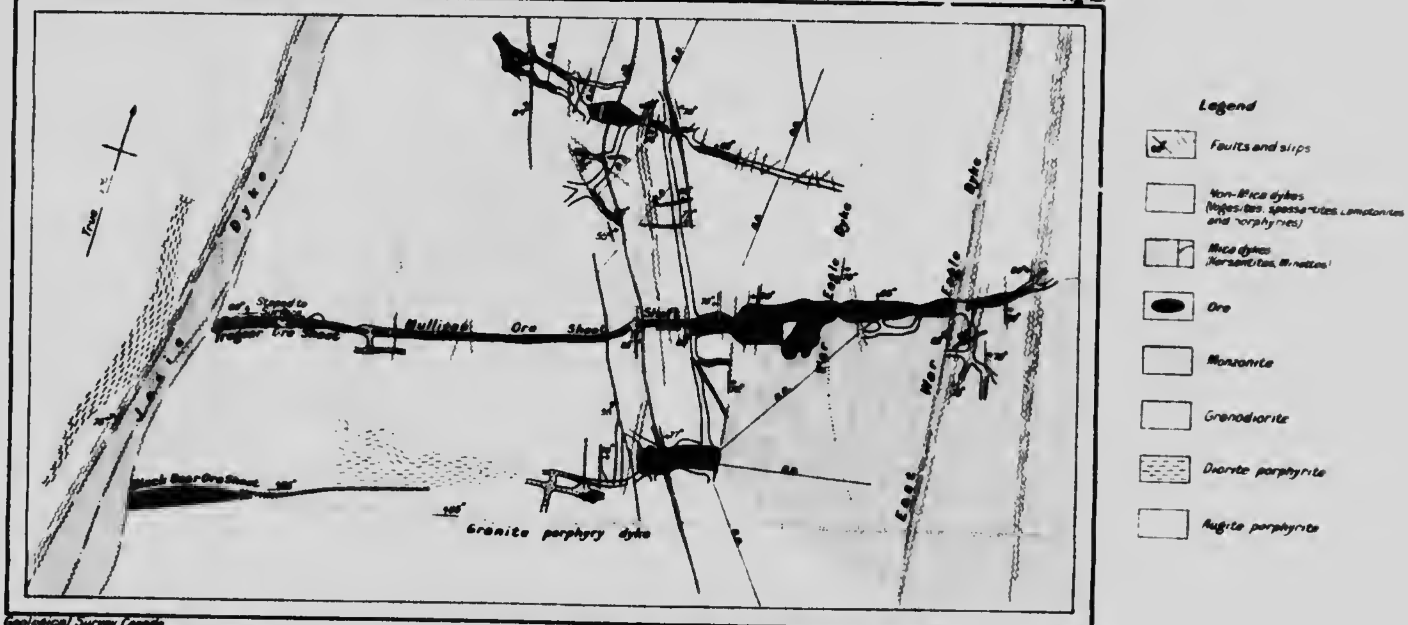
The higher grades of ore are confined to certain bands or pay streaks in the shoot parallel to the trend of the lode. The high grade bands vary in width from an inch up to several feet. Where the veins are continuously stoped they consist in many places of two or more closely spaced ore streaks composed of almost pure sulphides, which may be called hanging-wall streaks or foot-wall streaks according to their position in the vein. There is the same variation in the vertical distribution of values in the shoots as there is horizontally as shown by the difference in the grades of various stopes on the same veins.

The rich bands pass into leaner portions where the ore is disseminated, filling small fissures and brecciated zones that in some cases form small veins of good ore running for considerable distances away from the main deposit. This is particularly noticeable in contact shoots between augite porphyrite and granodiorite or diorite porphyrite. The ore boundary on the granodiorite or diorite porphyrite side is transitional and forms a commercial rather than a structural wall. The deposit becomes more in the nature of a stockwork as for example the LeRoi 895 shoot (Plate XII). The leaner portions of the country rock in and adjoining the veins are characterized by the presence of quartz in grains and aggregates together with biotite and hornblende and less frequently pyroxene, all largely the result of metasomatic action. There are great variations in the values and proportionate amounts of gold, silver, and copper in the ore shoots. The amount of gold in the ores varies considerably and does not appear to depend on the presence of any one mineral that is visible to the naked eye. Perhaps more frequently than not ore rich in copper is also rich in gold. It is consequently impossible to judge of the ore by inspection, samples of promising looking material may prove on assay to be low grade, and what is considered 'waste' may run three or four ounces. The average copper percentage of the ores in the upper levels of the mines is appreciably higher than in the lower levels, whereas the gold values remain about the same or are higher.[1] With depth the ores are on the whole more siliceous and more difficult to smelt. It must be remembered, however, that the difference between the values of ore shipped in the early days and that shipped at present, only in part represents a lowering of the grade of ore in depth. In part, it is the result of mining lower grade material that formerly would not pay, but which, under present conditions, is profitable ore. It is true, nevertheless, that outcropping veins show some surface enrichment, in some cases to a considerable distance below the weathered surface.

The variation in values appears to be dependent in many cases upon the nature of the country rock. The ore shoots with a monzonite foot-wall or with both walls of monzonite, as for example many shoots in the Centre Star-LeRoi Main vein, are as a rule lower in grade than the shoots on the contact borders of diorite porphyrite tongues or granodiorite stocks or in fissures altogether in augite porphyrite.

[1] High-grade copper ore similar to that of the upper levels occurs in the deepest workings (16th) of the War Eagle mine. Augite porphyrite is apparently the 'kindly' copper rock and diorite porphyrite and granodiorite the 'kindly' gold rocks of the camp.

Fig. 12



Geological Survey, Canada

Plan of **450-foot level** (elevation 3451 feet above sea-level) **Le Roi Mine, Rossland, B.C.**

Scale of feet

0 100 200 400

To accompany Memoir by C.W. Drysdale

Wide streaks of almost solid sulphides are in many places present in veins cutting monzonite but are invariably low grade. There are exceptions, however, in the case of the Centre Star No. 461 and No. 470 stopes which had fair-grade ore in monzonite east of the Nickel Plate dyke (Map 1518 in pocket). In the No. 461 stope the ore is low grade above the sill floor becoming better grade below on approach to the contact. Some fair grade ore ($8 to $9 per ton in No. 539 stope) has also been stoped from the main vein fissure in monzonite in eastern Centre Star ground several hundred feet from where the fissure broke away from the contact with augite porphyrite. On the 300-foot level of the LeRoi mine there are two narrow erratic veins in monzonite, one striking north 60 degrees east with good ore on the sill-floor but becoming leaner above. The stope on this vein is about 100 feet long. The other vein strikes north 70 degrees west and dips 30 degrees to the northeast. The ore is from 1 to 3 feet wide and averages $6 in gold and 0·8 per cent copper. Such stopes in monzonite, however, are few and far between. The manner in which the LeRoi South vein ore shoot is cut off by the monzonite on the 450-foot level is indicated on the accompanying plan (Figure 12).

In the Centre Star-LeRoi Main vein the heaviest ore deposition has taken place near the foot-wall which is very regular, distinct, and marked by a narrow seam of calcite. This calcite seam forms a reliable *indicator* of the position of the vein where the mineralization is slight. The Peyton and the veins in the lower workings of the War Eagle mine have similar calcite indicators on their foot-walls. There is no well defined structural hanging-wall to the Centre Star-LeRoi main ore shoot, the ore fading gradually into waste. In the case of the War Eagle ore shoots of the upper workings, the hanging-wall is generally the most distinct and best mineralized with irregular extensions into the foot-wall side. The appearance of the vein between ore shoots may be seen in the accompanying photograph (Plate XVII).

As already stated some of the richest ore shoots occur on contacts between diorite porphyrite and augite porphyrite. The No. 1352 ore shoot of the War Eagle mine has a hanging-wall of diorite porphyrite and a foot-wall of augite porphyrite (Plate XIII), whereas the No. 1354 shoot on the same level lies on the other border (northeast border) of the same diorite porphyrite tongue having an augite porphyrite hanging-wall and diorite porphyrite foot-wall (Map 1518 in pocket). The two shoots are separated by a fault along the Centre Star dyke. The War Eagle 656A stope on the 6th level is 40 feet wide in places and is stoped for 10 floors. This very rich ore shoot has a foot-wall of diorite porphyrite and a hanging-wall of augite porphyrite. In a very general way, the highest copper values in the district come from portions of the ore shoots that represent replaced augite porphyrite. The high-grade copper ore in the veins is either altogether enclosed within augite porphyrite walls or as in the case of contact ore shoots is only in the augite porphyrite wall. For example, the ore in No. 1452 stope of the War Eagle mine has high copper values on the foot-wall or augite porphyrite side of the shoot and low copper and higher gold values on the hanging-wall side which is replaced diorite porphyrite. A similar case of influence of rock formation in distribution of gold and copper values may be instanced from the LeRoi South vein on the 1350-foot level. The hanging-wall ore which represented replaced granodiorite (stock equivalent of diorite porphyrite tongue) contained high gold values, and low copper, whereas the foot-wall ore in augite porphyrite contained high copper and low gold values. The veins in the LeRoi lower levels (1650 and 1750-foot levels) change in character where the fissure zone leaves the augite porphyrite contact and penetrates the underlying granodiorite stock. The Nos. 1612 and 1663 stopes on the 1650-foot level of the LeRoi mine average 6 feet in width and are stoped horizontally for 150 feet and over 100 feet vertically. The gold values were high in the ore shoots, averaging $25 to the ton. The ore was pyrrhotite and pyrite with a little chalcopyrite and considerable quartz as filling and in blebs surrounded by pyrrhotite.

Localization of Ore Shoots.

Many factors have been influential in the localization of the ore shoots. Some of the main causes operative, which are in part physical or mechanical and in part chemical, are as follows:

(1.) *The physical character of the country rock composing the ore-bearing ground.* The character of the rock has not only been influential as already pointed out in the control of the fissuring but also in the localization of the ore shoots within the fissures. Contacts between solid, homogeneous, formational units have been favourable places for thorough fracturing and shearing. In this way the country rock in such zones has been rendered more permeable to the mineralizing solutions which have been permitted to circulate within a restricted zone of moderate width and to replace the sheared and brecciated rocks of both formations. The ore shoots in the LeRoi and War Eagle mines are generally localized, but not always along contacts between augite porphyrite and monzonite and between the former and granodiorite or diorite porphyrite. As already mentioned under the section on faulting, the Tregear ore shoot lies along the north border of a granodiorite stock and the Black Bear along the south border. The Mulligan ore shoot[1] in the LeRoi, follows the south border of the extension of the same granodiorite stock (Map 1518 in pocket) and follows the contact from the level of the Black Bear tunnel down to the 1050-foot level. The largest and richest ore shoots in the Centre Star mine are contact shoots (Plate XIV). The ore shoots in such cases appear to be limited to those portions of the vein fissure traversing the formational contact.

(2.) *The contacts of veins with faults having impervious walls or with strong dykes—particularly the foot-wall or underside of dykes.* These contacts have been favourable places for local enrichment and the formation of ore shoots. The mineralizing solutions have apparently been cut off or dammed back by the impervious dyke with the result that ore has concentrated along its border. An example of the above is cited from the Centre Star 4th level where good ore ends abruptly at a mica dyke although the sulphides in the vein continue uninterruptedly beyond the dyke. In many other instances ore shoots terminate against dykes or faults, in some places swelling to enormous

[1] The average assay of the ore from the Mulligan stope on the 300-foot level of the LeRoi was 1 oz. in gold and 1 per cent in copper.

widths or becoming L-shaped against the dyke or fault plane.

(3.) *The intersection of mineralized cross-fractures with the veins.* Ore shoots are localized in some cases at the intersection of mineralized cross-fractures with the veins.[1] Such intersections as in the case of a part of No. 1086 stope on the 10th intermediate level in the War Eagle mine were enriched, whereas elsewhere in the same vicinity impoverishments have resulted at the junctions. Enrichments of this nature have taken place at the intersection of the Iron Mask and Centre Star North veins on the 4th level of the Iron Mask mine. There are more cases of such enrichment in the upper than in the lower levels. The intersections of vein fractures have afforded a chance for the mineralizing solutions to mingle and either enrich or impoverish the vein. At the acute-angled intersections and where the veins are close together for long distances, much crushed and brecciated material results and conditions for wide or rich ore shoots are more favourable than where the intersections are nearly at right angles.[2] For instance, on the 6th level of the War Eagle the fault "K" vein and main War Eagle vein which are parallel for some distance intersect at an acute angle to form a large rich shoot varying from 5 to 20 feet in width of ore averaging $16 per ton. The main War Eagle vein north and away from the intersection is only 4½ feet wide and averages $13.20 per ton.

(4.) *Decrease in temperature and pressure in ascending mineral solutions.* Conditions favourable for the localization of ore shoots would be brought about by the decrease of temperature and pressure which the ascending solutions would be subject to on reaching higher levels and possibly through the mingling of solutions from different sources. The latter possibility is suggested since some such agency must be assumed to account for the nature of the pitches and dips of the ore shoots. The work of the earliest ascending solutions and gases, which were probably more active chemical agents than later solutions, is represented in the lower levels of the Centre Star mine by

[1] Lindgren points out that ore shoots due to intersections are more common in deposits that have been formed near the surface than in deposits of deep seated origin. Econ. Geol. 1, p. 43.

[2] The Nature of Ore Deposits, R. Beck, p. 391.

the wide, pronounced vein structure, made up in large part of high temperature secondary minerals.

(5.) *The chemical character of the wall rock.* The position and structural relations of some of the ore shoots indicate that the chemical character of the wall rock probably played an important rôle in their localization. The more salic diorite porphyrite appears to have been more readily replaced by the ore bearing solutions than the femic augite porphyrite. An example of the above is cited from the Josie mine where the shoots in the Annie vein invariably widen and are richer where the vein fissure traverses diorite porphyrite than where it traverses augite porphyrite. Possibly, the pyrite in the altered augite porphyrite adjoining the intrusive diorite porphyrite may have played a part in the precipitation of values.

(6.) *Chemical reaction.* Chemical reaction between the mineralizing solutions carrying gold and those carrying the solid minerals, such as chalcopyrite, pyrrhotite, and molybdenite may have been a factor in the localization of the ore shoots. The common association of gold with chalcopyrite and molybdenite seems to indicate that such a reaction has taken place.[1]

ROCK ALTERATION.

The country rock formations are in places very highly and extensively altered, chiefly by replacement processes connected with the ascent of heated igneous and hydrothermal solutions and the formation of the ores. The ground in the War Eagle and Centre Star mines in the proximity of the monzonite chonolith is more difficult to map than that of the LeRoi and Josie on account of the contact metamorphism produced by the intrusion of the monzonite. The wall rocks to the veins and fissures are altered for great distances, with the development of a siliceous formation differing a great deal in chemical and physical character from the original rocks. The feldspars are clouded and silicified, the augite in places is altered to uralite, and secondary biotite is developed. In the lower levels of the Centre Star mine, for instance, where the vein fissure penetrates

[1] Stokes (H. N.): Economic Geology 1 (1906) p. 650.

chiefly the underlying granodiorite stock, the latter is altered to a white, siliceous, spotted rock. This rock contains considerable epidote, secondary silica, banded calcite (in the vein proper), finely disseminated biotite grains, and is peppered with iron pyrites. Rock alteration is found to be becoming more widespread as greater depths are attained and the underlying batholith approached.

The main causes of alteration have been the vein forming processes in which the initial stage was probably chloritization accompanied by pyritization. The uprising thermal waters and gases attacked first the iron silicates, augite, hornblende and biotite, forming chlorite, epidote, secondary silica, and iron pyrites. The plagioclase and orthoclase feldspars were gradually altered, resulting in the formation of sericite and secondary silica. In the case of straight silicification of augite porphyrite, however, in the Josie mine, the augite phenocrysts were the last to be replaced and stand out prominently in a white silicified groundmass (Plate XV A).

OXIDATION.

There is comparatively little oxidation of the ores by surface waters containing free oxygen except in the case of ores along a few fractures; and the iron and copper sulphides remain unchanged within a few feet of the surface. If deep weathering ever took place, all trace of it has been swept away by subsequent erosion and Pleistocene glaciation. The actual outcrop or iron cap is a reddish brown sintery mass of rotted rock containing residual quartz, limonite, kaolin, and chlorite from which the sulphides have been leached. Slight stains of copper carbonates and silicates are sparingly present, and in protected places an iron-sulphate coating occurs. As may be inferred, no zone of rich copper sulphides exists below the present oxidized surface although it is quite possible that such a zone of secondary enrichment may have existed formerly but has since been removed by erosion. It was difficult for the prospector in the early days to prospect the Rossland shear-zone type of vein on account of the indefiniteness of the vein structure amid the much oxidized and iron-stained surface rocks of Red mountain. Nearly all the work was done along one wall although there appeared in places a certain parallelism of lines of fracture for some distances away from the wall. The best ore, however, appeared to follow the one wall and graded gradually into waste.

UNDERGROUND TEMPERATURE AND WATER.

Observations were made in 1906 by R. W. Brock and from 1907 to 1914 by Mr. M. E. Purcell of the temperature of the rocks at various levels in some of the mines in order to determine the increase of temperature with depth (*geothermal gradient*). In taking such observations several factors have to be considered, such as the length of time which has elapsed since the rocks were disclosed, the seepage of cooler waters from upper levels, or of heated waters from below, air currents, machinery in operation, the varying thermal conductivity of rocks and other minor but still influential factors.

The temperatures were taken with chemical thermometers fitted with wooden handles 4 feet long, having openings to permit reading and to leave the bulbs free. Observations were taken whenever possible in drill holes in crosscuts where there was a minimum circulation of air. The thermometer was placed the length of the handle in the hole, and at first the mouth of the hole was plugged; but it was found that no difference in readings resulted when the holes were left open.[1]

Thirty temperature readings taken on ten levels of the War Eagle mine from the 2nd to the 16th level, and twenty-four readings from twelve levels of the Centre Star mine from the 2nd to the 16th level have been kindly furnished by M. E. Purcell, Superintendent of the Centre Star-War Eagle mines. Mr. Purcell has given the exact location, time exposed, and varying conditions under which the readings were taken.

On account of the varying conditions under which the measurements were taken and the great number of influencing factors, as mentioned above, that should be considered before

[1] Summary Rept., Geol. Surv., Can., 1906, pp. 60, 61.

presenting any definite results or conclusions it has been deemed advisable not to plot increment curves from the determined average temperature at different elevations, but simply to state that from the information at hand the figures indicate that the mine temperatures increase in a rather regular manner from the surface to the deepest working. This rate of increase as calculated for the Centre Star mine amounts to 1 degree in 84 feet and for the War Eagle mine 1 degree in 65 feet. The minimum temperature was 1 degree Centigrade taken on April 1, 1907, in No. 218 crosscut of the War Eagle mine. The time exposed was two days. The maximum temperature was 27¾ degrees Centigrade taken on January 12, 1914, in No. 1417 winze (320 feet below No. 1421 drift) of the War Eagle mine. The time exposed was two days. The temperature of the water in No. 1673 winze of the Centre Star mine below No. 1672 drift was also 27¾ degrees Centigrade as recorded by Mr. Purcell on January 20, 1914.

The quantity of water pumped does not vary, at least immediately, with the rainfall. The amount of water is estimated to be from 250,000 to 500,000 gallons per 24 hours. Ground water stands at about 50 feet. The upper levels down to the 400-foot level are quite wet where the normal surface waters have found courses through fractures and stopes locally lowering the water table. In this zone flat diamond-drill holes are always wet and some carry a large flow of water. Below the 400-foot level the amount of water steadily decreases until at 1,000 feet (below 3,000 feet above sea-level) the workings are practically dry excepting in a few places where persistent secondary slip planes or mine workings have afforded local channels for the water to percolate downward. Where old water courses have existed in the deeper levels and damp portions of the workings have become warm and dried, epsomite needles are abundant. This fact suggests that the mine waters in depth were sulphate waters containing considerable magnesium and possibly aluminum obtained from the pyrite and wall rocks.

CHARACTER OF ORES AND GANGUES.

CLASSIFICATION OF ORES.

On the basis of mineral content the ores have been classified by Brock as:—

(*a*) Massive pyrrhotite and chalcopyrite ores with some pyrite and occasionally a little arsenopyrite, massive or mixed with rock matter and gangue (Plate I). Free gold occurs, but it is rarely to be seen with the naked eye, although the proportion of free gold runs from 10 per cent to 50 per cent of the total gold contents. Rarely, some molybdenite and magnetite are found in this, the typical ore of the camp. Galena and blende have been found at one or two points. The pyrrhotite at times contains up to 0·65 per cent nickel and 0·59 cobalt.

(*b*) Massive coarse-grained pyrrhotite carrying very little copper and little gold.

(*c*) Veins of pyrite and marcasite with arsenopyrite and perhaps galena and blende (South Belt). Silver may form an important part of the values in such veins.

(*d*) Impregnations of arsenopyrite, pyrrhotite, pyrite, molybdenite, a little chalcopyrite, bismuthinite, and native gold, particularly in and around small pegmatitic or aplitic alkalic syenite dykes (Giant, Jumbo).[1]

(*e*) Gold bearing quartz veins carrying some iron, copper, and lead sulphides (O. K. and I. X. L.).

NATURE, PARAGENESIS, AND VALUE OF ORE AND GANGUE MINERALS.

The gangue is principally country rock, with some quartz and, in places, calcite. The country rock is generally altered. In addition to its impregnation or replacement by the sulphide minerals, the formation of biotite and silica (sometimes in separate layers, constituting a banded brown and white rock) is the principal change, but chlorite and hornblende are also extensively formed in places, and muscovite, tourmaline, garnet,

[1] The arsenopyrite in this camp is frequently if not always cobaltiferous.

and wollastonite also occur. Zeolites (chiefly apophyllite and chabazite) are frequently found where alteration by thermal solutions is pronounced. Epidote was observed in the Jumbo mine[1] where molybdenite and bismuthinite are uncommonly prevalent.

The ore varies considerably in appearance and composition in different parts of the same mine. Typically, it consists of more or less altered rock matter, although in places fresh-looking rock is seen, with reticulating veins or irregular masses and impregnations of pyrrhotite and varying amounts of chalcopyrite and perhaps a little quartz, the sulphides forming 50 to 75 per cent of the mass (Plate XV B). The sulphides are usually intimately intermixed or intergrown. They, in many places, show marked banded structure as shown in Plates I and XVIA, the latter taken in the No. 1452 stope of the War Eagle mine (foot-wall section). The banding is probably due, in the main, to replacement along closely spaced fissures or planes of movement, or possibly it is due to the original sheeted structure at the borders of the diorite-porphyrite tongues, or it may be due to shearing of the early formed ore masses. The chalcopyrite is in many cases later in forming than the pyrrhotite, occurring in veins and impregnations in it. Sometimes arsenopyrite and pyrite occur with the chalcopyrite. From this typical ore all transitions occur, between solid sulphides on the one hand forming larger masses or shoots, and rock matter or gangue on the other with little apparent mineralization, but carrying pay values, and sometimes a high percentage of gold. Consequently, constant sampling and assaying is necessary to distinguish ore from waste. In places, the ore is quartzose, and calcite is occasionally abundant as gangue.

In the Giant and Jumbo mines the quantity of copper is negligible. In the former, the ore is largely rock matter impregnated with and containing stringers and masses of arsenopyrite, pyrrhotite, and molybdenite, whereas in the latter pyrrhotite is the most abundant sulphide, but a little arsenopyrite, molybdenite, bismuthinite, and visible free gold occur. In

[1] Telluride of gold is said to occur in Jumbo ore, but the specimens so far examined have failed to respond to tellurium tests.

these two mines the proportions of sulphides to rock matter are comparatively small. In the White Bear and Spitzee mines pyrite is more abundant, as is also the case in the South Belt properties.

The values in typical ores of the camp are largely in gold, with copper and a little silver. The ores mined from near the surface were, on an average, much richer, the first 128,428 tons shipped averaging 1·46 ounce of gold per ton, 1·96 ounce of silver per ton, and 1·73 per cent of copper (after smelting deduction of 1·3 per cent). But the proportion of free gold does not appear to diminish in depth, and some of the ore encountered in the lowest levels compares favourably with that of the earliest shipments. The gold values do not appear to be dependent upon the presence of any one mineral, although in many cases ore richer in chalcopyrite is also richer in gold, but exceptions are frequent. The fine-grained variety of pyrrhotite in some instances is gold bearing whereas the coarse-grained variety is invariably very low grade. The copper content reaches in local instances 10 or 15 per cent. Ore running $4 and under is graded poor; from $4 to $8 medium; from $8 to $15 good; and from $15 up, very good.

The following average analyses may be taken as typical of the ores being mined in the larger producers.

Year of shipments.	Gold ozs. per ton.	Silver ozs. per ton.	Copper per cent wet.	Iron per cent.	Silica per cent.	Alumina per cent.	Lime per cent.	Sulphur per cent.
				War Eagle Mine.				
1903.....	0·40	1·2	1·3	16·0	42·5	17·5	7·0	7·5
1904.....	0·35	0·9	1·2	14·7	42·8	18·3	5·5	7·0
1905.....	0·36	0·7	1·0	14·5	43·0	18·5	6·0	6·2
1906.....	0·33	0·6	1·2	14·2	43·2	18·0	5·6	6·5
1907.....	0·49	1·3	1·5	17·7	40·3	14·0	6·5	9·0
1908.....	0·94	1·4	2·8	16·5	40·9	13·8	8·1	8·8
1914.....	0·48	0·3	0·7	17·1	42·3	16·0	10·2	9·5
				Centre Star Mine.				
1903.....	0·53	0·3	0·9	20·8	38·8	13·0	5·0	9·0
1904.....	0·42	0·3	0·7	20·6	38·8	15·0	4·1	10·0
1905.....	0·42	0·4	0·8	22·2	35·9	15·2	5·3	9·0
1906.....	0·46	0·2	0·6	18·8	40·0	16·9	4·0	6·6
1907.....	0·41	0·3	0·5	19·0	41·8	44·4	5·5	7·0
1914.....	0·35	0·2	0·5	14·0	47·2	16·7	9·8	7·3
				Idaho Mine.				
1914.....	0·19	0·25	0·73	15·9	45·2	15·4	3·9	7·1
	0·20	0·24	0·74	14·3	45·2	15·6	3·6	7·1
	0·21	0·36	0·50	14·1	45·3	16·3	5·2	6·7
	0·18	0·20	0·70	11·3	51·1	16·8	8·2	6·0
				LeRoi Mine.				
1914.....	0·45	0·49	1·07	11·7	44·3	19·3	4·7	5·9
	0·45	0·28	1·17	14·0	46·0	13·4	5·5	5·6
	0·39	0·39	1·43	17·2	44·0	15·3	8·3	8·4
	0·28	0·25	0·53	14·1	45·1	15·1	7·5	5·1
	0·24	0·55	3·00	17·0	41·0	12·5	7·6	7·0
	0·23	0·29	0·45	27·6	31·9	9·2	5·7	16·4
				Crown Point Mine.				
1906.....	0·39	0·28	0·50	34·9	24·7	14·9	7·6	14·3
	0·69	0·23	0·66	32·6	26·3	8·7	9·5	16·3
	0·31	0·20	0·50	27·9	30·4	13·6	8·0	12·4
	0·25	0·17	0·47	27·5	31·8	9·7	8·7	11·3

MINERALOGY.

In the following description of the minerals occurring in the Rossland district those found only as rock forming constituents are not included. Descriptions of those will be found in the general geology section (Chapter II, Part II).

While the list of minerals found is rather large, well-crystallized specimens are the exception and the ore minerals are practically always massive. Most of the minerals are found in close relationship to the veins. The order of arrangement follows Dana's classification according to chemical composition. The list is as follows:

Native elements	Gold, silver.
Sulphides	Chalcopyrite, pyrrhotite, pyrite, gersdorffite, galena, sphalerite, stibnite, bismuthinite, molybdenite, marcasite, arsenopyrite.
Oxides	Quartz, magnetite, limonite.
Arsenate	Erythrite.
Carbonates	Calcite, malachite, azurite.
Silicates	Wollastonite, actinolite, garnet, epidote, prehnite, tourmaline, apophyllite, gmelinite, natrolite, laumontite, chabazite, grünerite, muscovite, biotite, chlorite, serpentine.
Sulphate	Epsomite.

Native Elements.

Gold (*Au*). Native gold occurs in impregnations of arsenopyrite, pyrrhotite, pyrite, molybdenite, and bismuthinite near alkalic syenite dykes at the Giant and Jumbo mines. It is also found in small flakes in quartz veins in the mines of the O.K. group as well as in finely disseminated specks, and rusty patches in quartz ore from the foot-wall of No. 1686 stope in the War Eagle mine. A part of the gold of the ordinary sulphide ores is in the free state, the percentage of the free milling gold varying from 10 to 50 per cent of the total gold content. The relative percentage of free gold remains constant to the deepest workings of the mines.

In what form the combined gold occurs has not been determined. Tellurides have been reported by assayers in specimens of ore from the main mines, and from rich specimens from the

Jumbo, but so far tests on material stated to be similar, made by Mr. Brock, and by Mr. Connor of the Mines Branch, have failed to yield reactions for tellurium. It is quite possible, however, that it is present at isolated points, and possibly some of the minutely disseminated gold may be in this form. Outside of the possible tellurides, bismuthinite is perhaps the mineral richest in gold. In the Jumbo, this mineral occurs in masses and aggregates up to one inch in diameter. In thin sections and fine concentrates of typical Red Mountain ore a mineral which may be bismuthinite has been detected. Chalcopyrite often carries gold sometimes in considerable amount, but its gold values vary within wide limits. Pyrite is usually auriferous to some extent, and pyrrhotite has ordinarily a small gold content. Arsenopyrite is generally a gold carrier, but varies in richness. The molybdenite of the Giant is said to assay about $7 in gold to the ton. Free gold occurs in No. 1354 stope of the War Eagle mine impregnating molybdenite. Gold occurs at a few points adjoining the veins, in mineralized fault planes formed subsequently to the main vein formation.

Silver (*Ag*). The ores are always argentiferous but no native silver has been reported. Wherever galena occurs it is silver-bearing, but even in the ores free from galena, silver is present. It seems likely that it is associated with the sulphides in a relationship similar to that of the gold.

SULPHIDES.

Chalcopyrite (*$CuFeS_2$: Sulphur 35, Copper 34·5, Iron 30·5 per cent*). Possibly the most important ore mineral of the camp is chalcopyrite. It is always massive and both coarse and fine-grained, occurring as veinlets and impregnations in association with pyrrhotite and pyrite. An extremely fine-grained variety is occasionally encountered in the Josie mine. It varies considerably in amount, in the various ores, even of the same lode, but is present at least in small quantities in practically all of them. The Josie mine, where it is present in proportionately greatest amount, furnishes the finest specimens of this fine-grained variety. Chalcopyrite has not been observed crystallized. It carries both gold and silver values. A large part of the ore contains only a small amount of chalcopyrite, with less than one per cent copper. Rarely, however, ore shoots are found in which the sulphides consist largely of chalcopyrite and the copper content will run up to 10 or 15 per cent (Plate XI.) The chalcopyrite is in large part of the same age as the pyrrhotite although in some cases it appears to be younger. In places, it would seem that it had been concentrated by secondary action in primary ore or along subsequent fault planes in the immediate vicinity of the vein. The very finely disseminated particles of chalcopyrite developed in the pyrrhotite and silicate minerals of the ore renders its concentration in an ore dressing plant difficult.

Pyrrhotite (Fe_8S_9: Sulphur about 39, Iron about 61, per cent). Pyrrhotite or magnetic iron pyrites is one of the most abundant and important ore minerals. It is massive and granular in character, both coarse and fine-grained, and probably of different ages of deposition. Some specimens show the pyrrhotite as distinct veinlets cutting chalcopyrite, but this does not seem to always hold true. One or two specimens have been found in the Centre Star mine with pyrrhotite in crystal-like forms apparently hexagonal prisms about 8 mm. long. The pyrrhotite is auriferous, but the coarse-grained varieties so common in the monzonite country are usually low grade. An exception to this generalization may be cited from the War Eagle No. 1352 stope where coarse-grained pyrrhotite carried several ounces in gold. Here, however, the country rock is porphyrite and not monzonite. The pyrrhotite nearly always carries a determinable amount of nickel and a trace of cobalt. C. W. Dickson[1] states that the Rossland pyrrhotite agrees with the formula Fe_8S_9. In the Sudbury ore he states that the nickel did not replace part of the iron in pyrrhotite but occurred in the mineral pentlandite. So far no pentlandite has been recognized at Rossland but gersdorffite[2] NiAsS has been reported.

Analyses of pyrrhotite from the Monte Christo property gave NiO 0·13, Co trace. Samples from the Evening Star ran

[1] T. A. I. M. E., Feb. 1903, p. 22.
[2] Summary Report 1901, p. 163 H.

NiO 0·67, Co 1·58. Pyrrhotite is one of the first formed of the ore minerals and in only slightly altered wall rock may be the only ore-mineral formed.

Pyrite (*FeS_2: Iron 46·6, Sulphur, 53·4 per cent*). Pyrite of several generations is present in the rocks and ores. In the Mount Roberts' slates it is a constant accessory often forming cubes and cubo octahedra, a third of an inch in diameter. In the vein it is usually massive and is probably of different periods of mineralization. Some of the pyrite carries very little gold whereas in other places it seems to rank with the pyrrhotite and chalcopyrite as an ore mineral. As a rule the pyrite shows in No. 944 stope of the Josie mine, no crystal outlines in the ore, but samples from the 14th level of the War Eagle mine contain large unmodified octahedra. Cubes of pyrite up to 1¾ inches in diameter occur surrounded by chalcopyrite.

Gersdorffite (*NiAsS: Nickel 35·4, Arsenic 45·3, Sulphur 19·3 per cent*). Nickel sulpharsenide has been reported in small octahedral crystals distributed through sulphide ore, which shows an intimate association of massive pyrrhotite and chalcopyrite, from the Columbia-Kootenay vein[1] and also from the War Eagle mine.

The following analyses of ores containing gersdorffite, from the Columbia-Kootenay and Evening Star mines, were made by F. G. Wait:

	1	2
Gangue	29·63	62·73
Copper	Present	Present
Nickel	0·65	0·25
Cobalt	trace	0·59
Nickel (in the metallic portion)	0·98	0·67
Cobalt (in the metallic portion)	.....	0·58

1. Columbia-Kootenay mine.
2. Evening Star mine.

Galena (*Pb S: Lead 86·6, Sulphur 13·4 per cent*). Lead sulphide is found rather sparingly in the Centre Star-War Eagle-Josie group of mines, but, in the South Belt properties it

[1] Ann. Rept. Geol. Sur., Can., 1901, pp. 117 H, 151 H, 163 H.

becomes one of the more important ore minerals. At the Lily May mine considerable galena occurs in the massive form showing cleavage cubes a quarter of an inch in diameter. It is argentiferous and associated with sphalerite, chalcopyrite, pyrrhotite, and a little stibnite.

Sphalerite or Blende (*ZnS: Zinc 67, Sulphur 33 per cent*). In association with galena, zinc sulphide is one of the prominent minerals in the ores of the South Belt. It is found rather rarely in the deposits of Red mountain. A specimen from the 11th intermediate level of the War Eagle mine shows a brownish-black variety of sphalerite cutting vein-like through chalcopyrite and pyrrhotite. Massive fine-grained sphalerite of a deep brownish colour was also observed as small irregular veinlets and blebs in a greenish siliceous rock from the 900-foot level of the Josie mine.

Stibnite (*Sb_2S_3: Sulphur 28·6, Antimony 71·4 per cent*). Stibnite occurs sparingly in a fine-grained massive form at the Lily May mine. It is associated with sphalerite, galena, pyrrhotite, and chalcopyrite.

Bismuthinite (*Bi_2S_3: Bismuth 81·2, Sulphur 18·8 per cent*). Bismuth sulphide occurs in impregnations near pulaskite (alkalic syenite) dykes at the Giant and Jumbo mines. Particularly in the small aplitic dykes from the alkalic syenite of the Jumbo mine and in fractures and joints in the adjoining country rock, good specimens of the mineral may be obtained. It occurs in particles or aggregates up to an inch or two in diameter. It usually shows perfect cleavage and a lustre intermediate between lead-grey and tin-white. It may be distinguished from galena which it sometimes resembles by its lighter colour, by the lack of cubical cleavage and the suggestion of a fibrous structure on the cleavage faces, by its inferior hardness, and by its being somewhat sectile. Pyrrhotite and other sulphides are associated with bismuthinite. In the country rock it is often seen as a thin film along cracks and fractures. Visible free gold is frequently found with it. A mineral which has the same colour and lustre and which may be bismuthinite was seen in thin sections of the gold-copper ores.

Molybdenite (*MoS_2: Molybdenum 60, Sulphur 40 per cent*). Molybdenite occurs in a fine-grained massive form and as scaly aggregates in masses or veinlets, associated with the other sulphides of the ores. At the Velvet mine on Sheep creek 10 miles west of Rossland, there is a lens of soft flaky molybdenite 2 feet wide by 3 inches across. The mineral is a common mineral in the veins of the Coxey and Novelty claims on the west slope of Red mountain. Here, it is the massive, fine-grained variety. In the Novelty ore arsenopyrite with but little chalcopyrite is present, while in that from the Coxey arsenopyrite is almost absent and chalcopyrite rather abundant. The two claims are located on different parts of the same vein. Molybdenite also occurs on the St. Elmo and Deer Park claims and is most abundant in the Giant ore, associated with arsenopyrite, pyrrhotite, a little chalcopyrite, and magnetite. It forms frequently along small fractures in the rock, and at the intersections of such fractures develops into masses, in some places a foot in diameter, of pure molybdenite. The pulp from samples of 3,000 tons of ore shipped, according to information furnished by Mr. R. Marsh, ran 3 per cent in molybdenum (Mo). In a stope of the Jumbo mine, against the main mass of alkali syenite, the ore is rich in molybdenite. Molybdenite is occasionally found in the Centre Star and War Eagle mines where it is very fine-grained and usually forms very thin layers along fracture planes. In the lower levels of the War Eagle mine it is intimately associated with free gold where the gangue is altered diorite porphyrite.

Marcasite (*FeS_2: Iron 46·5, Sulphur 53·4 per cent*). Marcasite is reported to occur in South Belt veins.

Arsenopyrite (*FeAsS: Iron 34·3, Sulphur 19·7, Arsenic 40 per cent*). Arsenopyrite occurs with sulphides as impregnations, stringers, or bunches in the country rocks and also occasionally as a constituent of the vein filling. In the stratified rocks of the South Belt and of Red mountain, it is disseminated in the same manner as the pyrite and by its weathering helps to give the rusty colouring to the Mount Roberts formation. Wherever much arsenopyrite is present the gossan assumes a yellowish colour. In the Coxey-Novelty vein arsenopyrite is a prominent mineral along with molybdenite and some chalcopyrite. Here it is a fine-grained massive variety. In the South Belt, crystals were found in the Deer Park vein showing the usual combination of the brachydome *q*(011) and macrodome *e*(101). The arsenopyrite is nearly always cobaltiferous and some of it may approach danaite (FeCo) S_2 (FeCo) As in composition (4 to 10 per cent cobalt replacing iron of the arsenopyrite). An analysis of such a specimen gave the following results.[1]

As	S	Fe	Co
47·60	19·70	29·65	3·05

Oxides.

Quartz (*Si O_2: Silicon 46·7, Oxygen 53·3 per cent*). Quartz occurs as a massive milky-white mineral in veins at the mines of the O. K. group. It carries free gold and some sulphides. The rocks near the main veins in all the mines are often highly silicified and quartz stringers are found in the workings. It also occurs as blebs and masses in the sulphides of the ores.

Magnetite (*Fe_3O_4: Iron 72·4, Oxygen 27·6 per cent*). Massive magnetite showing good octahedral cleavage was found on the Sunset and Deer Park dumps in the South Belt. It is also sparingly a constituent of the Red Mountain ores. In thin sections it may frequently be seen in close association with pyrrhotite and chalcopyrite. It is also found in microscopic particles with the arsenopyrite-molybdenite ores of the Giant and Jumbo mines in which it in some places adjoins or surrounds as a thin rim, arsenopyrite grains. It is also scattered through the minerals adjoining the lodes in isolated particles. Specimens from the Novelty and Coxey claims show rather large amounts of magnetite.

Limonite (*2 Fe_2O_3.3 H_2O: Iron 59·8, Oxygen 25·7, Water 14·5 per cent*). Hydrated iron oxides, mostly limonite, are found abundantly wherever the surface waters have had an opportunity to act. The rusty colour from which Red mountain derives its name, is due to the alteration of disseminated sulphides to limonite. Fissures where surface waters seep downward into

[1] Ann. Rept. Geol. Surv., Can., 1895, p. 13 R.

the ores, are filled with soft earthy limonite and the walls of the workings are covered with a thin coating of the mineral. In old drifts stalagmites of limonite are forming consisting of a hard brownish-black outer shell with a soft, earthy filling.

Arsenate.

Erythrite (*$Co_3As_2O_8 8H_2O$: Arsenic Pentoxide 38·4, Cobalt Protoxide 37·5, Water 24·1 per cent*). Hydrous cobalt arsenate (cobalt bloom) forms as an earthy alteration product from cobaltiferous minerals. It is found chiefly as a thin coating on pyrrhotite or arsenopyrite. Bladed crystals have been reported from the Evening Star claim. On the exposed surfaces of danaite, the cobaltiferous arsenopyrite, a beautiful pink earthy encrustation of erythrite, is in some places formed.

Carbonates.

Calcite (*$CaCO_3$: Lime 56·0, Carbon Dioxide 44·0 per cent*). Calcite is found in two varieties: a massive granular form filling fissures and as an impregnation in the rocks; and as fine crystals in vugs and open fissures. Some individuals are almost cubes with curved faces due to the development of vicinal planes (Plate XVIII). Their colours range between white and colourless and most of the crystals are transparent. The curved faces render measurement difficult, but they approach the rhombohedron $\epsilon(01\bar{1}1)$. These are often twinned with $c(0001)$ as twinning plane. Other specimens show combinations of the base, rhombohedra, and scalenohedra. The scalenohedral faces are dull and striated while the other forms are bright and smooth. Measurements are not satisfactory but approximate an index $(12\bar{3}2)$ for the scalenohedron which the cleavage shows to be a negative form. A doubtful series of faces gives the index $07\bar{7}5$. Another specimen shows a combination of the basal pinacoid $c(0001)$, a scalenohedron with curved and striated faces, possibly $(12\bar{3}2)$, a rhombohedron corresponding to $M(40\bar{4}1)$ and a series of rhombohedra the intermediate and best developed of which gives angles nearly agreeing with the index $\Phi(05\bar{5}4)$. Thus the forms recognized are : $c(0001)$, $\epsilon(01\bar{1}1)$, $\Phi(05\bar{5}4)$, $M(40\bar{4}1)$, $f(02\bar{2}1)$, $\pi(07\bar{7}5)$, $12\bar{3}2$(?) (Dana's symbols).

Malachite (*$CuCO_3Cu\ (OH)_2$: Cupric Oxide 71·9, Carbon Dioxide 19·9, Water 8·2 per cent*). Green copper carbonate is the common alteration product of the copper-bearing ores. It forms coatings on cleavage planes and other openings, and colours the gouge in the upper portions of the fissures. It can be seen in the process of deposition wherever downward seeping surface-waters trickle into the mine workings.

Azurite (*$2CuCO_3$. $Cu(OH)_2$: Cupric Oxide 69·2, Carbon Dioxide 25·6, Water 5·2 per cent.*) Blue carbonate of copper is not so common but was observed in a small cavity in quartz at the O.K. mine.

Silicates.

Wollastonite (*$CaSiO_3$: Lime 48·3, Silica 51·7 per cent*). Wollastonite occurs as a white fibrous mineral in the altered rock of the Giant ore-body associated with pyroxene, arsenopyrite, and molybdenite. The optical properties of a greyish-bladed mineral from the War Eagle mine indicate that it should be referred to this species.

Actinolite (*$Ca\ (MgFe)_3\ Si_4O_{12}$*). Actinolite occurs in a sample of ore from the 600-foot level of the LeRoi mine (Plate XIX A). It forms rosettes of silky-green needles between which chalcopyrite and pyrrhotite have been deposited. Also in a small cavity in monzonite from the City of Spokane tunnel and in the lower levels of the War Eagle mine, small dark green radiating needles of actinolite occur. It is an associate of the chalcopyrite ore of the Deer Park mine and in general seems to be rather frequently developed as a secondary mineral near ore-bearing fissures.

Garnet (*$Ca_3Fe_2\ (SiO_4)_3$: Lime 33·0, Iron Sesquioxide 31·5, Silica 35·5 per cent*). Massive reddish-brown garnet occurs in the ores occasionally and in vugs small deep-red crystals are sometimes found, as for instance in No. 895 stope of the LeRoi mine. The usual form is the trapezohedron and occasionally well formed dodecahedra and icositetrahedra. In the ore the garnet is generally associated with pyrrhotite and chalcopyrite, which also occur in fractures in the garnet, and with quartz. In slightly altered country rock it is sometimes found with quartz, sericite, and rarely epidote, as in the granitic rock of the 1350-foot level of the LeRoi mine and Josie 900-foot level east. Deep red-garnet crystals occur in the hanging-wall of the LeRoi No. 1086 stope (Tregear shoot).

Epidote ($HCa_2(AlFe)_3Si_3O_{13}$). Epidote is a frequent secondary product of rock alteration and is found in fissures and irregular masses in all formations, but more especially in the older granitic rocks. In the deeper levels the rocks sometimes exhibit a faint banding that seems to be due in part to the presence of epidote along certain zones.

Prehnite ($H_2Ca_2Al_2(SiO_4)_3$: *Lime 27·1, Alumina 24·8, Silica 43·7, Water 4·4 per cent*). A large specimen of prehnite from a drusy cavity in No. 3 tunnel of the War Eagle mine was collected and presented to the Geological Survey by Superintendent M. E. Purcell of the Centre Star mine (Plate XX). Mr. Eugene Poitevin of the Mineralogical Division reports as follows concerning the specimen: "Definite crystals were not found on the specimen observed. The mineral has a tendency to appear in translucent, coralloidal structure, olive green in colour, fading into white on exposure. Minute isometric crystals of iron pyrite are disseminated on the prehnite."

Tourmaline (*Complex Borosilicate*). Rather rarely slender black prisms of tourmaline form in association with the vein fillings.

Apophyllite ($H_7KCa_4(SiO_3)_8+4\frac{1}{2}H_2O$: *Potash 5·2, Lime 25·0, Silica 53·7, Water 16·1 per cent*). Apophyllite is one of the most common of the crystallized minerals in the vugs and the open fissures. Crystals of three different habits have been noted.

(*a*) Crystals from 12 to 25 mm. in length of the type common in apophyllite consisting of the almost cubic form of the prism and basal pinacoid. The corners are usually modified by the unit pyramid. The colour of this variety is white with a pearly lustre.

(*b*) The second type has the prism relatively elongated parallel to the *c*-axis and the pyramid developed to the exclusion of the basal pinacoid. The colour is a faint pink.

(*c*) The third type is flat tabular. The prism is only slightly developed and unstriated. The base and unit pyramid are the prominent forms. The crystals are aggregated either in parallel groups with the basal faces in contact or in radiating growths (Plate XXI). The colour is pink.

Apophyllite of the first type with crystals one-fifth of an inch in diameter forms an incrustation on brecciated vein matter on the 1200-foot level of the Centre Star mine. Crystals from the second level approach the second type, but still retain a small basal pinacoid.

Two specimens were examined by Mr. Eugene Poitevin who reports, "one exhibits a rose-red tint while the other is white or colourless. Both are transparent and possess a pearly lustre on the base *c*(001). In general most of the crystal faces are corroded giving indefinite reflections.

The cube and the pyramidal-like crystals showing the forms *a*(100), *c*(001) and *p* (111) are the dominating habits of the rose-red variety.

The usual short square crystals with the prism *a*(100), the base *c*(001) and the pyramids *p*(111) are characteristic of the white colourless apophyllite."

Gmelinite (*In part* $(Na_2Ca)\ Al_2Si_4O_{12}+6H_2O$) *and Natrolite* $(Na_2Al_2Si_3O_{10}+2H_2O)$ have also been reported.[1]

Laumontite $(H_4Ca\ Al_2Si_4O_{14}+2H_2O)$. This mineral is also commonly found among the minerals of the vugs. It forms delicate needle-like crystals showing the unit prism terminated by the orthodome $e(\bar{2}01)$. When first obtained the crystals of laumontite are bright and transparent, but on exposure to surface conditions they lose water and soon become white and opaque and finally disintegrate.

Chabazite ($(CaNa_2)\ Al_2Si_4O_{12}+6H_2O$). Chabazite occurs under the same conditions and in association with laumontite. It forms almost cubic rhombohedra one-third of an inch in diameter and often forms penetration twins. The variety is white with a delicate pearly lustre.

Grünerite ($(Na_2Ca)\ Al_2Si_4O_{12}+6\ H_2O$). Grünerite has been reported to occur as reddish-white well-formed translucent

[1] Geol. Surv., Can. Ann. Rept., Vol. XII, 1899, p. 21 R.

crystals of rhombohedral habit occurring in the War Eagle workings.[1]

Muscovite ($(HK) AlSiO_4$). Muscovite is common as an alteration product and a constituent of the zone of secondary minerals developed by the ore solutions. It is most frequently formed at the expense of feldspar, but is not wholly confined to such alteration. It occurs in some places in large plates but more frequently in small sericite scales.

Biotite ($(HK)_2 (MgFe)_4 (AlFe)_2 Si_4O_{16}$). Biotite or black mica is also produced rather commonly in the neighbourhood of the ores as a secondary product in the alteration of the country rock, during the ore-forming processes. This formation of biotite in the country rock by mineralizing agents is rather unique, being characteristic of dynamic metamorphism rather than of ordinary mineralization as noted by Lindgren.[2] Here, however, its formation takes place in the vein and wall rocks, in the same way as, and accompanying the formation of, the sulphide minerals of the ore, and seems to be due to the reaction of the mineralizing agents on the minerals of the country rock. The coloured constituents such as pyroxene and hornblende are usually the first to alter to biotite, but the feldspathic and other minerals are also replaced by it. Its formation is not confined to any one country rock, but like the ores, it takes place in all, even in the siliceous stratified rocks, which become biotitized to resemble the extreme alteration products of the porphyrites and monzonite. The biotite generally develops in very small, usually microscopic flakes, associated with quartz, hornblende, chlorite, etc. The sulphides, where extensively developed, give the rock a reddish-brown colour and these along with silicified layers yield a very fine-grained banded, stratified-like material.

Chlorite (*Silicate of Aluminum with Ferrous Iron and Magnesium and Chemically Combined Water*). This mineral is found in large amounts as a secondary product in relationship similar to muscovite and biotite. The chlorite most frequently forms from the dark coloured constituents of the original rocks.

[1] Ann. Rept. Geol. Sur., Can., 1899, p. 2 R.
[2] Trans. Am. Inst., Mining Engineers, 1900, p. 69.

Serpentine ($H_4Mg_3Si_2O_9$). Impure serpentine forms a rock type exposed at various places near Rossland. An outcrop is found on the Great Northern railway near the O. K. mine. It is probably a product of the alteration of a pyroxenite or similar basic rock. Serpentine is also common in fissures and along fault surfaces.

SULPHATE.

Epsomite ($MgSO_4\ 7H_2O$). A silky hair-like incrustation frequently covers the walls of the warm drier workings. In undisturbed places these crystals often reach a length of 1 to 1½ inches usually in curved forms. The substance examined consisted almost entirely of magnesium sulphate. A small amount of alumina was present and may represent a slight admixture of aluminum sulphates.

ORIGIN OF ORE DEPOSITS.

The ore deposits must be either primary, formed at the same time as the country rock, or secondary, formed at a later period. They must be either of igneous origin or ot[illegible] origin. Each of these possibilities has found advocates. Largely from the mineralogical resemblance between these ores and the Sudbury copper-nickel ores and from the fact that an important country rock in both cases is a rather basic igneous rock, it has been urged that the Rossland deposits have been formed by the segregation, at particular points, of the basic constituents, such as sulphides, of the country rock while it was yet in a molten condition. In that case the deposits would be primary (contemporaneous) or *syngenetic*. Few who have personally examined the Rossland deposits will maintain this theory, for it is absolutely negatived by all the facts that are known regarding the mode of occurrence of the ores. From the way in which the ore occurs in veins and lodes, along fractures or bands of fractures. and replacing the minerals of various country rocks, it is evident that the deposits are secondary (*epigenetic*), that is, formed after the country rock through the agency of aqueous, mineral-laden solutions closely connected with igneous activity.

An additional proof of this origin of the ores is afforded by an examination of microscopic sections of the ore which show the secondary origin of all the ore minerals, and the gradual replacement of the original components of the rocks by them.

The ore deposits of Rossland, then, may be classified as epigenetic replacement deposits along shear or sheeted fissure zones. That is, the sheared and brecciated country rock along such fissure zones has been slowly transformed into ore through the action of hot, alkaline, aqueous solutions and gases ascending from below under conditions of high temperature and pressure.[1] The ores as indicated by their coarse eutectic texture[2] and the minerals present have been deposited in the deep-vein zone[3] but under conditions approaching that of the contact metamorphic zone. The transformation of the minerals of the shear zone into others of different chemical composition was effected by practically simultaneous (or concomitant) solution and precipitation or in one word '*replacement*' (metasomatism). In such a process the reactions take place in part in rigid rocks of the anamorphic zone[4] where the new minerals are forced to make room for themselves by solution of the host minerals: in that case, the volume of the replacing minerals would equal that of the minerals replaced and no spaces of solution would be left. The force of crystallization would be of no direct influence, but solution would prevail at places of maximum pressure and deposition at those of minimum pressure. Exceptional supplies of heat contributed by igneous intrusion probably carry such reactions of the so-called anamorphic zone close to the surface.

The conclusion that the direction of movement of the ore transporting agents was upward, is corroborated by the manner

[1] Pressure tends to cause the crystallization of minerals of small molecular volume and has, as Van't Hoff has demonstrated, little influence upon the crystallization of any particular mineral. A few degrees of temperature can counteract the effect of many atmospheres. Van't Hoff, J. H.: "Physical Chemistry in the Service of the Sciences," Chicago, 1903, p. 123.

[2] A texture similar to that in some igneous rocks such as for instance graphic granite where two minerals (quartz and feldspar) are intimately intergrown. It shows that the minerals have crystallized simultaneously.

[3] W. H. Emmons, "A Genetic Classification of Minerals": Econ. Geol. Vol. III, No. 7, pp. 611-627.

W. Lindgren, "The Relation of Ore Depostion to Physical Conditions": Econ. Geol., Vol. II, pp. 105-127.

E. T. Allen, "Studies in Ore Deposition with Special Reference to the Sulphides of Iron": Jour. of Wash. Acad. of Sci. (1911), pp. 170-7. Pyrrhotite forms when the temperature is over 575° C.

[4] A term used by Van Hise meaning a zone coinciding with the zone of rock flowage, in which only sub-capillary openings exist and deformation is effected by granulation or recrystallization.

in which the veins branch and terminate upward, as well as by the way the ore in places is found concentrated along the foot-wall or underside of dykes and tongues. The ascending waters were probably propelled by the expansive force of the gases. Furthermore it was observed in the Josie mine that the augite of the augite porphyrite was the last mineral to be replaced by silica (Plate XV A). If the waters had been descending surface instead of ascending waters the reverse would have been the case, for such downward penetrating waters, charged with more or less carbon dioxide, would at ordinary temperatures gradually decompose the silicates particularly the pyroxene, amphibole, biotite, and the calcium feldspars; the alkalic feldspars would be more slowly attacked.

The source of the mineralizing solutions is a matter for much speculation. Brock discusses this question as follows:[1]

"All waters that circulate underground are chemical agents and are more or less efficient as vein-producers. They may be waters from the surface or meteoric waters descending through small fractures or cavities in the rocks and dissolving mineral matter from the rocks through which they pass, to deposit this material in major fractures, performing their work as they descend. Or they may be meteoric waters that have travelled a long distance below the surface and have acquired a high temperature in the depths to which they have reached, and on reascending on much the same principle as the water circulates in an ordinary heating system, they deposit the load of mineral matter they have acquired, in the highways used during their ascent. Or again, they may be waters that have been buried in sediments laid down near some ancient shore line, that after long ages, are permitted to escape through the fracturing of the overlying sediments, now consolidated into rocks. Or again, they may be what is termed juvenile waters brought up in molten rock magma, and given off by it during and after its irruption and consolidation, ascending to reach the earth's surface for the first time. Such magmatic waters would be almost certain to be highly charged with mineral matter in solution."

[1] Unpublished manuscript of R. W. Brock.

"The intrusion of molten magma by heating up the rocks would in any case greatly increase the efficiency of the underground waters, by raising their temperature, for on heating, water becomes a much more powerful solvent, and not only is the heated water able to attack and dissolve more strongly, but it can carry a heavier load of mineral matter. These heated ascending waters on entering a region of diminished temperature and pressure, or meeting with cool currents from nearer the surface or other conditions favourable for precipitation, will deposit their load of mineral matter, often exchanging it for material which they can dissolve out of the country rock, in this way forming veins and replacement veins. That hot ascending water does carry up mineral matter in solution and is able to form mineral veins is shown by the hot-spring deposits and the formation of mineral veins by hot-spring waters now going on in Nature's laboratories."[1]

The geological conditions in Rossland were favourable for the mineralizing action of underground waters. The orogenic disturbances fissured the country rocks, thus affording highways for the waters to follow. The great intrusions of molten magma from time to time afforded heat to increase the efficiency of the waters to a maximum, and probably furnished the mineral matter, and mineralizing waters themselves. The latter probability is well supported by the general character and relationship of the vein minerals, the country rock formations, and the intimate association of the veins with intrusive tongues of diorite porphyrite and granodiorite cupola stocks[2] of late Jurassic age.

It seems safe to infer from the data at hand that the ore solutions were derived in large part from a deep-lying molten portion of a magma reservoir as 'after effects' of the intrusion of the Trail batholith. The diorite porphyrite tongues with which the ores are closely related are thought to have originated

[1] A. Daubree, Mem. sur la relation des sources thermales le Plombieres avec les filons metalliferes. Ann. d. Mines. V. Ser., Vol. XIII, pp. 227-256.

H. Miller, Uber die Beziehungen Zwischen Mineralquellen und Eizgangen in nordlichen Böhmen und in Sachsen. B. V. Cotta's Gangstudien III, pp. 261-309.

W. H. Weed, Mineral Vein Formation at Boulder Hot Springs, Montana; 21st Annual Rept. U. S. Geol. Surv., 1900, Part II, pp. 227-255 and Trans. Am. Inst., M. E., Vol. XXX.

[2] Since writing this an article has appeared entitled "Relation of Ore Deposits to Different Types of Intrusive Bodies" by B.S. Butler, who in referring to Utah deposits states: "The ore deposits associated with the laccoliths and deeper truncated stocks have been of comparatively slight commercial importance while associated with the apically-truncated stocks are deposits of great value." Econ. Geol. Vol. X, No. 2 (1915), pp. 101-122.

from the same source but represent the earliest tongue (aschistic dyke) intrusions accompanying the invasion of the granodiorite batholith. The tongues were probably injected under intense pressure into tension fractures which formed in the cover rocks due to batholithic doming and which they enlarged, whereas the ore solutions represent the later 'after effects' (solfatarism) of the same batholithic intrusion, having been forced into the younger shear zone and fissure fractures (due in large part to compressional stresses in the crust).

The closing phases of periods of volcanism are generally marked by 'eruptive after actions' and periods of solfatarism. The water that existed in the solution which constituted the batholithic magma, would, when the magma crystallized or was irrupted into higher levels of the outer crust, be liberated as one of the most volatile constituents, thus permitting its ascent to cooler levels. Much of the pyrite and quartz may have been derived from the granitic walls at great depths through chemical processes. The intensely altered condition of the Centre Star shear zone in depth is due probably to the high temperature and vigorous chemical activity of the gases and solutions passing upward. Such solutions had originally an abundance of hydrogen sulphide and potash[1] and extracted sodium and calcium from the wall rocks as a result of their high temperature, adding sulphur to form pyrite, and potash to form biotite, thus becoming more alkaline on ascending to upper regions. In upper and cooler levels the gases would condense to liquid solution; precipitation would begin by reduction of pressure and temperature or by reactions with the adjoining rock minerals. Meteoric waters may have mingled with the magmatic and this again would cause deposition; ultimately the still warm waters may have issued as ascending springs at the surface.

That there was more than one period of mineralization in Rossland seems evident from the manner in which the gold values are distributed through the sulphide veins. The gold values in some sulphide veins cease abruptly at the intersection of lamprophyre dykes or slip planes with the vein, whereas the sulphide vein, too low grade to mine, continues uninterruptedly

[1] See chemical analyses of fresh and altered wall rocks on pages 205, 223.

beyond the dyke. The dyke appears to have played the part of an impervious dam preventing the younger gold-bearing solutions from circulating farther; consequently they have deposited their burden of precious metal in the continuous vein which is older than the dyke. It will be remembered that 10 to 50 per cent of the total gold content in the ores is in the free state and that the high gold values in the Jumbo, Giant, Velvet, and Spitzee mines are closely associated with dykes of alkalic syenite (pulaskite).

It is inferred from the field data at hand that there were at least two periods of mineralization: in the first and main period there were magmatic emanations containing copper, sulphur, nickel, iron, gold, lead, silver, cobalt, antimony, and molybdenum, following the intrusion of the Trail batholith (granodiorite and monzonite); in the second period there were alkaline solutions containing gold following the intrusion of the Coryell batholith (pulaskite). The metallic gold in the alkaline solutions may have been precipitated by the chalcopyrite[1] and molybdenite. Further it is inferred that during the first main period of mineralization some of the veins were fractured (fault 'K') and brecciated, and ore genetically similar to the first deposits was introduced in cross fractures, or possibly fault 'K' antedates the time of ore deposition and represents a north and south channel. Such mineralized faults and cross fractures are particularly prominent in the augite porphyrite zone wedged between the War Eagle monzonite mass and the Centre Star embayment of the same rock mass, and exposed in the workings of the War Eagle and Iron Mask mines.

From an examination of the structural relations of the different formational units to the fissure veins and ore shoots and noting the manner in which the veins follow for long stretches formational contacts with the richest ore shoots on such contacts, it is inferred that the fissures and shear zones were in large part controlled in their development by the Mesozoic formational contacts. The firm homogeneous augite porphyrite of the batholithic cover, where reinforced and ribbed by the steeply-dipping cupola stocks and tongues of granodiorite and diorite

[1] Econ. Geol. I (1906) Stokes (H. N.) p. 650.

porphyrite, has been the most favourable ground for persistent fissure veins. The compressional stresses set up in the crust found such contacts lines of weakness for fissuring and formation of shear zones. Naturally, the fissures did not follow the exact contacts the whole way but traversed independently the rocks of both formations. The character of the ore whether high in copper or gold, or both, as well as the size and shape of the ore shoots, appears to be largely dependent upon the kind of country-rock formation and its varying susceptibility to fissuring and replacement.

The Rossland ore deposits resemble in many respects the well-known copper deposits at Namaqualand, Cape Colony, South Africa, which have been in operation since 1852. The ore is chalcopyrite, pyrrhotite, and bornite mixed with diorite. The ore from some of the shoots averages 21 per cent copper (Ookiep deposit), others average 6·90 per cent (Nababiep deposit), while on some properties it is mostly pyrrhotite and low in copper. The ore-bodies form lenticular masses (replacement deposits) in diorite dykes. The diorite dykes have a general northeast course and are intrusive into gneiss and schist whose bands run east and west and dip at a low angle southward. The ore-bearing fractures follow the diorite dykes having the same strike and dip. The diorite ordinarily carries traces of copper, as shown by the green-stained outcrop, but the workable ore shoots appear to be formed at points where the dyke is crossed by barren northwest fissures extending across the gneiss. The low eastward dip of the elongated lenses of ore seems to conform to the intersection of the dykes and the gently dipping gneisses. The Nababiep ore-body is a very large one, but the ore occurs scattered through the diorite.[1]

The Rossland deposits also possess some structural features in common with those described at Butte, Montana. There the ore-bearing fissure veins cut granite and appear to be closely connected with dykes of quartz porphyry (diorite porphyrite in the case of Rossland) whose trend and dip correspond in a general way to the trend and dip of the veins. Sales states that: "The principal part played by the quartz porphyry has apparent-

[1]"The Copper Mines of the World" by W. H. Weed, p. 130.

ly been the opening of the way for vein-forming waters of deep-seated origin to reach the higher regions where the ore deposits are now found. While the ultimate source of the metals of the ores was probably the original granite magma, the direct source may have been the same magma locally which furnished the quartz porphyry, the latter rock following the earliest fracturing and at the same time stimulating an upward movement of the ore-bearing waters[1]."

AGE OF ORE DEPOSITS.

As already noted, the ore deposits of Rossland have a complex history and were not all formed at one period in geological time. The deposits of to-day although chiefly dependent for their origin upon igneous intrusion—the constructional force—are also in large part dependent upon subsequent crustal movements and erosion—the destructional forces which have complicated and laid them bare. In order to give the reader as clear a mental picture as possible of the sequence and age of the geological events influential in the development of the Rossland ore deposits, the following summary has been tabulated:

1. Marine sedimentation and igneous activity of the Carboniferous period (Mount Roberts formation).
2. Deformation at close of the Palæozoic.
3. Triassic erosion and intrusion of augite porphyrite.
4. Jurassic mountain-making revolution, intrusion of Trail batholith and allied injections, extrusion of lavas and tuffs, intrusion of *lamprophyric dykes.*
5. *First main period of minerclization.* Replacement by sulphides along fissure and shear zones formed chiefly in the cover rocks of the Trail batholith and along formational contacts.
6. Cretaceous erosion cycle and *removal of probably several thousand feet of cover rocks* of batholith bringing possibly the upper extensions of some of the present veins close to the surface. Land surface brought down to one of low relief.

[1] Bull. Am. Inst. Min. Eng., No. 80, August 1913, pp. 1523-1631.

7. Laramide mountain-making revolution and re-elevation of Columbia range. *Faulting of veins.*
8. Eocene erosion and continental sedimentation. Sophie and Lake Mountain conglomerate.
9. Oligocene (?) deformation, *intrusion of porphyritic monzonite stocks and lamprophyre dykes;* erosion interval.
10. Miocene vulcanism. Intrusion of Coryell batholith and pulaskite porphyry dykes; intrusion of lamprophyric dykes.
11. *Second main period of mineralisation.* Secondary enrichment by ascending alkaline solutions containing free gold.
12. Intrusion of Sheppard alkalic granite stocks and dykes.
13. *Block faulting and intrusion of youngest lamprophyres.*
14. Pliocene erosion cycle. Production of present mature to late mature upland topography and removal of upward extensions of veins in upthrust fault block or 'horst.'
15. Late Pliocene uplift and erosion of deep valleys.
16. Pleistocene glaciation: *removal of possible oxidation zone of deposits:* accumulation of morainic material.
17. *Recent weathering and oxidation.*

CHAPTER IV.

DESCRIPTION OF MINES—NORTH BELT.

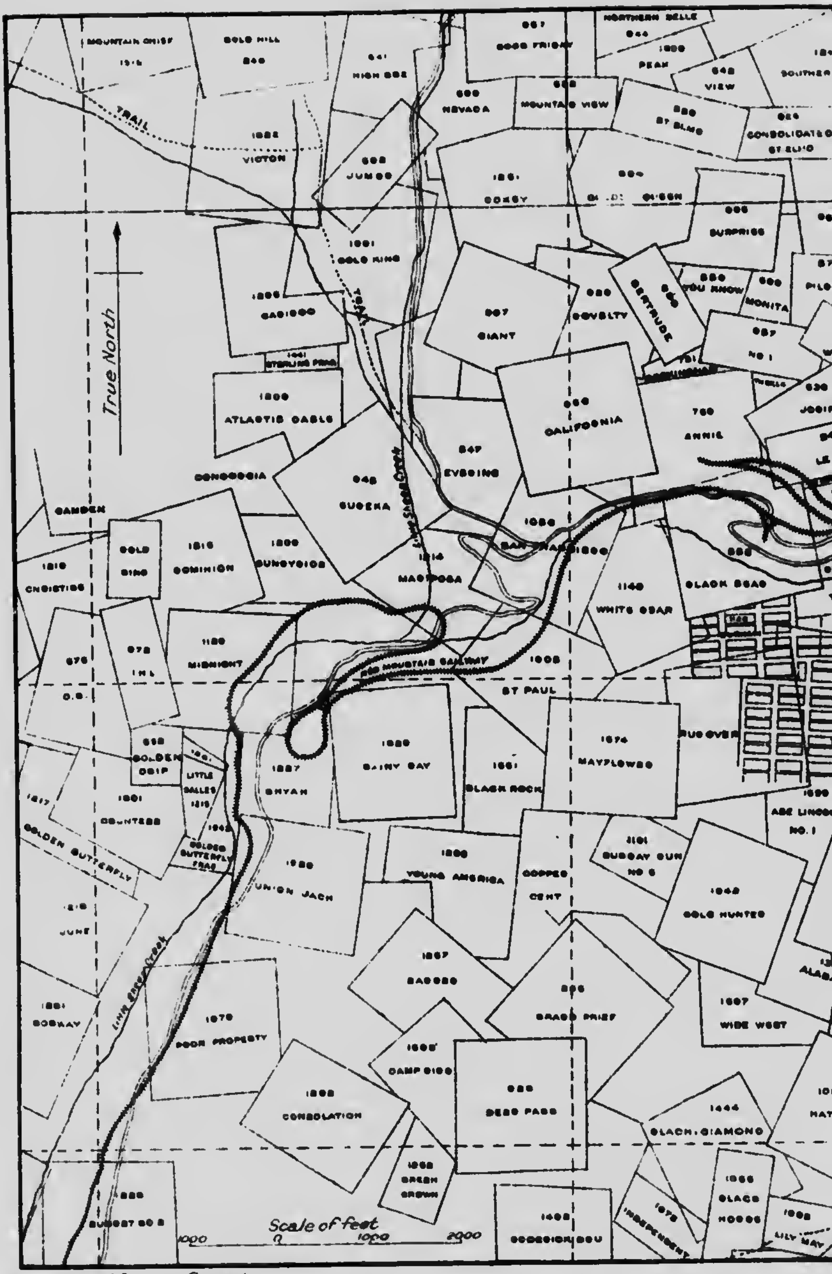
INTRODUCTION.

There are two main mineralized belts in the Rossland district known as the North and South belts respectively. The *North* belt is by far the most important and embraces the properties situated on Red, Monte Christo, Columbia-Kootenay, and O. K. mountains, thus including the Centre Star-War Eagle, LeRoi, and LeRoi No. 2 groups of producing mines. The *South* belt embraces mineralized land stretching from Lake mountain south of Rossland and Trail creek, to Deer Park mountain. This belt is still in the prospect stage of development and the ore-bodies with the exception of the Crown Point and Deer Park, have not yet been proved to be of large size although some of the fissures (dominantly east and west in strike) are very persistent and the ore of fair value. The ores differ from those of the North belt in the paucity of pyrrhotite and in the presence of much pyrite and arsenopyrite with some zinc blende, galena, and stibnite, whereas the silver values run higher than the gold.

The accompanying claim map (Figure 13) indicates the position of the different claims and properties in both the North and South belts.

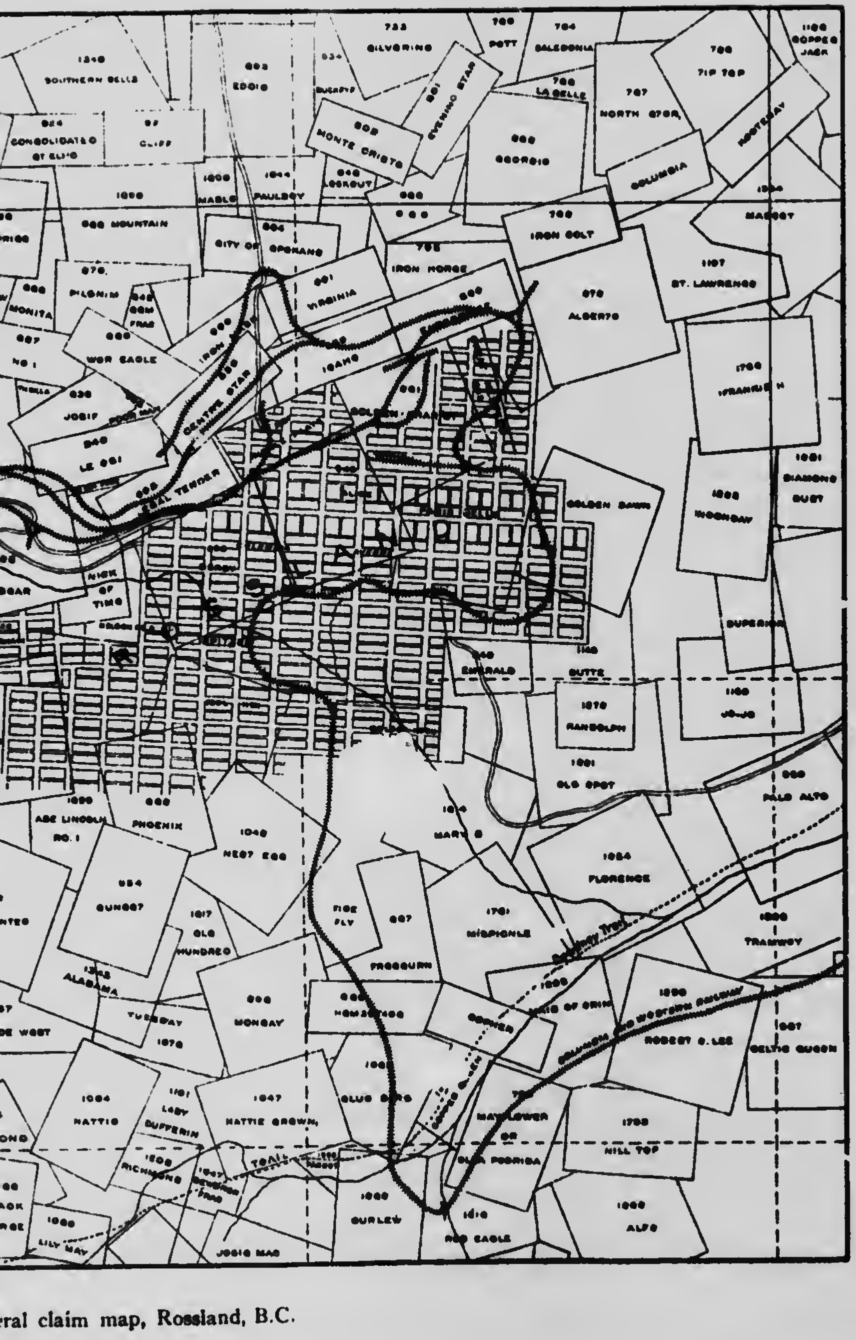
MINES OF THE CONSOLIDATED MINING AND SMELTING COMPANY OF CANADA.

The Consolidated Mining and Smelting Company of Canada was formed in 1905 and has a capitalization of $7,500,000, shares $100 par, issued $5,805,200. The company took over the following properties, either by direct ownership or by stock control: War Eagle Consolidated Mining and Development Company, Limited; Centre Star Mining Company; St. Eugene Consolidated Mining Company; the Rossland Power Company;



Geological Survey Canada.

Figure 13. Mineral claim



eral claim map, Rossland, B.C.

and the Trail smelter, formerly operated by the British Columbia Southern railway. In 1907, the Iron Mask, Idaho, and Enterprise mines at Rossland were purchased and the Phoenix Amalgamated Copper Mines, Limited, also the Keystone and Four Ace claims adjoining the Phoenix, located at Phoenix, B. C. In 1910, the company acquired the Molly Gibson group near Nelson and the No. 7 group in the Boundary district. In 1911, the company purchased control of the Fort Steele Mining and Smelting Company, Limited, owning the Sullivan silver-lead mine, near Fort Steele. In 1912, the company purchased all the property of the LeRoi Mining Company at Rossland, the Virginia mine, the Abe Lincoln mine, and the Iron Horse mine, all at Rossland, also the Silver King Mines, Limited, at Nelson. In 1914 the company purchased the Mabel, Paul Boy, Eddie J., and Annie E. claims, one-fifth interest in the Pilgrim claim, and the property of the Canadian Goldfields Syndicate in Rossland.

Dividends.

The dividends paid by the company for fiscal years were $234,940 in 1906; $480,005 in 1907; $66,940 in 1908; $232,176 in 1912; $464,352 in 1913; $464,376 in 1914; with total dividends to end of 1914 of $1,942,789.

Between 1895 and 1904 the old Centre Star Mining Company paid $210,000 in dividends. The War Eagle Consolidated Mining and Development Company paid $544,250 in dividends between June 1898 and February 1900.

Mining Methods.

The mines are opened up by means of inclined shafts with levels at intervals of 100 to 150 feet. Electric haulage is used on the main levels. The ore is mined[1] by overhead stoping, a system in which gravity facilitates all operations of breaking down the ore and rock. The stoping is done partly on the "shrinkage" system and partly by a method of square-set timbering. The square-set system is used on account of the

[1] For further details refer to "Mining Practice at Rossland" by R. B. Brinsmade, Mines and Minerals, March 1901, p. 363.

unfavourable nature of the ore-zone ground which is traversed in many places by lime seams rendering the walls to the stopes difficult to support. Local red fir and tamarack with some spruce and cedar are used in timbering[1].

Centre Star-War Eagle Group.

The Rossland mines which are operated by the Canadian Consolidated Company will be described under the two main groupings of Centre Star-War Eagle and LeRoi groups.

The following claims which are all situated on the lower slopes of Red and Monte Christo mountains are included in this group: Centre Star, War Eagle, Iron Mask, Mugwump, Idaho, Enterprise, Virginia, Red Mountain, Stewart Fraction, Pilgrim, City of Spokane, Iron Horse, Monte Christo, Butte Fraction, Lulla Fraction, Mabel, Paul Boy, Eddie J., and Annie E. The workings on the main claims in this group are at present connected by drifts and crosscuts and are being worked from the Centre Star shaft. The history and development of the principal properties may be referred to under that heading in the introductory chapter (Chapter I, Part I).

Location.

The mines are situated on the southeastern slope of Red mountain overlooking to the south and east the town of Rossland and Trail Creek valley. They adjoin the LeRoi and LeRoi No. 2 groups on the west.

Production.

According to the last annual report (September 30, 1914) of the Consolidated Mining and Smelting Company the total production of the Centre Star-War Eagle group since 1894 to date amounts to 2,206,343 tons of ore, containing 1,107,405 ounces of gold, 1,082,499 ounces of silver, and 36,065,200 pounds of copper, the gross value being $28,629,137.

[1] Four species of destructive fungi belonging to the genera *Trametes* and *Polyporus* were noted in the mines by John Macoun of the Geological Survey. To keep the algoid spores of the fungus out of the timbers and thus prevent rot it has been suggested to treat them with salt solution or creosote. Summary Report Geol. Surv., Can., 1908, pp. 187-188.

Equipment and Ore Handling.

The mine is equipped with eight electric locomotives, hauling two-ton side-dumping cars to the underground ore pockets of the Centre Star shaft. The ore pockets are on the hanging-wall side of the shaft, two on each level one directly behind the other, the front bin of 70 tons capacity, being for waste, and the 150-ton back bin for ore. The Centre Star mine has a MacDougall 200-gallon electric centrifugal turbine pump on the 4th level, one Aldrich 180-gallon quintuplex electric on the 6th, one No. 5 Cameron sinker on the 8th, one No. 7 Cameron sinker on the 12th, and a 10 × 7 × 5 Knowles sinker on both the 14th and 16th levels. The mines are equipped with electric signals throughout.

The old surface plant of the War Eagle mine which included an 1,100-foot incline tram, having a 300-foot drop down to the railway ore bins, was dismantled some years ago. To June 1913 the 1,500-foot three compartment War Eagle shaft sunk at 50 degrees was used for handling men and supplies. In connexion with the latter was a 300 horse-power geared hoist, run by compressed air which was reheated before using. The head works and engine room were destroyed by fire in June, 1913. The old shaft from the level of the No. 3 War Eagle tunnel, where a small hoist has been installed, is now used for handling timber and tools down to the 9th level.

All the ore from the Centre Star group is hoisted through a 2,200-foot three-compartment shaft (27½ ×6 feet clear of outside timbers), sunk at about 68 degrees with 16 levels opened at intervals of from 125 to 175 feet. This shaft is the deepest in Canada. The manner of handling and sorting ore at the Centre Star mines has been described by Superintendent M. E. Purcell who states:

"Ore is hoisted from the mine in 4½-ton self-dumping skips, and is dumped over a grizzly, the bars of which are spaced 1½ inches, the fines going into the fine ore bin and the middlings into another bin. Directly under the large bin containing the oversize, there is a 24 by 36 inch Farrel crusher with jaws set to a 4-inch opening. The coarse ore from the bins above feeds by gravitation to the rock crusher, and the fines, resulting from the crushing operations, goes into the fine ore bins, and the coarse ore into the same bin as the middlings. The ore is now reduced to two classes, viz., fine and coarse, and is in separate bins.

At the mouth of each bin is a chute filled with a rack and pinion ore-bin gate. Below each gate is a shaking apron. The ore descending from the bins is fed by the shaking apron on to a linkbelt steel conveyer, 58 feet from centre to centre. The belt for the coarse ore is 4 feet wide over all, and the fine ore belt 30 inches wide. These two conveyers dump the ore on two other conveyers of similar size and pattern and 302 feet 6 inches in length between centres. These long belts take the ore up at an angle of 10 degrees into the ore-sorting room, through which they travel horizontally, carrying an average load of 90 to 100 tons per hour. The load can be increased to 150 tons in an emergency.

In the ore-sorting room, which is 50 feet long and is well lighted and heated, men placed on both sides of the coarse-ore belt sort out the barren rock, bits of wood and steel by hand, and drop this refuse into chutes conveniently arranged, through which it descends into the waste bins below. The waste from the bins is sampled daily, as a check on the material thrown away, and special samples are taken occasionally from each waste-bin as an individual check on the ore-sorters.

The sorted ore, after passing the sorting-room, goes over a sampling mill, and a Vezin sampler cuts out a sample. The ore in going over the sampling mill falls into a bin situated over the west end of the main ore-bins at the railway track. From this bin there is a bucket conveyer, 95 feet between centres, that distributes the ore into the various bins ready for loading into the railway cars. The regular ore train running between Rossland and Smelter Junction consists of twelve 50-ton cars. In loading, the engine spots the cars under the bins; in this manner the entire train, containing approximately 600 tons of ore, is loaded in from 20 to 30 minutes.

In the head-works there are also special ore-bins which may be used in connexion with, or independent of, the regular ore-bins whenever it is desirable to sample a special lot of ore from any level, or any particular working place in the mine."

The Centre Star engine house has an 1,100-horse power 28×60 inch Nordberg hoist, with two 10-foot drums of 5-foot face. These are good for a 10-ton load to a depth of 3,000 feet and a speed of 2,000 feet per minute. They use a 1½-inch plow-steel hoisting rope. There is also a 500-horse-power 14×18 inch Wellman-Seaver-Morgan geared auxiliary hoist which is used for the lowering and hoisting of men. The main hoist takes skips 10 feet in height, boxed on 3 sides and open in front, having hinged bottoms. When hoisting ore the bottoms are turned back and 4½-ton skips are swung under to form a double skip.

The buildings at the Centre Star-War Eagle group include a large carpenter shop, a well equipped smithy, and a good machine shop for doing all ordinary repairing. These are all conveniently placed with respect to the collar of the Centre Star shaft and the portal of No. 3 tunnel of the War Eagle mine.

Power.

Electric power is used extensively, the mine taking current at 20,000 volts from the Bonnington Falls plant of the West Kootenay Power and Light Company, 35 miles distant. The current is stepped down at the mine to 2,000 volts for distribution and use. The compressor room has a 120-kilowatt direct current generator, driven by an alternating current motor, supplying current at 250 volts for the electric motors on the surface and underground, and for lighting purposes.

The Centre Star plant has two 40-drill compressors, one a Canadian-Rand Corliss duplex compound two-stage compressor, with 22-inch and 40-inch steam cylinders and 48-inch stroke, and with 28 × 32-inch air cylinders. The steam cylinders have been dispensed with and the compressor is rope driven by a 650-horse-power Westinghouse induction motor. The other compressor is a hybrid, built over from an Ingersoll straight-line with a duplex machine having two Canadian Rand cylinders, rope-driven, by a 600-horse-power Canadian Westinghouse synchronous motor. These two compressors supply the air for all the drills, the hoists at the War Eagle and LeRoi shafts, the 200-horse-power hoist at the winze on the 11th level of the War Eagle, and all the pumps except the electric ones.

General Development.

The total amount of development work underground in the Centre Star-War Eagle group of mines up to September 30, 1914, was 185,434·5 feet or 35·12 miles. During the fiscal year ending September 30, 1914, 11,824·5 feet of drifting and crosscutting, 1,108·5 feet of raising, 249·0 feet of sinking, and 10,479·1 feet of diamond drilling were done in the Centre Star-War Eagle group.[1]

Costs.

The following are costs for the year ending September 30, 1913, at the Centre Star-War Eagle mine:—

Drifts and crosscuts	$16.68 per foot.
Raises	37.60 per foot.
Winzes	56.16 per foot.
Diamond drilling	2.25 per foot.
Stoping	2.74 per ton stoped.
Development	1.74 per ton shipped.
Stoping	2.86 per ton shipped.

Character of the Ore.

The ore from the different mines of the Centre Star-War Eagle group, which consists of an intimate mixture of pyrrhotite, pyrite, and chalcopyrite in altered country-rock, varies a great deal in its gold, silver, and copper content from place to place. The ore from the Centre Star claim itself would perhaps average 0·6 per cent copper, 0·3 ounces in silver, and $7 to $10 in gold per ton. The War Eagle and LeRoi ore averages higher than the Centre Star, whereas the Iron Mask ore is about the same gold and silver but runs higher in copper.

The more siliceous ore from the lower levels of the group, which is closely associated with an intrusive tongue of diorite porphyrite and in many places represents the latter replaced, carries higher gold values than that of the upper levels which represents chiefly replaced augite porphyrite. The ore enclosed in monzonite and at great distances from the porphyrite is as a rule low grade in character although local enrichments have been found.

[1] Annual Report Consolidated Mining and Smelting Company, 1914.

Geological Structure.

The veins in the Centre Star group which contain the ore-bodies may be divided into two definite systems which have different trends (Figure 6). One system may for convenience be called the Centre Star, with general east and west trend, and the other, the War Eagle system, with northwest and southeast trend. The Centre Star system includes the main Centre Star vein which strikes through the Idaho and Enterprise claims, the Centre Star North vein, the Iron Mask North vein, and the Josie-Poorman vein; the War Eagle system includes the War Eagle vein with its parallel hanging-wall branches.

The ore shoots, as mentioned in the preceding chapter, occur in most cases along steeply dipping contacts. The main ore-producing contacts are between diorite porphyrite and augite porphyrite, and also between monzonite and the porphyrites. The size, shape, and pitch of the ore shoots in the Centre Star and War Eagle mines are shown in the longitudinal sections (Figures 8, 14) along with the intricate dyke and fault systems.

A transverse section through the War Eagle mine (Map 1518 in pocket) illustrates the manner in which the ore shoots have the tendency to become offset to the hanging-wall and indicates as well the structural relations of the ore shoots to the various country-rock formations.

The ground in the vicinity of the boundary lines between the War Eagle, Centre Star, and Iron Mask claims, where the augite porphyrite is almost surrounded by intrusive monzonite, is characterized by numerous veins (eight at least) striking in various directions. This ground, which is much fractured and traversed by a series of north and south faults (viz N,O,Q, etc.), contains many high-grade ore shoots, as for instance War Eagle 452M stope situated between the Poorman and Centre Star North veins and having ore running up to 12 per cent copper and $30 in gold per ton. This ore shoot has a hanging-wall of augite porphyrite and a foot-wall of diorite porphyrite and appears to terminate westward at a 20-foot spessartite dyke and fault Q. Fault Q also forms the west boundary of the

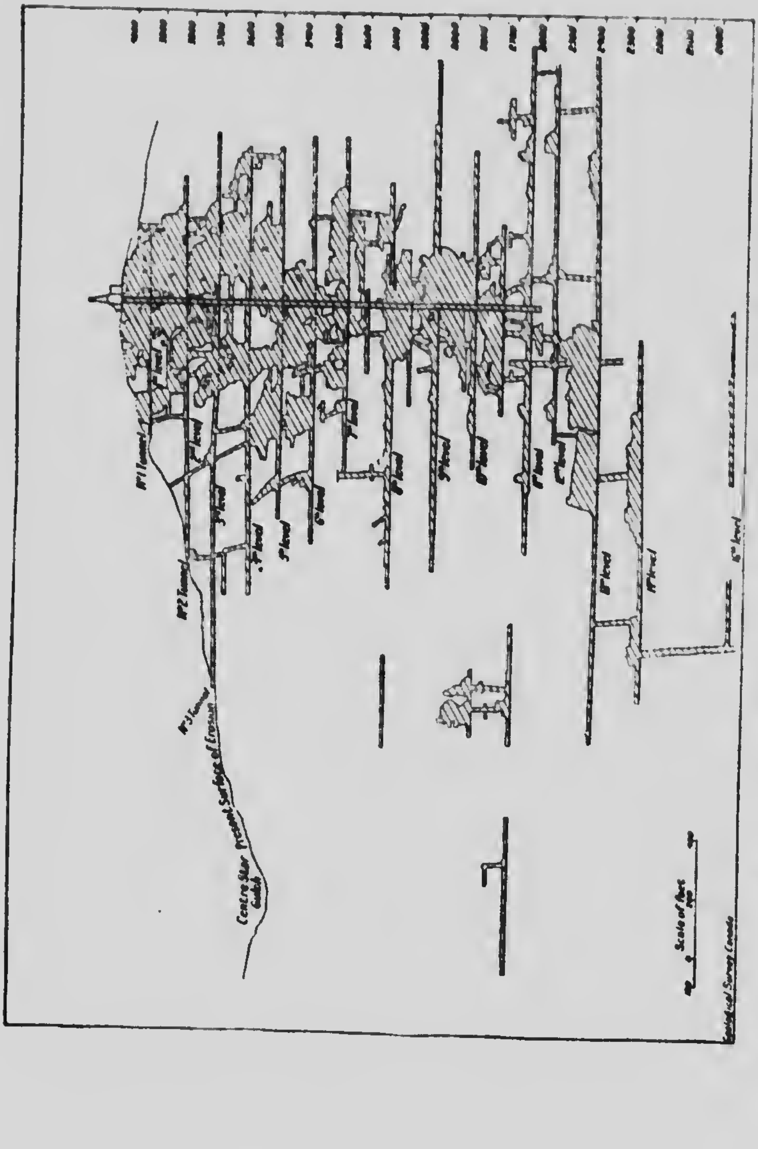


Figure 14. Longitudinal projection of the War Eagle mine, Rossland, B.C.

rich No. 555A War Eagle stope now stoped up above the Centre Star 2nd level. The Nos. 464A and 451M stopes on the Poorman vein are also high grade. The Nos. 458A and 459A stopes on the War Eagle vein have stope lengths of over 80 feet and a pitch length of 100 feet averaging $24.40 in gold and 3·6 per cent copper. On the Iron Mask 200-foot level which corresponds to the War Eagle 400-foot level the Iron Mask vein is cut off between the 250-and 200-foot levels by a south-dipping fault which is in turn cut by a north and south striking fault with steep dip to the east. This latter fault displaces horizontally the War Eagle, Centre North, and Iron Mask veins—the heave amounting to from 10 to 20 feet. Practically no values are derived from monzonite territory although the sulphide veins are strong within it.[1]

Iron Mask.

The Iron Mask vein was opened up first by a shaft sunk on its outcrop, a narrow crevice thought to be the continuation of the Josie vein. The shaft went down vertically for 20 feet when the vein widened to the full width of the shaft and contained a fine high-grade ore that averaged 2·3 ounces in gold. This high-grade ore persisted to the 100-foot level which was opened up in 1896. In 1897, the Iron Mask shipped considerable ore, but then shipments were deferred by reason of the law-suit pending with the adjacent Centre Star mine over extra lateral rights. In 1898, 3,370 tons were shipped for which $72,600 net cash was received from the smelter. In 1899, 5,378 tons were shipped with gross value of $70,268.87. In 1907 the Iron Mask was taken over by the Consolidated Mining and Smelting Company. The size and shape of the ore shoots on the Iron Mask Main, North, and South veins are shown in the accompanying projections (Figures 15, 16).[1]

Virginia.

The Virginia claim, which was located by Joe Morris in July 1890, adjoins the Iron Mask to the east. In 1896, the claim was being developed by a short crosscut tunnel run in

[1]See Addenda, p. 252.

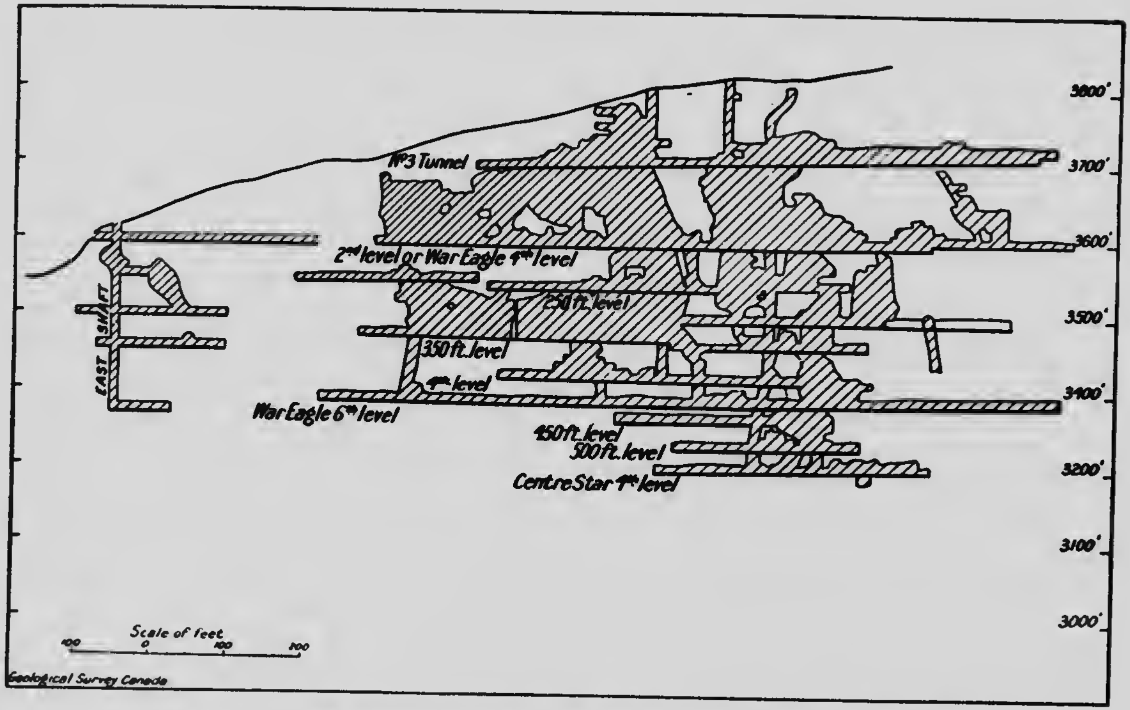


Figure 15. Longitudinal projection of Iron Mask mine, main vein, Rossland, B.C.

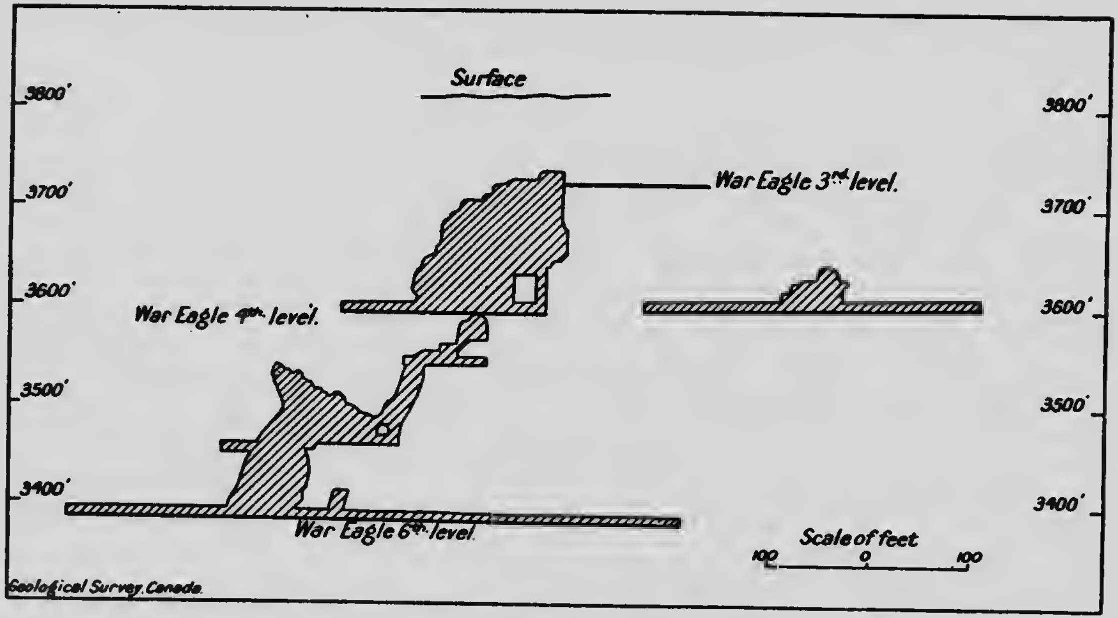


Figure 16. Longitudinal projection of North and South veins, Iron Mask mine, Rossland, B.C.

to tap an ore-body exposed in a small shaft farther up the hill. Previous to 1898 the shaft was down 400 feet and 816 feet of drifting had been done. The plant then comprised a 135-horse-power hoist, two No. 5 Cameron pumps, and power was supplied by the Monte Christo compressor.

The main sulphide ore-body was 25 feet wide in a vein striking east and west and dipping steeply to the north, but it was not of sufficiently good grade to ship. The country rock is entirely monzonite.

Red Mountain.

The Red Mountain claim which was located by Frank Hanna in April 1891, is situated north of the War Eagle an Pilgrim and west of the City of Spokane. Toward the west border of the claim is a shaft 20 feet deep and 350 feet east is a tunnel 85 feet in length which cut the vein 59 feet in from the portal. The vein outcrop which has an east and west strike and northerly dip shows as much as 3 to 4 feet of low-grade pyrrhotite with some chalcopyrite in quartz and altered country-rock (augite porphyrite) gangue. In a small cut east of the tunnel there is from 3 to 16 inches of solid pyrrhotite dipping 60 degrees north.

The country rocks are augite porphyrite, diorite porphyrite, and monzonite, the contact passing diagonally from the south-west to the northeast corner of the claim.

City of Spokane.

The City of Spokane claim, which was originally located by E. Haney and L. Corbin in May 1891, is situated in the saddle between Monte Christo and Red mountains, directly north of the Iron Mask and Virginia claims. The property was equipped in 1896 with an air compressor (3-drill 12 inch × 6 inch Rand), a 45-horse-power boiler, and employed 18 men.

Heavy sulphide ore was first disclosed in a prospect shaft toward the east border of the claim. The vein in which it was found had an east and west strike and northerly dip. A tunnel was driven easterly from near the centre of the claim, just above the road. The tunnel was off the ore at the start but 85 feet in encountered nearly 3 feet of solid pyrrhotite and iron pyrite, carrying, however, low copper and gold values. The country rock near the surface is entirely monzonite. The heavy sulphide follows the foot-wall side of a lamprophyre dyke, but on account of its low grade character has not been developed. Another small vein striking east and west is exposed in a prospect pit farther north on the claim.

Iron Horse.

The Iron Horse claim was located directly east of the Virginia on the south slope of Monte Christo mountain by S. St. Onge in July 1890. On it is a vein carrying heavy but low-grade sulphides which strike east and west dipping to the north at an angle of 60 degrees. Two prospect shafts are present on the claim. One of these shafts is of two compartments. Another shaft is sunk vertically for 50 feet and to it a tunnel was driven 100 feet long which intersected the low grade sulphides. Twelve hundred feet of diamond drilling was done in 1896 on this property. A shipment of 37 tons of ore was made in 1908 to the Trail smelter.

Iron Colt.

Adjoining the Iron Horse to the east is the Iron Colt claim which was located by Joe Michaud, August 6, 1890. The property has two tunnels No. 1 and No. 2; the former is 65 feet long and the latter with its portal on the Alberta claim and known as the Alberta tunnel is about 1,596 feet long. There are four open-cuts from 10 to 30 feet long and 5 to 10 feet deep and a 75-foot prospect shaft. Power was supplied by a 5-drill air-compressor plant. About 20 men were employed.

At 30 feet down, the shaft is in 2 feet of solid sulphide ore and follows the foot-wall of the vein. No. 2 tunnel has a drift on the vein which is 3 to 35 feet wide. The vein, which is possibly the westward extension of the Columbia-Kootenay vein, is striking north 63 degrees east with steep dip to the north, and contains the characteristic Columbia-Kootenay ore, light grey in colour, close textured, and containing calcite seams with patches of chalcopyrite scattered here and there. The Alberta tunnel is in monzonite, porphyritic monzonite, and pulaskite porphyry. The Iron Colt shaft is on the contact between the Mount Roberts formation west and monzonite east. The Mount Roberts sedimentaries here are striking north 20 degrees east with westwardly dip of 60 degrees. Work on the Iron Colt was suspended January 18, 1898, but continued for a short time in 1899. Since December 1899 about 748 feet of drift and crosscut work has been done on the property, but without discovery of shipping ore. The tunnel on the Iron Colt was expected to develop the North Star ore-body at a depth of 400 feet. From the North Star property 50 tons of mixed ore shipped to the Trail smelter in 1900 yielded returns of from $5.60 to $9.60 per ton.

MONTE CHRISTO.

The Monte Christo claim, which was located by S. St. Onge in August 1890, is situated on the west slope of Monte Christo mountain one mile north of Rossland.

A vein with east and west course and dip 70 to 75 degrees north outcrops as a heavy iron capping through nearly the entire length of the claim. This was prospected by several open-cuts and a prospect shaft 60 feet deep which disclosed 8 to 12 feet of solid pyrrhotite. The old prospect shaft dips north at 75 degrees for the first 30 feet then becomes gradually flatter.

The equipment of the mine, when in operation, consisted of one 15-horse-power hoist, one No. 6 Cameron pump, one 80-horse-power boiler and one 7-drill compressor, the latter two being installed near the creek 200 feet below the mine. About 20 men were employed.

The upper or No. 1 tunnel (elevation 4,035·18 feet A.T.) starts in a vein 2½ feet wide with a slight dip to the northeast. For about 75 feet the vein widens to the full width of the tunnel and steepens its dip to about 70 degrees. The ore is cut off by a vertical mica dyke and fault zone. The vein, which is well marked by a strong slip plane, was again encountered 210 feet in and drifted on for 300 feet to the face of the tunnel. Sixty feet back from the face, the vein, which varies in width from 2 feet to 2 inches, is faulted several feet. The large shoots of sulphides, mainly pyrrhotite, have proved valueless, assaying from traces to $2 or $3 in gold. The country rock is monzonite.

In the main or No. 2 tunnel (elevation 3,918·21 feet A.T.) the vein is present and carries a little higher gold and copper values. The face of the first crosscut to the south is in vein matter and a narrow stringer of vein rock appears 30 feet in on the second south crosscut where the vein is dipping 70 degrees north. It is again encountered 70 feet west of the long north crosscut where the tunnel follows it for about 300 feet when the vein was lost in a zone of north and south trending dykes and faults. This level is connected with the No. 1 tunnel level by a raise which has heavy sulphides in it. A 10-inch streak of arsenopyrite was found in ore on No. 2 tunnel level a few feet past the raise. The long north crosscut encountered two veins, one 220 feet in from the tunnel. This vein was drifted on for 60 feet. The other vein was cut 240 feet in and drifted on for 90 feet. Ore from the latter vein assayed 0·79 ounces in gold. Beyond this point the ground is highly altered, dyked, and mineralized and is the northern extension of the same zone which cut the main vein to the south. The main country rock is monzonite, although the stratified rocks of the Mount Roberts formation appear as banded red and green dense rocks whose contact with the granular monzonite lies beyond the extensive mineralized zone near the northwest corner of the claim. The monzonite appears to overlie, laccolith-like, the Mount Roberts banded, altered rock. It will be remembered that this same mass of monzonite was found to overlie in somewhat similar manner the porphyrites and Mount Roberts formation in the War Eagle mine (Map 1518 in pocket). Work on the Monte Christo was suspended in 1898, the total amount of development work being 5,050 feet (2,160 feet tunnelling, 300 feet shafting, 190 feet raising, and 2,400 feet of drifting).

BUCKEYE.

Adjoining the Monte Christo claim to the north is the Buckeye or Colonna claim on which is a tunnel (elevation

4,045·66 feet A.T.) driven on a narrow vein about 6 inches in width. Good copper values were found 120 feet in, south of a winze. A few feet farther east, however, the vein was lost in a fault zone. The country rock here is an altered rather coarse-grained monzonite. A vein 1½ feet wide with east and west strike and dip of 70 degrees north was encountered 430 feet in, but not drifted on. What is probably this vein was crosscut from the face of the tunnel and found to be a couple of feet wide. Beyond the dykes and fault, the country rock is somewhat granitic (in places mineralized) and a granitic agglomerate similar to that at the end of the Monte Christo tunnel is present. The end of the Buckeye tunnel is in a fine-grained, grey, sedimentary rock (Mount Roberts formation) which dips about 30 degrees to the west.

LeRoi Group.

Location.

The following claims are included in the LeRoi group: Le Roi[1], Black Bear, LeRoi Star Fraction, Pack Train Fraction, and Abe Lincoln.[2] They adjoin to the west and south the claims of the Centre Star-War Eagle group (Plate XXIII A). The first four claims were acquired in 1911 by the Consolidated Mining and Smelting Company, from the LeRoi Mining Company which had shipped since 1894 about 1,500,000 tons of ore with a gross value of over $20,000,000.

Production.

According to the 1914 annual report of the Consolidated Mining and Smelting Company the total production of the Le-Roi group from 1894 to date amounts to 1,682,237 tons of ore, containing 795,942 ounces of gold, 1,148,362 ounces of silver, and 46,451,012 pounds of copper, the gross value being $23,357,532.

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[1] The LeRoi claim was recorded by E. S. Topping, July 17, 1890.
[2] This property is in the South Belt (Chapter VI). For description see page 160.

Dividends.

The LeRoi has always had the reputation of being a rich dividend paying mine. Up to the time of the sale[1] of the property June 7, 1898, to the British American Corporation, the old LeRoi Mining Company had realized from its operations $975,000 in dividends, $400,000 of which was paid during the year 1897.

Following the sale, the shipments were temporarily cut down from 400 to 200 tons per day, to permit of more development work being done and to place development well in advance of stoping or ore extraction. The new company paid a dividend of 18·6d in the pound March 3, 1906, which was the first since November, 1899.

Development and Equipment.

The LeRoi mine has a 1,750-foot five-compartment shaft built on the hanging-wall side of the Main vein at an incline of 67° 12′. One compartment is used for pipes, manway, etc., and two are used for hoisting men and supplies. The other two are not in use at present. The shaft house is equipped with a Fraser and Chalmers hoist (20 × 30 inches) good for a depth of 3,000 feet, but this hoist is not being used. A smaller hoist having 6-foot drums, driven by compressed air from the Centre Star compressor, is now in use. Previous to 1899 the ore was hoisted through a shaft situated 300 feet west of the east-end line. It was begun and sunk on the hanging-wall side of the vein on a slope of 45 degrees to the north, which slope or dip after 60 feet began to steepen until from the 350-foot level down to the bottom (900-foot level) the shaft became nearly vertical. On the 9th level a triple electric 7½ × 15 inch Stillwell-Bierce-Smith-Vail pump, pumps 250 gallons per minute to the Black Bear tunnel level. Two smaller pumps on the 13th and one on the 1,650-foot level pump to the 9th level.

The main levels of the LeRoi mine are connected with those of the Centre Star mine and practically all the ore from the Le-

[1] The property and smelter were secured by purchasing the stock at a price which was said to represent nearly $4,000,000 for the property. For a description of the Northport smelter the reader is referred to "The Copper Handbook," 1906, p. 633.

Roi group is hoisted through the Centre Star shaft and handled in the same manner as the ore from the Centre Star group[1]. Some of the ore from the 1,650-foot level is being hoisted through the LeRoi shaft and shipped from the Black Bear tunnel. The station of the Black Bear tunnel, which has its portal at the lower workings (including concentrating plant) beside the railway about 800 feet west, is 268 feet below the collar of the LeRoi shaft. All the framing of timber, blacksmithing, and machine repair work is done at the lower workings and the Black Bear tunnel is, therefore, utilized a great deal for handling supplies and men. The property has full mining equipment including a 20-drill compressor driven by induction motor, power drills, pumps, and other necessaries.

The total amount of development underground up to September, 1914, in the LeRoi group of mines, was about 79,011·0 feet or 14·96 miles. During the year ending September 30, 1914, 3,026·5 feet of drifting and crosscutting, 220·5 feet of raising, 12·0 feet of sinking, and 12,016·5 feet of diamond drilling were done in the LeRoi group.

Costs.

The following are costs for the year ending September 30, 1913, at the LeRoi mine:—

Drifts and crosscuts	$16.61 per foot.
Raises	24.60 per foot.
Diamond drilling	2.22 per foot.
Stoping	3.23 per ton stoped.
Development	1.72 per ton shipped.
Stoping	3.05 per ton shipped.

Composition of Ores.

An average analysis of LeRoi ore shipped in 1914 is as follows:

FeO	SiO_2	CaO	MgO	Al_2O_3	Cu	S	Au	Ag
17	42	6·5	3·0	14	1·3	6	0·34	0·37

An average assay of 1,800 tons of LeRoi second class ore shipped in 1896, ran 1·34 ounces of gold, 1·4 ounces of silver, 1·6 per cent copper, or $27.97 per ton.

[1] See page 97 for method of handling ore on the surface.

Geological Structure.

The geological structure of the LeRoi mine as well as the Josie is much easier to decipher than that of the Centre Star and War Eagle mines. This is largely due to the fact that the LeRoi is farther away from the main mass of monzonite which was responsible for the intense alteration of the ore-bearing formations in its vicinity. An embayment, however, of the main mass extends nearly halfway across the LeRoi claim, appearing in plan as a hyperbola whose apex cuts off and forms the eastern termination of the ore shoots in the LeRoi South vein and whose northern side forms the foot-wall to the Main and Miller ore shoots of the Main vein. The older ore-bearing formations of the LeRoi which the monzonite cuts off are augite porphyrite (the 'kindly' copper rock), diorite porphyrite and granodiorite (the 'kindly' gold rocks). No Mount Roberts sedimentary formation was noted in the mine.

Cupola stocks of granodiorite and tongues of diorite porphyrite penetrate upward into the augite porphyrite roof rock from the underlying Trail batholith. The LeRoi veins with their included ore shoots are closely associated with such steeply dipping granitic intrusives. They are shown with their strike and dip in the accompanying plan (Map 1518 in pocket) and include the Main, North, Peyton, South, and Pack Train veins. All the veins, with the exception of the Peyton, have a general east and west (Centre Star) trend and a steep dip to the north, which corresponds to the strike and dip of the contacts with which the ore shoots are associated. The Peyton vein has a northwest and southeast trend corresponding to the War Eagle system. The Miller, Main (foot-wall monzonite), Mulligan (hanging-wall granodiorite), and Tregear (foot-wall granodiorite) ore shoots (Map 1518 in pocket) constitute one shear-zone vein, with a strike of south 68 degrees west, while the Black Bear and Centre Star South vein, constitute another with strike of south 62 or 63 degrees west. The shapes and sizes of the ore shoots are indicated in the accompanying longitudinal projections (Figures 17, 18, 19, and 20).

Intrusive into all the above formations and veins are a series of north and south striking mica and non-mica dykes which have prevailing westerly dips. The largest dyke of all is the Josie mica dyke (kersantite) along which a great fault has taken place. The Josie dyke fault dropped and heaved southward the veins and ore shoots which extended westward

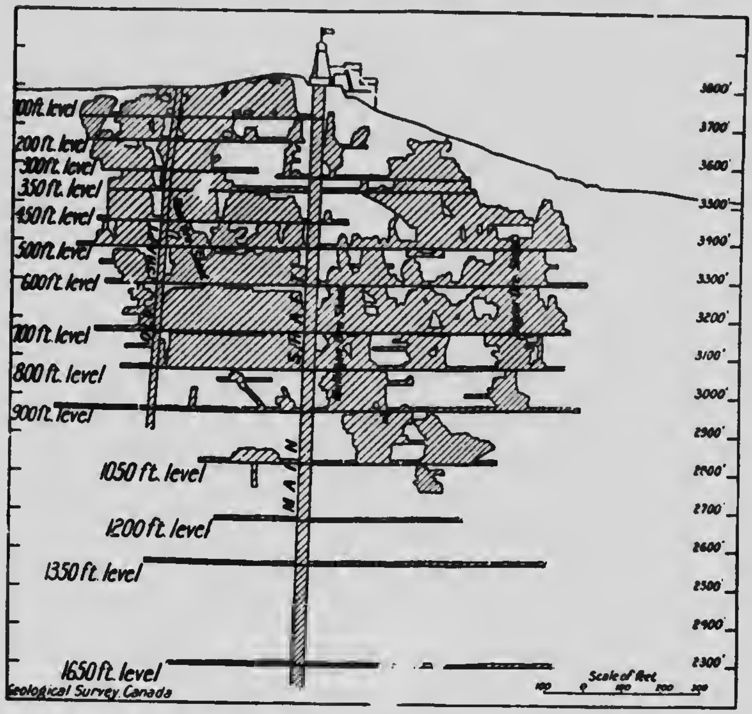


Figure 17. Longitudinal projection of the main vein, LeRoi mine, Rossland, B.C.

beyond the dyke. In the case of the Black Bear ore shoot the heave or horizontal displacement amounted to nearly 300 feet.[1] A granite porphyry dyke (Sheppard) which is in the foot-wall of the Black Bear ore shoot east of the Josie dyke and follows

[1] See Addenda, p. 252.

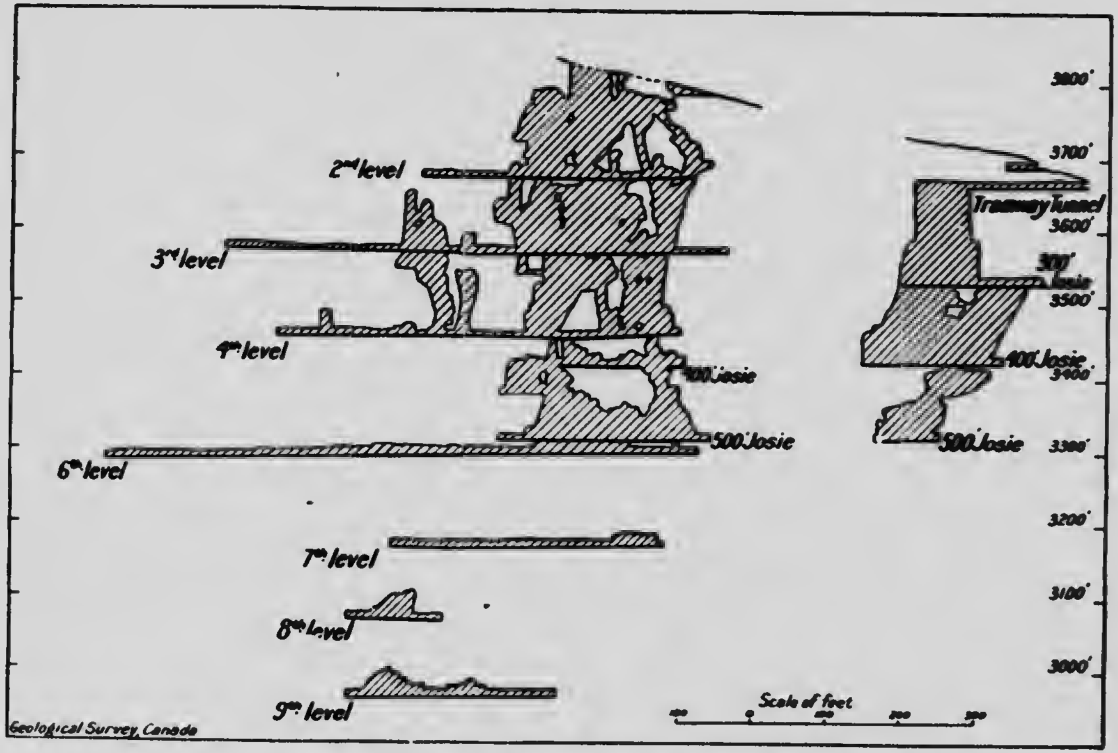


Figure 18. Longitudinal projection of North vein, LeRoi mine, Rossland, B.C.

the South vein right through into the Centre Star claim was found to be faulted along with the ore and in the foot-wall of the faulted end of the Black Bear shoot west of the dyke. There are many other faults in the mine but none with considerable throw. The veins west of the Josie dyke are intruded and cut off for a distance by an intrusive stock ("the plug") of porphyritic monzonite (See stereograms Map 1496 in pocket).

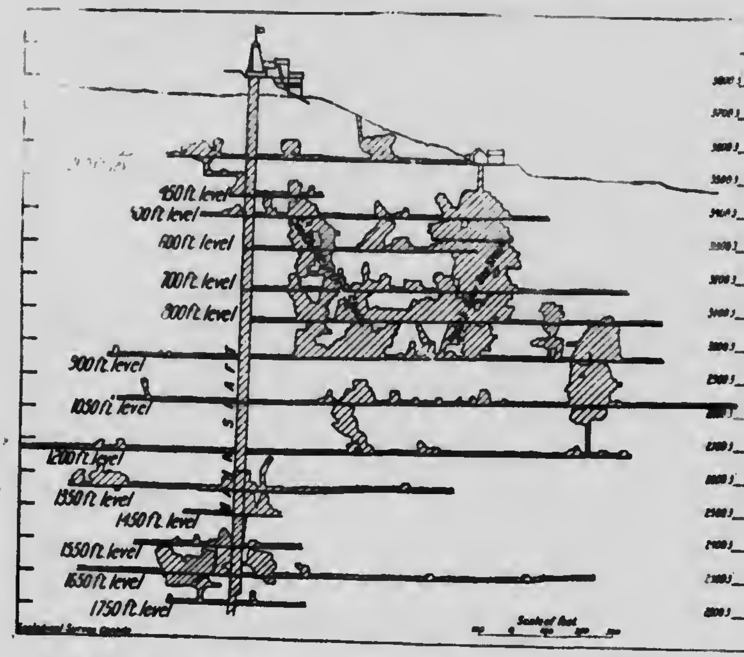


Figure 19. Longitudinal projection of the South vein, LeRoi mine, Rossland, B.C.

MINES OF THE LEROI NO. 2 LIMITED COMPANY.

The LeRoi No. 2 Limited Company was organized June 1, 1900, with a capitalization of £600,000, shares £5 par; fully issued and fully paid. The claims of the company are: Sydney Carton, Thekla, Annie, Lucky Queen, Alexander Hill, Captain

Scott, Surprise, You Know, Baltic Fraction, Rockingham, Rockingham Fraction, and part interest in the following: Josie, Number One, and Monita (Figure 13). The Josie was originally located by Henry Sharan July 28, 1890; the No. 1 by Samuel Creston on the same date (Plate XXIII A).

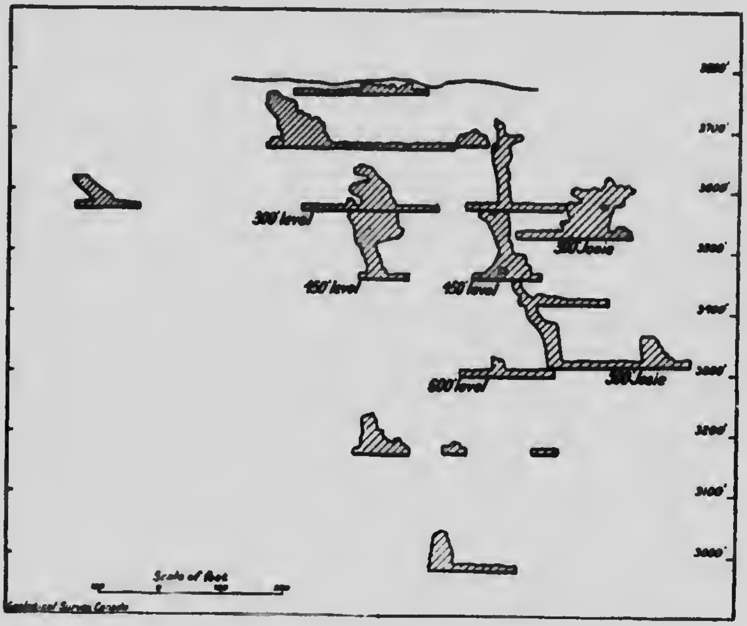


Figure 20. Longitudinal projection of Peyton vein, LeRoi mine, Rossland, B.C.

Dividends.

The LeRoi No. 2 Company has paid in dividends up to the end of 1911, £300,000 or £2 9s per share. The company paid 5s in 1901; 5s in 1902; 3s in 1904; 4s in 1905; 6s in 1906; 2s in 1907; 6s in 1908; 6s in 1909; 6s in 1910; 6s in 1911; 1s in 1912; 1s in 1914.

Production and Character of Ore.

The company's report for year ending September 30, 1913, shows that 51,625 tons were raised, and after the rejection of 16,072 tons waste, 19,023 tons were shipped to the smelter, and 16,530 tons sent to the concentrating plant. The ore is chalcopyrite, associated with pyrite and pyrrhotite in a siliceous gangue with average assay of 1·6 per cent copper, 0·87 ounces of silver, and 0·8 ounces of gold to the ton. Concentrating ore ranges from 0·4 to 0·5 per cent in copper value, with only about 20 per cent of the copper saved, the extraction of assay values in gold being 56 to 60 per cent. The shipping ore in 1913 averaged 12·8 dwt. of gold per ton, 1·2 ounces of silver per ton, and 1·94 per cent copper. The low grade ore averaged 2·4 dwt. of gold per ton, and 0·55 per cent copper, and from it was produced 1,595 tons of concentrate averaging 16·3 dwt. gold, 0·6 ounces of silver, and 0·9 per cent copper. In 1905 the smelting ore gave average returns of 3·62 per cent copper, 2·32 ounces of silver, and 1·184 ounces of gold per ton with total gross values of $35.78 per ton. An average value of smelting ore shipped in 1912 was 0·775 ounces in gold, 0·672 ounces in silver, and 1·39 per cent copper. The gross value of ore shipped in 1914 was $343,505.95 or $20.19 per ton composed as follows: gold at $20 per ounce, $12.13; silver at 52·8 cents per ounce, 0·93; copper at $13·56 per pound, $7.13. The following is a table of production for the LeRoi No. 2 Company's Rossland mines since 1902; diamond drilling and development work are also included:

Shipping Ore.

Year ending Sept. 30	Ore shipped tons.	Gold ozs.	Silver ozs.	Copper lbs.	Value per ton.	Diamond drilling ft.	Development narrow work, ft.
1903....	17550	11050	27968	980,000	$20.69	....	2396
1904....	21680	19716	30929	1030,000	24.80	3616	9714
1905....	12237	14494	28369	885,992	35.78	3121	2964
1906....	22673	19615	22054	803,409	24.34	4505	3579
1907....	17829	12603	13393	539,008	21.26	5088	2793
1908....	29648	28453	20489	910,354	23.60	7439	4572
1909....	29874	28353	22402	956,812	23.54	9820	3558
1910....	29776	26448	24079	970,996	22.38	11508	4362
1911....	27098	22725	19220	864,510	21.08	14932	5577
1912....	18257	14158	12281	507,499	20.10	14185	5845
1913....	19023	12232	22807	736,743	19.60	15075	4633
1914....	18632	10799	30715	955,852	20.19	12249	3729

Low Grade Ore Concentrated.

Year ending Sept. 30.	Tonnage treated.	Gold ozs.	Silver ozs.	Copper per cent.	Concentrates produced.	Gold ozs.	Silver ozs.	Copper per cent.
1904......	11601	0·191	0·279	0·522	523 tons	2·116	1·650	2·169
1905......	10678	0·166	0·306	0·545	425	2·542	2·218	2·613
1906......	10580	0·149	0·207	0·372	664	1·326	1·043	1·22
1907......	11840	0·084	0·144	0·396	706	0·933	0·859	1·222
1908......	15044	0·107	0·137	0·46	1129	1·023	0·56	0·96
1909......	15015	0·113	0·178	0·527	834	1·551	0·947	1·625
1910......	17265	0·122	0·255	0·554	1368	1·297	0·748	1·144
1911......	18366	0·144	0·199	0·514	1589	1·425	0·747	1·29
1912......	17116	0·137		0·5	1658	1·096	0·643	1·14
1913......	16530	0·12		0·55	1595	0·818	0·635	0·905
1914......	12170				1322			

Development.

Development in the LeRoi No. 2 is carried on from the 1,300-foot Josie main shaft (74 degrees incline) and from three tunnels, two on the Josie and one on the Poorman claim. The workings are connected underground with the LeRoi mine on the 300, 500, 900, 1,300, and 1,500-foot levels. Until proper connexions are made with the Josie shaft, the LeRoi No. 2 Company is at present hoisting ore from its South Rodney ore-body on the Josie 1,500-foot level (LeRoi 1,650-foot level) up the LeRoi shaft. During 1904 and 1905 the company drilled 6,738 feet of diamond-drill holes and two drills are kept almost continuously in operation. Development in 1912 consisted of diamond drilling 14,185 feet; narrow work (drifting, cross-cutting, raising, and sinking) 5,845 feet.

Development in the No. 1 mine is not so extensive and the workings have underground connexion with the Josie mine on the 500-foot level. Previous to 1899 there were only two or three shallow prospect pits. About that time a tunnel (elevation 3,924 feet A.T.) was commenced and driven 450 feet disclosing an ore shoot nearly 200 feet long and 2 or 3 feet wide, consisting of siliceous ore, carrying gold, silver, and copper, with values ranging from $6 to $25 per ton. About 300 feet east of this tunnel is a three compartment shaft (elevation of collar 3,949 feet A.T.) sunk vertically for 850 feet with levels opened at 200, 300, 400, 600, and 850 feet. The vein which is west of the Josie dyke has the same strike and dip as the upper War Eagle vein and is very likely the faulted western end of it.

Mining, Milling, and Equipment.

Three classes of ore are mined: first-class, second-class, and milling ore. The ore is dumped from the skips over a grizzly of 4 × 1 inch spaces, and is sorted into shipping ore, milling ore, and waste. The milling ore is trammed to the concentrator.

The shrinkage system of stoping is used where the stopes are narrow, and square setting, where they are wide.

Equipment at the Josie shaft includes a 150-horse-power electric hoist with double conical drum, good for a depth of 1,000 feet. The hoist is driven by an induction motor taking power at 220 volts and has been in continuous operation for more than twelve years. A 600-horse-power compressor driven by an electric motor delivers 4,000 feet of free air per minute compressed to 100 pounds.[1] On the Josie 500-foot level there is a No. 2 four-stage high-lift turbine pump with 60-horse-power, form K motor which pumps to the 100-foot level or surface. The mine buildings include a machine shop, framing and carpenter shop, smithy, mine office, assay office, dry house, stable, shaft house including sorting floors and bins, superintendent's dwelling, and railway bins.

The concentrating mill across a small gulch from the Josie shaft is of 50 tons rated daily capacity. The ore is given a preliminary crushing in Blake crushers. It is then fed into two 6-foot Chilian mills and ground to approximately 20 to 30 mesh; the pulp is classified in three Jencke sizers and fed to three Wilfley tables. The concentrates are shipped, the middlings rewashed on an additional Wilfley table, and the tailings waste washed into the creek. The mill is driven by motors using about 80-horse-power to treat 60 tons per day.

[1] Previous to 1899, power for the Josie and No. 1 mine was obtained from a 4-inch main from the Le-Roi compressor and a steam hoisting plant was used at each mine. Now the Nickel-Plate compressor is leased.

An Elmore oil concentrator, the first one to be erected in Rossland, was installed in 1903, proving a technical but not a commercial success and was superseded by Wilfley tables. The concentrates average 1·8 per cent copper, 1 ounce of silver, and 1·3 ounces of gold per ton.

In 1912, 17,116 tons of ore were crushed, the average content being 0·137 ounces of gold and 0·5 per cent copper; 1,658 tons of concentrates produced over 1·096 ounces in gold, 0·643 ounces in silver per ton, and 1·41 per cent copper.

Costs.

The cost of stoping operations in the Josie mine averaged for 1912 about $2.78 per ton; for raising $23.63 per foot, and for drifting $13.88 per foot. The following table giving the exact cost of the work from 1903 to 1914 has been kindly supplied by Mr. Ernest Levy, General Manager of the Company.

Year ending Sept. 30	Diamond drilling, cost per foot.	Driving, cost per foot, raising and crosscutting.	Milling, cost per ton treated.	Smelting charges, cost per ton smelted direct and indirect	Ore production cost per ton.				Ore sorting cost per ton.		General expenses.	Power plant cost per ton.		Mine, general cost per ton.		Diamond drilling cost per ton.		Total cost per ton.
					Labour.	Explosives.	Illuminants.	Sundries.	Labour.	Supplies.		Labour.	Supplies.	Labour.	Supplies.	Labour.	Supplies.	
	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
1903	2.22	21.80	1.30	8.29	1.1374	0.2624	0.0334	0.0873	0.3009	0.0063	0.8373	0.1552	0.3303	0.4246	0.0888	0.1352	0.1844	3.9835
1904	2.70	13.72	?	7.641	1.2680	0.3418	0.0430	0.1622	0.2861	0.0114	0.6421	0.1487	0.5774	0.6240	0.1202	0.0902	0.1508	4.4659
1905	1.86	11.56	?	8.70	0.9019	0.2696	0.0410	0.0821	0.2126	......	1.0934	0.1334	0.4167	0.5784	0.0790	0.1292	0.2849	4.2222
1906	2.61	12.91	1.37	6.12	1.0728	0.2822	0.0353	0.0859	0.2832	......	0.5457	0.1204	0.4861	0.5321	0.0970	0.1151	0.1973	3.8531
1907	2.39	14.58	1.14	6.12	1.30	0.50	0.04	0.11	0.25	......	0.49	0.15	0.59	0.77	0.20	0.15	0.33	4.88
1908	1.96	14.17	1.16	5.55	1.04	0.50	0.03	0.06	0.19	......	0.36	0.08	0.44	0.41	0.13	0.14	0.22	3.60
1909	1.89	14.35	0.99	5.70	0.90	0.45	0.03	0.06	0.20	......	0.37	0.07	0.39	0.37	0.11	0.17	0.24	3.36
1910	1.73	17.72	0.91	5.90	0.76	0.32	0.03	0.04	0.21	......	0.35	0.07	0.36	0.33	0.07	0.17	0.25	2.96
1911	1.69	15.17	1.06	5.81	0.73	0.34	0.03	0.04	0.20	......	0.35	0.07	0.40	9.35	0.09	0.24	0.33	3.17
1912	1.60	14.38	1.09	5.77	0.73	0.30	0.03	0.06	0.18	......	0.44	0.08	0.47	0.40	0.09	0.29	0.39	3.46
1913	1.63	15.87	1.02	6.07	0.78	0.35	0.03	0.06	0.15	......	0.43	0.08	0.47	0.46	0.09	0.30	0.37	3.57
1914		21.45		5.98	0.83	0.35	0.03	0.06	0.19	......	0.47	0.10	0.49	0.70	0.10	0.35	0.35	4.02

Geological Structure.

As there is no monzonite present in the mine workings of the LeRoi No. 2 group, the geological structure is comparatively easy to work out. The "plug" of porphyritic monzonite described in the LeRoi mine is also encountered here in the south-westerly workings of the Josie mine. The ores are associated with cupola stocks of granodiorite and tongues of diorite porphyrite intrusive into augite porphyrite. The tongues of diorite porphyrite east of the Josie dyke are not so persistent and regular as those west of the dyke and the same is true of the ore-bodies.

The following veins are included in the LeRoi No. 2 group: Josie, North Annie, Annie, Hamilton, No. 1, Holywell, the North and South Rodney, Poorman, Clover, Peyton, and Shackleton. The Josie vein is narrower than the average in the district but has ore a great deal richer than the average, much of it carrying copper values up to 4 per cent and one ounce of gold per ton. The Josie, Annie, and North and South Rodney veins have the east and west (Centre Star) trends with steep dips to north corresponding to the contacts, whereas the No. 1 vein belongs to the northwest-southeast (War Eagle) system and is in all probability the faulted end of the War Eagle vein itself. The Hamilton and Holywell veins have strikes intermediate between the No. 1 and Josie veins.

The Annie vein carries the highest values where it replaces the diorite porphyrite. Where the vein leaves it and penetrates the augite porphyrite alone the values run out. The North and South Rodney veins are the faulted ends of the LeRoi main and south veins. This fault which is a normal one took place along the Josie dyke. The North Rodney lies, like the Tregear ore shoot of the Main vein, on the north border of a granodiorite stock, whereas the South Rodney, corresponding to the Black Bear shoot on the LeRoi South vein, is on the south border of the same stock with a hanging-wall of granodiorite and foot-wall of augite porphyrite. The ore-bearing ground to the west of the Josie dyke fault has been dropped vertically as well as heaved as much as 300 feet to the foot-wall.

A winze is at present being sunk on the South Rodney ore shoot on the Josie 1,500-foot level (LeRoi 1,650-foot level). Ore averaging $16 per ton and in places 22 feet wide was followed continuously for 98 feet when the altered augite porphyrite of the foot-wall (locally porphyrite schist) appeared to cut the ore off for the next 50 feet. At a depth of 147 feet, however, the altered granodiorite of the stock again came in and with it better values. Cross-cuts for diamond-drill purposes were made 187·5 feet down. Samples taken from the 1,600-foot level (LeRoi 1,750-foot level), opened up from the winze west of the 'horst'[1], averaged 0·65 ounces in gold and 11·4 per cent copper across a 4-foot face.

No. 52 ore shoot on the 7th level of the Josie mine 240 feet west of the "White" dyke and 737 shoot was encountered in March, 1914. It has a hanging-wall of diorite porphyrite and a foot-wall of augite porphyrite. The average assays were as follows:

Year	Month	No. of Samples	Width in inches.	Gold in ounces.	Copper in per cent.
1914	March	9	37	0·18	6·6
	April..........	19	41	0·22	10·2
	May	22	31	0·32	11·4
	June	14	27	0·34	10·9
	July	2	27	0·19	6·7
	December	16	20	0·35	6·2
1915	January	10	26	0·14	3·8
	March	14	75	0·22	5·0
	April..........	16	69	0·57	9·1
	May	21	38	0·50	9·2
	June	19	45	0·43	7·3

[1] See pages 37, 57.

CHAPTER V.

DESCRIPTION OF MINES—NORTH BELT (*Continued*).

MINES OF THE ROSSLAND-KOOTENAY MINING COMPANY, LIMITED.

The Rossland-Kootenay Mining Company was organized May 17, 1902, with a capitalization of £150,000, shares £1 par, issued stock £148,607, as a reconstruction of the Rossland-Great Western Mines, Limited, and Kootenay Mining Company, Limited. The company owns 171 acres of Rossland mineral land including the Columbia-Kootenay, Great Western, Nickel Plate, and Golden Chariot claims. The mines of the company have been idle since 1904 excepting during a short period in 1912 when the company gave a lease on the Nickel Plate mine on a royalty basis to Messrs. Ruffner and Rice.

NICKEL PLATE MINE.

The Nickel Plate claim was recorded by Edwin Haney and Lyman Carter September 5, 1890. It is situated as may be seen in the accompanying claim map, immediately south of the Centre Star and Idaho claims (Figure 13). In 1893, a 50-foot shaft was sunk on an outcrop of pyritic vein matter 18 inches wide that is said to have assayed $150 to the ton. In the 1896 Bureau of Mines Report for British Columbia, Mr. W. A. Carlyle reports as follows: "Considerable careful development work has been done on this property, a shaft 150 feet having been sunk along a smooth wall with some ore present. At the 100-foot level a drift has been driven over 100 feet east and 110 feet west (July), showing more or less ore, dip 60 degrees north. From the shaft a crosscut has been driven 285 feet north through the diorite, intersecting at 110 feet a shoot of ore, which, in a stope 25 feet high, is 2 to 3 feet wide, of solid sulphites, consisting of pyrrhotite and copper pyrites, stated to be of high grade. The ore is also found scattered through this rock or gangue, and over a hundred tons are on the dump awaiting better shipping facilities, as the line of railway is surveyed to cross the claim near the shaft that will give easy access to the smelters. The crosscut will connect with the air-shaft, which is now being sunk near where on the surface some ore is showing and, after further development work proves up the value of the claim, a large and complete hoisting plant will be installed, the present plant—a 12-horse-power boiler, blower, and a Knowle's sinking pump—being sufficient for the present exploratory work. Number of men employed, 22. In Centre Star Gulch a shaft is being sunk on a vein that outcrops there, and ore is being taken out."

In April 1898 the Nickel Plate was pumped out and work confined to the 200-foot level where nearly 2,000 feet of drifting and crosscutting were done which disclosed two veins 300 feet apart, 6 to 30 inches wide, of chalcopyrite and pyrrhotite ore, assaying from $2 to $22 in gold and 3 to 12 per cent in copper. The mine at that date had a 10-drill Ingersoll Sargeant air compressor with two 60-horse-power boilers, water jet condenser, etc. which supplied air to from five to seven drills on both the Great Western and Nickel Plate properties.

In 1899, 2,370 feet of development work was done which consisted of 1,930 feet of drifting and 440 feet of sinking. About 25 men were employed. In 1911, 362 tons of ore were shipped to the Trail smelter. The leasers in 1912 shipped 101 tons from a shoot 6 to 18 inches wide, of $40 ore. The mine was full of water during the field seasons of 1913 and 1914 and could not be examined.

The future of this property hinges a great deal on the nature of the country rock formations whether granodiorite or monzonite, and the presence of porphyrite. The fissuring is present and should the coarse secondary hornblende monzonite represent a border phase of the monzonite then the monzonite contact strikes toward the Great Western and might be ore bearing.

Great Western and Golden Chariot.

The Great Western and Golden Chariot claims are located at the base of Monte Christo mountain and within the city limits of Rossland. The Great Western is a narrow fractional claim east of the full-sized Golden Chariot claim (Figure 13). The claims are traversed in a northeast and southwest direction by a wide iron-stained mineral zone in which three prospect shafts have shown low-grade gold ore assaying $3 to $4 per ton. The ore is in places massive pyrrhotite. In most places, however, the vein consists of altered monzonite impregnated with pyrrhotite and some pyrite and chalcopyrite with calcite and altered country-rock gangue.

Vertical and inclined diamond-drill holes were drilled from the bottom of a 50-foot shaft (No. 1 shaft) near the centre of the property. Near the west end is exposed a 2½-foot vein of solid sulphides, carrying low gold values. A shaft is sunk 22 feet on this vein at this point (No. 2 shaft). No. 3 shaft was sunk on the vein at the eastern end of the property and the first 12 feet was in solid ore which contained considerable quartz. The sulphides are both coarse-grained pyrrhotite and pyrite and low grade although much of the ore is fine-grained with some chalcopyrite intermixed.

In 1898 a two-compartment shaft was sunk 230 feet and drifting was in progress along the vein at the 200-foot level. The shaft was sunk deeper and it was the intention to continue it and open up a 300-foot level. In 1899, 500 feet of development work was done on the Great Western. Since that date the mine has been idle.

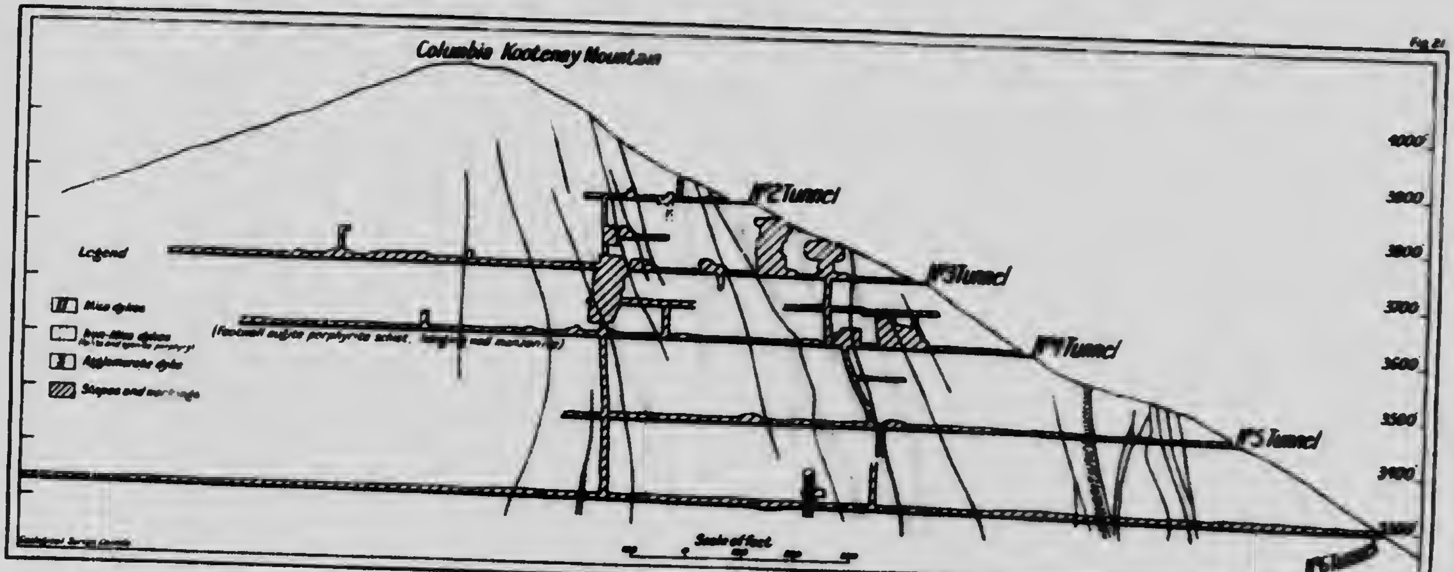
A zone probably a couple of hundred feet wide, of very coarse monzonite containing much secondary hornblende, traverses the middle of the property in a northeast and southwest direction, the same band that is exposed near the Canadian Pacific Railway station and on the LeRoi trail. Similar dykes of this coarse hornblendic monzonite occur in the Centre Star-War Eagle mine particularly in the vicinity of the Iron Mask property. An outlier of the Mount Roberts formation and a small patch of augite porphyrite are present in the southeastern portion of the property.

Columbia-Kootenay Mine.

The Columbia-Kootenay mine is situated on the northeast flank of Kootenay mountain 1¾ miles northeast of Rossland. The Columbia claim was located by R. E. Lemon, July 28, 1890, and the Kootenay claim by Phil Aspinwall, September 4, 1890. Considerable prospect work has been done on this property which has disclosed a mineralized zone with northeast and southwest trend and dip of from 45 to 75 degrees northwest, which passes through both claims. This mineralized zone follows a contact between biotite-bearing monzonite which forms the hanging-wall and the older augite porphyrite which forms the foot-wall and which the ore appears to have replaced. No diorite porphyrite was noted. The vein on the surface is heavily iron-stained. Pyrrhotite occurs both massive and disseminated through a hard fine-grained gangue with a little chalcopyrite. Mispickel or arsenical iron pyrite is also present in places. Much of the ore which is made up of sulphides in a calcite and altered rock gangue, appears to be laminated. The ore is also found massive or scattered through the gangue or along small fracture planes in the walls,

A feldspar porphyry dyke (pulaskite) 30 to 40 feet wide can be traced from the north end of the Columbia claim, where it crosses the upper tunnel at its mouth, southward, for over 2 miles. The dyke cuts the ore and does not appear to affect it in the least. The accompanying longitudinal projection (Figure 21) of the mine shows the shape of the ore shoots and extent of development work as well as the dyking system present.

Two carloads of ore were shipped prior to 1896 to the smelter to determine the value of the ore. One carload from one part of the mine proved too low grade but the other was reported to average over $50 in gold per ton. Up to 1898 about 4,700 feet of development work, comprising drifts, crosscuts, raises, and winzes had been done, of which 3,200 feet was work done during 1898. The property had at that time five adit tunnels Nos. 3, 4, 5, and 6 (Figure 21), all being advanced; the lower, No. 6 tunnel, is about 700 feet below the crest of the mountain and 400 feet above the bottom.



Longitudinal projection of Columbia-Kootenay Mine. Rossland. B.C.

In the tunnel the vein is found to be very straight with very few dislocations. It varies in width from a few inches to over 30 feet of nearly solid pyrrhotite. The equipment of the mine in 1898 consisted of a 20-drill Ingersoll Sargeant air compressor and 6-inch main to connect with the tunnels. No shipments were made in 1898. In 1899, 110 tons of ore were shipped, the gross value being $1,600. Development work amounted to 5,050 feet, 4,300 feet of drifting and 750 feet of sinking. Forty men were employed at that time. In 1904, the Rossland-Kootenay Mining Company took over the property. From January 1 to July 31, 1904, the work by the new company consisted of stoping about 5,068 tons of ore. One month's shipment averaged $11 per ton. In No. 6 tunnel the sulphides are sparse and appear for short distances, 100 feet at the most, with a width of from a few inches to one foot. Dykes are not so numerous on this level as on the upper levels and the country rock is a fine granular monzonite and porphyrite schist. In the long north crosscut from No. 6 tunnel, porphyrite is crosscut at 182 feet, and 300 feet in there was encountered a 50-foot altered zone full of calcite seams and slightly mineralized rock similar to parts of the vein.

In the case of the Columbia-Kootenay mine, like other Rossland mines, the persistence of the ore shoots depends almost entirely on geological structure and the most profitable ore shoots are contact shoots. It is rather significant that in this mine although there has been heavy sulphide mineralization along the monzonite-porphyrite contact there is an absence of both diorite porphyrite and the high gold values which are generally associated with the latter formation.

This property is well opened up and developed by adit tunnels and raises so that mining costs would be low, possibly not more than $2 per ton.

Since August, 1904, the Columbia-Kootenay mine, like the other Rossland properties owned by the Rossland-Kootenay Mining Company, has been idle. It is reported that it is the intention of the company to open up the mine shortly and spend from $50,000 to $100,000 on diamond drilling and exploratory work.

MASCOT.

The Mascot claim which adjoins the Columbia-Kootenay on the south and east (Figure 13) is not owned by the Rossland-Kootenay Mining Company, but on account of its proximity to the latter's property will be described here.

There are three main formations outcropping on this claim, a porphyrite-chert group (Mount Roberts), a granitic rock probably granodiorite, and a porphyritic monzonite. The northern half of the claim is in the porphyrite-chert group and the porphyritic monzonite occurs as a boss-like mass towards the south of the claim intrusive into the granitic formation. There are three tunnels and several prospect shafts on the claim. The upper or No. 1 tunnel discloses a couple of feet of fairly solid ore which is chiefly magnetite with little chalcopyrite.

The same vein is tapped by shaft No. 1 and by No. 2 tunnel. In shaft No. 3 is a 4- to 6-foot quartz vein carrying, it is said, good values. The No. 2 tunnel commences in faulted mineralized ground too severely altered to determine and cut by many syenitic and mica dykes. On the south wall the massive pyrrhotite displays pronounced spheroidal weathering. The country rock is an altered granitic type which extends to within 25 feet of winze No. 2 where the older chert commences. There is a pocket of ore at the contact of the two formations. The chert, which is the same banded rock typically developed at the White Bear and California, occurs at the first winze and is continuous between the various dykes to the second winze. There are several feet of ore on the wall of the winze station (No. 3 winze) which comes in again in the crosscut just west of the station. The vein is 2 feet wide of solid sulphide in a quartz gangue. The syenite was found to contain some chalcopyrite although the ore in the vein itself has very little of the copper sulphide. Some of the syenite dykes have porcelainous-chilled borders and contain inclusions of limestone, granite, and other rocks. A good example of mixed or composite dykes is found (Figure 10) in the south wall of the No. 2 tunnel on the Mascot claim.

In No. 3 tunnel the cherts, where present, dip 60 degrees west, and here a syenite dyke displaying flow structure and a peculiar termination (Figure 22) was found intrusive into the granitic country rock.

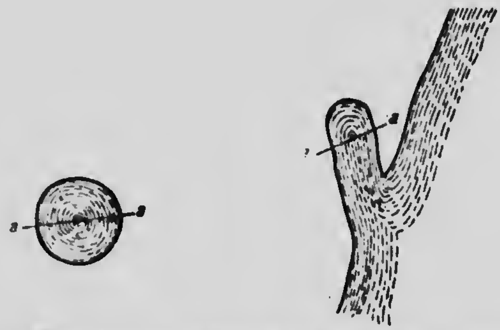


Figure 22. Flow structure in syenite dyke concentric in thumb-like protrusion, Columbia-Kootenay mine.

COMMANDER.

The Commander claim is situated on the lower slope of Columbia-Kootenay mountain, 1¼ miles southeast of Rossland on the old Trail road. It has an area of 52 acres. Development on the claim commenced in August, 1898, when a 5-foot by 9-foot shaft was sunk 100 feet in a mineralized zone 4 to 5 feet wide. The shaft followed a smooth wall for some distance, several tons of ore being taken out in the sinking. Considerable surface trenching has also been done. The ore is much disseminated through the country rock which is monzonite and assays in gold $3 to $4 per ton. It consists of coarse and fine-grained pyrite, pyrrhotite, and chalcopyrite the latter being more abundant than is commonly the case. A black copper oxide (melanterite ?) is present on the dumps of the property. A prominent pulaskite-porphyry dyke cuts through the property in a north and south direction just west of the shaft as well as a few smaller aplite dykes. Power was supplied by a 60-horse-power boiler and the property had a 3-drill air compressor, two power machines, a blacksmith shop, shaft house, and other buildings.

CLIFF-CONSOLIDATED ST. ELMO MINE.

The Cliff-Consolidated St. Elmo property is controlled by a local Rossland syndicate headed by Mr. L. A. Campbell. The Cliff claim, which is situated on the lower east slope of Red mountain one mile north of Rossland, was located in September, 1890, by Gay Ruder and has extra lateral rights. Immediately west of the Cliff the Consolidated St. Elmo claim was located in October of the same year (1890) by Will Springer.

In 1904, the Cliff was worked for a short time and 1,517 tons shipped, but so far the ore has proved to be of such a grade as to leave only a small margin of profit. The average analysis of the ore shipped in 1904 was: Ag 0·7 ounces, Au 0·23 ounces, Cu 1·4 per cent, FeO 27·0, SiO_2 30, Al_2O_3 12·8, CaO 7·0, S 13·0. In 1910 the Granby Consolidated Mining and Smelting Company acquired the property and did some diamond drilling.

The equipment of the Cliff included a 3-drill Ingersoll-Sargeant compressor and a 35-horse-power boiler. On the Consolidated St. Elmo there is a shaft 48 feet deep and a tunnel about 60 feet long which follows a slip plane along which is 5 feet of solid pyrrhotite and pyrite and some scattered chalcopyrite. Considerable sulphide ore is piled up near the shaft.

There is a well-defined vein on this claim dipping from 60 to 70 degrees north which can be traced nearly the whole length of the claim and is thought to be continuous through the St. Elmo Consolidated, St. Elmo, Mountain View, and the Monte Christo claims.

Much surface work has been done, but the surface ore, as a rule, carries only traces of gold. About the centre of the claim is a 45-foot shaft full of water, with several tons of ore at the top, and below in the hillside several open-cuts along the vein from which there has been taken high grade ore.

The ore-body was first encountered in a tunnel (No. 1 tunnel) 350 feet long, with 100 feet of crosscut. The first 90 feet was in solid ore of low-grade character ($8 to $9 per ton) and averaging 4 feet in width. A slip was then encountered which threw the ore 20 feet to the northwest where it continued for 65 feet, beyond which it is much broken and a small stringer of ore 2 to 10 inches wide is found running east and west.

One hundred and twenty feet lower down is tunnel No. 2[1] which was driven west on the same vein which dips 40 to 50 degrees north. The vein above is narrow and forked but becomes wider below this level. In a shaft there is good copper ore above, which is absent below. For 65 feet, the tunnel is all in a coarse-grained pyrrhotite, 21 feet wide in places, that assayed a few dollars in gold. A fault of 5 feet to the north was here encountered and then the ore shoot continued 90 feet farther, being in places 12 feet wide but also low grade. The vein pinched down to about 3 feet 80 feet farther in and then the ore seemed to become disseminated and lost in a zone of faults. Two main faults and several mica dykes were encountered in No. 2 tunnel. The faults have the tendency to shift the veins sometimes to the hanging-wall and sometimes to the foot-wall, whereas the dykes appear to cut through the veins without displacing their trend.

No. 3 tunnel, farther down the hill, is 65 feet south of No. 2 tunnel and follows a narrow vein not more than 3 or 4 feet wide with dip of 43 degrees north. The ore in the vein continues to a zone of faults and dykes where it is lost. Beyond the dykes a small streak of ore appears near the face of the tunnel consisting of massive pyrrhotite with some chalcopyrite and pyrite. The shaft was probably sunk on this 8-inch streak which is nearly vertical. On the surface the ore in this vein is from 1 to 2 feet wide.

The vein is either faulted between No. 2 and No. 3 tunnels or the No. 3 tunnel vein has no connexion with the vein first discovered. If the latter is the case and the first vein is the hanging-wall shoot and the second vein the foot-wall shoot then the two shoots are components of one vein with a width of about 65 feet and it might be expected that the two shoots would unite in depth. However, since undoubted faulting has taken place in this ground, it seems more probable that both belong to the same vein which has been faulted. The country rock of the mine is augite porphyrite, although the lower and eastern portion of the Cliff claim is underlain by diorite porphyrite and a small exposure of diorite porphyrite outcrops farther up

[1] Inaccessible in 1913 and 1914 on account of water.

the hill. The diorite porphyrite tongues appear to strike with the vein fissures and not as indicated on the geological map (Map 1002). The vein at the surface has both walls composed of augite porphyrite. The presence, however, of diorite porphyrite on the surface in the foot-wall country and the silicified character of the augite porphyrite in the neighbourhood of the vein point towards the presence of this favourable formation in depth. An intersection of the vein with diorite porphyrite in depth would be likely to bring in better values.

SOUTHERN BELLE.

Adjoining the Cliff-Consolidated St. Elmo on the north is the Southern Belle claim which has a small vein (one foot wide in places) with sulphide ore that runs as much as $20 per ton. There is a winze 50 feet deep sunk on a 2-foot mineralized zone. Another prospect shaft is sunk on a pyrite vein 2 feet wide with strike of south 77 degrees west, and dip 80 degrees north. This is the same vein disclosed in the lower tunnel and contains three bands of low grade pyrite 6 inches, 1 foot, and 2 inches in width respectively. The country rock is augite porphyrite.

ST. ELMO.

Adjoining the Consolidated St. Elmo to the west is the St. Elmo claim. Near the west end of this claim is a large prominent cliff exposure of a very quartzose rock (Mount Roberts formation)containing pyrite, pyrrhotite, zinc blende, and a little chalcopyrite, and deeply stained with red iron oxides. Just east of this exposure is a 100-foot tunnel driven to the northwest, in a fine-grained dioritic rock with much iron and copper pyrite disseminated through the mass. Nearer the east end is the main St. Elmo tunnel 225 feet long with a short crosscut. The tunnel is driven along an east and west wall from which sulphide ore containing some molybdenite, blende, and galena in calcite-quartz gangue was extracted. The zinc blende and pyrite appear to have crystallized simultaneously in the same veinlet. The country rock is in part mineralized Mount Roberts formation into which the vein peters out. Diorite porphyrite is also present.

A tunnel driven from the Consolidated St. Elmo, encountered at 140 feet a large body of fine-grained ore. In 1899 the end of this tunnel was still 140 feet east of the St. Elmo line. In 1908, 77 tons of ore were shipped from the St. Elmo property to the Trail smelter.

VIEW.

To the north of and adjoining the St. Elmo claim near the summit of Red mountain, is situated the View claim. A tunnel 45 feet long begins on a vein about 15 inches wide and follows southwest along a narrow width of ore that, in the face of the tunnel, widened to nearly 3 feet of mixed ore, consisting of pyrrhotite with a fair percentage of chalcopyrite. This ore shoot was further opened up by a shaft sunk 12 or 14 feet, in which are exposed two strong walls enclosing 5 or 6 feet of ore. Of this ore 15 inches is solid sulphide, picked specimens of which might assay 15 per cent copper. The country rock is Mount Roberts formation.

MOUNTAIN VIEW, PEAK, SAM HAYES FRACTION.

Adjoining the St. Elmo claim to the west is the Mountain View claim, on which it was reported in 1893 there was a vein 30 feet wide and 200 feet in length the ore of which averaged about $25 to the ton in gold. There is exposed in a small prospect tunnel considerable mixed ore. Below this exposure a main tunnel was being commenced in 1896. In this claim as well as in the adjoining Peak and Sam Hayes fraction the surface rock is heavily iron-stained, but very little work has yet been done to determine the extent of mineralization. The country rock is the Mount Roberts formation highly silicified and impregnated with iron.

GOOD FRIDAY.

The Good Friday claim is situated on Red mountain north of and adjoining the Mountain View claim. Development consists of about 950 feet of tunnelling and shafting. In 1896 when the property was being worked tunnelling cost about $16 per foot and shaft sinking $20 per foot. There are two short tunnels near a group of cabins. The lower tunnel which is near the base of the hill shows no ore, only a granitic rock. The upper tunnel is driven in a wide band of mineralized agglomerate similar to that on the Coxey claim. This band strikes in the direction of the Jumbo mine and contains pyrite, galena, and zinc blende. Some diorite porphyrite also outcrops on this property.

NORTHERN BELLE.

The Northern Belle claim is situated on Red mountain north of the St. Elmo and Peak claims. Two veins striking east and west are exposed on the property as well as a north and south striking vein which cuts the other two at right angles. The latter had been opened up between the east and west veins and was well marked.

WHITE BEAR MINE.

The White Bear claim is bounded on the north by the California property and on the east by the Black Bear claim of the LeRoi group.

Previous to 1898 the length of the shaft was 250 feet. It was well timbered. The total drifting amounted to 400 feet. There were crosscuts at the 100 and 200-foot levels which showed from 7 to 10 feet of vein matter. The mine equipment then included a 60-horse-power boiler, a 20-horse-power hoist, a 4-drill compressor, three Rand-drill machines, one station pump, and one No. 5 Cameron pump. Ten men were being employed.

In 1899 the main shaft was sunk to 368 feet and drifting amounted to 750 feet. By 1902 development had reached the 900-foot level. The barren Mount Roberts formation had been sunk through at 500 feet and diorite porphyrite and ore encountered. In 1904 the Consolidated White Bear Mining Company constructed an Elmore plant of larger dimensions than that of the LeRoi No. 2 Company. This plant included many labour saving devices.

In May 1905 the mine closed down, but resumed operations again in March, 1906. In 1907, the company located an ore shoot just west of the porphyritic monzonite which was 12 feet wide, consisting of almost solid pyrrhotite and chalcopyrite running 1 to 1·5 per cent copper and $2 to $3 in gold per ton. The Consolidated White Bear Mining Company closed down in the latter part of October, 1907, and has been idle ever since.

The mine workings were inaccessible during the field season of 1913. The following is an extract of a paper by Mr. H. H. Yuill on the White Bear mine[1] which gives a good synopsis of the development work done to date on this property:

"There has been a considerable amount of exploratory work done in trying to find the extensions of these [the LeRoi and Black Bear] veins. In 1902, when the present management took charge, a shaft had been sunk to 350 feet, and an aggregate of 1,000 feet of cross-cutting done on the 150-,200,- and 350-foot levels. These workings were all in a formation [Mount Roberts formation] in which none of the pay veins of the camp had been found, and, as no ore had been encountered, the company decided to sink the shaft deeper. At 420 feet they passed out of the overlying formation, which is an overflow of altered basic volcanic rock, into the porphyrite formation in which the pay ores of the camp occur. A station was cut at 680 feet, called the 700-foot station, and crosscuts were run easterly and westerly from the shaft.

In the westerly crosscut a low grade vein was found, which was called the 'West Vein.' It has a northwesterly and southeasterly course or strike. This "West" vein belongs to the second system of veins found in Rossland camp, that is, it is part of a different system from that to which the LeRoi and Black Bear veins belong, as the latter have a general southwesterly and northeasterly strike, practically at right angles to the West vein. The strike of the West vein corresponds very closely to that of the vein encountered in the Evening and Giant claims. It may be the southeasterly extension of one of these.

[1] Jour. Can. Min. Inst., Vol. XI, 1908, pp. 525-544.

In the easterly crosscut three veins were encountered: No. 1 and No. 2 were small and of low grade ore. No. 3 was a large vein of low grade ore with a few streaks of higher grade ore in it. These veins have the same general strike as the West vein (Figure 23) and undoubtedly belong to the same system although a contrary opinion was held by the consulting engineer of the company at the time of the discovery of these veins, November, 1902.

The mineralized fissure zone was thought at that time (1902) to be the westerly extension of the LeRoi and Black Bear veins.

The management. . . . . . sunk the shaft to 900 feet, cut stations at 800 feet and 950 feet, and ran crosscuts easterly and westerly as on the 700-foot level . . . . They developed the West vein, but, finding it to be very low grade, directed all their energies to locating the ore-bodies east of the shaft. The veins of the 700-foot level were found to continue to the 800- and two of them to the 950-foot level, but No. 3 was not located on the 950-foot level. Therefore, the management raised to the 800-foot level from where they thought ore should be if it were continuous and in place. At 900 feet they struck ore and ran a drift. The highest grade ore in the mine has been taken from this intermediate level.

The No. 3 vein (Figure 24) was picked up in the 950-foot level August 1, 1907, with ore of as good grade as in the intermediate.

The ore consists of country rock more or less impregnated by pyrrhotite, accompanied in places by small proportions of chalcopyrite, pyrite, arsenopyrite, and quartz. The pyrrhotite when it occurs by itself, even in solid masses, as it does in the 700-foot level, carries very little gold. The chalcopyrite is the principal carrier of gold, and ore of commercial value occurs only in those localities where chalcopyrite and pyrite, sometimes with arsenopyrite, have been deposited with the pyrrhotite.[1] In certain parts of the mine the ore carries some lime which slacks when exposed to the air.

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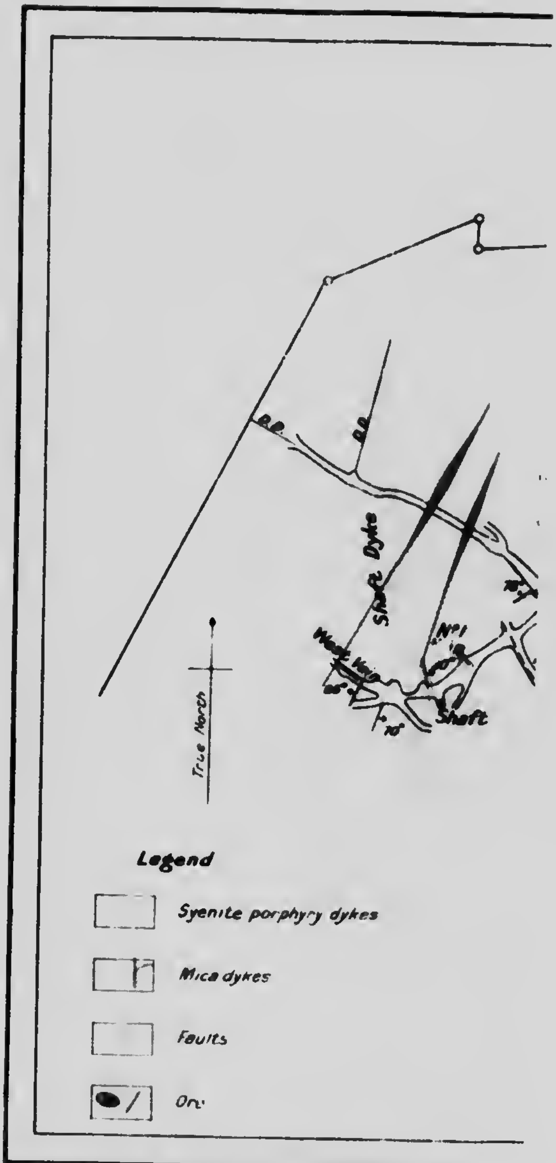
[1] The average analysis of 9 cars shipped in 1905 was: Ag 0·5, Au 0·2, Cu 1·6, FeO 16·0, SiO_2 43·0, Al_2O_3 13·0, CaO 6·0, S 7·0.



Geological Survey, Canada

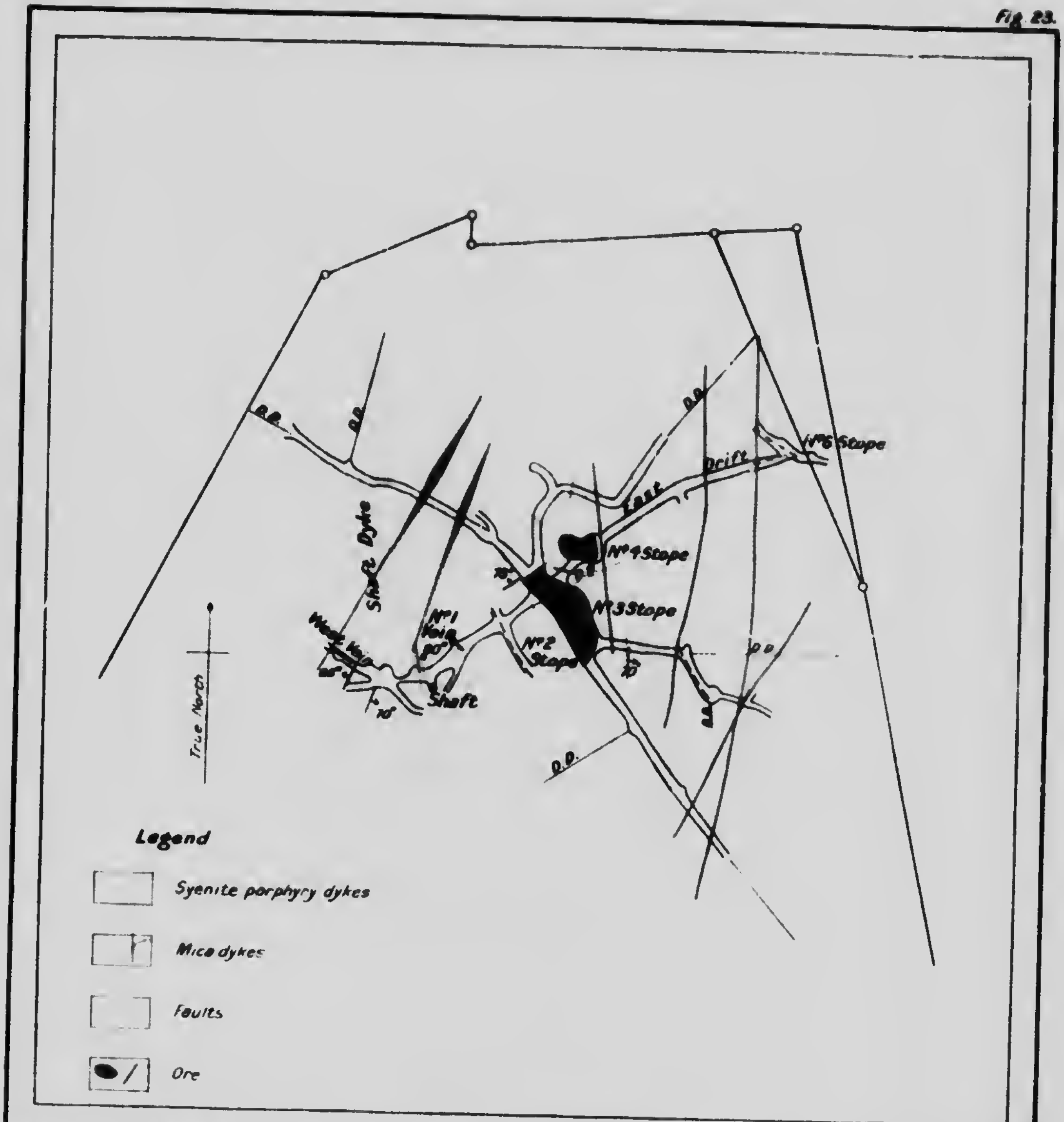
Plan of **850-foot level Wh**

Scale

0 100

To accompany Memoir by C W Drysdale

Fig. 23.



Geological Survey, Canada

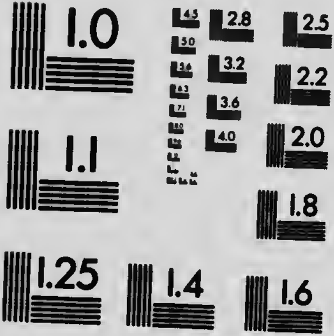
1550

Plan of 850-foot level White Bear Mine, Rossland, B.C.

Scale of feet

0 100 200 300 400

To accompany Memoir by C. W. Drysdale


1.0
1.1
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1.6
1.8
2.0
2.2
2.5
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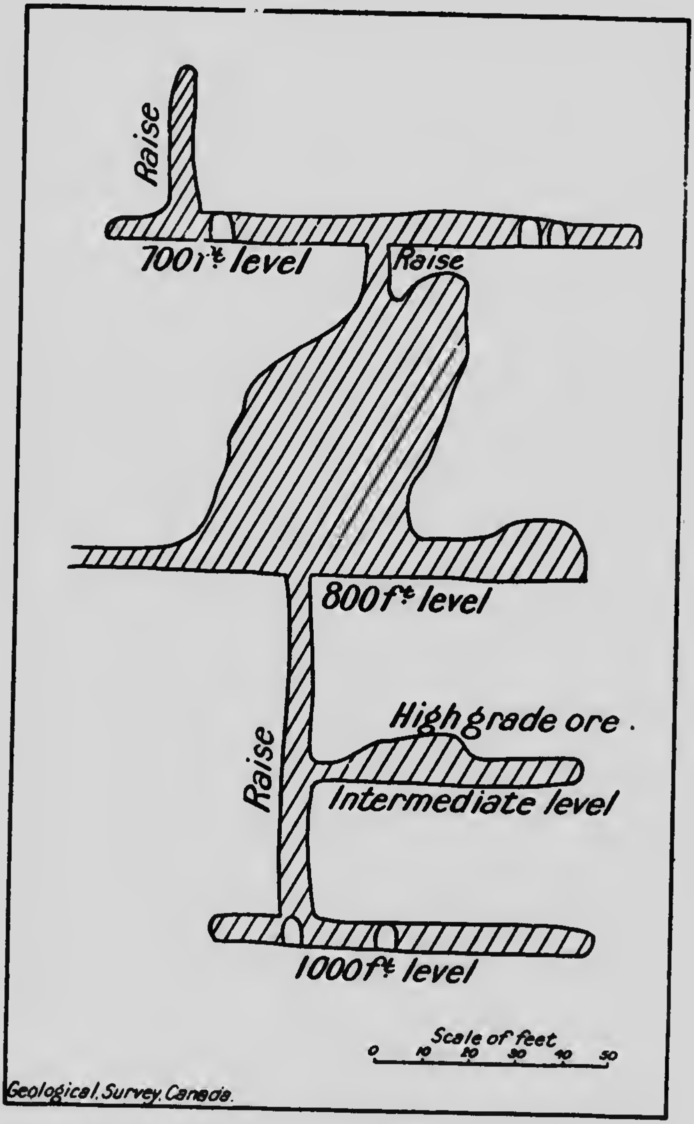

Figure 24. Longitudinal projection of No. 3 vein, White Bear mine, Rossland, B.C.

As is the case in all the other mines of the camp innumerable shattered zones and dykes are encountered, often accompanied by faults, which in some cases cut the ore off. Frequently, however, the ore continues right through the dykes. Two kinds of dykes are found: (1) the hard mica dykes which are mica lamprophyres. . . . . (2) the soft or black dykes, which are so greatly altered and decomposed that their identification is difficult."

SPITZEE MINE.

The Spitzee Mining Company was organized in 1905 as a reconstruction of the Spitzee Gold Mines, Limited, with a capitalization of $350,000, shares $5 par. The mine was worked for a short time by this company, but had to close down owing to lack of funds.

The Spitzee mine, which is situated in the middle of the town beside Trail creek, has produced to September, 1905, about 5,000 tons of ore averaging $12 per ton in values. In 1907 the property was bonded to the LeRoi Mining Company and a little diamond drilling was done. The LeRoi Company, however, failed to redeem the bond and the mine has been idle since 1908. The property is worked from a vertical shaft with 100-foot and 200-foot levels opened up from it. On the 100-foot level the stope ends against pulaskite. In the vicinity of the winze the pulaskite is slightly impregnated by sulphides near joint planes. A 6-inch streak of ore is present along the contact of the pulaskite and the monzonite. The monzonite is quite coarse-grained in places. Some of the mica dykes are faulted from 3 to 8 feet and composite mica and non-mica dykes are present. One dyke parallels the drift dipping to the north at an angle of 60 degrees and on it occurs 1½ feet of ore. Pulaskite is present on the 200-foot level at the shaft station and for 5 feet east of it. Elsewhere tongues of pulaskite cut the monzonite which is coarsely granular in places, as for instance in the north crosscut. Mineralization is present along joint planes.

The ore consists of veinlets, stringers, or impregnations of pyrite, pyrrhotite, and chalcopyrite traversing the country rock. The average analysis of ore from 200 cars shipped in 1906 was: Ag 0·5 ounce, Au 0·25 ounce, Cu 0·7 per cent, FeO 15·0 per cent, SiO_2 42·0 per cent, Al_2O_3 17·0 per cent, CaO 5·0 per cent, S 7·2 per cent. Small veins parallel or branch off from the main vein which varies a great deal in width and is cut by slip planes. The vein dips to the north at an angle of 60 degrees and in the south crosscut the pay streak varies from 15 inches to 2 feet in width. There is a certain amount of mineralization along joints in dykes and in the pulaskite, but the ground is not so well impregnated with ore as is the monzonite country rock.

GIANT-CALIFORNIA MINING COMPANY.

The Giant-California Mining Company was organized in 1907 as successor of the Giant Mining Company, Limited. The capitalization of the company is $5,000,000, shares $100 par, in $400,000 of 7 per cent preferred, and $4,600,000 ordinary stock.

Giant Mine.

The Giant mine is located north and west of and adjoining the California and Novelty claims (Figure 13). It has about 500 feet of workings and shipped 4,344 tons of ore, before suspending operations in 1903. In 1902, under the management of Mr. M. E. Purcell, good results were obtained from ore treatment and the operating expenses were paid by ore receipts after the shipments were started.

The Giant ore contains sulphides of cobalt, nickel, arsenic, iron, and molybdenite all with gold. The average analysis of ore from 100 cars shipped in 1903 was: Au 0·9 ounces, Cu 0·1 per cent, FeO 12·5 per cent, SiO_2 50·0 per cent, Al_2O_3 16·0 per cent, CaO 10·0 per cent, S 4·0 per cent. The strike of the vein is in a [illegible]erly and southerly direction with steep dip to the east. The country rock is Mount Roberts formation and the ore shoot is located on a contact of pulaskite porphyry (mica syenite porphyry) at the intersection of co-ordinate fracture planes striking nearly at right angles. The pulaskite porphyry forms the hanging-wall of the ore shoot in the upper part of the stope and the foot-wall in the lower.

CALIFORNIA MINE.

The California claim adjoins the Annie claim on the west and is 1,500 feet west of the LeRoi and Josie mines on the south slope of Red mountain. The mine has a 1,000-foot tunnel with a 200-foot winze, which is practically a blind shaft planned to be sunk to the 550-foot level. Also near the southern end of this claim is a 50-foot tunnel running north into barren country rock and higher up the hill are several shallow cuts and trenches.

The equipment includes a small hoist and 10-drill duplex Rand air compressor using electric power.

No. 1 tunnel was started on a pyritic vein following a contact between diorite and quartzite. This ore assayed from $1.50 to $3 per ton. The tunnel was driven 350 feet in on the vein crosscutting in one place a 6-inch streak of mispickel which carried no gold values. Some samples of this mineral ran 35 per cent arsenic. The main California tunnel is in the Mount Roberts formation whose stratified members are pronouncedly crossbedded in places (Plate X A). A prospect shaft was started on a vein striking north and south and dipping east, which is said to have assayed on the surface $60.50 per ton. The ore was followed for 35 feet when it played out. The quartzite of the Mount Roberts formation has specks of chalcopyrite disseminated through the mass and much pyrite. In places such mineralization is concentrated in definite bands 60 to 110 feet wide which as a rule follow the micaceous syenite porphyry dykes. This holds true for the Novelty, Coxey, Giant, and other properties underlain by the Mount Roberts formation.

In 1899, 78 feet of drifting was done on the California, a wagon road was constructed, and more buildings were erected at a cost of $4,300. Twenty-five men were employed on the property at that time. A Montreal syndicate operated it under an option for $50,000 and took out a small shipment of paying ore. The Bennett syndicate had charge for six months, the MacIntosh syndicate for two years, and then in the early part of July, 1907, the Giant-California Mining Company commenced operations but only woıked for a short time. Since then the Granby Consolidated Mining and Smelting Company had the property under option, and it is said spent over $80,000 in development, chiefly with the diamond drill, before throwing up the option. Of late years the property has been idle, although the California was leased for a few months in 1912 and 1913 when a shipment of ore was made from the dumps. In 1914 the LeRoi No. 2 Company took over the property of the Giant-California Mining Company.

On this property as on the White Bear it will be necessary to sink through the overlying cover of Mount Roberts sedimentaries before encountering favourable ore-bearing ground.

COXEY.

The Coxey claim is situated directly north of the Giant and has very similar geological conditions.

The development work consists of two tunnels, one shaft, and several open-cuts. In No. 1 tunnel the ground is much fractured particularly in the vicinity of the ore which consists of pyrite and chalcopyrite in a siliceous gangue. The best ore is present along a mica dyke and varies up to one foot in width. Chalcopyrite is present along several fractures forming in places irregular zones one foot in diameter which appear to dip to the west similarly to the vein at the winze. The fractures, however, are very irregular, and only a few are mineralized. Such surface enriched deposits may be of secondary origin. Shaft No. 1 discloses a well defined vein striking in a northerly and southerly direction and dipping to the east at an angle of 72 degrees. It follows the east wall of a syenite porphyry dyke. This vein carries some good copper values, the ore consisting of pyrite, pyrrhotite, chalcopyrite, molybdenite, the pyrite occurring in plates and dodecahedra. This vein should intersect the No. 1 tunnel near its mouth. In shaft No. 2 there is a little molybdenite and chalcopyrite.

No. 2 is the main tunnel and crosscuts through slightly mineralized cherty and biotite-bearing rocks of the Mount Roberts formation until it encounters a mineralized fissure zone with sulphides best developed near the fissure. The mineralization continues to a set of dykes and from there to the end there is little or no ore present.

The mineralized zone or vein is very siliceous and carries pyrrhotite, molybdenite, a little chalcopyrite, and considerable pyrite. The sulphides also occur as impregnations in the country rock. The country rock in the vicinity of the vein is much altered to garnet, and occasionally epidote is present in streaks or blotches. Mica and non-mica dykes are present in the tunnel. The banded rocks of the Mount Roberts formation dip to the southwest.

The south crosscut follows a slip plane and the country rock is brecciated and calcified with slight mineralization in the slip plane itself. The north crosscut also follows a slip plane on its east wall with one foot of vein matter developed in it. This mineralization was strong for a few feet east, but played out to the west and is entirely absent in the face of the short crosscut.

A tongue of diorite porphyrite outcrops on this property and may be traced for considerable distances. The strike of the western border of the diorite porphyrite tongue in contact with the Mount Roberts chert formation is north 30 degrees west.

NOVELTY.

The Novelty claim is a fraction bounded by the following claims: on the west by the Giant, the north by the Coxey, the east by the Gertrude, and the south by the California.

Most of the development work on this claim was done prior to 1896 and consisted of several open-cuts and prospect shafts which disclosed three veins. The main vein was opened up the whole length of the claim and assays of the ore obtained from it ran as high as $28 to the ton in gold. The ore is very similar to that on the Coxey and contains molybdenite in the filling of a shattered granodiorite.

GERTRUDE.

The Gertrude claim is located north of the California and Annie claims and adjoins on the east the Novelty claim. It was staked by Will Springer, July 28, 1890, and $14,134 has been expended on it in development work and buildings.

The main workings consist of a tunnel and prospect shaft, the latter dipping 70 degrees east and containing very little ore. The country rock is Mount Roberts formation underlain probably on the east side by augite porphyrite. The stratified rocks of the Mount Roberts formation strike south 20 degrees west and flatten up a little toward the centre of the tunnel and become more highly inclined near the shaft. There is a little mineralization in the vicinity of a granitic dyke. At the shaft where the granitic rock appears there are a few streaks of ore along bedding planes and in the granitic rock itself. There is a fault near the entrance of the tunnel, but it was impossible to determine the amount of the throw. Seams of calcite are present. The ore on the dump consists of pyrrhotite, chalcopyrite, pyrite, and arsenopyrite with a little molybdenite.

EVENING STAR.

The Evening Star claim owned by the Evening Star Gold Mining Company was originally located by John McKinley and Chas. Dundal in September, 1890. It is a 20-acre claim situated on t[illegible]e of Monte Christo mountain between the Monte C[illegible] Georgia claims and one mile north of Rossland. [illegible]e cobaltiferous mispickel, danaite, was found on th[illegible].

The claim which is mainly underlain by Mount Roberts formation has a large exposure of much decomposed rock through which two veins appear to run. The main vein, which is wide and irregular, strikes about north 43 degrees east (magnetic) and contains ore consisting of arsenopyrite and pyrite with a little chalcopyrite. The wall rock is a cherty silicified rock of the Mount Roberts formation and through it the ore occurs in bunches and reticulating masses. Considerable stoping has been done and two open-cuts disclose a strong vein of pyrrhotite and chalcopyrite which lines up with the main vein. In 1896 the mine shipped 22 tons of surface ore to a Tacoma smelter which netted $32.80 in gold per ton according to statement made by Mr. H. B. Nicholls, secretary-treasurer of the company. A tunnel (Old Cronin tunnel) was at that time run into the vein matter for 50 feet, but without meeting ore. A shaft was then sunk above the mouth of the tunnel, but at 15 feet the vein flattened out to the horizontal. Work was then resumed in the Old Cronin tunnel and a few more feet disclosed a small stringer of ore, carrying molybdenite, and free gold in quartz gangue. This stringer widened out to a considerable width, and had a dip of 45 degrees to the west. Some of this ore was reported to assay as high as $1,600 per ton. The average ore ran about $20 per ton, is highly siliceous, and carries a fair percentage of both iron and copper. Sylvanite, the gold telluride, was also reported. Sixty feet below this tunnel a second tunnel was driven which was expected to encounter the ore at 135 feet. Eleven men were being employed in 1896. In 1897 some more ore was encountered, but the mine had to close down on account of lack of funds. In 1898, 260 feet of drifting, 85 feet in the upper tunnel and 175 feet in the lower, was accomplished. A new ore shoot 4 feet wide and 20 feet long, as exposed by drifting, was reported as being encountered in the upper tunnel. This ore is said to have averaged some $24 per ton in gold. After encountering this ore shoot, drifting was begun in the lower tunnel which is 60 feet below, to cut the same ore shoot. In 1908, the property was leased and 877 tons of ore shipped to the Trail smelter.

JUMBO MINE.

The Jumbo claim, which was recorded by A. D. Coplen, September 3, 1890, has an area of 21·6 acres and is located 2½ miles west of Rossland on the west bank of the east fork of Sheep creek. This property was owned and operated by the Jumbo Gold Mining Company of Spokane.

W. A. Carlyle reports on the property in 1896, as follows: "On this claim is a very prominent exposure of iron-stained fine-grained eruptive rock with more or less decomposed sulphides in which a shaft was sunk showing some low-grade ore, and afterwards a tunnel was run in about 260 feet with about 125 feet of crosscuts. For 150 feet there was no ore, then the tunnel entered and continued for near' ; 90 feet in a body of very low grade, coarse-grained pyrrhoutte. in which, however, there is ore containing some copper pyrite, mispickel, and calcite that carries enough value in gold to make it shipping ore. No ore has yet been sold. A good wagon road, 1½ miles long, has been built from where the Red Mountain railway intersects the Northport road up to the mine, and a new tunnel is now begun about 200 feet north and 175 feet below the upper tunnel described, and as this advances, crosscuts will be run. The trend or conditions of this large body of sulphides are not known, but immediately to the west is what appears to be a large dyke of very coarse-grained syenitic rock from 200 to 300 feet wide, strike north and south. (Seven men were being employed in 1896.)

Near the claim the *High Ore* is being prospected by a tunnel at the north end line of the Jumbo for the continuation of the Jumbo ore shoot, while across the creek the *Nevada* is also running a tunnel in search of the same."

In 1897 work progressed a id much more low grade material was disclosed. In 1899, 500 feet of tunnelling was accomplished. In 1904, the mine shipped about 12,000 tons of ore to the Granby smelter at Grand Forks, B.C. In 1905, the Jumbo was working a small force of men and making regular shipments. The mine was suppiied with steam and electric power, compressed air, etc., and the company planned on b· ''ng a 6,000-foot areal tram from the mine to the Columbia and 1 Mountain railway. In 1906, the mine operated until Marc.. 10, when it closed for 2 months and then operated until August 1 and closed for the remainder of the year. After operating for several years and after shipping about 30,000 tons, the mine shut down in 1906 and has been idle ever since, having extracted the known ore.

The vein ranges up to 30 feet and more in width and is developed both underground, and on the surface by open-cuts. The ores carry from $7 to $20 per t n in gross values; the pure pyrrhotite only runs $4 per ton, but where syenite dykes cut through the vein the gold values are reported to have run up to $600 or even $1,000 per ton. The siliceous ore carries the values and the presence of a blotched sparry rock is a good indication of values. Fine-grained syenite or aplitic dykes are closely connected with the rich pay streaks and such dykes are in places impregnated with or have in seams sylvanite (?) pyrite, pyrrhotite, chalcopyrite, bismuthinite, and free gold. Pegmatitic facies in places also have bismuthinite and octahedra of pyrite in reticulating and branching veinlets, lenses, and irregular impregnations about one inch in length.

No. 1 tunnel of the Jumbo has at its entrance a small dyke of syenite in contact with a mineralized white, siliceous chert rock (Mount Roberts formation). The same rock is present in the stopes but with chlorite, mica, and other secondary minerals developed and pyrite or pyrrhotite scattered through in pin points. In other localities the vein is almost all sulphides. The dykes of aplite or syenite are intrusive into the vein at low angles and are themselves mineralized. They appear to make rich pay streaks. On the hanging-wall of the vein there is a gneissic rock that often contains free gold, bismuthinite, and other sulphides impregnated in the rock or more generally along seams in close proximity to the aplite dykes. Telluride of gold has been reported from the aplites. Tourmaline occurs along seams in the country rock. The fault which forms the west end of the glory hole runs through the rich stope and to the south drift. Dykes of syenite may be seen in the glory hole. The ore in it contains a large percentage of pyrrhotite most heavily developed on the south wall. Ore from the winze drift ran $29 and from the long crosscut $10 to $12 per ton. The alkalic syenite (pulaskite) is in the 'backs' or roofs of the west stopes. The stope on the southeast side, which is of low-grade ore, discloses syenite dykes cut by slip planes. Along these planes masses of pyrrhotite are developed up to several inches in width which are in turn cut and faulted by slips. There appears to be a tendency for the western blocks all through to be dropped down. An intermediate tunnel connects with what is known as the "molybdenite stope" which lies along the eastern edge of the alkalic syenite (pulaskite) intrusive. Here, there is a series of slips mineralized with pyrrhotite and impregnated with molybdenite; some of the latter mineral is in the syenite itself.

The No. 2 tunnel of the Jumbo commences in a cherty siliceous rock more or less mineralized with pyrrhotite. A grey granitic rock is also present much altered in places and cut by a diamond-drill hole near the north crosscut. This granitic rock contains a few bands or inclusions of the quartzose rock. There is one prominent mica dyke and beyond that the tunnel is in the alkalic syenite (pulaskite). The country rock is chiefly the grey to green siliceous member of the Mount Roberts formation which is reddish where mineralized. The altered bands in it are usually narrow with pyrite seams down the centre. The south wall of this tunnel is more altered than the north and a dyke of syenite cutting the Mount Roberts formation is pyritized.

No. 3 tunnel of the Jumbo traverses a fine, grey, argillaceous member of the Mount Roberts formation containing a little pyrite, also a soft reddish micaceous member, and a calcareous member dipping at a high angle to the north. The almost vertical contact, between the calcareous rock and the alkalic syenite, is mineralized with molybdenite, arsenopyrite, tellurides(?), bismuthinite, chalcopyrite, pyrite, pyrrhotite, and tourmaline. The country rock at the contact is much shattered and the alkalic syenite appears to have corroded it.

GOLD HILL.

The Gold Hill claim northwest of the Jumbo mine was located in 1894 and on it a fair sized vein of high-grade ore outcrops. A 50-foot shaft was sunk and 10 tons of ore shipped which it is said averaged 100 ounces of silver to the ton. A crosscut tunnel was driven 350 feet west from a point farther down the hill to intersect this vein in depth, but without success. The face of this tunnel is in a light-brown spotted rock containing quartz blebs, the same rock that is present at the upper tunnel. At the upper tunnel, however, it was cut by quartz stringers or veinlets containing pyrrhotite and some calcite along with the quartz. Drusy cavities are present in the veinlets. The country rock is black argillite (Mount Roberts formation) with some coarser, banded, brown rock resembling an ash bed or tuff. The stratified rocks strike parallel to the hill side or north and south, and dip west at high angles. An agglomerate is present containing fragments that resemble the rocks from Red mountain. The eastern portion of the Gold Hill claim is underlain by a syenite porphyry (pulaskite) which may be traced 600 feet up the hill.

DELAWARE.

The Delaware claim is located directly northwest of the Gold Hill claim. The country rock is a banded siliceous stratified formation with agglomerate on both sides of it. Brownish and yellowish garnet and green epidote are present as secondary minerals. The agglomerate is mineralized along seams with pyrite and a little chalcopyrite.

WALLINGFORD GROUP.

This group of claims consists of the Wallingford, Minnie, Minnie No. 1, Summit, and Wallingford Fraction comprising 100 acres of crown-granted land and 60 acres not crown-granted. The claims are situated in Wallingford basin on the north slopes of Record mountain.

The development work, so far as done, is all on the Wallingford, and comprises 200 feet of tunnelling, and 54 feet of shafting (40 feet in No. 1 shaft and 14 feet in No. 2 shaft).

The ore contains gold, silver, and copper. The country rock is a pink syenite (pulaskite) intrusive into andesitic lava beds, tuffs, and agglomerates. Seven men were employed in 1897.

ATLANTIC CABLE.

The Atlantic Cable claim is situated southwest of the Gold King and Jumbo claims. Previous to 1898, the development work comprised 27½ feet of shaft well timbered and 55 feet of shaft straightened and retimbered; also 122 feet of crosscut and drifts from tunnels driven in the hillside at 100- and 200-foot levels. Power was supplied then by a California horse whin. On an average, four men were employed. Work was suspended in 1898.

Several tons of siliceous ore are on the prospect dumps containing siderite and pyrrhotite in an altered slate gangue. One shaft which dips 70 degrees west is over 200 feet deep in Mount Roberts silicified argillite.

O. K. AND I. X. L. MINES.

The O. K. and I. X. L. properties are the only free-milling properties in the Rossland camp. The O. K. was located by John Y. Cole, June 1892, and the I. X. L. by Thos. Heady, May 1891. The claims are situated on the south slope of Mount Roberts, off the Northport road 2½ miles west of Rossland. The O. K. claim is owned by the O. K. Gold Mining Company.

Traversing the claim is a regular gold-quartz fissure vein striking a little south of east, 2 to 3 feet wide, and carrying a goodly percentage of iron and copper sulphides and galena as well as the copper carbonates malachite and azurite. The ore assayed $178 and $200 per ton and upwards. Mr. W. F. Ferrier found 2½ ounces of gold in 6 square inches of ore. The average ore, however, would run about $38 per ton. An average analysis of ore from part of a car shipped was: Ag 0·85 ounces, Au 4·85 ounces, Cu 2·5 per cent, FeO 13·6 per cent, SiO_2 53·0 per cent, CaO 5·0 per cent, S 7·1 per cent. The country rocks are fine-grained eruptives, serpentine, and sericite schists. The serpentine is probably an altered basic phase of the augite porphyrite.

In 1893, a tunnel extended 100 feet and from it there was a raise of 70 feet. The vein had an average width of 4 feet. In 1894, the tunnel was extended another 100 feet, an upraise of 70 feet made, and 250 tons of ore were shipped. During September, 1893, the three owners of the mine by means of a hand mortar alone extracted $4,000 in one week. In 1894, 125 feet of tunnelling was done and a 5-stamp mill erected. A gold brick from the O. K. mill valued at $2,000 was sent to Spokane the same year. In 1896, the property had three tunnels, one about

70 feet long, the second 400 feet, and the upper nearly 300 feet. The tunnels are closely spaced vertically as the vein appears to flatten out. When the upper tunnel was in 96 feet a break and cross ledge were encountered which interfered with the development for a time. The break was successfully passed, however, and the vein found as true as ever on the other side. The vein presented the usual characteristics, varying much in width from a few inches to 5 or 6 feet of ore. In it considerable stoping had been done.

The ore went to a small 5-stamp mill, where the free gold was amalgamated; thence to concentrators, a Perfection bumping table and a Woodbury machine, to recover the sulphides. The erection of a new mill was commenced in 1896, to contain at first two 5-stamp batteries, two Blake crushers, automatic feeders, and concentrators. In the engine room two 40-horse-power boilers and a 5-drill Rand air compressor, for operating rock drills, and a diamond-core drill were to be installed. It was planned to bring ore from the mine by a gravity car tram, 600 feet long and dropping about 200 feet, while the water for the mill would be pumped up with a steam pump from Sheep creek. It is stated that ore to the value of about $20,000 has been taken from this mine.

In 1904, the I. X. L. was operated under lease for some time and 600 tons of ore were put through the O. K. mill at a loss to the lessee. In 1906, the O. K. and I. X. L. furnished very rich gold-quartz ore from a vein in serpentine, but the vein does not reach the lowest level. Sixty-five tons were milled before the lease was thrown up. In 1908, the I. X. L. shipped 6 tons, valued at $500; and in 1909, 21 tons from the I. X. L. and 12 tons from the O. K. were shipped to the Trail smelter. In 1911, 97 tons were shipped. Sheriff R. L. Evans leased the I. X. L. in 1912 and shipped 12 tons running about $60 per ton. A small shipment was made in 1913 by lessees.

The two lower tunnels on the property are caved, as well as the main tunnel which is full of water for about 200 feet in. The upper workings are accessible; here the quartz vein has been well stoped out and appears to flatten. The ore is very rich, but in small pockets.

EUREKA.

The Eureka claim is situated between the I. X. L. and the California mine. On the property there is a vein of quartz outcropping on the east side of Little Sheep creek which carries pyrite and a little molybdenite and chalcopyrite. The vein matter weathers very readily forming cellular quartz. Pyrite is present in cubes and octahedra and resembles in colour marcasite. The pyritized fracture planes have a general north and south trend. A tunnel driven below fails to disclose the downward continuation of the vein. The country rock is Trail granodiorite.

GOLD KING.

The Gold King claim is situated due north of the I. X. L. on the slope of the main valley. Several quartz showings on which a little work has been done, are present. The country rock is stratified (Mount Roberts formation) and is cut by a granitic dyke probably altered syenite. The stratified rocks are brecciated by faults and calcified—the calcite developed as a binder in long hexagonal crystals terminated by rough nail-head-spar (rhombohedra).

FLOSSIE.

The Flossie claim adjoins the Gold King to the south and is also underlain by the stratified rocks of the Mount Roberts formation, intruded by feldspar porphyry dykes (pulaskite) and impregnated with pyrite in such a manner as to give rusty outcrops. There are two tunnels: one in the northern part of the claim on the east side of the creek, which strikes north 60 degrees west and is 175 feet long; the other tunnel is west of the creek. The last 25 feet of the first tunnel is in a grey alkalic syenite (pulaskite). Boulders of this formation were found on the property to contain inclusions of the stratified Mount Roberts formation, which display pronounced absorption rims up to 3 inches.

VELVET-PORTLAND MINES.

Although not within the area of the Rossland map-area the Velvet-Portland mines will be described here on account of their proximity to Rossland, the similarity of their ores, and the amount of development work that has been done on them.

The Velvet-Portland property is situated 6½ miles southwest from Rossland on the northwest slope of Sophie mountain in the valley of Big Sheep creek opposite Santa Rosa creek (Plate XXIII B). It is 9¼ miles by wagon road to the Great Northern railway siding.

O. Geldness and Jeff Lewis were the original locators. Olans Geldness located the Velvet claim on September 12, 1896, for Jefferson Davis. The Portland was located by John Cromie on April 3, 1896. A good outcrop of copper-gold ore was discovered in 1897 while doing assessment work just 300 feet from the end line of the Triumph claim. In 1897 an English company represented by Sir Chas. Tupper secured the Velvet and other claims on Sophie mountain (Bluebell, Triumph Whoo-up, Last Chance, and Velvet Fraction). In 1899 development on the Velvet claim consisted of 564 feet of drifting, 460 feet of crosscutting, 55 feet of sinking, and 75 feet of raising. About 25 men were being employed. On the Portland property 250 feet of drifting, and 147 feet of sinking were done, 12 men being employed. In 1902, the operating expenses were paid out of the ore receipts after shipments were started. The ore was shipped to the Hall smelter at Nelson. The old company spent over £20,000 in development. The shaft was sunk to the 300-foot level, with levels at 100 feet, 160 feet, and 250 feet. At these respective levels there were drifts 300 feet, 250 feet, and 100 feet in length. The total amount of underground development was 2,000 feet. Work was suspended in 1903 and the management changed.

At a distance of 1,450 feet down the hill from the top of the shaft a tunnel was opened for the purpose of driving in at a depth of 300 feet or thereabouts, with a view to draining the mine. In 1904, the Velvet-Portland Mining Company constructed a small concentrating plant using straight water concentration. The plant included two crushers, six gravity stamps, six steam

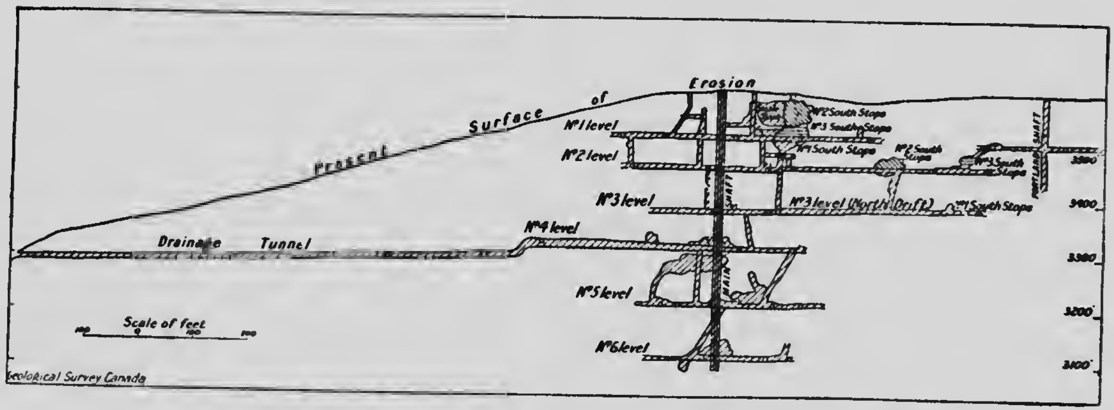

Figure 25. Longitudinal (north and south) projection through Velvet mine, Rossland, B.C.

stamps, five Jenckes concentrating tables, sacking and loading platforms for the concentrates and scales. With the exception of a three-days run of the mill no work was done at the Velvet during 1905. The mine was operated for a few weeks and employed 15 men during the early part of the summer of 1906. On the 4th level 260 feet of drifting was accomplished in 1906, of which 110 feet were in ore. The work had to be suspended,

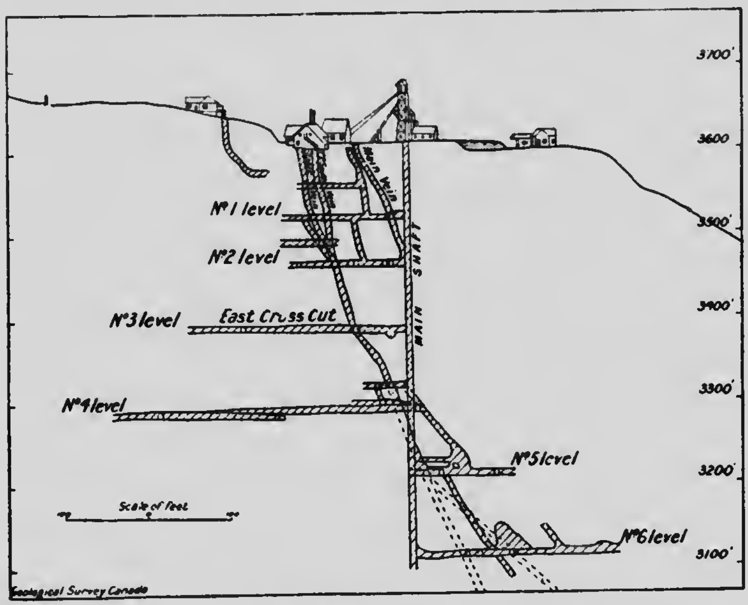

Figure 26. Transverse (east and west) projection through Velvet mine, Rossland, B.C.

however, on account of lack of funds. In 1909, 188 tons of ore were shipped and in 1910 the property was leased to Ed. Ehrenberg of Spokane who shipped 664 tons of good grade ore. At present the cost of transportation, including the long haul to the railway, is so great that the property could not be profitably worked. The size and shape of the ore shoots and extent of mine workings are shown in the accompanying longitudinal and transverse sections (Figures 25, 26).

Samples analysed by the LeRoi No. 2 Company, from a 2-foot vein of solid ore on the No. 3 level of the Velvet mine, ran as follows:

Gold	0·61 ounces.
Silver	2·39 ounces.
Copper	13·30 per cent.
Iron	27·60 per cent.
Silica	26·60 per cent.
Sulphur	19·80 per cent.

A general sample of advancing face[1] on No. 4 level from a vein of indeterminate width gave the following results:

Gold	0·52 ounces.
Silver	0·30 ounces.
Copper	0·60 per cent.
Iron	16·70 per cent.
Silica	46·50 per cent.

A sample from the sill of No. 3 level ran 1·00 ounce in gold, 0·60 ounce in silver, and 1·00 per cent copper; another sample assayed 0·19 ounce in gold, 1·21 ounces in silver, and 2·90 per cent copper; another piece with more sulphide than the preceding, ran 0·80 ounce in gold, 1·60 ounces in silver, and 3·70 per cent copper. The cost of drifting at this mine amounted to about $16 per foot.

The fissure veins, which are replacement veins with wall rocks impregnated for some feet, strike north and south parallel to the main dyking system and dip to the west at steep angles. There are many dykes cutting through the ore-bearing ground some of which are pulaskite (alkalic syenite) tongues (aschistic or undifferentiated dykes) from the underlying Coryell batholith and others complementary dykes (diaschistic or differentiated dykes). The dykes invariably show pronounced chilled borders and all the enrichments in the veins occur either alongside such dykes or at the intersection of slip planes. The most productive area in the mine and the one most cut up by dykes is that south of the Main Velvet shaft. The upper three levels are in a zone of marked oxidation which appears to extend in places down to the 4th level. Good sulphide ore running $12 per ton up to 48 inches in width, but averaging 24 inches, occurs on the 4th level.

[1] This face was being worked when the mine was closed down.

The average content of the ore which was drifted on for 110 feet before the mine was closed down, ran 0·58 ounce in gold, 0·73 ounce in silver, and 1·9 per cent copper. The values in the ore fluctuate very rapidly; in some localities running high in gold and low in copper and in others the reverse is true.

Besides the main north and south vein there are a few east and west striking veins that so far have proved short and unimportant. The country rock is a mottled grey irruptive rock, with coarse siliceous and chloritic phases, which is much epidotized in places. There is also a severely altered, silicified, eruptive rock. Serpentine and altered chloritic rock with which magnetite is associated, are also present in depth and tapped by diamond-drill holes. The 75-foot shaft on the Portland claim is in greenstone belonging to the Rossland Volcanic group which is much pyritized, silicified, and broken by slip planes. It was impossible to examine below the 4th level on account of water.

The topographic conditions of the mine are very favourable for crosscut tunnelling. The shaft collar is 1,240 feet above the creek bottom and the valley slope is so steep that the 600-foot level of the mine could be tapped by a tunnel driven 1,600 feet in from a point farther down the hill. A 1,200-foot level in the mine could be tapped by a 2,700-foot crosscut tunnel. There is plenty of good cedar and fir timber convenient to the property for mining purposes.

LORD ROBERTS.

The Lord Roberts claim is situated at an altitude of 5,350 feet above sea-level near Rock creek on the divide between Sullivan and Murphy creeks, a few miles north of Rossland. The property is owned by S. Forteath and M. McIver. Outcropping on this claim is a vein some 30 feet in width striking east and west and dipping steeply to the north. Magnetite is developed on the south side of the vein and pyrrhotite on the north side. An upper trench opened up on the vein discloses a fine-grained dyke of micaceous syenite porphyry (pulaskite porphyry) which follows the hanging-wall. Besides the bluish massive magnetite and pyrrhotite there is considerable pyrite, epidote, hornblende, feldspar, and garnet present in the vein. A pegmatite vein 3 inches wide cuts through the ore in a horizontal direction. About the middle of the claim are two open-cuts 30 feet or more in length, which expose a vein containing magnetite and pyrite on the south side and pyrrhotite and about 0·2 or 0·3 per cent chalcopyrite on the north side. Magnetite and pyrite are most abundant near the foot-wall and pyrrhotite and chalcopyrite near the hanging-wall.

The lowest shaft exposes magnetite, pyrrhotite, pyrite, bismuthinite (?), and chalcopyrite in a quartz-hornblende-feldspar gangue. The ore is in some places banded. This large deposit of magnetite is interesting as representing a Boundary Creek type of contact deposit in the immediate vicinity of Rossland. The deposit is close to the contact between the Trail granodiorite and the Rossland Volcanic group (augite porphyrite) with stratified rocks, including limestone.

GREEN MOUNTAIN.

Green Mountain claim is located on the north slope of Red mountain off the map-area about halfway between Sheep and Stony creeks. The property has been opened up by several crosscuts across the entire length of the claim. Development work comprises one 35-foot tunnel, a 65-foot tunnel, and an 80-foot shaft. The equipment in 1898 included a steam plant, machine shop, shaft house, and other buildings.

CHAPTER VI.

DESCRIPTION OF MINES—SOUTH BELT.

The South Bel' properties, which may be said to be all still in the prospect st..ge of development, will be described in their alphabetical order as follows: Abe Lincoln, Bluebird, Crown Point, Curlew, Deer Park, Florence, Gopher, Grand Prize, Hattie, Homestake, Mayflower, Maid of Erin and R. E. Lee, Monday, Phoenix, Richmond-Lily May group, Sunset, and Trilby.

Abe Lincoln.

The Abe Lincoln claim is located on the east slope of Deer Park mountain adjoining the Sunset and Phoenix claims to the east. It is owned by the Canadian Consolidated Mining and Smelting Company who acquired it in 1912.

There is an old shaft 197½ feet deep on the property with an 18-foot crosscut all full of water and inaccessible. The power for sinking this shaft was supplied by a horse whin. Stringers of pay ore were encountered in the workings. On the surface a small east and west striking vein, three-fourths of an inch wide, containing pyrite, pyr..)tite, and a little chalcopyrite, was noted. The country rock is monzonite much of which is coarsely granular. A wide granite porphyry dyke (Sheppard granite) outcrops not far to the north and west of the workings.

Bluebird Mine.

The Bluebird claim adjoins the Homestake to the south. The Columbia and Western railway passes through the centre of the claim. In 1908, 159 tons of ore were shipped from this p[illegible]rty; in 1909, 30 tons; in 1911, 52 tons; in 1912, 107 tons; [illegible]913, 53 tons; and in 1914, 38 tons, all by lessees.

The property which is owned by the Rosalia Mining Company is developed by a [illegible]aft striking south 76 degrees west and dipping north at an angle of 70 degrees, which follows the vein. It was reported that the first 97 feet of the shaft showed from one to 2½ feet of solid ore running east and west with no apparent structural foot-wall. The shaft is down between 200 and 300 feet and connected by a crosscut tunnel driven in below the railway track. The first 90 feet of this tunnel is in altered augite porphyrite; then for 35 feet it is in Mount Roberts chert, the augite porphyrite appearing again with inclusions of chert. In this tunnel at the foot of the shaft is disclosed a strong vein striking east and west and dipping steeply to the north. The length of the ore shoot is about 30 feet.

The vein varies in strike but has a general tendency to strike towards the Mayflower property. It is only a few inches wide, has an almost vertical dip, and consists of pyrite, zinc blende, galena, and fine white metallic needle-like crystals of stibnite often arranged in groups crossing or radiating from a centre. Galena and pyrite containing about 6 per cent zinc are associated with some stibnite, siderite (?), and mispickel or arsenopyrite. The pyrite is fine grained and in cubes and octahedra; the arsenopyrite is also in the usual prismatic crystals. The pyrite, arsenopyrite, and zinc blende are the most abundant minerals and together form probably 50 per cent of the ore. Quartz is the principal gangue mineral.

Twenty-five feet south of the shaft is a small vein from which several cars of similar grade ore were shipped. One hundred and fifty feet to the north of the same shaft is another vein from which a carload of carbonate ore running about $28 per ton was shipped. The country rocks include augite porphyrite and Mount Roberts cherts with some altered bands of limestone. One car of ore shipped in 1908 from the Bluebird mine netted $80 per ton; the average value, however, was $35 per ton. This property was unwatered early in 1915 with a view to doing further development work.

Crown Point Mine.

The Crown Point claim was recorded by Jas. Maher, August 20, 1890, south of Trail creek, on the north slope of Lake mountain, 2½ miles southeast of Rossland.

A wagon road one-half mile long connects the mine with the Columbia and Western Railway track from which a spur could easily be brought to a point below the main tunnel. This tunnel in 1896 was driven 350 feet to tap the ore shoot 150 feet west of the dyke, and 170 feet below the surface. In 1896 the Crown Point, Hidden Treasure, and White Star properties, all in this vicinity, were sold to Gooderham, Blackstock, and Struss for, it was reported. $350,000.

In 1905 the property was leased for 3 months but closed down on September 15. In 1906 the Canadian Consolidated took over the property and operated it for a few weeks during the months of May and June. They shipped 367 tons of the ore to the Trail smelter for fluxing purposes. Until April, 1895, the Crown Point was under different management, under whose direction a shaft or incline, with a dip of about 50 degrees, was sunk 130 feet. The shaft encountered at 60 feet a pinkish syenite dyke (pulaskite) which outcrops on the surface and is 30 to 40 feet wide, striking north and south, and dipping to the east at an angle of 60 degrees. This dyke contains phenocrysts of orthoclase up to one-half inch in diameter and displays a pronounced chilled border and flow structure. The pulaskite dyke is later than the ore and cuts it off. The lower workings consist of a drift at the depth of 70 feet, extending for 90 feet along the dyke, and having ore for 60 feet; while at 50 feet a winze was sunk 20 feet deep again along the wall of the dyke. At the bottom of this winze it was claimed there were 4 feet of solid sulphides averaging from $30 to $60 per ton in gold. The shipping ore averaged about $35 per ton. At the bottom a drift was run west 100 feet to a 50-foot crosscut, and an east drift of 75 feet was run with a 50-foot crosscut, all in barren diorite, the workings having probably been deflected from the ore zone by following along the pulaskite dyke. When the surface iron capping was removed there was exposed on either side of the dyke, apparently with little or no displacement, a body of massive pyrrhotite with some copper pyrites, 3 to 8 feet in width, striking a little north of west, and dipping south into the mountain at an angle varying from 45 to 60 degrees. At the top of the shaft the ore is about 7 feet wide, and down it for 35 feet it is 3 to 5 feet wide, whereas it is fully 7 feet wide where it was stoped out.

The Crown Point ore shoot is a typical Rossland type, occurring as it does along the border of a diorite porphyrite tongue intrusive into augite porphyrite. The hanging-wall is diorite porphyrite and foot-wall augite porphyrite. The crosscut tunnel does not disclose the vein nor the diorite porphyrite because the more recent pulaskite dyke intersects the tunnel just where the diorite porphyrite and vein would project. The average analysis of ore from 11 cars shipped in 1905 from the Crown Point mine to the Trail smelter was: Ag 0·3 ounce, Au 0·5 ounce, Cu 0·6 per cent, FeO 33·5 per cent, SiO_2 26 per cent, Al_2O_3 12 per cent, CaO 7·5 per cent, S 14·3 per cent.

Curlew.

The Curlew claim is south of and adjoins the Bluebird and is southwest of the Mayflower. The Columbia and Western railway traverses the northeast corner of the claim. The vein is considered to be a continuation of the Mayflower vein. The country rock is augite porphyrite and Mount Roberts formation. In 1908, 7 tons of ore were shipped to the Trail smelter. The property was leased in 1912 by S. Forteath and B. Oliver.

Deer Park Mine.

The Deer Park claim is located on the east side of Deer Park mountain 1½ miles southwest of Rossland. It has an area of 52 acres and is owned by the Deer Park Gold Mining Company.

The ore is pyrite and pyrrhotite occasionally massive but more often mixed with 50 per cent by volume of rock matter. A great deal of green actinolite in fibrous radiating masses and magnetite is associated with the ore. The presence of these minerals, the apparent lack of vein structure, and the position of the ore deposit on a monzonite contact, suggest that the deposit belongs to the contact metamorphic type. The mass of sulphide ore, which is one of the largest in the district, has a 60-foot vertical shaft (5 feet by 7 feet in the clear) sunk in it and a 47-foot crosscut all in very low-grade massive pyrrhotite. There is 46 feet of almost solid magnetite carrying a little copper and a trace of gold. In the bottom of the shaft in 1896 the ore was showing some change in that some chalcopyrite and streaks of quartz were visible in the solid mass of pyrrhotite, a fact which was thought might indicate an approaching improvement in the grade of the ore. The quartz which had molybdenite associated with it is said to have assayed from $10 to $100 in gold, averaging about $16 per ton. The veinlets of quartz increased in size with depth. The bottom of the shaft (about 95 feet deep), is in this type of ore which carries along with the molybdenite some iron sulphides. Arsenopyrite and pyrite crystals, the former in places twinned, were found in one of the open-cuts on this property. The high values appear to be with the molybdenite. The country rock is biotized augite porphyrite in contact with monzonite.

In 1898 development consisted of sinking the vertical shaft 112 feet deeper down to a depth of 305 feet, and drifting 290 feet as follows: 173 feet on the 200-foot level (including a winze 22 feet deep); 97 feet on the 100-foot level; and 20 feet on the 150-foot level. The shaft was sunk in mineralized rock the entire distance and encountered two pay-ore bodies, the first 5 feet wide and the second 2 feet wide, both below the 200-foot level. A drift on the 200-foot level is said to have disclosed considerable low-grade ore. A 7-drill air compressor plant, an 80-horse-power boiler, and two air drills, costing $5,500, were installed in 1898. The mine employed at the time 15 men and development work was advanced rapidly.

The ore-body on the 200-foot level was found to be about 20 feet wide with high-grade streaks 2 feet wide and extending north about 30 feet and south an indeterminate distance, the whole averaging about $18 per ton. The same ore-body was encountered on the 150-foot level. There are several dykes traversing the ore-bearing ground some of which are spessartite dykes with large phenocrysts of hornblende and biotite crystals one-half inch in diameter. The country rock on the 200-foot level appears to be spotted with white on account of the kaolinization of feldspar in the underlying monzonite. There is one foot of fair ore along the contact of the actinolite bearing rock (altered augite porphyrite ?) and the monzonite. A lower prospect shaft is in brecciated biotized porphyrite in a cement of quartz and pyrite. The quartzose ore on the property contains mostly pyrite and some arsenopyrite with a little calcite. The quartz is a coarse white saccharoidal variety and there is very little chalcopyrite present in the ore. Pyrrhotite and pyrite were found continuous in the same veinlet. The main workings have very little brecciated ore like that in the lower shaft and have magnetite intermixed with the sulphides and actinolite.

Florence.

The Florence claim is situated in the bottom of Trail Creek valley just north of the R. E. Lee and Maid of Erin claims. On it is a small prospect shaft and several open-cuts or strippings which show pyritized monzonite containing occasional inclusions of altered porphyrite.

Gopher.

The Gopher claim which adjoins the Homestake to the east was recorded by Joe Michaud August 6, 1890. It is owned by the Homestake stock company.

The Gopher tunnel traversed a slaty rock severely broken and traversed by slip planes. A little mineralization is present at the beginning of the tunnel on the south side near a dyke, although the vein itself is on the north side. An agglomerate also occurs which contains many granitic rock fragments and towards the face of the tunnel the slaty rocks of the Mount Roberts formation appear. No fast lines can be drawn between the ash rock, the porphyrite agglomerate, and the granitic agglomerate, all three appearing to grade into one another up to the "main fault." The dominant trend for the master joint planes and slips is north and south.

Grand Prize.

The Grand Prize claim is located north of and adjoining the Deer Park claim on Deer Park mountain.

Two prospect shafts of 25 and 38 feet, respectively, have been sunk on this property. Three men were being employed in 1898. The country rock is monzonite.

Hattie.

The Hattie claim is situated northwest of and adjoining the Richmond claim.

Little work had been done on this property up to 1912 when the Richmond Consolidated Mining Company took it over. A little pyrite occurs in veinlets throughout the stratified rocks of the Mount Roberts formation. Augite porphyrite and monzonite also outcrop on this claim. The main vein opened up strikes east and west, is 3 inches wide, and dips from 85 degrees south to vertical. Ore from a prospect pit on this vein where the country rock is monzonite is said to have assayed $12 in gold and 3·2 per cent in copper.

Homestake Mine.

The Homestake claim was staked and recorded by Joe Morris (probably Maurice) and Bordeau in May 1890 and was one of the earliest locations in Rossland, being only second to the Lily May itself. It has an area of 21·3 acres and is located three-fourths of a mile south of Rossland on the Columbia and Western railway. In 1896 the property was under bond to the Homestake Gold Mining Company.

The ore is iron pyrites and marcasite (?) ("white iron") with some copper pyrite and zinc blende in a calcite, quartz, and altered country rock gangue. The average analysis of ore from four cars shipped in 1903 was Ag 2·8 ounces, Au 0·04 ounce, Cu 0·3 per cent, FeO 24·7 per cent, SiO_2 38·7 per cent, CaO 5·1 per cent, S 10·5 per cent. The vein strikes east and west, dips 70 degrees to the north, and may be traced for nearly 700 feet through the claim by means of open-cuts and trenches. A tunnel runs in a considerable distance but is not on the vein, whereas at the mouth is a small shaft said to be all in ore. Galena is present on the dump. A short distance east are two shafts, 75 feet apart and connected by a drift, one being 90 feet deep. In these workings is ore, of which about 100 tons were on the dump, 50 or 60 feet from the tramway.

In 1898 a shaft was sunk 110 feet and 630 feet of drifting and 29 feet of crosscutting were accomplished. The mine was worked intermittently during a portion of 1902, 18 men being employed. In 1905, the property was leased for several months but closed down in the autumn. Fourteen tons of ore were shipped in 1908 and the old owners of the property sunk a shaft near the east end of the claim to a depth of 16 feet and disclosed 2 feet of good ore in the bottom.

The workings at present consist of a 105-foot surface tunnel not connected with the main shaft; 100 feet of workings on the 100-foot level connected with the surface by an old 50-foot shaft; 220 feet of workings, on the 200-foot level; and an adit tunnel 1,920 feet long on the 300-foot level. All the above workings with the exception of the surface tunnel are connected with the main shaft.

The vein strikes north 80 degrees west and dips steeply to the north. The ore is pyrite, pyrrhotite, and a little chalcopyrite. On the 200-foot level, 100 feet west of the shaft, is a fault zone 25 feet in width. West of this main fault the rock is agglomerate, but the granitic boulders are not very noticeable and a lot of fine "ash" rock or tuff is present. The vein is 6 feet wide with two bands of sulphides, one 9 inches in width on the foot-wall and the other 1½ feet on the hanging-wall. Ore from the Homestake runs high in silver and some samples are said to have assayed up to $132 and $150 per ton in silver. There is present in the upper workings of the Homestake augite porphyrite agglomerate with many granitic fragments, the latter becoming more prominent in depth. There is considerable granodiorite present on the 300-foot level. Spessartite dykes are found on the 200-foot level one of which forms the hanging-wall of a heavy sulphide vein.

Mayflower Mine.

The Mayflower claim is located one mile south of Rossland on the Columbia and Western railway and is owned by Spokane people. It was staked in 1899 and ore obtained from it ran as high as 120 ounces in silver and $12 per ton in gold. In 1895 a tunnel was driven 50 feet exposing a vein 3 feet wide which ran 40 ounces in silver and $8 in gold. In the spring of 1896 the excavation of the railway grade exposed a new vein hitherto unknown. Work upon this vein disclosed a body of galena and carbonate ore for a distance of 400 feet. A tunnel 40 feet long was driven from the grade of the railway on this vein and galena and mispickel assaying from 30 to 200 ounces of silver per ton and as high as $20 in gold were reported. The tunnel at track level was advanced to 100 feet in length in 1896. The vein opened up in the tunnel, strikes east and west and dips from 70 to 80 degrees north. For 30 feet in the tunnel the ore was oxidized, then the solid fresh ore was encountered composed of iron pyrites with a large proportion of galena as well as some zinc blende in a calcite gangue. The chief values are in silver. In a shipment which netted $56 per ton, $40 of that amount was in silver, $10 in gold and $6 in lead.

The vein varies in width from a few inches to 3 feet, strikes north 60 degrees east, and can be traced for a considerable distance through the claim. A parallel vein to the north has been more or less developed. A winze was sunk vertically near the mouth of the tunnel which runs in from the railway track and at 15 feet the ore is reported to have averaged 200 ounces in silver and carried the usual amount of gold. On the surface near the shaft house the vein is 4 inches wide. The vein is opened in the first couple of cuts up the hill, but after that the trenches are evidently off the vein. The winze was sunk deeper and the ore was found to widen to 3 feet on the hanging-wall. Assays of this ore showed aggregate value in gold, silver, and copper of $100 per ton.

The ore is very similar to that of the Bluebird mine but more massive. Blende, galena, a little arsenopyrite in crystals, pyrite, and pyrrhotite occur in the ore which in places is well banded. The country rock is augite porphyrite and the stratified members of the Mount Roberts formation. In 1908, 36 tons of ore were shipped to the Trail smelter. In 1911 Martin Daly and R. Hooper leased the property and did work on a parallel vein outcropping below the railway track.

MAID OF ERIN AND R. E. LEE.

The Maid of Erin and R. E. Lee claims are situated immediately east of the Mayflower and Gopher claims about one mile south of Rossland on the Columbia and Western railway.

The principal work has been done near the centre of the dividing end line of the two claims; as on the R. E. Lee, there is a 30-foot tunnel with a 20-foot drift, in the floor of which can be seen 2 or 3 feet of mixed ore in a lead running east and west (south 68 degrees west) and dipping to the north at 60 degrees. The vein is striking towards the Homestake and is probably the same vein. About 50 feet west of the 30-foot tunnel but on the Maid of Erin, is the main shaft, 74 feet deep, with a level at 50 feet, running 47 feet east, and a crosscut 24 feet north. The ore is fine-grained mispickel or arsenopyrite, pyrrhotite, and pyrite with some chalcopyrite and zinc blende. The values of the ore have not been ascertained, but it was reported that from 12 tons taken from the tunnel the net smelter return was $458 in gold for the lot. About 500 feet south of the lead a 30-foot shaft is sunk in a second vein of mispickel, 2 to 14 inches wide, said to assay well in gold, and dip and strike the same as the main vein.

MONDAY.

The Monday claim adjoins the Homestake claim to the west.

A shaft is sunk on a vein striking north 56 degrees east with dip 75 degrees north. There are about 6 tons of ore on the dump, composed of heavy pyrrhotite and pyrite with a little chalcopyrite. The country rock is monzonite which is in places impregnated with sulphides, and where that is the case, the chalcopyrite appears to be more abundant than in the heavy sulphide vein itself.

Southwest of this shaft and about 100 yards distant is a prospect pit exposing much low-grade sulphides.

Phoenix.

In 1912 Messrs. Whiteford and Trewhella obtained a lease on the Phoenix claim which adjoins the Abe Lincoln and Sunset claims (Figure 13). They uncovered a vein 2 feet to 4 feet wide having 6 to 18 inches of gold-copper ore in each wall. A shaft was sunk 30 feet and 94 tons of ore averaging $25 a ton were shipped.

Richmond-Lily May Group.

The Richmond-Lily May group of claims (about 100 acres) is owned and operated by the Richmond Consolidated Mines Company, Limited. The group includes the following claims: Lily May, Richmond, Black Horse, Sunbeam, Hattie, Dewdrop, and Alice D. The Lily May, on which most of the work has been done, has an area of 13·87 acres. It is located 1¼ miles south of Rossland on the Dewdney trail. This is the oldest claim in the camp, having been located in 1889 by Jos. Bourgeois but recorded in 1890 by Oliver Bordeau. It was one of the principal mines in the district in 1890 and had a 4-foot vein disclosed in a 30-foot shaft striking northwest by southeast and dipping 50 to 60 degrees to the northeast. The ore carried about 80 ounces of silver to the ton, picked samples running up to 180 ounces. A tunnel striking north 55 degrees east is driven about 50 feet below in which the vein is exposed for nearly the whole length of the tunnel except where interrupted by faults or dykes. Solid sulphides are present, 8 inches wide near the entrance, which widen to 2 feet near the shaft and narrow again at the face. The dip of the vein on this level is 53 degrees north. The country rock, which is stratified and altered, sedimentary and eruptive rock of the Mount Roberts formation, is either impregnated with pyrite and blende (dark brown) or the sulphide is present in veinlets traversing it. The Mount Roberts formation has a north and south trend with dip of 35 degrees westward. Galena and stibnite also occur in the ore which has a quartz gangue. To the south and also to the north prospect shafts and trenches point to the existence of parallel veins on this property.

On February 1, 1899, the ownership of the claims was transferred to a new company called the English-Canadian Company. At that time the equipment consisted of an 80-horse-power boiler, 5-drill air compressor, two machine drills, and a blacksmith shop. The total development work amounted to 485 feet. Nine men were being employed.

The property was leased for a short time in 1905 and closed in the autumn. It remained idle from then until 1912 when the present company acquired the property. During the summers of 1912 and 1913 active development work was undertaken under the management of J. L. Warner and nine buildings were erected. Twelve tons of ore were shipped from the Lily May as a sample shipment in 1912. The ore ran $32 per ton in silver, lead, and gold. The equipment of the property now includes a 22×14×18 inch Sullivan (class W.J.) air compressor driven by a 200-horse-power induction motor, a Washington Iron Works 8×10 inch hoist with friction break driven by compressed air, all well housed under one roof. The incline shaft has been enlarged and timbered and level stations put in. A No. 6 Cameron pump handles the water at the bottom of the shaft and a small Northey pump lifts the water from a dump in the drift. Considerable surface trenching and stripping of veins on the Richmond claim was done recently and some of the best showings were found to be near the monzonite contact and at dyke intersections elsewhere.

SUNSET.

The Sunset claim is situated southeast of and adjoins the Abe Lincoln claim. The road to the Richmond-Lily May and other South Belt properties passes through the property.

There is an 80-foot shaft on the property sunk on a 6 inch vein of sulphide ore. In 1908, nineteen tons of ore were shipped to the Trail smelter. Several tons of this heavy sulphide ore are lying on the dump. The ore is massive pyrrhotite and magnetite with a fair amount of chalcopyrite intermixed in a quartz and altered monzonite gangue. Several hundred feet of work has been done in the Sunset tunnel and there is visible much pyrrhotite with a very little chalcopyrite. The country rock is monzonite.

Trilby.

The Trilby claim is situated east of the R. E. Lee and in the southeast corner of the map-area. It is owned by Messrs. MacDonald, MacDonnell, Costello, and Murphy. The property was developed by three shafts on the vein in the early days and considerable drifting was done from one of these shafts. This shaft was recently pumped out to see what ore there was in the bottom workings as very little was known about the property.

PART II.

PART II.

CHAPTER I.

PHYSIOGRAPHY.

INTRODUCTION.

The following brief description of the physiography of Rossland and vicinity is intended for readers interested in land forms and their physiographic development. The treatment is, of necessity, very inadequate on account of the short time allotted to this subject in the field. The physiographic material obtained, however, will be presented here with the hope that the facts recorded and the suggestions and correlations made, may aid future workers in this field and possibly may throw additional light on some of the broader phases of British Columbian physiography.

The practical bearing of physiography and erosional processes upon certain problems, not only in general geology but also in economic geology[1], is becoming increasingly felt among mining geologists. Furthermore, topographic and geographic facts may be more readily understood and remembered if their origin and reasons for existence are given.

The inferences upon which the conclusions are based regarding the origin and history of the Rossland land forms have been drawn from a comparison of the Rossland topography with that of other better known physiographic provinces, from the character and structure of the underlying rocks, and from evidence as to the amount of work accomplished during present and previous periods of erosion. It is here that physiography largely overlaps structural geology. A natural and satisfactory classification of land forms and decisions as to the types of mountains, valleys, and plains present cannot be formulated until the geological history of the region has been ascertained.

[1] Spencer, A. C., Trans. Amer. Inst. of Min. Eng., Oct. 1904, Umpleby, J. B., An Old Erosion Surface in Idaho: Jour. of Geol., XX, No. 2, 1912, pp. 129-149.

DESCRIPTION OF TOPOGRAPHY AND STAGE OF DISSECTION.

REGIONAL.

The Rossland district lies within the Columbia Mountain system—a system extending from the Columbia lava plains in Washington northward to the Great Bend in the Columbia river about 80 miles north of Revelstoke, British Columbia. The system grades imperceptibly westward into the lower, more subdued topography of the Interior plateau. The boundary line between the two topographic units has been placed by R. A. Daly[1] along the Thompson river, Adams lake, and the Westkettle river in British Columbia, whereas in Washington it is determined by the lower Okanagan valley. Eastward, the Columbia Mountain system grades into the more lofty and rugged alpine topography of the Selkirk mountains. It is separated from the latter by the Great Selkirk valley within which lie the Arrow lakes and a stretch of the Columbia river.

The Columbia system includes the Rossland mountains, the Christina range, the Midway mountains, and other subordinate ranges which trend in a general north and south direction and are in places separated by deep longitudinal valleys here and there occupied by lakes.

The Rossland mountains are bounded on the east by the Selkirk valley (Columbia river) and on the west by the meridional valley occupied by Christina lake and the lower Kettle river.[2]

LOCAL.

The Rossland mining camp is situated at an elevation of 3,400 feet above sea-level on the lower rocky benches of Red and Monte Christo mountains immediately east of a low divide (*col*)[3] between the Trail Creek drainage basin or modified cirque and the deep valley of Little Sheep creek to the west. The

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[1] Daly, R. A., "The Nomenclature of the North American Cordillera": Geog. Jour., Vol. 27, June, 1906, p. 588.

[2] Daly, R. A., Memoir No. 38, Geol. Surv., Can., 1912, p. 319.

[3] A term used to designate a common form of crest-line in glaciated mountains. It is a concave curve (theoretically a hyperbola) formed by adjacent cirque glaciers cutting down a crest-line from opposite sides and lowering it at their points of tangency.

mountains, Tamarack (4,420 feet A.T.), Deer Park, Red, Monte Christo (4,250 feet, A.T.), and Columbia and Kootenay (4,080 feet A.T.), which surround the Trail Creek cirque and on whose lower slopes the mines are located, are a series of round-topped hills rising from 800 to 1,500 feet above the level of the town (Plate XXV).[1] They are furrowed by gullies and gulches which owe their position in many cases to the soft character of the underlying rocks. The Centre Star and Josie gulches which follow wide mica lamprophyre dykes are of this character (See stereograms, Map 146A, in pocket).

Effect of Glaciation upon Topography.

The hill slopes and summits bear evidence, in the presence of glacial striæ, and smoothed and polished surfaces, of having been overridden by ice which has scratched, smoothed, and softened the contours of the pre-Glacial topography. Erratic boulders and drift were left stranded high on the uplands upon the retreat of the glacial ice. In dealing with the present land surfaces, therefore, it must be remembered that they represent a combination of normal and glacial forms. Although glaciation has obscured in a few places, particularly in the deeper valleys, pre-Glacial topographic features, it has not entirely obliterated them. The upland pre-Glacial surfaces which had a thin cover of ice as compared with the deep valleys, have been least modified and the summits above, approximately the 6,600-foot contour, were never buried under ice but stood as islands or "*nunataks*" above the ice sheet. Regarding the glaciation of this region, Daly writes: "From the Columbia river to the Similkameen river, a distance of 100 miles, the mountains crossed by the Boundary are at only two places high enough to show the maximum height of the ice-cap. The one locality is Record Mountain ridge and its northern continuation toward Old Glory mountain. The other favourable locality is at Mt. St. Thomas and the ridge running southward from it. The usual criteria for both ridges showed that the general cap did not submerge any slopes higher than the present 6,600-foot

[1] Refer to West Kootenay Map Sheet No. 792: or Map 81A accompanying Memoir 38.

contour. Observations made on Mt. Chopaka just west of the Similkameen river, showed that the upper limit of the ice was there at about the 7,200-foot contour. The surface of the cap thus slowly declined from the Okanagan range to the Columbia river at an average rate of 6 feet to the mile.

The ice-cap was about 4,500 feet deep over Sheep Creek valley, Christina lake, and the Kettle River valley. The maximum thicknesses in the Boundary belt, about 6,300 feet, were to be found over the Osoyoos Lake and Similkameen River valleys. The average thickness throughout the 100 miles was about 3,000 feet.

The average directions of ice-movement across summits were, for the Rossland, Christina, and Midway mountains, about S. 20° E."[1]

The upland slopes of the Columbia Mountain system have in places been severely sculptured by alpine glaciers, but not to the same extent as in the Selkirks where the glacial cycle of erosion, in many places, dominates the topography and renders the determination of the physiographic history difficult.

Older Upland Topography.

Within the restricted limits of the Rossland map-area there are no broad flat upland facets suggestive of remnants of an older uplifted and dissected surface of erosion or *peneplain*. The topography, on the other hand, presents all the features characteristic of one period of normal and glacial erosion which had reached a mature stage of topographic development prior to regional uplift and the incisement of Sheep and Trail creeks.

A summit view, however, from Lake mountain or any other eminence above 5,000 feet in elevation, displays gently flowing summit topography, presenting a relatively even sinuous sky line (Plate XXIV). Surmounting this rolling upland country occur, here and there, residual *monadnocks* or higher mountain peaks, as for instance Old Glory mountain (7,792 feet A.T.) 7 miles northwest of Rossland (Plate XXV). The mature topography in the vicinity of Rossland lies below this summit

[1] Geology of North American Cordillera: Geol. Surv., Can., Memoir No. 38, p. 589.

upland although the tops of Red, Tamarack, and Columbia-Kootenay mountains almost attain its height. Around the immediate vicinity of Rossland, therefore, erosion has reached beyond the mature stage of topographic development, the divides are rounded instead of flat hill tops, and the streams are steadily falling off in efficiency as sculpturing agents. The accompanying photograph (Plate III) taken from the Velvet mine on Sophie mountain and looking up the valley of Big Sheep creek, shows the older upland surfaces and flat interstream areas as well as the younger, entrenched valleys separated from the former by "topographic shoulders or unconformities."[1] Above the change of slope is the older cycle surface; below is the younger.

The uppermost surface of erosion is only present in a comparatively few of the highland areas, having been in most cases, as around Rossland, maturely dissected and all traces of it obliterated. The mature and even late mature upland surface which lies below the summit surface, on the other hand, covers vast stretches of territory and is quite separable from the remnants of the upper and older surface of erosion. The upland slopes are in places thickly mantled with morainic drift and glacial erratics; but the upland valleys do not bear evidence of such powerful glaciation as do the lower and younger entrenched valleys where the ice confined between the valley walls had greater head and concentrated power to smooth and modify the pre-Glacial forms.

Younger Valley Topography.

Beneath the upland surfaces are deeply entrenched, smooth walled, U-shaped valleys whose lower courses are smooth and well glaciated. The longitudinal valleys whose courses most nearly corresponded to the direction of the old ice stream show signs of more intense glacial scour than do the transverse valleys. Along the valley sides may be seen facetted spurs, tributary hanging valleys, and alluvial cones. The upper portions of the valleys are corrugated and head in broad glacial amphitheatres or cirques.

[1] A term to indicate the break of slope involved in a two-cycle topographic system.

The larger valley bottoms are partially filled with fluvio-glacial materials which are in the form of terrace steps sloping gently toward the rivers. The terrace steps or "bench lands," which rise from several feet to in some cases several hundred feet above the level of the rivers, are very fertile and yield good crops of fruits and vegetables.

Post-Glacial Gorges and Ravines.

Small canyons or gorges and ravines varying from several feet up to several hundred feet in depth are in places sharply incised below the younger valleys as for instance in Little Sheep Creek and Trail Creek valleys. The gorge in Little Sheep Creek valley at the O. K. mill grades into a veritable canyon at Silica and continues as such for considerable stretches.

Such gorges and ravines whose whole widths of bottoms are as a rule fully occupied by the streams bear no evidence of glaciation. They are probably due to the normal attempts of the streams since the retreat of the valley ice, to cut down their channels to grade. The glacially denuded headwater regions supplied but little waste for the streams to carry down. With such consequent reduction in waste supply and only moderate reduction in volume of water the streams incised gorges and ravines where formerly they had built up outwash plains.

DIFFERENT HYPOTHESES OF PHYSIOGRAPHIC DEVELOPMENT.

In explanation of the above relief and erosional features a one cle, two-cycle, or three-cycle hypothesis of physiographic development may be advanced. The term *cycle* is here used not in the sense of a completed cycle but for a period of erosion during an episode of crustal stability. When regional uplift takes place a new river history commences and such erosion intervals are usually spoken of as *erosion cycles*. Interruptions due to diastrophic movement may take place at any stage in a cycle of erosion and as the late Professor James Geikie stated "it is doubtful if any region of uplift has ever passed through a complete cycle of erosion."[1]

[1] The Origin of Mountains: by James Geikie, p. 281.

ONE-CYCLE HYPOTHESIS.

The hypothesis of a one-cycle development has been advanced by Daly not only for the Rocky Mountain system proper but also for the Purcell, Selkirk, and Cascade ranges. He states "......the one-cycle hypothesis, whereby only one major episode of deformation (the Laramide) and one erosion-cycle (including all of Tertiary time) are postulated, seems competent to explain the present topography."[1] Concerning the physiography of the Bonnington-Rossland mountains, Daly writes as follows:

"This field of relatively old, deformed volcanic rocks and of batholithic intrusives may be conveniently treated as a physiographic unit. Its local base level is the Columbia at about 1,350 feet above sea; the mountains are generally under 6,000 feet with one notable peak, Old Glory mountain, reaching the height of 7,800 feet. With few exceptions the whole region is heavily forested.

This region may be described as somewhat past maturity of dissection. Horns are extremely rare: graded slopes are the rule, with contours and profiles generally well rounded. Nearly all of the Boundary belt has here been glaciated, with the resulting smoothness of angles under the ice-cap both by erosion and, in places, considerable deposition of a drift veneer. The ice-cap has, however, dc[illegible] to effect the pre-Glacial, late-mature character of this [illegible] landscape. The summits are relatively low here not o[illegible] because the rocks have wasted somewhat more rapidly than in the more easterly ranges but more especially because the rocks of the Rossland district were not lifted nearly so high as those of the Nelson range at least.

The drainage history is largely undecipherable. The general arrangement of the streams suggests, however, the hypothesis that the original form of the thick Rossland volcanic pile controlled it in some measure, though consequent drainage down the slopes of the orograph[illegible]cks of Laramide date must have also been developed. Too little is known as to the bed-rock structure in the region to give certain clues on these ques-

[1] Geology of North American Cordillera: Geol. Surv., Can., Memoir No. 38 (1912) p. 609.

tions. Western Sheep creek and the Christina Lake valley are apparently located on meridional faults and may represent the erosion channels of consequent streams originally formed on the down-thrown blocks near the fault planes. The western two-thirds of the Coryell batholith is drained by streams in such courses as to suggest that this part of the drainage system is a direct result of the greater "hardness" of the batholithic mass as compared with the country-rocks. That is, in this region the drainage once existing on the batholithic cover has been locally replaced by drainage which is centrifugal from the batholith because erosion has lowered the softer rocks all about. Such streams are not consequent on the initial relief of the batholithic cover but are consequent on the intrusion of the batholith, as well as subsequent to the beginning of the erosion cycle affecting the cover. To indicate the composite character of this kind of drainage the writer has proposed the adjective, "subconsequent."[1] The Coryell area does not furnish a very good case of subconsequent streams, in the sense that it is still difficult to prove such origin for them; yet there can be little doubt that the batholithic syenite is harder than the schists and volcanics round about. The course of the Columbia river at the Forty-ninth parallel is an open problem. It is locally superposed on the Trail granodiorite but almost nothing is known which gives a detailed notion as to the origin of the valley in the batholithic roof.

Among the many physiographic details of these mountains only one will be here mentioned—the well-known system of terraces of the Columbia valley. Simple as these gravel benches are in appearance, their complete history cannot yet be written. Much field-work needs to be done on each side of the Boundary and for hundreds of miles up and down the river, before the facts are sufficiently accumulated."[2]

Under such a one-cycle hypothesis, in which the mountains are assumed to be tectonic mountains of Laramide revolution age, consequent drainage would be expected with lack of adjustment of streams to hard and soft rocks (subsequent drainage).

[1] Geology of Ascutney mountain, Vermont, Bull. U. S. Geol. Surv., No. 209, 1903, p. 11.
[2] Op. Cit. pp. 613-614.

The reverse is the case and the writer found no evidence in the vicinity of Rossland of consequent drainage. There is evidence however for subsequent drainage in the upper portion of Sheep creek (page 36) and tributaries of Trail creek (page 177). Furthermore the manner in which the Columbia river meanders independently over various rock terranes, transverse in one river stretch to the regional structure and with it in another, is highly suggestive of an antecedent river[1] whose course has been inherited from an ancient sluggishly flowing river meandering over a peneplain which has since been uplifted and deeply dissected.

Under the one-cycle hypothesis in which the original tectonic mountains have reached a post mature stage of topographic development a gently rounded upland would be expected grading imperceptibly into the valley topography and lacking any pronounced breaks in slope. This is not the case as may be seen in the photograph (Plate III). Furthermore, the one-cycle hypothesis fails to explain the pronounced topographic shoulders or unconformities which are to say the least very suggestive of a more than one-cycle origin.

TWO-CYCLE HYPOTHESIS.

The hypothesis of a two-cycle development has been advocated by Dawson[2] for the Interior plateau, by Schofield[3] for the Purcell range, by Russell,[4] Willis,[5] Smith,[6] Brooks,[7] and Cairnes,[8] for the Cascade and Coast ranges and by Willis and others for the youthful Rocky mountains.

There is a great difference of opinion, however, regarding the age of the uplifted erosion surface. Schofield advocates an uplifted Cretaceous peneplain for the Purcell range, Dawson and Umpleby an uplifted Eocene peneplain for the interior of

[1]The Columbia river in Washington has been concluded to be an antecedent river by G. O. Smith, U. S. Geol. Surv. Prof. Paper 19, pp. 32-34.
[2] Bull. Geol. Soc. of Am., Vol. XII, 1901, p. 89.
[3] Science Conspectus, Boston, Vol. IV, No. 5, 1914, pp. 122-128.
Geol. Surv., Can., Memoir 76 (1915), p. 162.
[4] Russell, I. C., Twentieth Annual Report, U. S. Geol. Surv., Part II, 1900, pp. 140-144.
[5] Willis, B., Prof. Paper, No. 19, U. S. Geol. Surv., pp 48 and 68-70.
[6] Smith, G. O., Prof. Paper, No. 19, U. S. Geol. Surv., 1903, p. 28.
[7] Brooks, A. H., Geol. and Geography of Alaska; U. S. Geol. Surv., [illegible] Paper, No. 45, p. 271.
[8] Cairnes, D. D., Geol. of the Wheaton District: Geol. Surv., Can., Memoir No. 31, p. 83.

British Colu. ıbia and Washington, and Brooks, Willis, Smith, Russell, and others, an uplifted Miocene or late Tertiary peneplain.

Dissected Eocene Erosion Surface.

In the Interior Plateau physiographic province Dawson was the first to recognize an ancient peneplain surface upon which remnants of Oligocene and Miocene deposits lay. He assumed it to be of Eocene age "chiefly because no deposits referable to the Eocene or earliest Tertiary have been found in this part of the Cordillera."[1] This erosion surface has since that date been generally referred to in the literature as the Eocene peneplain of British Columbia and has been extended and correlated to only a slight extent both into Washington[2] and Alaska.[3]

Dissected Cretaceous Erosion Surface.

The Cretaceous instead of Eocene age of the peneplain (really a palæoplain) in the Interior plateau has been advocated by the writer. The reasons for doubting the validity of an Eocene period of peneplanation have already been stated elsewhere[4] and will not be repeated here.

Very few remnants of the Cretaceous peneplain have survived Tertiary erosion, although its influence may be seen in the present upland topography and larger drainage features. It may be correlated with the nearly level plain of aggradation near sea-level which surrounded it at the close of the Cretaceous period.[5]

Dissected Miocene-Pliocene Erosion Surface.

The upland facets and subdued slopes of the mountain highlands as well as the subequality of the mountain peaks

[1] Dawson, G. M., Bull. Geol. Soc. of Am., Vol. 12, 1901, p. 89.
[2] Umpleby, J. B., Washington State Survey Bull. No. 1, 1910, p. 11.
[3] Brooks, A. H., Geography and Geology of Alaska, Prof. Paper, 45, 1906, p. 279.
[4] Geology of Franklin Mining Camp, B. C.; Geol. Surv., Can., Memoir No. 56, 1914, pp. 38-44.
[5] Jour. of Geol., Vol. XX111, No. 2 (1915), p. 102.

have been accounted for by many observers as due to the dissection of a late Tertiary or Pliocene peneplain.[1]

A late mature upland erosion surface is present in Franklin mining camp 42 miles northwest of Rossland also in the Columbia Mountain system. There the erosion surface bevels uptilted Miocene volcanics which are present in the bottom of a broad deeply dissected intermontane trough.[2] This erosion surface has been correlated[3] with a peneplain surface found by the writer, truncating anticlinal domes of Lower Miocene volcanics in the Kamloops district, Interior Plateau physiographic province.

This peneplain was found to be confined to the Interior plateau and when traced westward into the Coast range graded into late mature and mature upland surfaces. The transition belt between peneplain and mature upland topography averages in width about 15 miles bordering the mountains. This late mature upland topography is included in the Interior Plateau physiographic province.[4] The Interior plateau, as a unit, however, has probably been influenced a great deal by the older Cretaceous palæoplain which still dominates the topography in places.[5]

The Interior plateau may represent a plateau of accumulation made up of Tertiary sedimentaries and volcanics lying upon a basement Cretaceous peneplain in process of being dissected. The volcanics have been locally warped and possibly bevelled through arid erosive forces. As Daly has pointed out in his discussion on a general Tertiary peneplain in the Cascade mountains,[6] "The recent studies of Passarge and Davis seem to prove the possibility of "levelling without base levelling" over large tracts of arid mountain-land. There is reason to think that the belt east of the present high Cascades may have been dry and subject to heavy wind-erosion for a comparatively long time. Under the control of the wind in an arid or subarid

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[1] Brooks, A. H., Geography and Geology of Alaska: U. S. G. S. No. 45, p. 271.
Spencer, A. C., Pacific Mountain System in British Columbia and Alaska: Bull. Geol. Soc. Am., vol. 14, 1903, pp. 117-132.

[2] Geology of Franklin Mining Camp. B. C.; Geol. Surv., Can., Memoir No. 56 (1915), pp. 18-21.

[3] Int. Geol. Congress, XII, Guide Book No. 8, p. 236, Summary Report Geol. Surv., Can., 1912, p. 123.

[4] Physiography of the Beaverdell map-area and the southern part of the Interior plateaus of B.C., by Leopold Reinecke. Geol. Surv., Can., Museum Bulletin No. 11, Geol. Series No. 23 (1915), pp. 1-58.

[5] Guide Book No. 8, Part II, Int. Geol. Congress XII, 1913, p. 236.

[6] Geol. of North American Cordillera: Geol. Surv., Can., Memoir No. 38, p. 627.

district newly uplifted rock-folds would suffer specially rapid attack."[1]

The arguments against a general late Tertiary peneplanation of the Cascades and Rockies may be found in Daly's report on the North American Cordillera.[2]

Under the second hypothesis of a two-cycle development according to which uninterrupted erosion has lasted ever since the time of uplift a simpler type of topography would be expected in which the valley slopes would grade uniformly from flat summits to valley bottom which is not the case at Rossland. Furthermore, transverse sections through the mountains would not display such pronounced topographic breaks at more than one elevation as they apparently do. Then again there is evidence westward in the Interior Plateau region of more than two main cycles of erosion which must be considered in accounting for the present relief. The erosional as well as volcanic history of the bordering Columbia Mountain system is closely related to that of the Interior plateau although the results of erosion, as has been seen, differ considerably. For the above reasons the two-cycle hypothesis of development fails to fully explain the topography of the Rossland mountains.

THREE-CYCLE HYPOTHESIS.

A third hypothesis still remains to be considered—that of the three-cycle development for the Rossland mountains. It is suggested that the subequality of the mountain summits, and presence of relatively flat upland stretches in certain highland areas, may be due to the influence of a former uplifted Cretaceous peneplain (corresponding to the palæoplain of the Interior Plateau province) (Plate XXV). The broad flaring upland valleys and lower upland stretches of from mature to late mature topographic development may represent the work of a composite Tertiary erosion cycle (late Tertiary peneplain of Interior Plateau province and lowland plains elsewhere), and the youthful entrenched valleys are to be referred to a pre-Glacial

[1] Davis, W. M., Jour. of Geology, Vol. 13, 1905, p. 382.
[2] Geol. Surv., Can., Memoir 38, pp. 605-631.

cycle (youthful valleys of the Interior plateau entrenched beneath late Tertiary erosion surface).

The three-cycle hypothesis of physiographic development seems best suited to explain the field facts and is here advanced as an alternative working hypothesis to account for the complex topography of the Columbia Mountain system.

CORRELATION.

Having in a very summary manner described the structure of the mass, the stage of dissection, and hypotheses of physiographic development the various topographic units will now be traced eastward and westward and correlated with surfaces of erosion in adjoining provinces.

The Rossland upper summit upland may be correlated with the Cretaceous peneplain of the Purcell[1] range and the Cretaceous palæoplain of the Interior plateau. The lower upland stretches of Rossland and mature to late mature highland topography may be correlated with the Tertiary peneplain of the Interior plateau, the mature highland topography of the Coast range, and the post youthful valleys and lower late mature and peneplain areas in the broader valley bottoms of the Purcell range. In the case of the latter range, however, there is no evidence of more than one Tertiary cycle and the pre-Glacial cycle of Rossland is lacking. The Tertiary peneplain of the Purcells, on the other hand, of very local occurrence occupies the present valley bottoms and with the exception of post-Glacial cutting has not been deeply dissected.

PHYSIOGRAPHIC HISTORY.

The physiographic history of the district is included in a succeeding chapter on geological history (page 244) to which section the reader is referred for a connected account of the sequence of events in the life history of this portion of the Rossland mountains.

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[1] Schofield, S. J., "Geol. of Cranbrook map-area": Geol. Surv., Can., Memoir 76 (1915), p. 162.

CONCLUSION.

It is concluded that the Rossland mountains belong to the subsequent or relict class and that the topography owes its present form to a rather complex physiographic history of which the present represents only a single phase. The major events, whose influence still remains stamped upon the landscape and which should be considered in any interpretation of the present relief, include three main periods of erosion separated by profound diastrophic movements and vulcanism and at least one and probably two periods of glaciation. The erosion periods are in order of importance from the standpoint of the present relief, the Glacial and pre-Glacial cycles, the Tertiary cycle which was interrupted by local disturbances, and the Cretaceous cycle of erosion.

The influence of the Cretaceous cycle may be seen only in a few flat summit areas, in the subequality of the mountain peaks, in the antecedent character of some of the rivers, and in the broader geographic relations of the mountain provinces to the intermontane plateau provinces. The Tertiary cycle accomplished the extensive dissection of the upwarped Cretaceous erosion surface and in many places reduced the topography to maturity, as at Rossland, and even late maturity in some broad intermontane troughs as at Franklin mining camp in the same mountain system. The Tertiary cycle of erosion was interrupted at times by local volcanic cycles which did not, however, influence the present scenery as much as did normal erosion acting upon the volcanic rocks, modified and directed by geological structure.

The steep-walled youthful valleys below the upland stretches are to be ascribed to the work of rejuvenated streams following the Pliocene regional uplift and prior to glaciation. The pre-Glacial topography has been modified by at least one period of glaciation and probably two; but no field evidence bearing on this problem of multiple glaciation in the British Columbia cordilleras was obtained at Rossland.

CHAPTER II.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The distribution, character, structure, age, and origin of the various rock formations exposed in the Rossland district will here be discussed.

REGIONAL.

The Rossland district lies within the "Western Geosynclinal Belt" of the North American cordillera[1] extending from northeastern Alaska to southern California. It is bounded at this latitude by the Purcell trench to the east and the Strait of Georgia to the west. This belt is characterized by the rarity in it of formations older than the Carboniferous, by the extreme alteration of the youngest Palæozoic and older Mesozoic formations, by the great variety of its igneous rocks both intrusive and extrusive,[2] by its complex history during the Tertiary era, and by the wealth of its mineral resources.

LOCAL.

ıe oldest formation in the Rossland district is the Mount Roberts formation which has been tentatively correlated with Dawson's Câche Creek group in the Kamloops district, and LeRoy's Knobhill and Brooklyn formations at Phoenix of Carboniferous age. The formation consists of much altered and deformed marine sediments and tuff beds which occur in isolated areas and inclusions amidst the dominantly igneous formations.

Three main periods of volcanic activity are recorded: the first in the Triassic of an augite porphyrite magma, the

[1] Geology of North American Cordillera: Geol. Surv., Can., Memoir 38, p. 555.

[2] Daly mentions that within a radius of 5 miles from Rossland 108 rock types have already been discovered; Memoir No. 38, Geol. Surv., Can.

second contemporaneous with the "late Jurassic revolution" of granodioritic and monzonitic magmas, and the third during the Miocene of an alkalic magma. The periods of vulcanism are closely connected with the periods of ore deposition. The district is traversed by innumerable dykes which range in composition from aplites to lamprophyres and have dominant north and south trends. Glacial debris is irregularly scattered over the district as well as recent stream gravels.

Table of Formations.

Quaternary		Stream deposits, boulder clay, alluvium.
Miocene	Sheppard formation Coryell formation	Granite porphyry. Syenite and syenite porphyry (pulaskite).
Oligocene(?)		Porphyritic monzonite.
Eocene(?)	Sophie and Lake Mountain formation	Conglomerate, sandstone, shale.
Upper Jurassic	Trail formation	Granodiorite and monzonite, diorite porphyrite, andesitic and latitic lava and tuff.
Triassic (?)		Augite porphyrite, agglomerate, and tuff. Serpentine and pyroxenite.
Carboniferous	Mount Roberts formation	Quartzite, slate, crystalline limestone, and altered tuff.

Much of the following material is taken from Dr. G. A. Young's description of the various formations in his unpublished manuscript on the "Areal Geology of the Rossland Mining Camp" which embodies the results of field work and geological mapping during the season of 1906. Recent work by Daly in this region and new and better underground exposures showing age relationships of different formations have slightly modified some of the earlier conclusions so that the sequence of formations indicated on the map legend differs from that given in this memoir (Map Nos. 1002, 1004 in pocket).

DISTRIBUTION OF FORMATIONS.

"The general distribution of the various geological bodies within the area mapped on a scale of 1,200 feet to the inch (of which the 400-foot sheet covers but a portion), need only be mentioned here as briefly as possible, since their arrangement will be best understood by referring to the geological sheets. The eastern half of the area is largely occupied by the western portion of the monzonite body which, ending in the south-western part of the district, extends eastward beyond the limits of the map, over a distance in all of about 5 miles. Its southern boundary, while within the limits of the sheet, follows a general easterly line, while its northern border, commencing at the western end, runs easterly to about the centre of the area. There it turns rather abruptly to the north and continues along the eastern, lower slopes of Red mountain till at a short distance beyond the northern limits of the sheet, it quickly turns to the east and returning, crosses diagonally the northeastern corner of the area.

"Outside of the part occupied by the monzonite, the country is underlain largely by slates or their altered forms, alternating with sills and perhaps flows of augite porphyrite. The sediments as a rule, dip towards the west and have a general north and south strike with which the band-like distribution of the augite porphyrite corresponds. Typical porphyrite is exposed over the eastern slopes of Red mountain whose summit lies just beyond the northern border of and to the west of the central line of the district. This zone of augite porphyrite is bounded on the east by the northerly trending monzonite area, while on the west it is limited by a band of altered sediments and perhaps tuffs of the Mount Roberts group, the contact following a north and south direction. This augite porphyrite or a very similar rock reappears in the northeast angle of the district and with the exception of a few narrow bands of shales and slates, largely occupies the southern portions of the area beyond the monzonite body. A third area of the porphyrite occurs towards the west interbanded with sediments.

"The sediments of the Mount Roberts group, occupy the western half of Red mountain, dipping at low angles to the west as though overlying along their eastern margin the above, first mentioned band of augite porphyrite. The bedded rocks extend westward across their strike to the further side of the upper part of the valley of Sheep Creek where they are cut by a dyke-like area of pulaskite pursuing a north and south direction. This band of pulaskite probably marks the site of an extensive fault and separates the gently inclined beds of Red mountain on the east from an assemblage of less altered but highly tilted slates on the west. These sedimentary rocks also belong to the Mount Roberts group and possess a north and south strike. They extend westerly up the eastern face of the adjoining mountains till they are followed apparently conformably, by a band of volcanic agglomerate. Beyond this agglomerate and outside of the area mapped, a series of porphyrites, andesites and tuffs succeed and make up the bulk of Mount Roberts and O.K. mountains.

"In this southwestern quarter of the area of the sheet, the valley of Sheep creek cuts diagonally across the southern end of the pulaskite dyke already referred to and which there intrudes a considerable area of the Nelson [Trail] granodiorite interposed between the syenite and the westerly end of the monzonite. Towards the southwestern corner of the area there also occurs a large, rudely circular area of serpentine. Besides the body of pulaskite referred to, three other areas of the same rock are known, all invading the monzonite either close to the city or within its limits. A type of monzonite designated as porphyritic monzonite, occupies a number of distinct, usually relatively small areas within either the main monzonite mass or the augite porphyrite. Diorite porphyrite is very abundant on the slopes of Red mountain either within the augite porphyrite or the bedded rocks of the Red Mountain group. This igneous rock forms both dyke-like masses and quite irregular usually small bodies. Various dykes both acid and basic, are common throughout the whole district save within the areas of pulaskite. The dykes though often individually having irregular courses, possess a pronounced general north and south strike."

DETAILED DESCRIPTION OF FORMATIONS.

PALÆOZOIC.

CARBONIFEROUS.

Mount Roberts Formation.

Distribution. "The rocks herewith grouped together are largely slates or what appear to be more highly altered forms of the same rocks and they occur in a number of separate areas about the central monzonite body. They are well exposed in a broad band occupying the western part of Red mountain and extending down its southern slopes to meet the monzonite along the foot of Deer Park ridge. A second wide band separated from the first by a narrow belt of igneous rocks, lies near the western border of the area of the sheet, on the lower eastern slopes of the mountains of the Record Ridge group. A third zone occurs on the western side of Deer Park ridge overlooking Sheep Creek valley and a fourth on the summit of Monte Christo and extending over the depression between it and C. and K. mountain. Small, discontinuous, and irregular bands and patches of these rocks, left unmapped, are found also within the body of augite porphyrite occupying part of C. and K. mountain. The areas on Red mountain and C. and K. mountain, embrace, however, many exposures of diorite porphyrite in the form of dykes and larger, often very irregular bodies which have been left unmapped on the smaller scaled sheet, though over considerable stretches of country the diorite porphyrite is as abundant as the slaty rocks themselves.

Lithology. "The rocks of the Mount Roberts formation are present in a comparatively unaltered condition throughout the wide band along the lower slopes of the mountains of the western boundary. There the rocks in many instances are soft, dense, at times probably carbonaceous, black slates. These grade into lighter coloured and more arenaceous forms, often containing tiny quartz grains while in other places the rocks become calcareous. Over considerable areas the slates are lighter coloured and harder but usually are finely banded, the banding being due to variations in colour, in size of grain and of composition: in all cases the banding and slaty parting coincide. These rocks as indicated by a collection of fossils obtained by R. W. Brock, from one locality in this band, are of Carboniferous age. Dark slates resembling some of the above are found also in the two bands of this formation within the augite porphyrite along the southern boundary of the sheet and the rocks of the area on Deer Park ridge have the same general characters.

"On the lower, western slopes of Red mountain, dark rocks outcrop which resemble the above but usually are harder and lack the prominent slaty parting. They are interbanded with more siliceous, lighter coloured varieties which with many areas of diorite porphyrite form the bulk of the exposures within the areas mapped as underlain by the Mount Roberts formation on Red and Monte Christo mountains. In general the rocks of these areas are very hard, very siliceous in appearance and of a light or dark greenish colour passing into dark brown. They usually preserve a finely banded structure, evidently indicating the original bedding planes; but in many places silicification and the rusty weathering resulting from the decomposition of the almost universal, finely disseminated pyrites, has obliterated the original characters and it is possible that at times the beds are really of tuffaceous origin. On the whole, however, they apparently represent altered forms of slates like those of the previously described western band. These rocks sometimes highly altered, at other times preserving more of their original appearances, also occur in broken band-like areas and over smaller more irregular outcrops within the augite porphyrite on C. and K. mountain.

"That the various assemblages of bedded rocks within the district are part of one formation seems highly probable. The rocks of Red mountain in many places in spite of their alteration, possess features in common with the slates on the west. This relation is indicated also by the already described occurrence on the lower western slopes of Red mountain of comparatively unaltered slates almost identical in character with the beds to the west.

Structure. "Since not only in the area mapped but also in the surrounding district, the bedded rocks have a general dip to the westward, it would seem very probable that proceeding westerly, they are arranged in an ascending series and therefore that the beds of volcanic agglomerate (to be described later), appearing just within the western border, overlie them. The thickness of the sediments of the two broader bands has been estimated to be about 1,200 feet in each case. The values obtained must be regarded only as approximations to the truth, yet they at least indicate a minimum thickness of 1,200 feet for the Mor[illegible] formation.

"T[illegible]eds of the Mount Roberts group nearly everywhere dip to the west there are many local and sometimes abrupt variations both of the dip and strike. Within the area occupying the western portion of Red mountain, the strike is usually to the west of north and the value of the angle of westerly dip commonly varies between 10 and 30 degrees. Throughout the band of these rocks to the west of the above and from which it is separated by a comparatively narrow zone of igneous rocks, the direction of the strike is the same, nearly north and south, but the beds are highly inclined and usually in an approximately vertical position. This sudden change in the value of the angle of dip seems almost certainly, to be due to a fault along which afterwards has appeared, the dyke of pulaskite intervening between the two areas of bedded rocks. This fault apparently had formed before the intrusion of the majority of the dykes since they have the same general vertical attitudes both east and west of the supposed fault but whether the dislocation occurred before or after the intrusion of the large body of granodiorite of Mesozoic age now found in the valley of Sheep creek, is not so evident. The small amount of evidence collected would, however, indicate that this fault had appeared before the granodiorite invasion.

"Within the area on Monte Christo mountain and over the two bands in the southern portion of the sheet, the rocks while preserving a northerly strike and generally a westerly inclination, show rather large variations in the angle of dip which ranges from 20 to 30 degrees. The sedimentary rocks of the area on

Deer Park mountain, seem to be arranged in large and small blocks variously orientated so that the direction of strike and angle of dip vary rapidly from point to point. The movements which have thus ruptured the sedimentary rocks seem also to have extended into the neighbouring augite porphyrite and near the contact, small, block-like bodies of the slates have been incorporated within the locally brecciated porphyrite.

"A zone of fracturing at times at least 300 yards wide includes the granodiorite of the two small areas near the summit and extends down the south face of Red mountain. Within this zone the rocks are usually highly brecciated and on a rock surface often appear as a mosaic of fragments varying in size from a few inches to a number of yards in diameter but still preserving their banded structures. Certain dark dykes also have been involved in the crushing and at times the rock appears like an agglomerate or even simulates a conglomerate. This occurrence, evidently formed in post-Jurassic times since the granodiorite also has been included, represents the most conspicuous zone of brecciation seen, but over most of the area on Red mountain and those to the eastward, there are many, often sudden local variations in the attitudes of the beds which may represent other zones of dislocation having a similar north and south trend.

"Evidence of faulting following planes having a general east and west direction is common along the contact of the western band of the slates and the volcanic agglomerate of the western border. There, wherever suitable exposures occur, the rocks seem to be cut by a multitude of east and west faults with throws varying from a fraction of an inch up to several feet. These faults seemed to have counterbalanced the effects of one another and for a distance of a mile and a half, the contact of the two formations preserves a uniform course parallel with the strike of the rocks, in spite of the countless faults at right angles to this direction.

"The strata also show flexures as evidenced by the curving of the line of contact between the western band of the bedded formation and the band of augite porphyrite extending north from Sheep Creek valley. The two bands of slaty rocks enclosed by the areas of augite porphyrite along the southern boundary of the areas also commence to bend around to the westward just at the edge of the sheet and the slates there assume northeast and southwest strikes.

Metamorphism. "The processes of alteration which have so greatly hardened and silicified the bedded rocks on Red mountain do not seem to be directly attributable to the intrusion of the pulaskite. If the metamorphism was directly due to the appearance of this igneous mass, it would be expected that the alteration would be greatest in the immediate neighbourhood of this rock and would decrease in amount away from it. Almost the reverse seems to be true since the largest body of this type occurs just west of the upper part of Sheep creek whereas the least altered members of the Mount Roberts formation on Red mountain, are found along the lower, western slopes of the mountain opposite to the pulaskite dyke. That the syenite has produced some metamorphism cannot be denied, since as at the Jumbo mine situated on the contact of the pulaskite and the altered sediments, the latter rocks have locally been more severely altered with the production of much finely divided biotite. On the other hand the slates bordering the pulaskite on the west have remained comparatively unaltered up to within a few feet of the igneous body. This immunity from metamorphism may, however, be partly due to the fact that the slates there lie in a nearly vertical position and strike parallel with the direction of the contact, so that the parting planes would not afford a ready means of access to the metamorphosing agents accompanying the intrusion of the pulaskite. Bands of but little altered slates are intimately associated with the augite porphyrite as for instance, towards the centre of the southern portion of the area. These same areas of slate also lie but a short distance from the monzonite body. The great changes experienced by the sediments thus do not seem attributable to either the intrusion of the monzonite nor to the occurrence of the augite porphyrite.

"The general metamorphism of the sedimentary rocks on Red mountain possibly may be due to the intrusion of the Nelson granodiorite since the borders of the main batholithic body of this rock lie within a mile northwards of Red mountain while a considerable area of the same granitic type occurs on the slope of Sheep Creek valley. Also, towards the summit of Red mountain occur small patches and vein-like outcrops of the granodiorite within the altered beds. [In the mines the granodiorite becomes more prominent with depth.] Thus the general area of Red mountain would appear to be underlain at no very great depth by bodies of the granitic magma and therefore it would be expected that the sedimentary rocks of this locality would in all probability be considerably metamorphosed.

"Since, however, the metamorphosed sediments are also largely impregnated with sulphides, so much so indeed, that a fragment of the bedded series taken at haphazard from anywhere in the Red Mountain band, is almost certain to reveal some finely disseminated sulphide, it would seem not unlikely that the deposition of the sulphides and at least a part of the silicification and alteration of the sediments were simultaneous, due to the same general agents. Since the sulphides probably owe their origin to the same forces that lead to the formation of the ore bodies of the camp, it would follow that at least some part of the metamorphism of the Mount Roberts formation was due to the same phenomena. The discussion of the probable origin of the ore bodies of the camp is treated in another part of this volume and need not be entered into here. It seemed worthy of note to the present writer, however, that the areas within which the sedimentary rocks are so highly altered and so generally inpregnated with the sulphides, are also those in which occur so abundantly the dykes and irregular bodies of diorite porphyrite while, outside of these areas, the diorite porphyrite is either altogether absent or of but very limited extent.

Age and Origin. "The bedded, undoubtedly largely sedimentary rocks composing the Mount Roberts formation within the area of the Rossland mining district are, as shown by their fossil content, of Carboniferous age."

Dr. H. M. Ami has furnished the following preliminary report on a collection of fossils from the east slope of O. K. mountain.

"In 1906, Mr. R. W. Brock made a small, but interesting collection of imperfectly preserved fossils from the metamorphosed and greatly disturbed rocks of the mining district of Rossland in British Columbia. The fossils occur in shattered and altered angular fragments of impure limestone. From the character and nature of the invertebrate remains, corals, bryozoa, and brachiopoda found in this brecciated formation the limestone is without doubt of marine origin. The fauna represented in the collection—so far as the very wretched state of preservation of the material allows the forms to be identified—is ascribed to the Upper Carboniferous, the upper division of the Carboniferous system, and consists of the following genera and species:—

Anthozoa.
1. *Zaphrentis* sp.

Bryozoa.
2. *Stenopora*, or *Rhombopora* sp.

Brachiopoda.
3. *Productus semireticulatus.*
4. *Productus* sp.
5. *Martinia* sp.
6. *Spirifer* sp., cf *Spirifer cameratus.*"

"The Mount Roberts formation is the oldest known formation within the limits of the camp and is cut by all of the igneous bodies. The sediments are the monuments of a remote age when the greater part of British Columbia was beneath the sea and formed a basin of deposition in which were accumulated great quantities of detrital matter, or heavy deposits of limestone built up during times of clearer water. This age, the Carboniferous period, also was characterized by the widespread occurrence of volcanic phenomena, probably largely of marine types and which gave rise to coarse and fine volcanic ejectementa, lava flows and intrusive sheets.

"Within the area under discussion, the Carboniferous limestones are absent but the detrital beds and the results of the volcanic action are very evident The strata of this period were built up in a probably, horizontal manner and on older formations since hidden from view or destroyed by the immense, deep-seated igneous intrusions of later times. The Carboniferous formations in the present area, thus epresent a portion of the geological foundation into which the igneous bodies of the camp were intruded. Before the appearance of the granodiorite and monzonite masses, the general westerly dip had been imparted to the Carboniferous sediments and the strata of the southern portion of the area were folded so that the strike changed from north and south to more nearly east and west.

The general geological history of British Columbia would indicate that this deformation of the measures may have taken place during Permian times when the western country seems to have been uplifted and probably subjected to differential movements. A period of more profound deformation took place in Jurassic or perhaps early Cretaceous times during which the widespread Nelson [Trail] granodiorite forced its way upwards. Apparently to one or other of these epochs of crustal movements, must be assigned the date of the major disturbances of the Carboniferous strata of Rossland."

MESOZOIC.

Triassic(?)

Volcanic Agglomerate.

Distribution. "An area of agglomerate occurs along the northern half of the western boundary of the district and is part of a band extending in a north and south direction for about 2 miles with a maximum width of 350 yards but with an average breadth of only about one half of this amount. The body is not cut off by later rocks nor terminated by faults but gradually ends, the outcrops occupying an elongated lenticular area.

Lithology. "The agglomerate consists largely of coarse fragmental material alternating with finer grained, tuffaceous beds. The fragments frequently show in relief on weathered surfaces, are usually oval of outline though often angular and range in size from pieces 5 or 6 inches in diameter down to small grains. The materials of the fragments include quartz, slates, and altered volcanics. These usually are lighter coloured than the base in which they lie and which commonly has a greenish colour. The individual fragments are arranged with their longer diameters parallel to the strike and occur in bands of fragments roughly assorted according to size. These bands alternate with others that are finer grained, distinctly bedded and of a greenish grey or brownish colour and which when examined under the microscope, are seen to be tuffs.

Structure. "The rocks of the agglomerate band have a very prominent north and south strike and the beds are vertical as in the case of the slates of the area immediately to the east which they directly succeed and with which they appear to be strictly conformable. The agglomerate beds seem to mark the results of a neighbouring volcanic explosion which may have lead up to the formation of the volcanic rocks succeeding the agglomerate on the west. These lie wholly without the area of the present sheet and outcrop on the slopes of the mountains of the Record group where they are cut by a large area of the presumably Tertiary pulaskite. They comprise various types of andesitic rocks with interbedded tuffs frequently presenting a marked bedded structure by means of which the attitude of this volcanic series is seen to pass gradually from a vertical one on the lower slopes, to a horizontal one on the summits of the mountains.

Age. "These andesites, tuffs, etc., compose the newer assemblage of volcanics referred to by R. G. McConnell and R. W. Brock in their several summaries. The above authors tentatively correlated these newer volcanics of Record ridge with the "Beaver Mountain group" thought to be possibly of post-Cretaceous age. That these volcanic rocks are newer than the underlying Carboniferous is evident and since they are so unlike any other described groups within the Carboniferous series of the region, it seems highly probable that they at least, are of post-Carboniferous age. Under this view of the situation, since the Permian is generally lacking in British Columbia, they would naturally fall in the Triassic, whose members do not always appear to be distinctly unconformable on the younger Carboniferous group.

"Since the presumably Triassic beds undoubtedly have suffered from the same main orogenic movements as the underlying Carboniferous series, it follows that the major disturbances of the Carboniferous rocks of the Rossland mining camp, took place in post-Triassic times and therefore probably during the Jurassic revolution. The remaining geological history of the camp is concerned only with that of igneous bodies injected after the period of great disturbances and always at considerable depths beneath the old land surfaces of succeeding ages. The igneous bodies were not exposed till long after their formation when the coverings of Carboniferous, Triassic, and probably later periods were partly or wholly removed by erosion."

Augite Porphyrite Intrusives.

Distribution. "Four main areas of augite porphyrite are shown on the map. The summit of C. and K. mountain, situated towards the northeastern corner of the camp, is occupied by the porphyrite. The rock also occurs on the eastern slopes of Red mountain over a broad band-like area extending south to the foot of the mountain wher› it is interrupted by the monzonite which also bounds it on its eastern side while along the western margin, it is in contact with the bedded series. A third area of the augite porphyrite, also with a general north and south trend, is found near the western border of the district, in part bounded by the bedded series but seemingly cut off in its northern extension by the pulaskite and on the south by the serpentine. The southern portion of the area is largely underlain by the porphyrite or a similar rock and there includes two bands of the already described sedimentary rocks.

"The augite porphyrite of the different localities shows a considerable variation in its general appearance but the exposures of this rock on Red mountain and in the southeast corner of the area of the sheet, closely resemble one another. The porphyrite on C. and K. mountain is also very similar in its main aspects while in the other areas, the rocks differ in several respects.

Lithology. "The augite porphyrite as exposed on the east face of Red mountain, is of a very dark greyish or greenish black colour and is studded with numerous stout prisms of greenish black pyroxene and hornblende. These larger individuals lie in a very fine-grained, dark ground in which often may be distinguished small cleavage faces of lighter coloured feldspa and at times the dark ground assumes a greyish hue due to a general increase in the size of the feldspar composing it. The larger crystals or phenocrysts of augite and hornblende are very noticeable and often reach a length of one quarter of an inch but more commonly are less than one half this size, while in places, especially near the contact with the bedded rocks, these individuals sink to still smaller dimensions.

"A very common feature of the rock is its agglomeratic structure which is usually quite distinct on weathered surfaces where the exposures then seem to be composed of oval or rounded fragments of a porphyrite slightly different in colour or texture from the material in which they lie. The fragments vary in size and numbers locally and sometimes, over considerable areas, disappear altogether. They are often several inches or more in diameter, and usually coarser and often lighter in colour than the enclosing material but otherwise so closely resemble it that on fresh surfaces the structure frequently is barely noticeable.

"As already stated, the porphyrite occupying the south-eastern portion of the area of the map is much like that of Red mountain and this is also true to a lesser extent of the porphyrite of C. and K. mountain where the rock, however, is on the whole, finer grained. The augite porphyrite of much of the southern area and of the band on the slopes of the mountains of the Record group, while probably of the same origin and of like chemical composition, is in places, unlike it in general appearance. This variety is of a dark greyish or greenish black colour with very numerous small, often rather slender prisms of dark augite and hornblende and lighter coloured feldspars lying in a fine-grained, dark greenish or greyish ground. At times the pyroxene phenocrysts become larger and stouter in habit and the rock then closely approximates in appearance the variety on Red mountain. An agglomeratic structure is not uncommon though over considerable areas it is absent. The western portion of this body in places looks much like a dark green tuff as also does the rock of the band on the west side of Sheep creek. The rock in these latter localities usually is of a very dark green colour, fine grained, sometimes almost dense but at other times many small cleavage faces of hornblende and feldspar are visible. In places the rock has a decidedly sheared structure, breaking irregularly along certain planes. Portions of the rock in this area may be tuffs but for the greater part, the material seems to represent a sheared and often much decomposed porphyrite of the same variety as that of Deer Park ridge and slopes.

"The augite porphyrite of Red mountain when examined in thin sections under the microscope is seen to be composed of phenocrysts of augite, hornblende and plagioclase feldspars lying in a fine ground chiefly of plagioclase feldspar and hornblende. The hornblende is usually much more abundant than the augite, has a green colour, low pleochroism, a confused or matted structure and an imperfect cleavage while in the case of the larger individuals there often is a central portion of colourless augite so that it seems probable that much of the hornblende is secondary. [The hornblende phase occurs in the mine workings in close proximity to the diorite porphyrite tongues.] The phenocrysts are often complex, twins or intergrowths having stout prismatic forms and sections from the prism zone are often terminated by low pyramids, while basal sections are rounded or eight-sided. The phenocrysts of feldspar usually are broad, lath-shaped, and frequently are as large or larger than those of hornblende or pyroxene. They show albite twinning often accompanied by carlsbad twinning, while rather faint zonal structures are common. The values of the extinction angles of the twinned feldspars indicate that they are largely labradorite. The hornblende of the ground mass usually occurs in small, quite irregular forms and the feldspars of the base seem to be mainly if not altogether plagioclase varieties.

"The structure is often decidedly porphyritic but the proportions and characters of the chief constituents vary. Sometimes the phenocrysts by their size are separated sharply from the ground, sometimes this distinction is nearly lost. In certain cases the ground is a very fine granular mixture while in others the feldspars have crystalline outlines and may even be of a comparatively large size. At times the feldspar phenocrysts numerically predominate over those of augite and hornblende, at other times the reverse is true and though the ground is distinctly feldspathic the hornblende in it is occasionally very abundant.

"Microscopically the augite porphyrites composing most of the southern area show the general characters of the above types but the phenocrysts are smaller and more slender in habit, this being particularly noticeable in the case of the dark coloured constituents. The feldspars are usually the more abundant and but rarely show zonal structures while original, brown hornblende as well as colourless augite and secondary hornblende occur in the form of phenocrysts.

"The rocks of the third and finer grained types of the western part of Deer Park ridge and of the opposite slopes of Sheep Creek valley are seen under the microscope to be largely decomposed and frequently contain much secondary calcite and chlorite. Sometimes in spite of the decomposition they retain the general characteristics of the second type of augite porphyrite while at other times they have structures simulating a pyroclastic rock but in some cases at least, this appearance seems to be due to shearing and alteration."

Chemical analysis made by the Mines Branch of (1) a fresh specimen of augite porphyrite taken from the 4th level of the War Eagle mine and (2) the same rock where altered in the vein, yielded the following results:

Analyses of Augite Porphyrite.

	1.	2.[1]
SiO_2	50·89	40·02
TiO_2	0·80	0·46
Al_2O_3	17·00	16·13
Fe_2O_3	0·97	?
FeO	7·60	14·98
MnO	0·14	0·11
MgO	5·41	12·90
CaO	9·82	1·05
K_2O	1·31	8·17
Na_2O	3·35	0·67
H_2O at 110° C	0·06	0·13
H_2O above 110° C	1·14	2·82
P_2O_5	0·19	0·30
CO_2	0·28	0·24
S	0·43	0·39
CuO	none	none
	99·39	98·37

[1]The altered type (2) it will be noted, is higher in Mg, K, and Fe and lower in SiO_2, Ca, and Na than the fresh type.

Origin of Agglomeratic Structure. "The agglomeratic structure of the augite porphyrite as typically exposed over the area of this rock on Red mountain, seems best explained as having formed after the body of rock assumed its present position in relation with the sediments in contact with it on the west. The embedded fragments differ apparently only in texture from their host while their outlines are irregularly rounded or oval and give no evidence of representing already solidified material caught up by a fluid body nor of being fragmentary volcanic ejectementa. The absence of vesicular or scoriaceous structures and other related phenomena, seems to preclude the possibility of the agglomeratic habit having resulted mechanically through movements in a cooling lava flow.

"On the other hand, the general appearance and distribution of the fragments does suggest that they represent the remains of an older body which while still in a fluid condition, was injected by a second volume of the same magma and in which part of the first irrupted matter resisted any attempt at a thorough mixture of the matter of the two periods. Such an invasion could in this instance, hardly have been followed by any decided movements of the still fluid mass as a whole, that is after the augite porphyrite had reached its present position or otherwise, the included fragments would surely have been notably elongated in the direction of flow. If such an explanation as the above, of the origin of the agglomeratic structure, be adopted then it would appear that the mass of augite porphyrite of Red mountain represents a sill or intrusive sheet and not a lava flow for the conditions under which a flow forms would scarcely permit of the action of the above supposed phenomena.

"The various types of augite porphyrite are very common in the district immediately around Rossland, forming a large part of the original Rossland volcanic group. Over considerable areas, the porphyrite rapidly alternates with thin bands of bedded material not unlike sediments but probably often of tuffaceous origin. In many instances in the area outside of the present sheet, the porphyrite seems to pass into a variety containing numerous foreign rock fragments. Sometimes the transition from the true porphyrite to these agglomerates is rapid as if the two distinct varieties of rock were present but in many cases and over large areas the transition is so gradual that it is often difficult to decide to which type the rock belongs.

There thus seems to be practically all gradations from an augite porphyrite to a volcanic agglomerate.

Origin. "Such conditions indicate that probably the bodies of augite porphyrite represent both sills and contemporaneous surface flows. Their general relations with the bedded rocks would also bear out either conclusion since there is a very close parallelism between the direction of strike of the associated sediments and perhaps tuffs and the line of contact of the two types, this being still observable in spite of the subsequent disturbances. Still the phenomena presented by the band on Red mountain all point to the formation of at least this particular body as a very thick sheet intruded after the manner of a sill between the bedding planes of the now altered sediments of the Mount Roberts formation and the upper line of contact of the body may be followed on the northern slopes of the conical mass of Red mountain, bending to the westward in the manner the structure would demand.

"As already indicated, the augite porphyrite in places has distinctly been envolved in faulting and shearing movements of considerable magnitude. The exposures of the band of this rock on the west side of Sheep creek exemplify the shearing of this rock along planes having a north and south direction. On the summit of Deer Park ridge, along a zone of faulting, blocks of slate seem to have been entangled in the porphyrite which is also brecciated and much altered along a narrow strip continuing southwards. In the other areas of porphyrite it was difficult to form any idea of the extent to which the rock has been subjected to earth movements but it was evident that faulting and fracturing had taken place at least in two major directions, one approximately north and south, the other east and west.

"The somewhat notable, though it was thought not essential, differences presented by the porphyrite of most of the southern area of the sheet, may indicate that the rocks of this area should have been separated from those occupied by the varieties more like those typically exposed on Red mountain. Yet the general structural features seem to show that this southern body is the prolongation of the band of augite porphyrite of Red mountain; and that the two minor bands of intercalated sediments in the south express the continuation of the areas of similar rocks on the ridge of Monte Christo and C. and K. mountains lying east of Red mountain. Such a deduction seems warranted by the way the strata of the two minor bands of the southern part of the sheet are found to swing to the west when followed beyond the borders of the area while a parallel westerly swing may be traced in the sediments along their contact with the porphyrite in the south-western part of the sheet, just west of the end of the monzonite mass."

Age and Correlation. The augite porphyrite resembles in many respects similar intrusives of the Nicola group in the Kamloops district.[1] Daly mentions this resemblance in his report on the geology of the International Boundary line. He states "the more massive phases of the Rossland Volcanic group resemble the Nicola Triassic lavas on South Thompson river."[2]

Both on account of their resemblance to rocks of the Nicola group and on account of their freshness compared to the highly altered Palæozoic types the augite porphyrites of the Rossland Volcanic group have been provisionally placed in the Triassic and correlated with the Nicola group. Other members of the so-called Rossland Volcanic group are of still younger age as shown by the following unpublished notes by the late Professor D. P. Penhallow on fossil plants from a locality 4 miles south of Rossland.

"The specimens from Paterson, B.C. are contained in a highly metamorphosed shale derived from the Rossland volcanics. In 1903, I determined a collection from this same region, made by Dr. R. A. Daly of the International Boundary Survey. In 1905 Dr. Daly made a second collection of Cretaceous plants from a locality about 120 miles to the westward, and it has been possible to correlate the two in such a manner as to show that they, in all probability, represent the same horizon. These results are now in course of publication in the Transactions of the Royal Society of Canada. Their chief interest at the moment, is to be found in their relation to the Paterson specimens, the age and possible identity of which may be ascertained through them.

[1] Summary Report, Geol. Surv., Can., 1912, pp. 133-135.
[2] Geol. Surv., Can., Memoir No. 38, p. 372.

Reference has been made to the highly metamorphosed character of the matrix in which the Paterson specimens are embedded. This implies a corresponding breaking up and alteration of the plants which are occasionally pyritized, though in the collection of 1903, nearly all the specimens were so modified. The majority of the specimens were reduced to mere fragments of impressions with a residue of infiltrated silica, while others were found in various stages of graphite formation, one specimen being wholly converted into that form of carbon with no trace of structure. Under the conditions of extreme alteration and fragmentation, it is exceedingly difficult to satisfactorily correlate the specimens with known genera or species, and their study requires an unusual amount of care. A very critical comparison with previously recognized species, by means of specimens, figures and accurate measurements, has permitted conclusions to be reached which it is believed represent a fairly correct correlation. The specimens embrace the following:

No. 1. Fragments of the stipes and frond rachises of ferns.

In describing the collection from the Rossland volcanics, made by Dr. Daly in 1903, the highly pyritized fragments of stem-like remains were referred to ferns of which they were supposed to be portions of stipes and various parts of the rachises of fronds. An inspection of the 1903 collection from the Cascade mountains shows apparently identical remains but in a far better state of preservation because of their inclusion in an unaltered shale. It became possible to correlate the two and to confirm the conclusions previously drawn as to their filicinean character. But in the latter collection, the fern fragments were intimately associated with two species of readily determined ferns, *Gleichenia gilbert-thompsoni* and *Aspidium fredericksburgense*. In consequence of very close association with the former, as also because of certain gross structural peculiarities, the fragments were referred to it, provisionally, although there is no valid reason for supposing that some of them did not also belong to the latter.

Precisely the same specimens are represented in the Paterson collection, and the conclusion is reached that they also represent the remains of *Gleichenia* and *Aspidium*.

No. 2. Fragment of an inflorescence?

This obscure specimen is only 1 centimetre wide and 2 centimetres long. It shows a siliceous residue and bears several scars or slight projections like emergent organs, arranged in flat spirals. The character of this specimen is altogether too indefinite for a proper identification, but it seems probable that it may be a portion of the central axis of a cycadaceous inflorescence.

No. 3. This specimen is a fragment of a laminated and striated body several centimetres long and about 2.5 centimetres wide. It is composed of a number of narrow prismatic bodies extending the entire length of the specimen, and overlapping in such a manner as to suggest a much compressed rhizome of a fern of the type of *Osmunda*, which it is believed to be. Comparison with the rhizome of *Osmundites skidegatensis*, serves to confirm this view.

No. 4. Fragments of rather broad, strap-shaped leaves characterized by their fine parallel nerves. Similar fragments were found in the collection of 1903, but they were not correlated with any recognized species. As now presented, these fragments are to be regarded as portions of the pinnæ of some cycadaceous plant, and from their breadth and nervation, they seem to approach *Ctenophyllum grandifolium.* The fact that this genus is not yet known from this horizon in Canada, would seem to suggest a doubt as to the correctness of the reference. Were the specimens somewhat narrower, they might well be referred to *Dioönites borealis*, Dn., which has been recorded by Dawson for the Kootenay formation of Martin creek, British Columbia. Remains of this genus are also well known elsewhere in British Columbia, and it seems to have had a wide distribution in that horizon. There can be little doubt that the Paterson specimens belong to this or a nearly related genus.

No. 5. Various and rather numerous fragments presenting two forms of preservation.

5a. Numerous narrow and linear impressions with a siliceous residue. These are evidently fragments of leaves, although they present no evidence of venation or structure of any kind. Comparison with the next shows them to be the same.

5b. A single specimen consists of a series of parallel and linear bodies, the original organic matter of which has been entirely converted into graphite. The members of the series are about 110 millimetres in length and possibly incomplete; 2-4 millimetres in width and distant 2-4 millimetres. At what may be regarded as the base of the series, there is a thickish body 4·5 millimetres broad. It seems to be somewhat out of place, but it crosses the other parts approximately at right angles and is evidently a rachis. The whole may be regarded as a portion of a cycadaceous frond.

In the 1903 collection, specimens were found which showed many features of *Cycadites* to which they were referred, and the present plant undoubtedly belongs to the same genus, or one nearly related to it. The somewhat widespread occurrence of *Dioönites* within the same horizon, and the recognition of *Cycadites longifolius*, Font. in the Kootenay formation, afford good reason for the supposition that others must be represented more or less abundantly.

From the amount of graphite present, it is evident that the various parts of the original plant were voluminous and that they also were characterized by a high degree of resistance to decay, features of great prominence in such types as *Cycadites* and *Dioönites.*

A very critical comparison with *Dioönites buchianus*, Schimp., as figured by Fontaine, shows a very remarkable resemblance between the two. An almost equally close resemblance is found by comparison with *Ctenophyllum*, and there can be little doubt that the specimen belongs to one of these genera.

No. 6. A broad, flat specimen, evidently the remains of a portion of a thick and very durable leaf. The original material has been almost wholly converted into graphite, but it shows with some prominence, numerous fine, parallel and rather closely set veins crossed, at right angles and at short intervals of little more than 1 millimetre, by veinlets. The whole aspect of the specimen is precisely that presented by *Sphenozamites rogersianus*, Font., and it seems probable that this is a correct correlation, although this species is not at present known to the Kootenay of British Columbia.

The probability that most of the specimens discussed are cycadaceous, is greatly strengthened by the fact that in an account of the Cretaceous flora of British Columbia in 1885, Sir Willam Dawson records the occurrence in the Kootenay formation at Martin creek, of three species of *Zamites*, one of *Anomozamites*, one *Sphenozamites*, one *Podozamites* and one *Dioönites*. These and other records make it clear that the Cretaceous flora of Kootenay age in that region was characterized by an abundant cycadaceous vegetation.

Gleichenis gilbert-thompsoni and *Aspidium fredericksburgense* are both characteristic types of Lower Cretaceous plants of Potomac or Kootenay age, and their occurrence in the Paterson collection, as well as the general facies of the specimens, definitely place that locality in the Kootenay horizon, a result in direct accord with conclusions already reached with respect to the age of the Rossland volcanics."

Serpentine and Pyroxenite.

Distribution. "A body of serpentine occupies part of the valley of Sheep creek and extends up the slopes on both sides. The mass has a roughly rectangular outline with a breadth and length of about one-half mile.

Lithology. "The serpentine over the whole area is quite uniform in appearance being dense and of a dull black colour weathering light green, brownish or yellowish. The rock seems to be wholly of serpentine and preserves no direct evidence of its original mineral composition. In places it contains very narrow, short seams of asbestos.

Structure. "The serpentine area is surrounded on nearly all sides by the sediments and porphyrites of the Carboniferous series. The outlines of the body suggest that it represents a vertical stock or perhaps volcanic neck intruded through the already disturbed, highly-inclined slates and along the probable lines of weakness that lead to the localization of the intrusion of the monzonite.

Age. "The age of the serpentine is somewhat uncertain. On the previous maps of the district it has been indicated as being of Palæozoic age but it apparently appeared after the main period of tilting and folding of the Carboniferous series and therefore is probably of Mesozoic or younger age. The rock is cut by dykes and also by a small body of pulaskite.

Pyroxenite.

"A short distance to the east of the serpentine body, along the railway on the west side of Sheep creek, is a very limited area of pyroxenite enclosed in augite porphyrite. The whole exposure of the rock is limited to a few square yards. It is of a dark greyish-black colour, has a hackly fracture and is composed of augite individuals with curving faces often an eighth of an inch in length. Under the microscope the pyroxene is seen to be a colourless augite and it composes the whole rock. The age of this outcrop of pyroxenite is unknown. The rock was not recognized elsewhere, possibly it is related in origin with the neighbouring mass of serpentine which may have been derived from a similar rock."

Both serpentine and pyroxenite are provisionally referred to the Triassic.

UPPER JURASSIC.

Trail Batholith and Stocks of Granodiorite.

Distribution. The Trail or Nelson granodiorite batholith which has its best development around Trail underlies the Rossland district, and outcrops on both sides of Sheep creek for nearly a mile in a north and south direction. "Close to the eastern border of this irregular area is a small outcrop of the same rock surrounded by sedimentary beds whereas two small areas of the same type occur near the summit of Red mountain also within the bedded rocks. Elsewhere near the top of the mountain are small patches of the granodiorite.

"The two small areas of granodiorite near the top of Red mountain lie within the broad zone of brecciation extending down the south slope of the mountain and already referred to in the description of the Carboniferous sediments. Within these two areas the rock seems to be composed of fragments varying in size from blocks several yards in diameter down to mere specks lying in a fine granular, greenish ground which is often reddish or brownish at the surface. Over much of the area the rock has the appearance of a rather coarse conglomerate or agglomerate composed of the somewhat angular fragments which are readily seen to be of normal granodiorite. The material of the ground apparently represents the granite in a finely crushed state and the rock affords a fine example of an autoclastic type."

Stocks of granodiorite are exposed in the underground workings of the mines.

Lithology. The granodiorite is a greyish, granular, crystalline rock varying from medium-grained to coarse-grained and composed of plagioclase and orthoclase feldspar, biotite, dark green hornblende, and visible but not abundant quartz. The feldspars are the most abundant constituent and occur in tabular individuals with sharp outlines that appear very distinctly on weathered surfaces. The granodiorite in places shows evidences of strain and of having been subjected to great pressure in the presence of gneissic and autoclastic structures. Under the microscope the granodiorite is an equigranular rock made up of both orthoclase and plagioclase feldspars, the plagioclase varying from an acid labradorite to a basic andesine, the latter sometimes zoned. The other essential constituents are quartz, biotite, and hornblende. Magnetite, apatite, and titanite, are the principal accessory constituents. Epidote is a common secondary mineral.

A typical fresh specimen of the granodiorite collected by Daly from a railway cutting 2 miles west of Trail was analysed by Mr. M. F. Connor, with the following result:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	SrO	BaO	Na_2O
62·08	0·73	16·61	1·53	3·72	0·11	2·44	5·20	0·03	0·09	3·18

K_2O	H_2O at 110°C	H_2O above 110°C	P_2O_5
3·29	0·16	1·00	0·30—100·47 Sp. Gr. 2·754

"Calculated norm:

Quartz	15·48
Orthoclase	19·46
Albite	27·25
Anorthite	21·13
Diopside	11·52
Magnetite	2·08
Ilmenite	1·36
Apatite	·62
Water	1·16
	100·06

The mode (Rosiwal method) is approximately:

Quartz	25·9
Andesine	28·1
Orthoclase and microcline	19·2
Biotite	13·4
Hornblende	12·3
Magnetite	·6
Apatite	·3
Titanite	·2
Zircon	trace
	100·0

In the norm classification the rock enters the sodipotassic subrang, harzose, of the alkalicalcic rang, tonalase, in the dosalane order, austrare; although the ratio of potash molecules to soda molecules is very close to the limit separating harzose from tonalose. According to the older classification the rock is a basic granodiorite."[1]

Structure. The granodiorite occurs in irregular-shaped crosscutting masses and stocks (cupola stocks of Daly), intrusive into the Mount Roberts formation and augite porphyrite. Inclusions of the intruded rocks occur in the granodiorite, particularly near the borders of the intrusion.

The relation of the granodiorite to the monzonite is not very clearly seen on the surface and it is very difficult to distinguish between the two rocks in places. On the northwest slope of Deer Park mountain the porphyritic monzonite appears to cut the granodiorite and in the mines both monzonite and porphyritic monzonite cut the granodiorite.

Origin. The nature of the origin of the Trail granodiorite has been suggested by R. A. Daly from a study of its contacts with the older rocks which it appears to have replaced. Its contact-shatter zone with the older Palæozoic complex is unusually broad and well displayed along the eastern side of the Columbia river.[2]

The magmatic stoping hypothesis as described by Daly, Barrell, and others seems best to explain the facts of the case. According to this hypothesis the granodiorite batholith worked its way upward from a deep-seated magma reservoir through

[1] Geol. Surv., Can., Memoir No. 38, p. 347.

[2] See Plate XXXIII and Map No. 8, Memoir 38, Geol. Surv., Can. See also Plate XIXB (a) of this memoir.

the overlying rocks of the solid crust, by sending off tongues or apophyses into them, stoping off fragments, and filling the space formerly occupied by the overlying rocks or, in other words, replacing them. Under these conditions the most intense metamorphism would take place in the cover rocks, while the steep, wall rocks of the batholith would suffer less alteration, and this is found to be the case in the field. The stoping has been in part accomplished by the injection of apophyses or tongues of diorite porphyrite into the roof rocks. The tongues were injected under high pressure and temperature conditions (similar to the action of a blowpipe) into deep-seated fissures probably formed in the roof rocks (chiefly augite porphyrite) at the time of batholithic doming. Tongues of this kind are well exposed in the mines and pass transitionally into the granodiorite of the stocks and batholith itself.[1]

Age. The date of the intrusion of the Trail or Nelson granodiorite has been assigned to the late Jurassic or post Jurassic by McConnell, Brock, and Daly. Within the area of the present sheet, there is no evidence of its precise age, other than that it is later than the main orogenic movements, which occurred, probably, in Jurassic times, and older than the Coryell batholith of pulaskite.

Diorite Porphyrite Tongues.

Distribution. A border and dyke facies of the granodiorite is a rock known locally as diorite porphyrite. The diorite porphyrite is confined largely to the area of augite porphyrite and sedimentary rocks on Red mountain and in the depression between Monte Crhisto and C. and K. mountains. It occurs, though only sparingly, in the augite porphyrite of the southeastern portion of the map-area. The distribution of this rock is shown only on the geological sheet of the area mapped on the scale of 400 feet to the inch and the outlines of the bodies shown on the map are indicated in many cases only diagrammatically, for it was but rarely that the surface exposures were sufficiently numerous to allow of the determination of the actual outlines of

[1] The transition from diorite porphyrite to granodiorite may be well seen in the lower levels of the LeRoi and Centre Star mines, particularly on the 1,350-foot level of the LeRoi where numerous crosscuts disclose the rocks.

these apparently often highly irregular masses. It was possible to obtain more complete data regarding the form, trend, and dip of the diorite porphyrite tongues in the mine workings where they are very plentiful and are apparently closely connected with the ore deposits.

Lithology. The diorite porphyrites range in colour from light grey to dark greenish black and are composed of numerous dark, slender prisms of hornblende and pyroxene and many lath-like feldspars, lying in a fine, crystalline, greyish ground. There are two distinct gradational phases, a hornblende phase and a feldspar phase. In the hornblende phase the needle-like, often parallel, crystals of hornblende are characteristic and usually measure about one-twentieth of an inch in length, though not infrequently they include a few larger and stouter individuals. The tabular phenocrysts of feldspar which are not so noticeable in the hornblende phase are very abundant in the feldspar phase and give the rock a decidedly spotted appearance. On slightly weathered surfaces the partly kaolinized white feldspars stand out very prominently. In certain localities the phenocrysts and especially those of feldspar, are so abundant that the porphyritic appearance is almost lost and the rock passes into the fine granular granodiorite of the cupola stocks (see page 28 for chemical analyses of diorite porphyrite and granodiorite).

"Corresponding with their macroscopic appearances, the diorite porphyrites, microscopically, show many variations. They are all porphyritic, the phenocrysts including plagioclase feldspar, hornblende, and pyroxene lying in a ground of feldspars, quartz and hornblende. The plagioclase phenocrysts have comparatively slender forms in some cases showing zonal structures. The extinction angles indicate that in different cases the feldspars range in composition from andesine to acid labradorite. The phenocrysts of hornblende are brownish green while those of pyroxene are of a pale green colour and both minerals occur in slender forms, sometimes one silicate sometimes the other predominating. The relative amounts of the phenocrysts of feldspar and of coloured constitutents fluctuate widely, at times those of the feldspar are by far the most abundant while in other instances they are almost completely absent.

"The base varies both in structure and mineralogical composition. Sometimes it is very finely granular with a sharp distinction between it and the crystals of the first generation while in other cases the contrast between phenocrysts and ground is almost lost. Hornblende appears to be virtually the only coloured constituent of the ground, it occurs in irregular grains sometimes very abundant, sometimes only sparingly present. Feldspars usually predominate in the ground and are usually of plagioclase varieties which in certain cases have quite irregular outlines while at other times they occur in small laths. In the finely granular type of base, quartz is sometimes fairly abundant and then is accompanied by an untwinned feldspar, probably orthoclase."

Structure. The intrusive masses of diorite porphyrite are very irregular in outline in places, as indicated on the large scaled map. The rock occurs chiefly in dykes or tongue-like forms, which both in plan and transverse vertical section branch or expand to form masses of considerable size. Besides the persistent, steeply-dipping, tongue-like masses, there are very irregular, in places oval-shaped, intrusions of diorite porphyrite that lie at low angles and appear as mushroom-shaped masses or miniature laccoliths. Examples of this erratic type of intrusion have been disclosed in the eastern workings of the Josie mine.

The pronounced flow structure of the hornblende and feldspars present in some of the steeper, more persistent tongues, suggests that these tongues may represent conduits through which the magma reached the surface to form the andesitic lavas and tuffs of Mount Roberts.

Age. The diorite porphyrite is much younger than the sediments and augite porphyrite which it intrudes and alters. It is older than both the monzonite and porphyritic monzonite, both of which send dykes through it. The younger age of the monzonite is well shown in the Centre Star mine (7th level and elsewhere) where the monzonite cuts off and truncates both diorite porphyrite, and augite porphyrite. The diorite porphyrite in places occurs in dyke-like forms that end abruptly against the boundaries of the monzonite (See Map 1002 in pocket). Underground in the LeRoi mine and elsewhere it was found to pass transitionally into a fine granular granodiorite at a distance varying from 50 to 100 feet from the border of the granitic mass.

The diorite porphyrite like the granodiorite is referred to the late Jurassic, although the relationships between the two formations in portions of the Josie mine appear to indicate that some portions of the granodiorite magma may have welled up slightly later than the diorite porphyrite and replaced part of it.

Andesite Flows and Tuff Beds.

Distribution. No andesites nor associated tuff beds outcrop within the map-area. The nearest exposures are on Mount Roberts where they lie at low angles on the steeply dipping older tuffs and agglomerates of Triassic (?) age.

Lithology. A normal type of andesite from the southeast slope of Mount Roberts is here described.

Megascopically it is holocrystalline, porphyritic, aphanitic, and dark greenish grey in colour; it has a dull lustre, and a dense subconchoidal to uneven fracture.

Under the microscope the following minerals were observed: chloritized hornblende with magnetite borders and plagioclase (labradorite and andesine) in prominent phenocrysts; magnetite, in small disseminated and octahedral grains, and orthoclase in small prisms. The feldspar and hornblende phenocrysts are enclosed in a groundmass composed of a felted mass of the same minerals with trachytoid structure and fluxional arrangement. The andesite on the summit of Mount Roberts, appears to pass into a dark augite phase. Chlorite and kaolin are the chief alteration products.

The volcanic tuffs are dark, dense, well stratified beds, which are intercalated with the andesite flows. Under the microscope the tuff shows sharp angular and rounded fragments of andesitic and other undeterminable fragments in a much altered base.

Origin and Age. The andesites and tuffs are provisionally referred to the late Jurassic batholithic invasion both on account of their mineralogical similarity to the diorite porphyrite with their common trachytic or flow structure and on account of their intermediate position on Record Mountain ridge between latites above (the extrusive equivalent of the monzonite) and Triassic (?) fragmentals below. The andesitic flows and pyroclastics, therefore, are considered to be the extrusive equivalents of the granodiorite and diorite porphyrite.

Monzonite Chonolith.

Distribution. "The monzonite body underlies about one half of the total area of the map sheet and as already stated, represents the western portion only, of a roughly oval mass about 5 miles long in an east and west direction and having a maximum width of about one and three-quarter miles. That part of the monzonite mass lying inside of the area of the map has a very irregular boundary which, commencing on the summit of Deer Park ridge first trends northeasterly and then north, passing along the western side of the Centre Star gulch. The boundary swings across this valley a short distance beyond the northern boundary of the area and pursuing a very irregular course, follows along the top of Monte Christo mountain and thence diagonally down the southern face of C. and K. mountain, sending a tongue across the summit of the latter. Beyond the eastern limits of the map-area, the boundary of the monzonite curves around the east face of C. and K. mountain towards the great body of Nelson granodiorite on the north, then turning back on itself, extends eastward across the valley of Trail creek to the slopes of Lookout mountain. The southern boundary of the monzonite from the greatest eastern extension of the body, takes a general westerly course, entering the area under discussion, along the side of Cherry ridge near the southeastern corner of the map-area and with a bend to the north, strikes westward to the top of Deer Park mountain near the southwestern corner of the area.

"Within the mass thus outlined are several intrusive bodies of porphyritic monzonite and pulaskite as well as a few areas of the bedded series and of the augite porphyrite. The greater part of the monzonitic body is surrounded by the Carboniferous sediments and associated augite porphyrite, the igneous mass cutting sharply across the general strike of these formations. Towards its western end the monzonite is limited by the considerable area of Nelson granodiorite found in the valley of Sheep creek.

"The large area of monzonite with its very irregular boundary, is not occupied by a simple body but by a number of varieties of rock having certain characteristics in common but still presenting much diversity in general appearance and composition. In colour they vary from nearly black to light grey, in grain from very fine to coarse, and in structure from granular to semi-porphyritic. Different types at times cut one another, and along the contacts, the younger varieties not infrequently are crowded with inclusions of the older; yet in other instances, types of quite diverse appearance seem to pass gradually into one another. The different varieties in some cases occupy large areas to the exclusion of other types, while in other places, they appear as dyke-like bodies or quite irregularly within one another.

"It was not thought profitable to attempt to separately map the different varieties of monzonite, especially as they are all believed to be closely related in origin and composition and to have been nearly contemporaneous. As regards the relative ages of the different varieties it would seem that in general, the coarser types are younger than the finer and that the more feldspathic, lighter coloured varieties are younger than the darker.

Lithology. "The coarsest type of monzonite and the one most readily separated in the field from the other varieties, occupies a large area stretching from the shaft of the Great Western mine to near the headworks of the LeRoi. Smaller areas of a similar type are common on the south face of Monte Christo mountain and also along the southwestern border of the monzonite body. This coarse type usually is of a dark colour and consists largely of dark, nearly black prisms of pyroxene or secondary hornblende, flakes of biotite and a light coloured feldspar, that gives the appearance of lying between the other constituents. In many instances the augite and hornblende form the bulk of the rock, occurring in both large and small, often ragged, prismatic forms frequently varying between one-quarter and one-half an inch in length. The dark brown biotite though never as plentiful as the other dark silicates, still is abundant and forms large irregular flakes. The feldspars are usually white or slightly greenish in colour and appear to lie between the prisms of augite and hornblende though when seen in thin sections they often have sharply rectangular outlines: they are almost exclusively of plagioclase varieties, often of the composition of labradorite.

"This type of monzonite frequently shows local variations along bands where the feldspars sometimes almost disappear, the rock then assumes a greenish black colour and is composed nearly altogether of coarsely crystalline hornblende and pyroxene with much biotite. Sometimes this type seems to end abruptly against the surrounding varieties of more normal monzonite while at other times it presents transition forms in which the feldspars increase in amount while the dark coloured constituents decrease in both size and quantity, the remaining larger individuals of pyroxene or hornblende may then give a porphyritic aspect to the rock. Along the southern border of the monzonite body this type or a related one, holds large poikilitics biotite flakes measuring a quarter of an inch or more in diameter and there cuts and holds inclusions of a finer grained variety of monzonite.

"The remaining varieties of monzonite present characters that often remain fairly constant over considerable areas and while examples from different localities may appear quite dissimilar yet they possess certain features in common and it would be quite possible to select a series of specimens showing a gradation from any one type to any other. The different kinds on the whole, are fine and even grained aggregates of white feldspars and dark, nearly black pyroxene, hornblende and biotite flakes. The various components usually are distributed uniformly so that on moderately fresh surfaces, the rocks present the appearance of being composed of a finely granular, white ground peppered with tiny dark grains and larger but still small, prismatic individuals of the dark coloured constituents. In both the finer and coarser-grained varieties, the relative amounts of the dark and light-coloured components vary from place to place and where the augite or hornblende is exceedingly abundant, the rock assumes a very dark greyish, almost black colour, especially noticeable in the case of the finer grained varieties. On the other hand, with increasing proportions of feldspars, the general colour becomes a lighter grey, a colour more often shown by the coarser than the finer grained kinds.

"Though the rocks are predominantly of a finer and even grained type yet it often happens that the dark pyroxene or hornblende occur partly in larger, prismatic individuals scattered through the finer, uniform material of the bulk of the rock. Very small scales of dark mica are usually present but as a rule in small proportions. Sometimes the minute, shining flakes of this mineral become quite abundant and in some instances larger, ragged individuals with diameters up to one half an inch are present and enclose the other constituents as in a meshwork.

"When thin sections of the monzonite are viewed under the microscope, the pyroxene is seen to be a pale green augite often forming prismatic individuals seldom measuring more than an eighth of an inch in length. The augite with secondary hornblende is always the chief and in some cases, virtually the only coloured constituent. At times it forms a large proportion of the whole rock, while in other cases, it is completely overshadowed by the feldspars. Brown biotite is usually present in the form of small scales or larger, irregular poikilitic flakes. The feldspars are predominantly, sometimes altogether, of plagioclase varieties. The individuals are generally lath-shaped and in many instances appear to be of the composition of acid labradorite. An alkali feldspar is often present and sometimes is quite abundant, either in irregular grains or in larger, plate-like bodies enclosing the plagioclase laths. Some of the varieties of monzonite contain much magnetite, others scarcely any while small, apatite crystals are almost universal."

A specimen of fresh granular monzonite (1) from the 700-foot level of LeRoi mine and another (2) from the same level altered by mineralization were analysed by Mr. M. F. Connor, and gave the following results:

Analyses of Monzonite.

	1.	2.[1]
SiO_2	54·49	37·32
TiO_2	0·70	0·87
Al_2O_3	16·51	19·30
Fe_2O_3	2·79	?
FeO	5·20	16·10
MnO	0·10	0·10
MgO	3·55	10·81
CaO	7·06	1·47
Na_2O	3·50	0·34
K_2O	4·36	8·55
H_2O at 110° C	0·07	0·14
H_2O above 110° C	1·18	3·01
P_2O_5	0·20	0·19
CO_2	0·10	trace
S	0·23	0·56
CuO	none	trace
	100·04	98·75

[1] The altered monzonite is higher in Al, FeO, Mg, K, and lower in Si, Ca, Na, than the fresh type.

"The calculated norm is:

Orthoclase	26·13
Albite	29·34
Anorthite	16·40
Diopside	14·56
Hypersthene	2·76
Olivine	3·04
Magnetite	4·18
Ilmenite	1.36
Pyrite	0·84
Apatite	0·31
Water and CO_2	1·35
	100·27

"According to the norm classification the rock enters the sodipotassic subrang, monzonose, of the domalkalic rang, monzonase, in the dosalane order, germanare. According to the older, mode, classification it is a typical monzonite.

"The chemical relations of this rock to the Rossland latites and to the calculated world-average for monzonite (reduced to 100 per cent) are shown in the following table:

	Rossland monzonite	Average of four Rossland latites	Average of twelve types of monzonite elsewhere
SiO_2	54·49	56·52	55·25
TiO_2	0·70	1·00	0·60
Al_2O_3	16·51	16·96	16·53
Fe_2O_3	2·79	1·10	3·03
FeO	5·20	4·51	4·37
MnO	0·10	0·14	0·15
MgO	3·55	4·01	4·20
CaO	7·06	5·93	7·19
SrO	......	0·13	......
BaO	......	0·16	......
Na_2O	3·50	3·36	3·48
K_2O	4·36	4·46	4·11
H_2O-	0·07	0·11	} 0·66
H_2O+	1·18	0·48	
P_2O_5	0·20	0·31	0·43
CO_2	0·10	0·34	......
S	0·23	......	......
FeS_2 and Fe_7S_8	......	0·23	......
	100·04	99·75	100·00

The table shows how faithful is the chemical resemblance of the stock rock to the average monzonite and to the lavas. As usual with lavas and corresponding plutonic species, the average latite is slightly higher in silica than the monzonite.[1]

Structure. "The monzonite is older than and is cut by the porphyritic monzonite, the pulaskite, and by a whole series of dykes. The large body of the monzonite though having a sinuous outline seldom seems to send offshoots of any size into the older Carboniferous sediments and associated porphyrites which so largely surround it. At three localities only, possible exceptions to this general rule were observed. Within the augite porphyrite near the southern boundary of the area and just to the east of the westerly band of the sediments, there is a

[1] Daly, R. A., Geol. Surv., Can., Memoir 38, p. 344.

small and apparently isolated outcrop of rather coarse monzonite like that of the neighbouring main body. Two small, seemingly isolated masses at least partly surrounded by augite porphyrite, occur within the city limits and along the line of the Great Northern railway near the border of the large monzonite area. Also, a tongue-like extension of the monzonite is shown on the map as extending across the summit of C. and K. mountain; this body is probably directly connected with the main area.

Origin. "The border of the central monzonite mass is concealed by drift along the slopes of the C. and K. mountain but towards the eastern margin of the map, it may be seen to lie close to the contact of the augite porphyrite and the area of porphyritic monzonite there exposed. From this position, proceeding eastward beyond the limits of the sheet, the line of contact of the monzonite with the older formations, swings around to the north on the slopes of C. and K. mountain which drop rapidly to the east. On this eastern face above the contact of the monzonite with the augite porphyrite occupying the summit of the hill, are a number of tunnels commencing in the porphyrite but whose dumps are composed largely of monzonite. It would seem that the porphyritic volcanic of C. and K. mountain is a comparatively shallow body occupying the upper portion of the hill but underlain by monzonite which, proceeding westward, gradually outcrops at successively higher levels along the south face of the ridge and finally occurs in what appears as dyke-like extension across the top of the hill. That is, the top of the body and a portion of the covering of the monzonitic mass seems still to be preserved at this point. This idea furnishes a reasonable explanation for the occurrence of the comparatively large area of the bedded series exposed in the northern part of the city of Rossland within the monzonite, and which probably represents a roof pendant. The same mode of origin may be true of the neighbouring smaller, detached area of similar rocks and also of the two small outcrops of augite porphyrite on the lower slopes of Monte Christo or, they may represent fragments torn from the measures once overlying or surrounding the monzonite.

"The larger part of the monzonite mass lies in the valley of Trail creek while its greatest extensions in a northerly direction are respectively up the Centre Star gulch and over the low country east of the slopes of C. and K. mountain. This possible connexion between the distribution of the monzonite and the lower lying portions of the country, may be purely fortuitous but when considered in relation with the apparent capping of the body on C. and K. mountain and the possible occurrence of roof pendants, it points to the conclusion that, within at least the area mapped, the exposures of monzonite belong to a section near the upward limits of the body. It is still possible that at some point or points, the monzonite extended on upwards through the overlying Carboniferous and probably later rocks and may have appeared at the surface as a volcano.

"The area of the monzonite thus appears to represent the upper portion of an igneous body in places still capped by its old rock roof or holding detached portions of it. The mass is not homogeneous but is composed of many varieties of what seem to be closely related types, the earliest of which are generally the finest in grain and darkest of colour while the later are coarser, as if they had cooled more slowly and are more feldspathic perhaps as the result of differentiation processes. In places the intruding varieties have cut portions that apparently already had solidified since the boundaries are distinct and well defined, in other cases they seem to have invaded masses still partly fluid since no abrupt change then separates the different kinds. Perhaps some of the finer masses represent portions that early had solidified along the upper bounding surfaces of the igneous mass and afterwards sank into the lower more central, still fluid portions.

"No direct evidence seemed to be offered in the field as to the methods by which the older sediments and augite porphyrite were removed to make place for the monzonite mass; neither did there appear to be any indications of the absorption of material by the monzonite. Possibly the somewhat abrupt change in the strike of the strata respectively north and south of the axis of the igneous body may indicate some more profound structural break pursuing a general east and west direction and which guided the upward penetrating magma and gave rise to its elongated cross section.

Age. "The monzonite is undoubtedly younger than the Carboniferous sediments and associated augite porphyrite. The structural relations as shown on the accompanying geological map (Map No. 1004 in pocket), indicate that the igneous rock was intruded after the major epoch of disturbances whereby the surrounding rocks were tilted and folded. The date of these prominent earth movements has already been discussed and the conclusion reached that they probably took place in Jurassic times. As a result of the line of reasoning adopted, it follows that the monzonite was intruded in the Jurassic or a later period. The view that the monzonite body was formed in Jurassic times is strengthened somewhat by the fact that within the great granite area to the north, the Nelson granodiorite in places presents a monzonite facies." It is considered that the Rossland monzonite is closely connected in origin with the granodiorite and shortly followed its intrusion.

Augite Latite Flows.

Distribution. No latites, so far as determined, outcrop within the limits of the map-area. Daly mentions their occurrence in the surrounding district "at widely spaced localities, among which are specially noted the area between Castle mountain (southeast slope) and Record Mountain ridge, the divide between Malde and Little Sheep creeks, and the bluffs on the west side of the Columbia river about 4 miles north of the line. The following brief description of a typical, relatively unaltered phase relates to one of the younger flows occurring on the unnamed conical peak west of the Murphy Creek-Gladstone trail and about 2 miles north of Stony creek. The volcanic rocks are there exceptionally well exposed above tree-line, where thick sheets of highly porphyritic latite alternate with more basaltic sheets and with coarse agglomerates composed of these lavas.

Lithology. "The latite when fresh is a deep greenish-grey to almost black rock bearing abundant phenocrysts of tabular plagioclase up to 3 millimetres in greatest diameters and of smaller, stout prisms of greenish-black pyroxene.

"Microscopic examination shows that the rock is uncrushed, the phenocrysts being unstrained and almost perfectly unaltered. The plagioclase is the more abundant. On (010) and in the zone of symmetrical extinctions for simultaneous Carlsbad-albite twins, individual crystals give extinction angles appropriate to the series from labradorite, Ab_3An_4, to bytownite, Ab_1An_3. Occasionally one of these basic individuals is surrounded with a narrow rim of orthoclase. The average plagioclase phenocrysts have about the composition of labradorite, Ab_2An_3. The pyroxene is a common, non-pleochroic, pale greenish augite of diopsidic habit.

"The ground-mass has been somewhat altered, with the generation of uralite in small needles, zoisite in rather rare granules, chlorite, abundant biotite, and more sericitic mica in minute foils and shreds. Orthoclase was not certainly detected in the ground-mass, which was originally hyalopilitic, with plagioclase microlites embedded in glass. Magnetite and apatite occur in the usual well-formed crystals.

"A specimen collected at this locality (No. 543) and answering to the foregoing description has been analysed by Mr. M. F. Connor, with result as follows:

Analyses of Augite Latites.

	1.	2.
SiO_2	54·54	56·19
TiO_2	0·96	0·69
Al_2O_3	18·10	16·76
Fe_2O_3	1·14	3·05
FeO	4·63	4·18
MnO	0·10	0·10
MgO	4·56	3·79
CaO	5·85	6·53
SrO	0·15	tr.
BaO	0·21	0·19
Na_2O	3·38	2·53
K_2O	5·44	4·46
H_2O at 110° C	0·10	0·34
H_2O above 110° C	0·50	0·66
P_2O_5	0·46	0·55
	100·12	100·02
Sp. gr.	2·745	

1. Rossland district.
2. Sierra Nevada.

The calculated norm is:

Orthoclase	32·25
Albite	26·20
Nephelite	1·42
Anorthite	17·79
Diopside	6·87
Olivine	10·18
Ilmenite	1·82
Magnetite	1·62
Apatite	1·24
Water	0·60
	99·99

"According to the norm classification the rock enters the sodipotassic subrang, monzonose, of the domalkalic rang, monzonase, in the dosalane order, germanare. The mineralogical and chemical composition and structure all perfectly match the typical augite latite of Table mountain, California, as originally described by Ransome.[1] The analysis of the more basic phase of the Table Mountain flow is entered in column 2 of the foregoing table.

"From the fresh rock just described all transitions to profoundly altered phases are represented in the area. The latite has often been transformed into a dark green, massive rock, still showing its porphyritic character by the presence of broken and altered feldspar phenocrysts or of uralitic pseudomorphs after the augite. For the rest the completely changed rock is, in thin section, seen to be a confused mass of epidote, calcite, quartz, chalcedony, chlorite, biotite, uralitic and actinolitic amphibole, zoisite, pyrite, etc., in ever varying proportion. Sometimes, though not often, an amygdaloidal structure is preserved. This is not so much because it has been obliterated by metamorphism as because these lavas were largely non-vesicular when first consolidated."[2]

Origin and Age. The latite on account of its having a similar chemical composition to the monzonite and on account of its position at the top of the surface series of lavas and tuffs is thought to represent the extrusive equivalents of the monzonite and to be slightly younger than the andesites and diorite porphyrite which are, probably, of late Jurassic age.

[1] Ransome, F. L., American Journal of Science, Ser. IV, Vol. 5, 1898, p. 359.
[2] Geol. Surv., Can., Memoir No. 38, pp. 324-326.

CENOZOIC.

TERTIARY.

Eocene (?)

Sophie and Lake Mountain Conglomerate. No conglomerate outcrops within the limits of the map-area, the nearest exposures occurring on Lake and Sophie mountains. The Lake Mountain occurrence first mapped by McConnell and re-examined by Daly, is about one mile southwest of Lake Mountain summit and about one-third of a square mile in area. It has been described by Daly as follows:

"The rock is there chiefly a coarse, massive conglomerate, dipping at an average angle of 20 degrees to the northeast and showing an apparent thickness of about 300 feet. The mass is truncated by an erosion-surface, so that 300 feet is a minimum thickness at the locality. At no point was the conglomerate found in actual contact with the Rossland volcanics which surround it. There are two possibilities as to the relation between the two formations: the conglomerate may overlie the volcanics, as postulated by McConnell, or, secondly, it may represent a pre-volcanic conglomerate forming a knob which was first buried under the lavas and since uncovered by their denudation. The choice between these alternatives is not ensured by any known fact. The comparatively low dips suggest that the first view is the correct one. At the same time, there are no lava fragments among the pebbles of the conglomerate which are composed of grey and greenish-grey quartzite, siliceous grit, vein quartz, phyllite, and slate. A few badly altered pebbles of a rock like granite are also present.

"Practically all of the material observed in the pebbles could have been derived from the Palæozoic and Pre-Cambrian terranes now exposed in the Selkirk range, 25 miles to the eastward; in the absence of any other known source, that place of origin appears probable. The pebbles are of all sizes, up to the diameter of one foot. They are of rounded, subangular, and angular shapes. In places the deposit approximates a true breccia in appearance. The imperfect rounding, and, in addition, the generally tumultuous aggregation of the pebbles suggest rapid deposition, as if by a rapid mountain stream. Small irregular lenses of quartz-sandstone and grit form the only breaks in the pebbly mass. Similar arenaceous material composes the cement of the conglomerate, which is also quite highly ferruginous. One dyke of basic andesite or latite (character not determined) and a large (mapped) apophysis of the Sheppard granite cut the conglomerate."

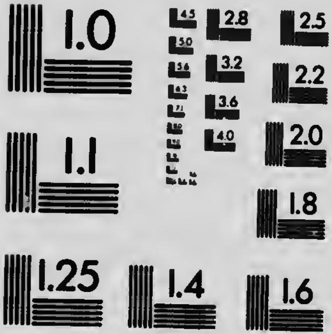
The Sophie Mountain occurrence on the summit of Sophie mountain at the International Boundary line has an areal extent of over a square mile. This occurrence has been examined in detail by Daly who states: "In structure, size of pebbles, and composition this rock resembles the conglomerate at Lake mountain very closely, but here there are a few pebbles of the neighbouring trap-rock as well as some of blackish chert and others of fine-grained granite, while the pebbles are more generally rounded than at Lake mountain. The cement is arenaceous. The sandy lenses range from 6 inches to 2 feet in thickness and are never continuous for any great distance on the outcrop. One hundred yards northeast of the Boundary monument a bed of sandy shale, containing poorly preserved dicotyledonous leaves, was found. These obscure fossils were examined by Professor Penhallow who reported as follows:

'The impression of a leaf is certainly a very poor one to found an opinion upon, and the difficulty is complicated by the crossing impressions of superimposed leaves. All I can do is to make a very wide guess. After very careful examination and consideration, I am inclined to think the leaves are those of *Ulmus speciosa*, Newb. If this determination is at all correct, then the age is Tertiary and possibly Miocene: I do not think it can be Cretaceous. Assuming this guess to be correct, I find the specimen to be quite in harmony with specimens in Mr. Lambe's collection from Coal gully, since in both cases the species is the same and the matrix has been similarly metamorphosed.'

"At the Boundary monument the conglomerate dips northwest at an average angle of 31 degrees. Seven hundred yards to the northwest of the monument the dip was again determined on sandy intercalations as 80 degrees to the southeast. Along

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



the Velvet mine wagon-road the average dip is about 75 degrees southeast. The attitude of the bedding is, on account of the massiveness of the conglomerate, very difficult to determine, but these readings suffice to show that the conglomerate has been greatly disturbed. The exposures are not sufficiently continuous to warrant a statement as to the thickness of the conglomerate: it is certainly a heavy deposit, possibly 1,000 or more feet thick. Just south of the monument it is seen, at one point, to be apparently resting on the older Rossland volcanics and in spite of the general lack of satisfactory contacts, this relation can scarely be doubted. At one horizon a 20-foot amygdaloidal sill (?) or flow of augite-biotite latite is interbedded with the conglomerate.

"At monument 174 the conglomerate is cut by several dykes of augite-biotite monzonite porphyry in composition similar to the flow just mentioned and to latite occurring on Record Mountain ridge to the northward."

The Sophie Mountain conglomerate was found also to contain, in one locality, fragments of limestone, in part leached out; and where the conglomerate was in contact with tongues of alkalic syenite (pulaskite) the dominantly cherty pebbles were cemented in a pulaskite matrix. The pulaskite dykes cutting the conglomerate invariably show pronounced, chilled borders and Brock mentions a locality on Sophie mountain where the conglomerate is mineralized along such an alkali porphyry dyke. "The process of mineralization may be seen, approaching the dyke, in all stages from unaltered conglomerate to solid ore."[1]

"*Correlation and Origin.* These conglomerate areas have all been mapped under the same colour, though it may well be that they are of different ages. Proceeding from east to west the pebbles of the different occurrences are composed more and more often of material which in the field is indistinguishable from the adjacent Rossland lavas. At the same time the pebbles become more rounded. The local character of the four areas—their alignment and the similarity in the composition of the quartzitic, phyllitic, and slaty pebbles to the rocks forming the Summit series and Priest River terrane as well as the

[1] Explanatory Notes to West Kootenay Map Sheet; Geol. Surv., Can., Map No. 792

Pend d'Oreille group of the Selkirks—these facts suggest the hypothesis that the conglomerate everywhere represents a heavy mass of river gravels, and that one or more streams flowing westward from the site of the present axis of the Selkirk range were responsible for the accumulations. The deposit of dicotyledonous leaves in the coarse Sophie Mountain conglomerate strongly indicates the fresh-water origin of that mass at least. It is clear, however, that we have nothing clear or decisive regarding the correlation of the conglomerate bodies with one another or with the recognized systems of rocks. The high probability is that they are all pre-Miocene and post-Jurassic.[1]"

Oligocene (?)

Porphyritic Monzonite Stocks. "Eight bodies of porphyritic monzonite occur within the area mapped, two of which are somewhat unlike the others but are probably closely connected with them in origin and composition. An area of this rock occurs on the eastern border of the district along the contact of the monzonite and augite porphyrite. The portion exhibited on the map is only a small part of the body which extends to the east and has a diameter of about one-half of a mile. Southwest of the above exposures and within the limits of Rossland, lies a second area of a similar rock while to the westward occur three other small bodies of it: one within the augite porphyrite of Red mountain, a second in the sediments, and a third cutting the augite porphyrite of the band west of Sheep creek. South of the monzonite and within augite porphyrite, occurs a somewhat irregular, lense-shaped body of this rock over 600 yards long. The remaining two areas occur on either side of Sheep creek with irregular, tongue and dyke-like outcrops probably continuous with one another though separated by an exposureless area.

"The porphyritic monzonite of most of these localities has a rather characteristic appearance and within any one body is remarkably uniform. Typically the rock is of a light grey colour, coarse grained and composed of rather large, stout prisms

[1] Geol. Surv., Can., Memoir No. 38, pp. 350-352.

of dark-green pyroxene and secondary hornblende, countless small rounded or hexagonal flakes of brown biotite and abundant feldspar. The numerous pyroxene and hornblende individuals usually are sharply rectangular of outline, the basal sections often eight-sided while sections from the prism zone are frequently terminated by pyramidal faces. The crystals commonly measure between one-eighth and one-quarter of an inch in length and occasionally attain even larger dimensions. The pyroxene and the small biotite flakes, the latter seldom over one-fortieth of an inch in diameter, are evenly distributed through the light feldspars which exceed the coloured constituents in amount though because of the dark colours of the latter, the reverse often seems to be the case. The feldspars have less regular crystal forms than the other constituents and vary much in size: the larger grains not uncommonly have cleavage faces nearly one-quarter of an inch in length.

"As seen under the microscope, the pyroxene is nearly colourless; the individuals are usually sharply idiomorphic and sometimes show prominent zonal structures. Green, secondary-like hornblende frequently forms a border to the crystals and in some cases seems to have wholly replaced the augite. The pyroxene frequently encloses small, irregular forms of plagioclase feldspar. The biotite is dark brown in colour and is often penetrated by small laths of plagioclase.

"The most abundant feldspar is an alkali type in rather irregular forms sometimes measuring 13 millimetres in length. They are sometimes mottled or show very distinctly, an intergrowth with a twinned plagioclase variety. These feldspars act as hosts to a multitude of small laths of plagioclase occurring sometimes singly, sometimes in groups. The plagioclase is well twinned according to the albite law, often accompanied by carlsbad twinning; measurements of the extinction angle indicate that the variety has the composition of andesine.

"The above descriptions apply to most of the areas but in some, the biotite seems to be more abundant, the flakes larger, while the individuals of pyroxene are relatively smaller. The two larger, dyke-like areas on the opposite side of Sheep creek show a variation in which the pyroxene and biotite have lost their sharply crystallographic outlines. The rock is of a rather light-grey colour and is composed of white feldspars, dark brown or nearly black biotite and dark-green augite and hornblende. The rock is moderately coarse and uniform of grain. The feldspars as indicated by their cleavage faces, seem to occur in rather irregular forms with an occasional individual larger than the rest. The exceedingly abundant biotite is present in roughly-rounded flakes whose cleavage faces occasionally measure one-tenth of an inch in diameter but commonly are much smaller. The dark augite and hornblende appear to be less abundant than the mica and seem to lie in irregular grains and groups of grains showing about the same variations in size as the biotite.

"Under the microscope the rock is seen to be composed essentially of alkali and plagioclase feldspars, biotite and augite. The abundant plagioclase occurs in rather broad, lath-like individuals or more irregular forms, usually showing very prominent zonal structures and from the values of the extinction angles, seemingly approximate acid labradorite in composition. The alkali-feldspars are less abundant and assume smaller, irregular forms or occur in large shapeless plates enclosing the plagioclase individuals. The deeply pleochroic, brown biotite and the light-green pyroxene occur in comparatively ragged individuals, sometimes enclosing irregular grains of plagioclase feldspar.

"Several areas of porphyritic monzonite were seen just outside the borders of the area but otherwise their distribution seems to be quite local. They apparently are younger than the monzonite though the contacts of these two types were always covered. The masses seem to send, in the form of dykes, finer grained, micaceous varieties into the diorite porphyrite." The relations with the Nelson granodiorite are not so clear, but the meagre evidence favours the view that the latter is the older and in the case of the tongue and dyke-like areas on Sheep creek, the porphyritic monzonite seems to have been intruded into the granodiorite.

"The porphyritic monzonite is mineralogically not unlike some of the coarser types of monzonite and its composition and structures indicate a close relationship between the two types. Their distribution is local, corresponding in a way with that of the monzonite and it seems probable that they represent a later phase of the monzonitic invasion. Their uniform characters and considerable extent, indicates a common origin from a rather large body, perhaps the original source of the monzonite mass." Certain contact facies of the Coryell batholith[1] are monzonites which appear to merge gradually into the normal pulaskite[2] so that it may be that the porphyritic monzonite of Rossland is closely connected genetically with the younger alkalic syenites.

"The two irregular, dyke-like bodies of porphyritic monzonite occurring on opposite sides of Sheep creek, are the first of a series of igneous intrusions occurring in this neighbourhood and it is not unlikely that they owe their position and general outline to the line of weakness along which the slates were faulted and which is now occupied by the broad dyke of pulaskite. The tendency of the porphyritic monzonite in the remaining areas to assume rounded or lenticular forms is very noticeable. Their outlines suggest the possibility that they represent cross-sections of pipe-like forms extending upwards through the once overlying Carboniferous and younger rocks and perhaps represent portions of old volcanic conduits.

"*Sheep Creek Diorite Porphyrite.* A large dyke of diorite porphyrite that differs in character from the previously described variety, occurs on the western side of Sheep creek, cutting the granodiorite and the porphyritic monzonite. This dyke rock is much weathered and the main, central portion of the dyke is composed of a pink, porphyritic rock made up of pink tabular or lath-like feldspars sometimes an inch long, with numerous rounded quartz phenocrysts and dark green spots probably representing decomposed pyroxene. Along the contacts in places for a width of several feet or more, the rock passes into a lamprophyric form, dark greenish in colour and composed of many rounded individuals of quartz lying in a

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[1] A stock of porphyritic monzonite (Salmon River monzonite) similar to those of Rossland forms prominent spheroidally weathered outcrops about 1 mile south of Ymir on the Nelson and Fort Sheppard railway. This stock contains a core of typically granular pulaskite almost identical with that of the Coryell batholith. The transition from the one to the other is sharp and may be seen well defined near the railway track. Geology of Ymir Mining Camp, Geol. Surv., Can., memoir in course of preparation.

[2] Daly, R. A., Geol. Surv., Can., Memoir No. 38, p. 360.

medium to fine-grained ground of distinct feldspars and spangled with tiny biotite flakes.

"Under the microscope the coarse, central portion of the dyke is found to be formed of large, stout, plagioclase individuals a few rounded quartz crystals and areas representing completely altered augite, lying in a fine-grained ground of small, rectangular feldspars often showing albite twinning, and quartz. Probably a considerable portion of the feldspars of the ground is orthoclase but on the whole, all are characterized by good outlines. The rather abundant quartz of the base occurs in small interstitial grains and in granophyric intergrowths with the untwinned feldspars.

"The finer grained, lamprophyric facies is mainly a mosaic of lath-like plagioclase feldspars heavily charged with flakes of reddish brown biotite distributed without any regard to the outlines of the feldspar individuals. Colourless augite is present in large forms with irregular outlines and rounded or embayed quartz phenocrysts are common.

"This type of rock was seen only at this one locality and probably represents an accompanying, later phase of granodiorite intruded along or near the old line of weakness already referred to."

Miocene.

Coryell Batholith and Pulaskite Intrusives. An alkalic syenite of the composition, predominantly, of pulaskite[1] occurs in irregular boss-like and dyke-like intrusions cutting all the preceding formations. "It occurs in five distinct areas within the sheet and seems to represent one of the youngest igneous rocks of the camp. Two of the areas are very small, one occurs within the serpentine body of Sheep creek and the other in the monzonite just east of Rossland. Within the city proper, is an almost elliptical area of the same rock surrounded by the monzonite, while south of this, on the slopes of Deer Park ridge and partly concealed by drift, is a larger, irregular body of the syenite penetrating the monzonite. To the west of Red mountain

[1] Pulaskite may be defined as a type of alkalic syenite between a normal syenite and a nepheline syenite with biotite as chief ferromagnesian constituent. Nordmarkite is a quartz-bearing pulaskite. Rosenbusch (H) Intrusiv-Gesteine, II, 1 (1907) p. 146.

cccurs the southern continuation of a dyke-like mass of the syenite which extends northwards beyond the limits of the sheet for about one mile.

"The pulaskite is a coarse-grained rock, typically of a pale pink colour and composed of long, rectangular feldspars quite often 1 to 2 inches in length. Besides the feldspars both biotite and hornblende are present, sometimes one, sometimes the other predominating but usually neither is at all abundant. The biotite occurs in small flakes and the dark green hornblende in small prisms or irregular grains.

"The pulaskite sometimes shows marked variations in grain or mineralogical composition. Sometimes the dark coloured constituents nearly disappear and the rock then is often coarser in grain than usual. At other times, often quite close to the feldspathic portions, the rock for this type becomes abnormally rich in the dark constituents.

"In the case of the small lenticular area in the main part of the city, the rock shows many sudden and exceptional changes. In places it becomes almost black from a great increase in the amount of biotite. In other parts, are vaguely concentric structures with a diameter of a few yards and in some cases the hornblende becomes very abundant in the form of slender prisms occasionally reaching a length of over two inches.

"Under the microscope, the abundant feldspars of the more normal pulaskite are seen to be largely lath-like individuals showing carlsbad twinning and many of them are comparatively coarse intergrowths of orthoclase and albite, the areas of the latter being distinctly twinned according to the albite law. There are all gradations from such individuals to others presenting a mottled appearance or in which one part of an individual is albite, the other a monoclinic variety of feldspar. The biotite is brown in colour, the individual flakes commonly ragged. The hornblende is a green variety and the individuals usually have fairly good prismatic outlines.

"A type specimen of pulaskite collected by Brock at a point north of Record mountain, was analysed by Dr. F. Dittrich of Heidelberg, and gave the following results:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O
62·59	0·54	17·23	1·51	2·02	tr.	1·30	1·99	5·50	6·74

P_2O_5	H_2O (direct)	CO_2	Cl	SO_3
0·11	0·30	trace	trace	trace—99·83

Another typical specimen collected by Daly on the summit (6,820 feet above sea-level) about 4 miles north of the Boundary and thus well toward the centre of the batholith has been studied quantitatively according to the Rosiwal method. The weight percentages of the constituents were found to be approximately as follows:

Quartz	5·1
Sodiferous orthoclase and microperthite	51·2
Andesine, Ab_4An_3	17·0
Hornblende	20·2
Augite	1·5
Magnetite	1·7
Titanite	1·6
Apatite and zircon	0·8
	100·0

"From these proportions the chemical composition of this specimen has been roughly calculated. It is assumed that the hornblende has the same composition as has the hornblende in the "quartz-monzonite" of Mt. Hoffman, California, and that the alkaline feldspars are present in the ratio of two of orthoclase to one of albite. The result is as follows:—

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	P_2O_5
59·2	0·7	15·9	2·2	2·7	2·8	4·9	3·6	5·8	0·4	0·4

Remainder
1·4—100·0

"The soda is probably too low, yet the calculation seems to show that the analysis made for Brock corresponds well with that of the typical specimens collected during the Boundary survey.

"The rock is evidently a typical hornblende-biotite pulaskite. In some cases the biotite is almost absent or is entirely so, though the composition is not otherwise essentially different giving an alkaline hornblende syenite. More rarely, the interstitial quartz increases notably and the syenite has the composition and habit of the more acid hornblende-biotite nordmarkite.

"The pulaskite seems to represent one of the last igneous intrusions within the area of the camp. The syenite distinctly cuts all the other types of rocks with the exception of the Sheppard granite porphyry and certain of the lamphropyric dykes and the latter seldom cut the syenite in spite of the fact that they are so numerous in the district. In the surrounding country, the pulaskite or Rossland alkali granite [Daly's Coryell batholith] occupies large areas of batholithic dimensions and all intermediate sized areas down to small dykes. Since in the Boundary district, this type of rock seems to be related in chemical composition with certain Tertiary volcanic flows, it is possible that some or all of the bodies may represent deeply eroded, conduits of ancient volcanoes. There is, however, no direct evidence of such having been the case with the bodies within the limits of the Rossland mining district.

"On the authority of McConnell and Brock, the age of the pulaskite is assumed to be Tertiary. Since the time of its formation the district has been extensively eroded. Probably thousands of feet of sedimentary and volcanic material, ranging in age from Carboniferous times on into the Tertiary, have been swept away and the once deeply-covered igneous complex laid bare. With the exception of the old Carboniferous sediments of the Mount Roberts group all the remaining rocks exposed within the area of the sheet are of igneous types. All, with the possible exception of the bodies of augite porphyrite, were intruded, cooled, and solidified while still far below the successive surfaces of the different geological ages."

Sheppard Granite Intrusives. Intrusive into the pulaskite south of the Spitzee mine occurs a prominent granite porphyry dyke. Similar dykes also occur in the LeRoi and Centre Star mines, where they cut both diorite porphyrite and monzonite. A large dyke (averaging over 100 feet in width) of granite porphyry striking roughly east-west, outcrops on the northern slope of Deer Park mountain, the exposure extending from the end of Davis street to the main granodiorite mass in Little Sheep Creek valley. An east-west trend at right angles to the normal direction of the younger dykes of the district, seems to be characteristic of this class of dyke rock.

"The granite porphyry is a light to dark-grey rock composed of numerous rounded phenocrysts of quartz, many white, tabular feldspars and tiny flakes of biotite lying in a fine-grained, dark bluish, sometimes greenish ground. The phenocrysts are very abundant, often appearing to equal the ground in amount frequently those of the feldspar measure one-tenth of an inch in length while the less numerous quartz individuals are smaller and the biotite only averages one-fortieth of an inch in diameter.

"Under the microscope, the feldspar phenocrysts are seen to be almost altogether tabular individuals of acid plagioclase. The quartz grains are rounded and embayed. The mica occurs partly in aggregates of tiny scales and a small amount of green hornblende is sometimes present. The ground consists of a fine-grained, interlocking mosaic of quartz and untwinned feldspars, the latter probably being orthoclase.

"Over the whole area of the granodiorite, the rock is very uniform in its general appearance. As evidenced by the granite porphyry, it has intrusive relations with the monzonite and older rocks. It is also younger than the diorite porphyrite, and porphyritic monzonite and pulaskite but is cut by a series of dykes."

The granite porphyry from Rossland resembles very closely Daly's Sheppard granite, exposed on the summit of Lake mountain where it is intrusive into early Tertiary conglomerate. The resemblance is so close that it is almost impossible to distinguish one from the other in hand specimens.

Mr. M. F. Connor made a chemical analysis of the Sheppard granite for Daly, which gave the following proportions:

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	SrO	BaO	Na_2O
77·09	0·05	13·04	0·82	0·26	tr.	0·12	0·63	none	none	3·11

K_2O	H_2O at 110° C	H_2O above 110° C	P_2O_5
4[illegible]	0·03	0·07	0·10—99·82 Sp. Gr. 2·600

The calculated norm is :

Quartz	40·50
Orthoclase	26·69
Albite	26·20
Anorthite	2·50
Corundum	2·04
Hypersthene	0·30
Magnetite	0·93
Hematite	0·16
Apatite	0·31
Water	0·10
	99·73

"In the norm classification the rock enters the sodipotassic subrang, alaskose, of the peralkalic rang, alaskose, in the persalane order, columbare. According to the older classification it is an aplitic, alkaline biotite granite."

The Sheppard granite may represent a complementary phase of the Coryell alkalic syenite and be its aplitic differentiate.

Lamprophyre Dykes. Rossland is noted for the innumerable lamprophyre dykes which cut all the veins and country rock formations in the mines and which invariably have a north and south trend.

"They are generally very dark grey or green, in some places almost black rocks usually fine grained, in places almost dense. Many varieties are porphyritic holding in a fine base, hexagonal flakes of biotite or small dark prisms of pyroxene and hornblende, while often small cleavage faces of larger feldspars may be detected. The ground of these rocks is always distinctly crystalline and often is coarse enough to show the individual components quite readily; and frequently it is seen to be charged with finely divided mica.

"When examined under the microscope, the dyke rocks are seen to present the structures and mineral characters not only of typical minettes, kersantites, spessartites, vogesites and odonites but also all intermediate forms between those rich in plagioclase and those rich in orthoclase on the one hand and between biotite-bearing types and those in which pyroxene with hornblende is the predominant coloured constituent, on the other. Though not a few thin sections were examined, no rock was seen that would be classed as a typical camptonite yet hornblende was a common and sometimes the chief coloured constituent.

"Besides the dark lamprophyres, other acid, light-coloured, feldspathic dykes occur such as those larger ones shown towards the eastern margin of the 400-foot sheet (Map No. 1002 in pocket). These dykes occur only exceptionally within the area studied but are numerous to the eastward. They seem to represent [illegible] forms, perhaps complementary to the lamprophyres.

"The great body of the dykes cut all of the rocks of the Rossland area. Their total number must be very great since underground in the mine workings, they probably average at least one in every twenty-five feet along sections in an east and west direction. Though on the surface only a very small proportion is exposed, they appear to be equally abundant throughout the area of the sheet. On a rare rock section, freed from the covering of soil, the dykes were seen to be as numerous as underground, to cross one another, to branch and coalesce in a most intricate manner, but yet preserved a general north and south trend and an approximately vertical attitude.

"The relative ages of the different varieties could not be satisfactorily determined. Their general uniform attitude over the whole district and the fact that they cut everything, indicate a comparatively recent age for the whole group. Their distribution gave no indication of a local origin, they seemed as abundant everywhere in the surrounding district." It would seem probable that the subalkalic varieties (kersantite and spessartite) are genetically related to the Nelson granodiorite: the intermediate varieties corresponding to the monzonite and the alkalic varieties (minette and vogesite) to the alkalic syenite or pulaskite.

QUATERNARY.

Pleistocene.

Boulder Clay and Alluvium. Boulder clay or till containing in places large boulder erratics carried by the ice from considerable distances to the north, lies as a thin mantle over a great part of the district. A large erratic block of alkalic syenite on the LeRoi wagon road has probably been transported from the Coryell batholith several miles northwestward. In sections exposed on the new Trail road and elsewhere, the boulder clay is seen to be fairly compact, light in colour, and made up of pebbles and subangular to rounded boulders of all sizes in a sandy-clay ground.

Great thicknesses of alluvial sands, silts, and clays are present at the junction of the Trail Creek valley with the valley of the Columbia above the town of Trail. The alluvium was probably laid down during the retreat of the ice in a glacial lake formed by the damming of the waters from the small Trail Creek glacier against the main Columbia Valley glacier.

CHAPTER III.

GEOLOGICAL HISTORY.

The geological history of Rossland has to do chiefly with igneous activity which has manifested itself from time to time on a grand scale and has played an important rôle in the production of the ore deposits. Intervening periods of crustal stability have permitted erosive agencies to sculpture the land surface, thus removing vast rock records of the past, and making it difficult to interpret the complete history of the region. From the fragmental data which remains, however, at least the main episodes and succession of geological and physiographic events may be outlined.

Palæozoic Erosion, Marine Sedimentation, and Igneous Activity.

The oldest rock records present are contained in the Mount Roberts formation of Carboniferous age. Prior to the Carboniferous this district probably formed a part of one of the many low-lying land areas or barriers ("Cascadia"[1]) surrounded by relatively shallow epicontinental seas that characterized the Palæozoic period. Active erosion, in which decomposition dominated over disintegration, proceeded and supplied much material to the bordering seas to form sediments. Marine life abounded in the seas. In course of time the land was worn down to a featureless plain nearly at sea-level (peneplain).

With the wearing down of the land and the accumulation of a great thickness of sediments in the bordering seas, crustal stresses were set up which in time found relief and adjustment through crustal movements. The result was that the mid-Palæozoic peneplain was downwarped and was submerged under a transgressing Devono-Carboniferous sea ("Vancouver sea"[2]). In this shallow, warm sea, which supported lowly

[1] Palæogeography of North America; Bull. Geol. Soc. Amer., Vol. XX, p. 469.
[2] Op. cit., p. 463.

marine life (brachiopoda, bryozoa, corals, etc.), sedimentation proceeded, with the accumulation of, first, arenaceous and argillaceous material and, later, calcareous material, the latter indicative of an expanding sea. Local volcanic activity caused tuffs to be interbedded with the normal deposits. The above sediments—the oldest in the district—through metamorphism and crystallization, consequent upon the many vicissitudes they passed through were altered to quartzite, slate, crystalline limestone, and altered tuff (Mount Roberts formation).

Deformation at Close of the Palæozoic.

After the deposition of the Mount Roberts formation the region was uplifted above the sea and probably never sank beneath it again although the Interior Plateau province to the west was submerged during the Triassic and earliest Jurassic.[1]

Although diastrophism was not so pronounced at this time in the Canadian cordillera as it was in the east ("Appalachian revolution") some deformation and folding accompanied the regional uplift. This is indicated both by unconformities between the Palæozoic and Mesozoic formations and by the degree of metamorphism each has suffered.

Triassic Erosion and Igneous Activity.

The Mesozoic period opened with vigorous erosion on the newly uplifted land which probably had a moderately strong relief.

During the Triassic, volcanic activity burst forth with the accumulation of agglomerates, tuffs, and lavas closely followed by augite-porphyrite sills which were injected under a considerable cover of Mount Roberts formation and superficial volcanics. Erosion continued and soon removed much of the superficial material.

Late Jurassic Orogeny, Vulcanism, and Mineralization.

During the Jurassic, erosion continued and nothing of great import happened until near the close of the epoch, when the great

[1] Summary Report, Geol Surv., Can., 1912, pp. 134, 147.

"Jurassic mountain-making revolution" took place. At this time, it is considered, the Columbia and other rugged mountain ranges in British Columbia were formed. Accompanying mountain-making and possibly genetically connected with it, was batholithic invasion (Trail granodiorite batholith) with all its closely related intrusions of different rock types (diorite-porphyrite tongues, granodiorite cupola stocks, andesitic lava flows and tuff beds, monzonite chonolith and latite flows, and complementary dykes).

After consolidation of the stocks, tongues, and upper portions of the batholith, the mass was subjected to horizontal compressive forces due to crustal readjustment which formed fissure and shear zones controlled in their directions and dips by those of the formational contacts. Mineralizing waters—"the after effects of vulcanism"—found access to the upper contact zone of the batholith and circulated through the fissured, sheared and brecciated country rocks along the borders of the granitic intrusives and even within them, altering the shear zones to ore-producing veins.

Following the Jurassic revolution the rugged and youthful topography of the Columbia range was probably very similar to that of the Rockies following the Laramide revolution. Like the latter, the Columbia range consisted then, of tectonic sedimentary mountains whose granitic cores had yet to be laid bare by erosion. The drainage was at first consequent to uplift and folding and in some localities disorganized by the outflow of lavas.

Cretaceous Erosion Cycle.

During the Cretaceous the rugged sedimentary mountains were slowly worn down. The Cretaceous cycle of erosion continued through a long period of crustal stability at a time when the climate was probably humid and large rivers drained into the bordering seas. Erosion was sufficient to remove from the late Jurassic batholith in many places the entire covering beneath which it solidified. The topography passed through all the stages of development from youth through adolescence to maturity and finally, by the close of the Cretaceous, to a condition of old age and local peneplanation. Over this vast monotonous plain, surmounted here and there by mountain masses of moderate relief, the rivers meandered sluggishly on their courses to the sea. The Columbia river probably inherits its present meandering course in this region from this old Cretaceous surface (antecedent river).

Laramide Orogenic Revolution.

Following Cretaceous erosion and the deposition of great thicknesses of sediments in the bordering Cretaceous geosynclinal seas, crustal unrest ensued which later on culminated in one of the greatest orographic disturbances recorded in the cordillera namely the "Laramide revolution." This revolution resulted in the overthrusting and faulting of the eastern cordillera and the formation of the Rocky mountains. In the Columbia and other ranges to the west of the Rockies, the orogeny was in the nature of a regional upwarping with maximum uplift along the old structural lines of the preceding Jurassic revolution. The broader features of the cordillera were outlined at this time. The climate in the mountains was probably cool and humid, while in a few localities of maximum uplift, as on the Columbia range, conditions may have been favourable for the support of alpine glaciers. The presence in early Tertiary conglomerates of Franklin mining camp[1] of boulders and pebbles similar to those of glacial origin suggests such an inference.

Eocene Continental Sedimentation and Igneous Activity.

The "Laramide revolution" began a new cycle of erosion, the drainage became invigorated, and some of the major rivers were deeply entrenched beneath the older Cretaceous erosion surface. Portions of the early Tertiary Colum ia mountains were then nearly as high and rugged as the present ranges as is evidenced by the contacts of the oldest Tertiary deposits with bed-rock and the coarse heterogeneous character of the tectonic sediments. At this time probably a river flowed westward from

[1] Geol. of Franklin Mining Camp, B. C.; Geol. Surv., Can., Memoir 56, pp. 65, 95.

the Selkirks towards the Pacific[1] a few miles south of Rossland. The boulders and sands laid down in its valley bottom may still be seen on the summits of Sophie and Lake mountains (Sophie and Lake Mountain conglomerate). The old valley bottom of Eocene time is now the mountain summit.

OLIGOCENE DEFORMATION AND EROSION INTERVAL.

Following the erosion and continental sedimentation of the Eocene deformative movements took place accompanied by the intrusion at Rossland of the porphyritic monzonite in the form of stocks and dykes. The Sophie and Lake Mountain conglomerate beds were deformed and local displacement of some of the veins probably took place at this time. Volcanic outbursts of rhyolitic lavas and fragmentals occurred in some localities and disorganized the local drainage systems. A period of crustal stability then ensued and an erosion interval removed vast thicknesses of early Tertiary sedimentary and volcanic records and reduced the topography to maturity and possibly late maturity in a few localities.

MIOCENE IGNEOUS ACTIVITY AND MINERALIZATION.

During the Miocene the erosive work of the Eocene and Oligocene continued, but was interrupted at Rossland, by another great period of batholithic invasion somewhat similar to the previous late Jurassic one. This batholithic invasion, however, known as the Coryell batholith, instead of being composed of granodiorite and related subalkalic rocks, was composed of the much rarer alkalic types (dominantly pulaskite). The southern border of this batholithic mass is exposed a few miles north of Rossland on Granite mountain, although tongues (aschistic dykes) and cupola stocks from it penetrate the rocks in the immediate vicinity of Rossland. At this time the vein fissures were probably further fractured and the sulphide deposits locally enriched by gold brought in by the alkaline mineralizing solutions connected with the Coryell batholith (second main

[1] Geol. of North America Cordillera. Geol. Surv., Can., Memoir 38, p. 352.

period of mineralization). Complementary augite camptonite and minette dykes were intruded slightly later in a general north and south direction, and are free from metamorphism or alteration of any kind along their contact lines. Their fine-grained texture with chilled borders of glass indicate that they must have cooled close to the surface. Composite dykes are very frequently encountered in the mine workings.

The youngest intrusions recorded are certain granite porphyry and lamprophyre dykes found cutting the pulaskite and good exposures of which may be seen on Deer Park hill and on the Trail road, a few miles below Rossland. The granite porphyry is correlated lithologically with the Sheppard granite which lies exposed on the summit of Lake mountain and elsewhere where it is intrusive into early Tertiary conglomerate (Lake Mountain conglomerate).

Pliocene Erosion and Upwarping.

This Miocene diastrophism and volcanic activity inaugurated a most important erosion cycle from the standpoint of the present topography, which lasted during a long period of crustal stability from the middle of the Miocene to the close of the Pliocene and resulted in the production in the Columbia range of an erosion surface of a mature to late mature stage of topographic development exhibiting broad flaring valleys. In the Interior Plateau province and other intermontane lowlands local peneplanation was accomplished. The drainage was well organized in respect to the main rivers. The topography did not reach, however, prior to uplift, the advanced stage of development of the previous Cretaceous erosion surface. The climate was gradually becoming cooler.

Pleistocene Valley Cutting and Glaciation.

The Tertiary closed and the Quaternary period began with a great regional upwarping of the late Tertiary erosion surface. The drainage was rejuvenated and a new cycle of erosion commenced which is still in progress. Steep-walled valleys were incised deeply beneath the older upland surface of maturity. These have since been smoothed and modified by a cycle of glacial erosion.

During the Pleistocene a refrigeration of climate took place and the Cordilleran ice sheet advanced from the north and northwest covering the whole region with the exception of some few peaks over 6,400 feet above sea-level, which stood as 'nunataks' or islands above the ice surface. The Cordilleran ice cap modified but slightly the upland topography, leaving in places glacial striæ and scourings. In retreating the glacier left morainic drift and erratics stranded high on the uplands. At least two periods of valley glaciation and alluviation probably succeeded the disappearance of the ice cap.

Recent.

The retreat of valley ice increased the eroding power of the streams which began the dissection of the valley-fill material and sharply incised the post-Glacial gorges and ravines. The work of frost, ice, snow, rain, and humus are further facilitating the disintegration and decomposition of the rock formations.

Summary of Geological History.

The geological and physiographic history of Rossland and vicinity may be briefly summarized in tabular form as follows:—

Palæozoic.

(1.) Deposition of arenaceous, argillaceous, and calcareous sediments with local tuff beds, in a Carboniferous sea (altered rock types of Mount Roberts formation). Warm tropical climate.

Mesozoic.

(2.) Uplift and deformation at the close of the Palæozoic which commenced new and lasting conditions of continental erosion and sedimentation; moderate relief of the land surface at the close of the Palæozoic worn down to slight relief by late Jurassic time; drainage at first consequent and disorganized, later subsequent and well organized; climate changed from probably humid and cool to semi-arid in the Jura-Triassic.

(3.) Triassic vulcanism. Erosion was interrupted during the Triassic by the outburst of volcanic activity, extrusion of lavas and pyroclastics, and intrusion of sills and dykes (agglomerate, tuff, and augite porphyrite of Rossland).

(4.) "Jurassic revolution" and birth of Columbia tectonic mountains; invasion of Trail batholith with related intrusives and extrusives (granodiorite, diorite porphyrite, monzonite, tuff, andesite, latite, and lamprophyre); first main period of mineralization; youthful topography in rugged sedimentary range with local volcanic peaks; disorganized consequent drainage.

(5.) Cretaceous deformation and erosion. Deformation during early Cretaceous (Comanchic) followed by Cretaceous cycle of erosion with probable production of peneplain (present summit upland surface of erosion). Present course of Columbia river probably inherited from this Cretaceous surface of erosion. Coarse textured topography.

(6.) "Laramide revolution" and epeirogenic upwarp of Cretaceous peneplain with maximum uplift along the axes of the present ranges; faulting of veins; probably humid cool climate.

Tertiary.

(7.) Eocene continental erosion and sedimentation (Sophie and Lake Mountain conglomerate); development of topography from state of youth through adolescence to maturity in places.

(8.) Oligocene diastrophism and intrusion of porphyritic monzonite and mica and non-mica dykes with local faulting of veins; followed by erosion interval which removed much of the loose continental deposits of early Tertiary and semi-tropical climate.

(9.) Miocene vulcanism and intrusion and extrusion of alkalic rocks (dominantly pulaskite). Second main period of mineralization. Intrusion of granite porphyry and lamprophyric dykes and further faulting.

(10.) Late Miocene and Pliocene cycle of erosion during long period of crustal stability; production of mature land surface around Rossland, late maturity in broad intermontane depressions and local peneplanation in the Interior Plateau province; climate becoming cooler; drainage well organized.

(11.) Differential uplift of epeirogenic character in late Pliocene or early Pleistocene; pre-Glacial erosion cycle and incision of Pliocene drainage beneath upland surfaces.

Quaternary.

(12.) Pleistocene erosion and glaciation; arctic climate with milder interglacial periods; Cordilleran ice cap softened the contours of the old upland topography, steepened the slopes of the youthful valleys, and left on its retreat much morainic and outwash material.

(13.) Post-Glacial erosion with excavation of valley-fill into river terraces by meandering Columbia river; incision of gorges, and ravines: subsoil, soil, and stream gravel formed.

Addenda.

Centre Star-War Eagle Group.

The following stopes are at present (1915) being worked: Nos. 651A, 954, 1086A, 1253A, and 1388 in the Centre Star mine and 251M, 361, 451, 557A, 558A, 653M, 667A, 667M, 668M, 687, 694, 769, 862A, 863A, 1165A, 1256, 1287, 1289, 1290, 1352, 1354, 1452, 1457, 1487, 1551, 1651, 1653, and 1686 in the War Eagle mine.

Le-Roi Group.

The following stopes west of the Josie dyke fault and on the south border of the granodiorite stock, have been opened up since June, 1914.

No. 1089,	78	feet long and	25	feet wide with average assay Au	$5.47	Cu.	2.0 %
" 1272,	118	" " "	25	" " " " " "	4.39	"	1.49%
" 1281,	55	" " "	26·5	" " " " " "	3.16	"	1.14%
" 1354J,	220	" " "	13	" " " " " "	9 53	"	3.54%
" 1688,	460	" " "	19	" " " " " "	6.88	"	2.0 %

No. 1093 stope on the north border of the stock is 201 feet long, 15½ feet wide and the ore has an average assay of $5.47 in gold and 2.0 per cent copper.

Iron Mask.

The No. 251M shoot of the Iron Mask has a stope length of 75 feet and has recently been stoped up for 60 feet with average assay values of $12.40 in gold and 0.9 per cent copper; also the No. 653M shoot with stope length of 90 feet averages $7.20 in gold and 2.0 per cent copper and is at present being worked.

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EXPLANATION OF PLATE II.

Rossland from Columbia and Kootenay mountain; lower slopes of Red mountain with principal mines to right; Mount Roberts in background and extreme right; Deer Park mountain in centre; South Belt properties to left in distance.

EXPLANATION OF PLATE II.

Rossland from Columbia and Kootenay mountain; lower slopes of Red mountain with principal mines to right; Mount Roberts in background extreme right; Deer Park mountain in centre; South Belt properties to left in distance.

Plate II.

EXPLANATION OF PLATE III.

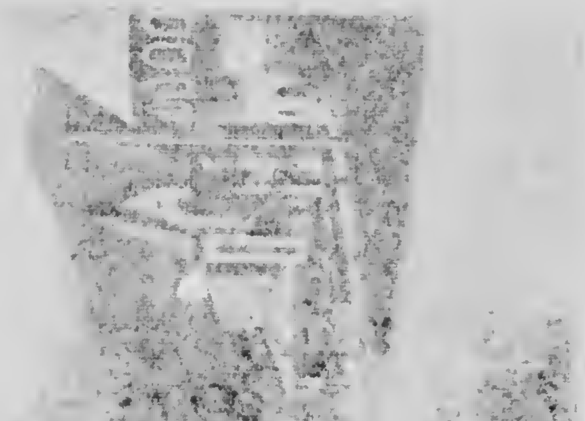
Sheep Creek valley from Velvet-Portland mine. Shows subdued upland slopes, deep glaciated valley, and typical scenery of the Columbia mountains. (See page 4.)

PLATE III.

EXPLANATION OF PLATE IV.

Columbia avenue, Rossland, in 1895.

PLATE IV.



EXPLANATION OF PLATE V.

Columbia avenue, Rossland, in 1914.

Plate V.

Explanation of Plate VI.

Country rocks of the veins (diamond-drill core specimens).

A. Contact between fine-grained augite porphyrite and diorite porphyrite. War Eagle mine (indicated by arrows).

B. Contact between coarse-grained augite porphyrite and diorite prophyrite. Josie mine (indicated by arrows).

C. Shows rapid transition from coarse to fine-grained augite porphyrite. Josie mine.

D. Porphyrite schist. War Eagle mine. (See page 50.)

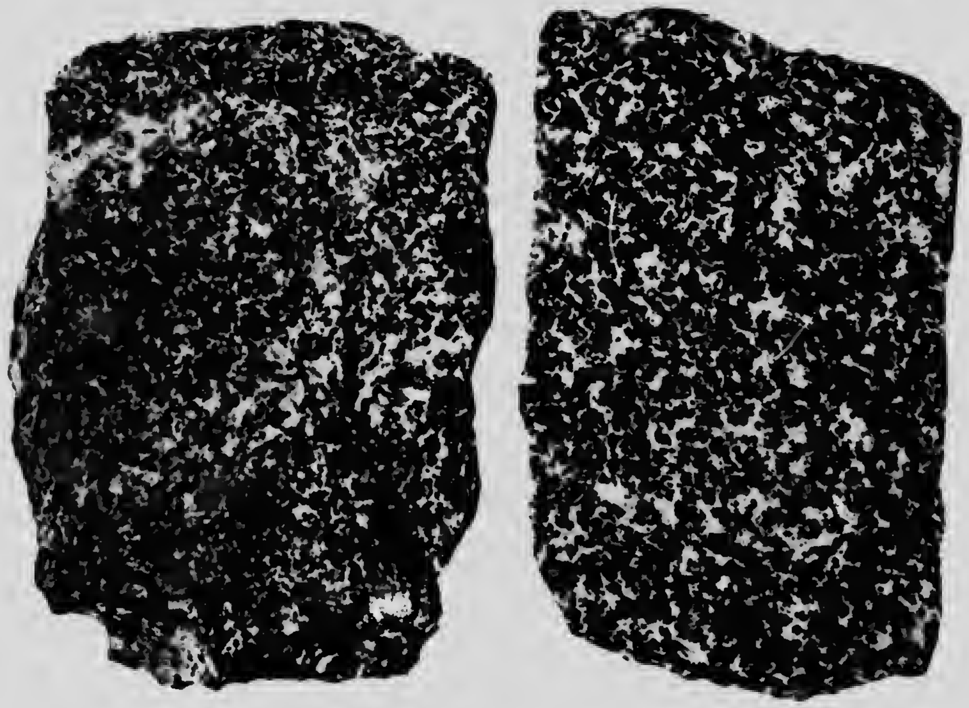
PLATE VI.

a *b* *c* *d*

Explanation of Plate VII.

A. Porphyritic monzonite, LeRoi mine.
B. Centre Star dyke, 16th level, Centre Star mine. (See page 30.)

PLATE VII.



A *B*

EXPLANATION OF PLATE VIII.

Conglomerate dyke ("White dyke" of Josie mine) cutting porphyritic monzonite. Great Northern Railway rock cut near LeRoi mine. (See page 31.)

EXPLANATION OF PLATE VIII.

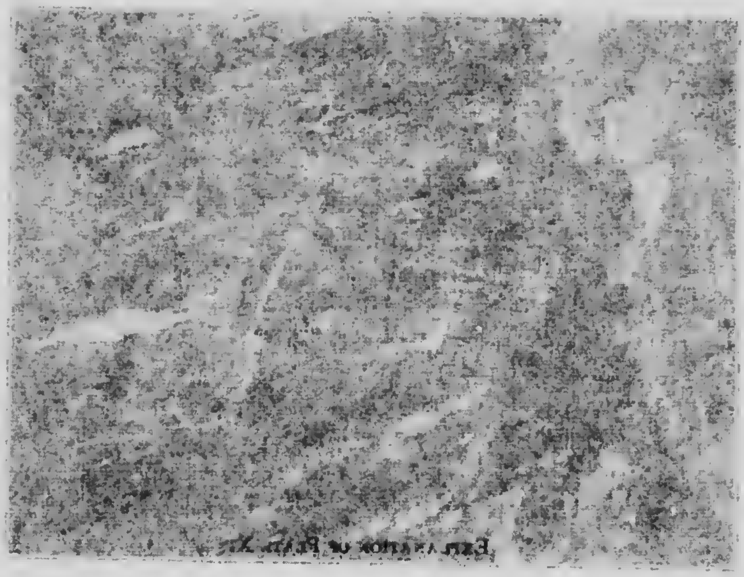
Conglomerate dyke ("White dyke" of Josie mine) cutting porphyritic monzonite. Great Northern Railway rock cut near LeRoi mine. (See page 31.)

Plate VIII.

EXPLANATION OF PLATE IX.

Faulted lamprophyre (camptonite) dyke cutting pulaskite porphyry. Fault indicated by white line. Rock cut on Trail road. (See pages 34, 57.)

PLATE IX.



Explanation of Plate X.

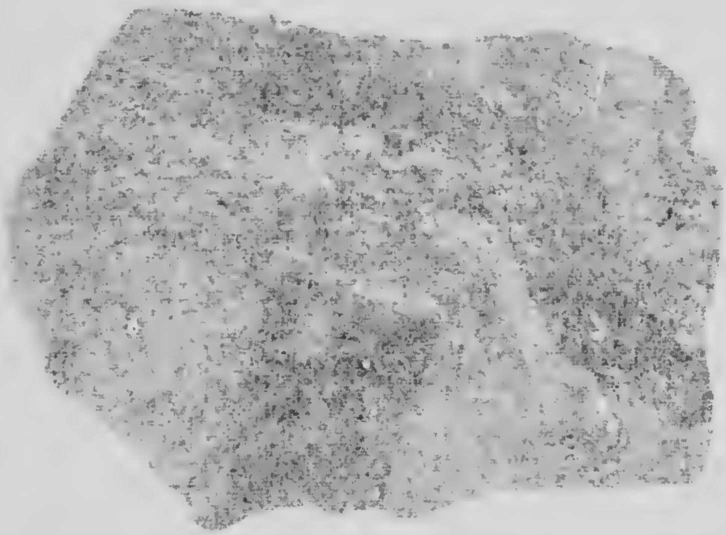
A. Cross-bedding in Mount Roberts formation. Main tunnel, California mine. (See page 34.)

B. Forking of veinlet on 10th intermediate level, War Eagle mine. (See page 48.)

PLATE X.

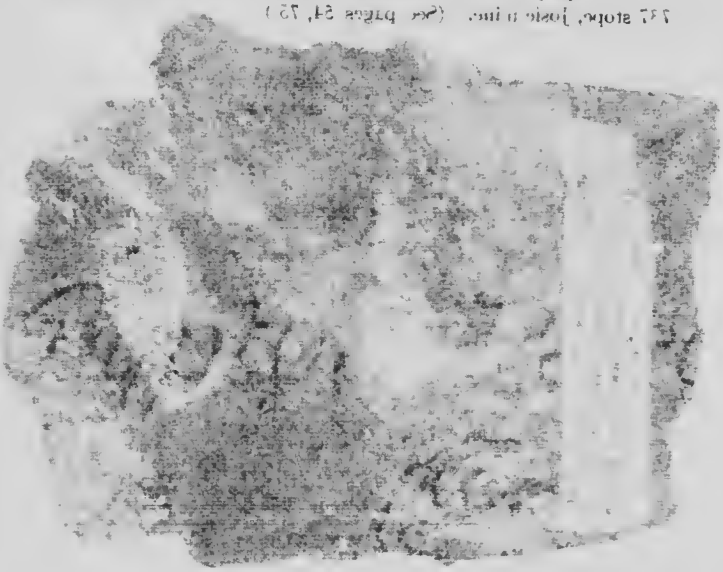
A.

B.



EXPLANATION OF PLATE XL.

A. and B. High-grade ore containing inclusion of lamprophyre dyke. No. 737 stope, Josie mine. (See pages 54, 75.)



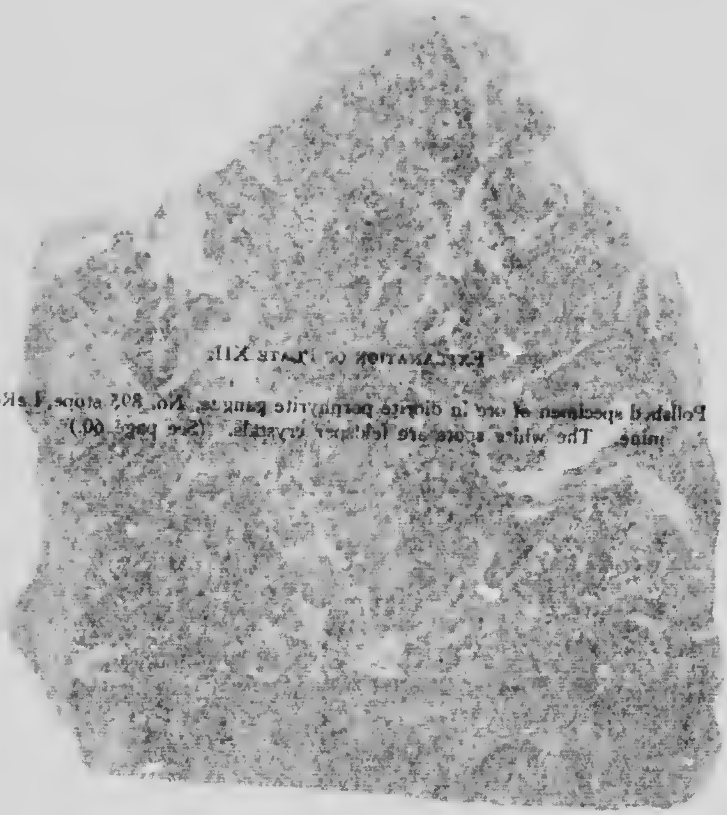
Explanation of Plate XI.

A. and B. High-grade ore containing inclusion of lamprophyre dyke. No. 737 stope, Josie mine. (See pages 54, 75.)

PLATE XI.

A.

B.



EXPLANATION OF PLATE XII.

Polished specimen of ore in diorite porphyrite gangue, No. 895 stope, LeRoi mine. The white spots are feldspar crystals. (See page 60.)

PLATE XII.

Explanation of Plate XIII.

Contact ore shoot; hanging-wall diorite porphyrite, foot-wall augite porphyrite. Shows square set system of timbering. No. 1352 stope. War Eagle mine. (See page 62.)

PLATE XIII.

278

PLATE XIV.

EXPLANATION OF PLATE XIV.

Contact ore shoot; hanging-wall augite porphyrite, foot-wall monzonite. No. 852 stope, Centre Star mine. (See page 63.)

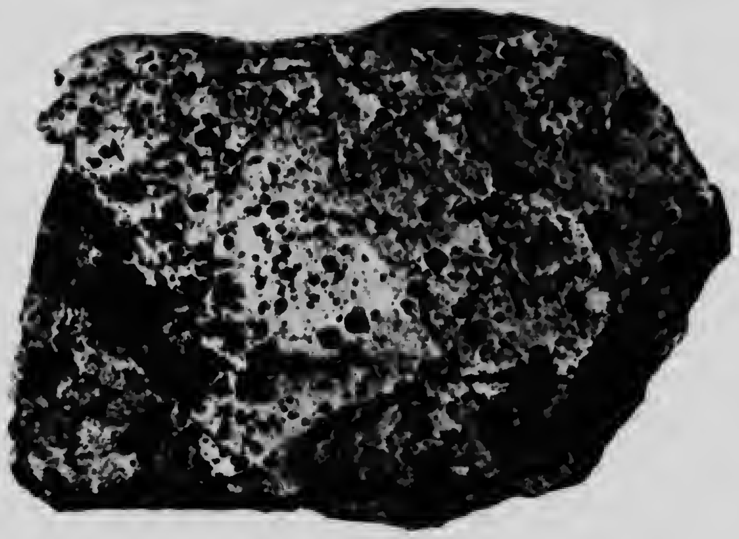
Plate XIV.

EXPLANATION OF PLATE XV.

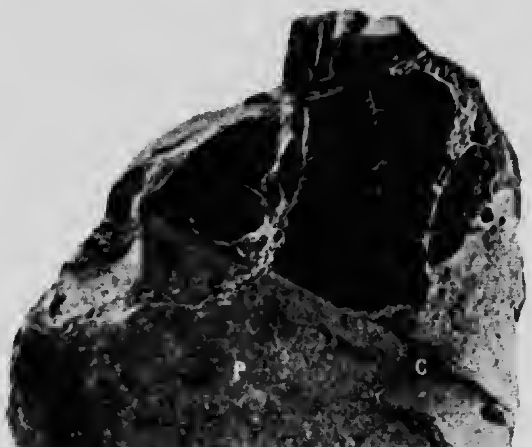
A. Augite porphyrite near vein. Groundmass replaced by silica but not augite phenocrysts, 9th level Josie mine. (See pages 66, 87.)

B. Polished specimen of LeRoi ore; P.-pyrrhotite C.-chalcopyrite; inclusion of augite porphyrite veined by sulphides. Some of the veinlets can be seen passing through dark augite crystals of the rock. (See page 70.)

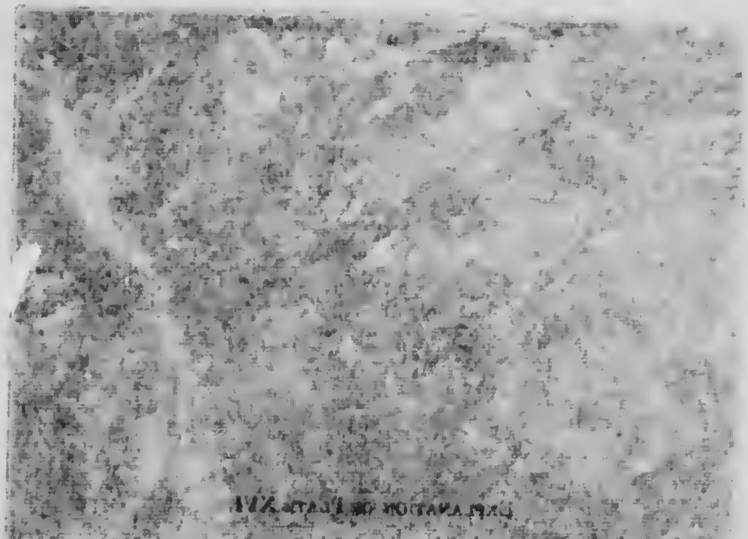
PLATE XV.



A.



B.



Explanation of Plate XVI.

A. "Face" of ore in No. 1452 stope, War Eagle mine. Shows banded structure. (See page 70.)

B. "Back" of ore in No. 1688 stope, LeRoi mine; Black Bear ore shoot west of Josie dyke fault, foot-wall augite porphyrite, hanging-wall granodiorite. (See page 57.) Total length of stope 460 feet, width 19.5 feet. Average assay: gold, $6.88; copper, 2.0 per cent.

PLATE XVI.

A.

B.

Explanation of Plate XVII.

Vein fissure between ore shoots, west of No. 1452 stope, War Eagle mine. Shows vein structure and fault back of timber. The white vein filling is calcite. (See page 61.)

PLATE XVII.

EXPLANATION OF PLATE XVIII.

Calcite crystals showing curved faces of cubes and twinning. LeRoi mine. (See page 80.)

PLATE XVIII.

Explanation of Plate XIX.

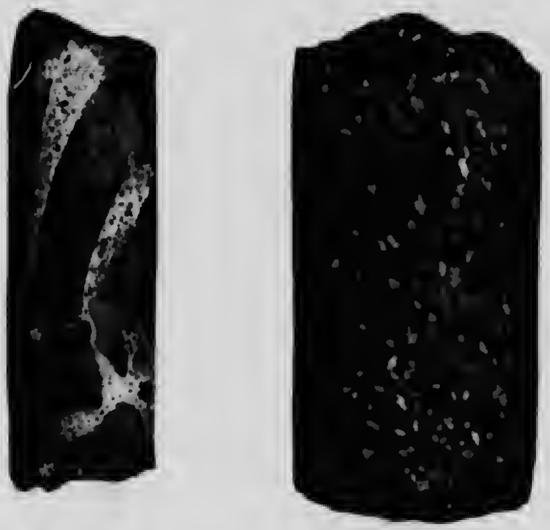
A. Ore in actinolite gangue, LeRoi mine. (See page 81.)

B. (a) Shattered augite porphyrite (granitic filling). Josie mine. (See page 214.)

(b) Sheppard granite porphyry. (See page 33.)

PLATE XIX.

A.

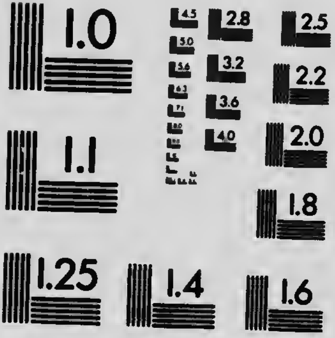


a b

B.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



EXPLANATION OF PLATE XX.

Prehnite from No. 3 tunnel of the War Eagle mine. (See page 82.)

PLATE XX.

EXPLANATION OF PLATE XXI.

Apophyllite crystals from the Centre Star mine. (See page 83.)

PLATE XXI.

EXPLANATION OF PLATE XXII.

Outcrop of the LeRoi main vein. LeRoi shaft house and superintendent's dwelling to right. (See page 48.)

ntendent's

Plate XXII.

Explanation of Plate XXIII.

A. Josie and LeRoi headworks from Annie claim; Josie left, LeRoi right, Lake mountain in right background. (See pages 110, 117.)

B. Velvet-Portland mine, Sophie mountain. Sheep Creek valley in background. (See page 154.)

PLATE XXIII.

pi right,

in back-

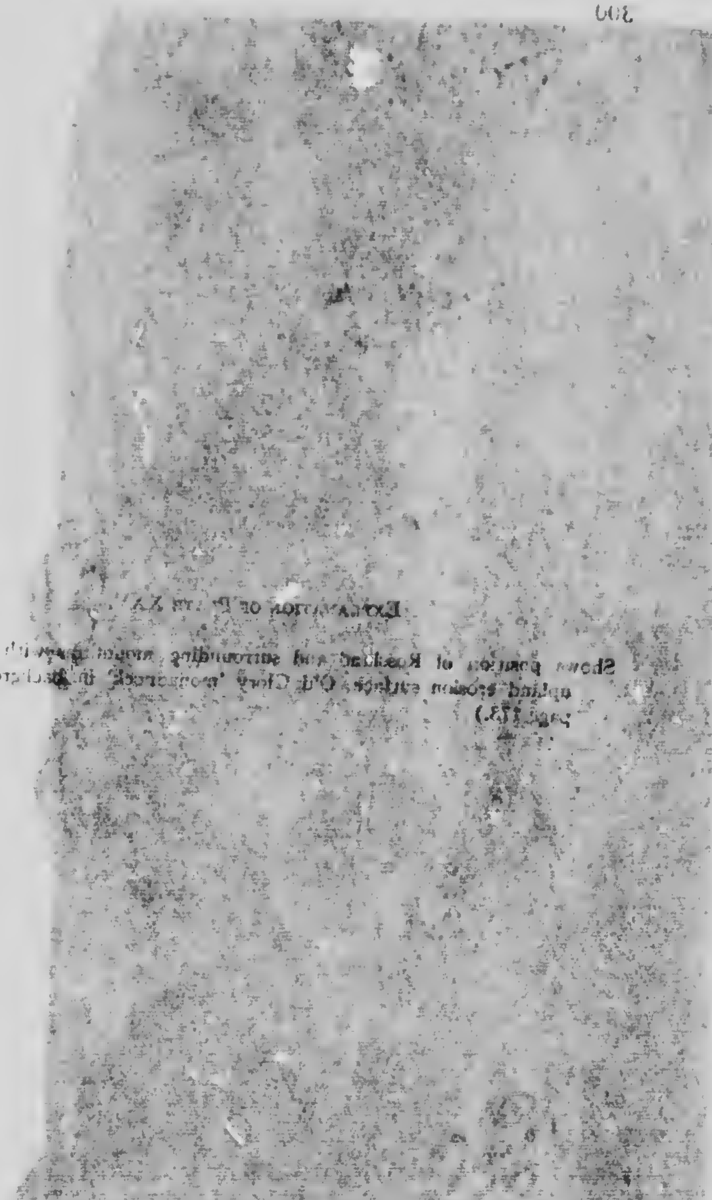
A.

B.

Explanation of Plate XXIV.

Upland erosion surface from LeRoi mine. Columbia valley in distance, Rossland in foreground. (Page 178.)

Plate XXIV.



Explanation of Plate XXV.

Shows position of Rossland and surrounding mountains with respect to upland erosion surface; Old Glory 'monadnock' in background. (See page 178.)

PLATE XXV.

INDEX.

A.

D.

E.

F.

G.

H.

I.

Q.

R.

S.

U.

V.

W.

Y.

Z.

LIST OF RECENT REPORTS OF THE 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 Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred 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 Lake Timiskaming—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 island between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austin 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. Le Roy.

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.

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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.

Summary Report for the calendar year 1914, No. 1503.

Report from the Anthropological Division. Separate from Summary Report 1913.

Report from the Topographical Division. Separate from Summary Report 1913.

Report from the Biological Division: Zoology. Separate from Summary Report 1914.

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.

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Museum Bulletin No. 6. *No. 3, Anthropological Series.* Pre-historic and present commerce among the Arctic Coast Eskimo—by N. Stefansson.

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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—by P. A. Taverner.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 58. *No. 48, Geological Series.* Texada island—by R. G. McConnell.

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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 65. *No. 53, Geological Series.* Clay and shale deposits of the western provinces, Part IV—by H. Ries.

MEMOIR 66. *No. 54, Geological Series.* Clay and shale deposits of the western provinces, Part V—by J. Keele.

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.

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.

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MEMOIR 76. *No. 62, Geological Series.* Geology of the Cranbrook map-area—by S. J. Schofield.

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MEMOIR 75. *No. 10, Anthropological Series.* Decorative art of Indian tribes of Connecticut—by Frank G. Speck.

Memoirs and Reports in Press, July 29, 1915.

MEMOIR 70. *No. 8, Anthropological Series.* Family hunting territories and social life of the various Algonkian bands of the Ottawa valley—by F. G. Speck.

MEMOIR 71. *No. 9, Anthropological Series.* Myths and folk-lore of the Timiskaming Algonquin and Timagami Ojibwa—by F. G. Speck.

MEMOIR 34. *No. 63, Geological Series.* The Devonian of southwestern Ontario—by C. R. Stauffer.

MEMOIR 77. *No. 64, Geological Series.* Geology and ore deposits of Rossland, B.C.—by C. W. Drysdale.

MEMOIR 78. *No. 66, Geological Series.* Wabana iron ore of Newfoundland—by A. O. Hayes.

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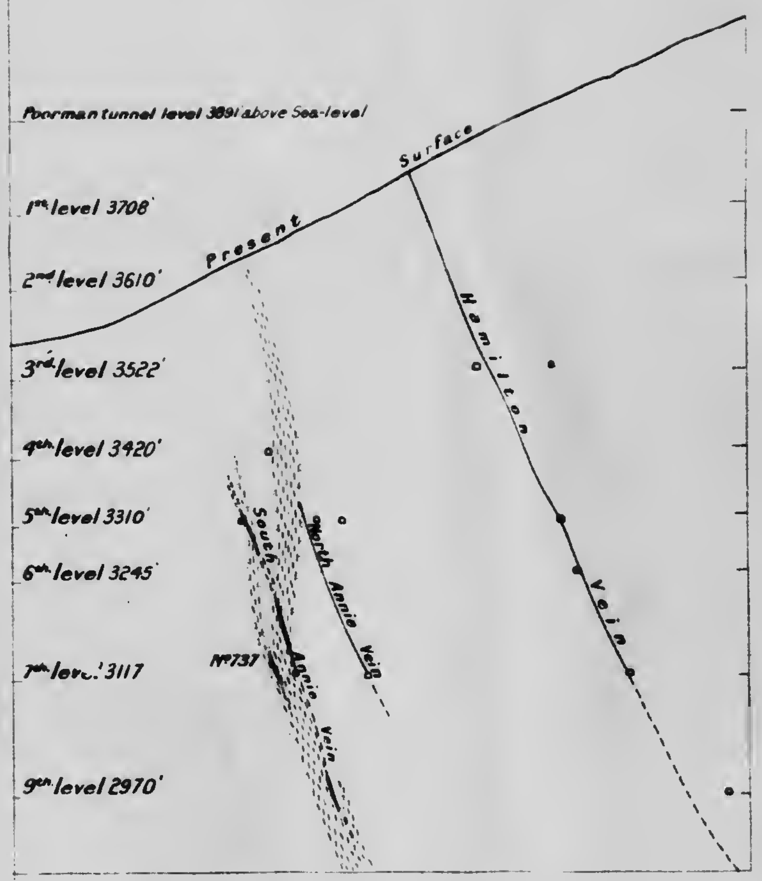
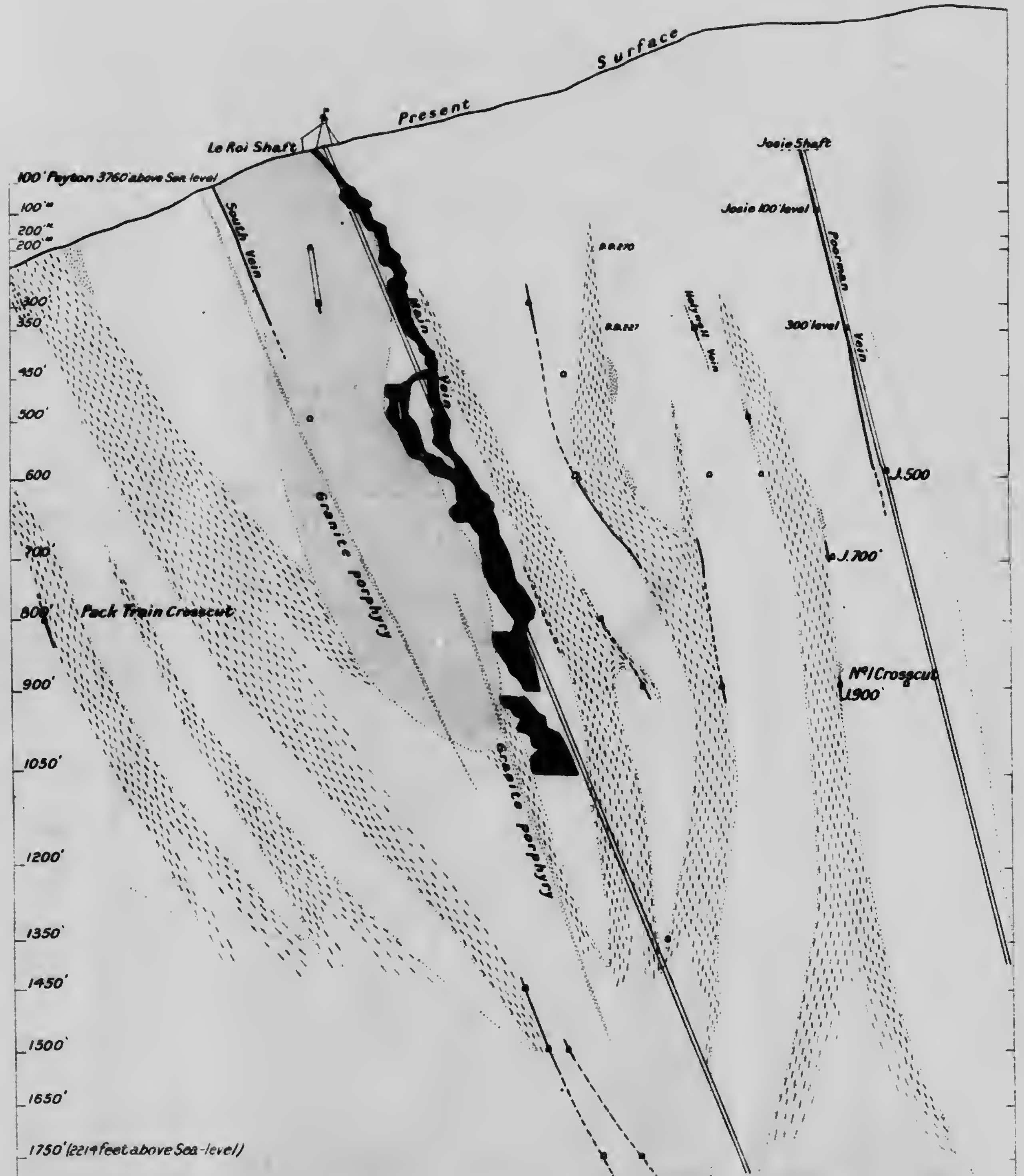
Museum Bulletin No. 18. *No. 28, Geological Series.* Structural relations of the Pre-Cambrian and Palæozoic rocks north of the Ottawa and St. Lawrence valleys—by E. M. Kindle and L. D. Burling.

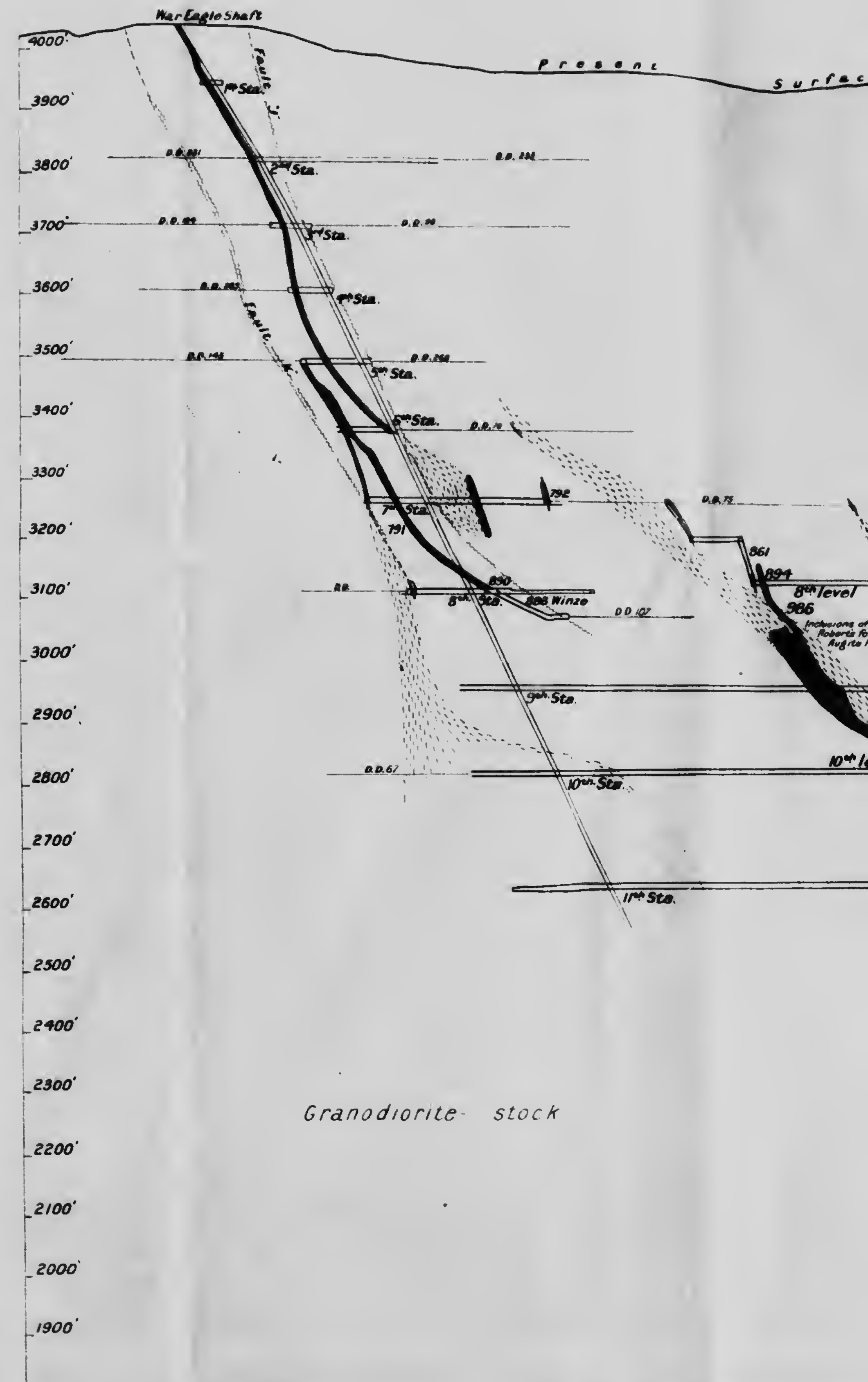
Museum Bulletin No. 19. *No. 7, Anthropological Series.* A sketch of the social organization of the Nass River Indians—by E. Sapir.



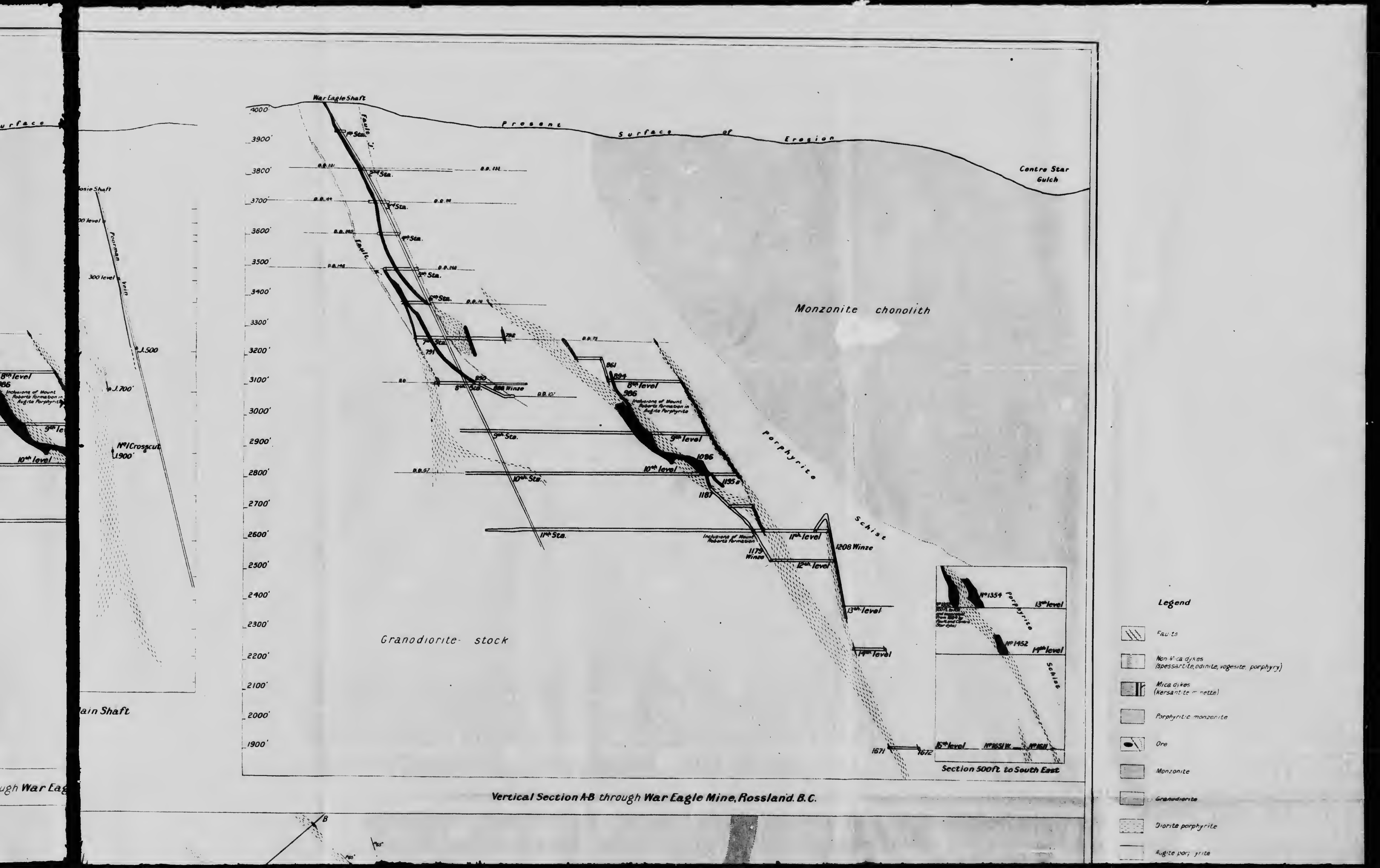
Vertical Section E-F through Annie and Hamilton Veins, Josie Mine



Vertical Section C-D through Le Roi Mine 125 feet east of Main Shaft



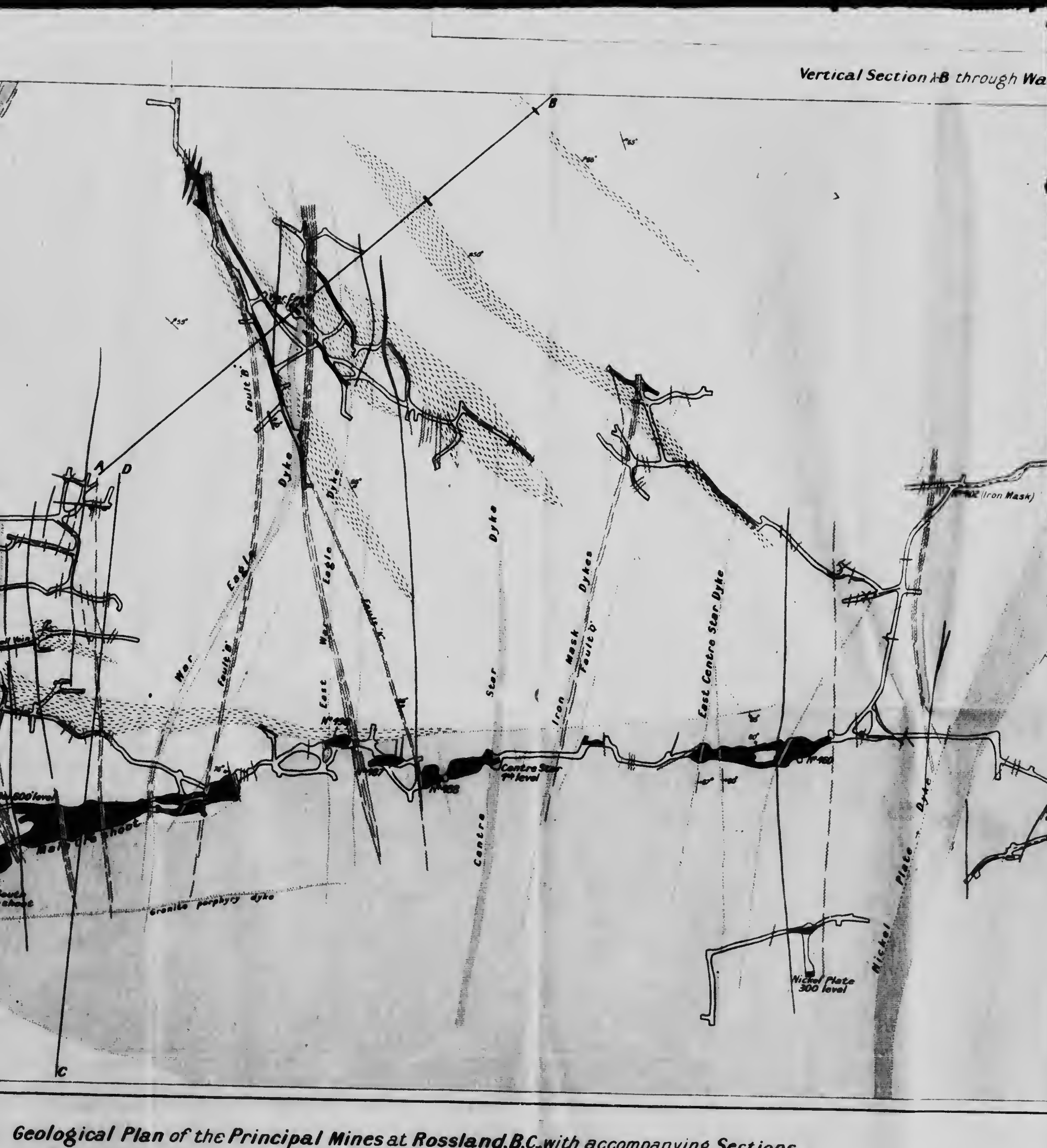
Vertical Section A-B through Wa



Vertical Section A-B through War Eagle Mine, Rossland, B.C.

Geological Survey, Canada.

Geol



Geological Plan of the Principal Mines at Rossland, B.C., with accompanying Sections

Scale of feet

100 50 0 200 400 600

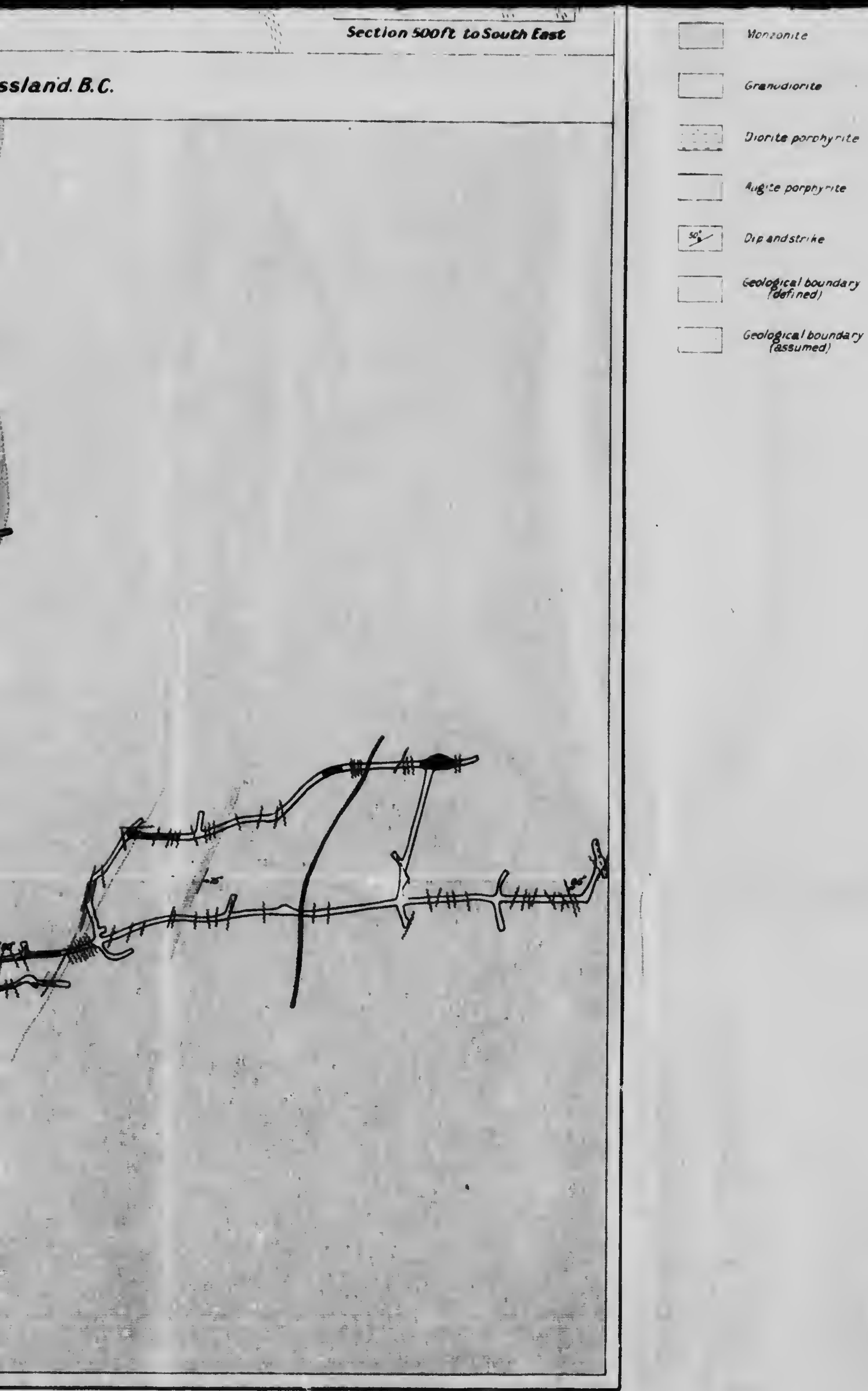
Metres

50 0 50 100 150 200

Vertical Section A-B through War Eagle Mine, Rossland

ines at Rossland, B.C., with accompanying Sections

Scale of feet
200 400 600
Metres
50 100 150 200


Section 500ft to South East
ssland. B.C.
Monzonite
Granodiorite
Diorite porphyrite
Augite porphyrite
Dip and strike
Geological boundary (defined)
Geological boundary (assumed)
1618


MICROCOPY RESOLUTION TEST CHART
(ANSI and ISO TEST CHART No. 2)
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

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Department of Mines

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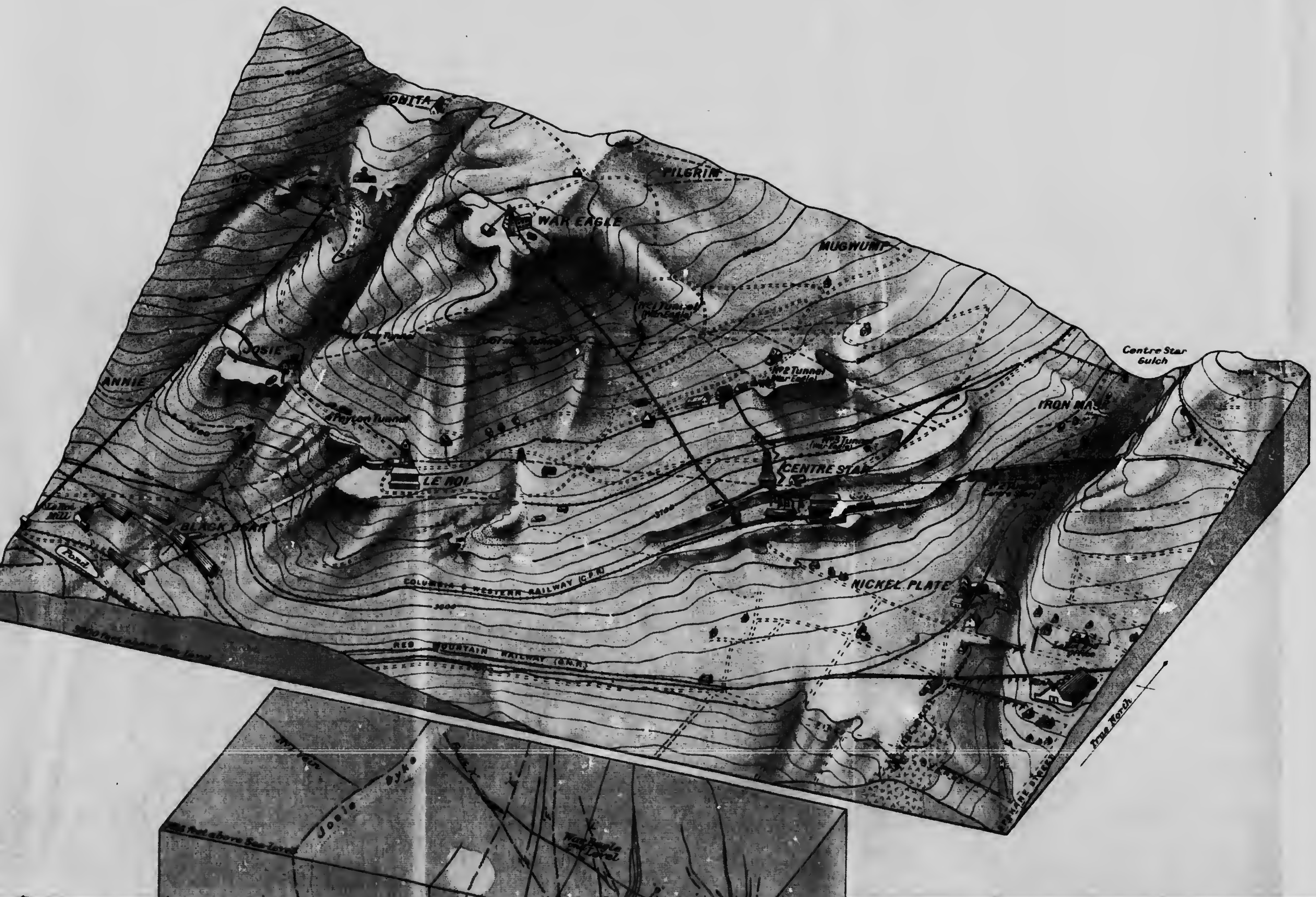
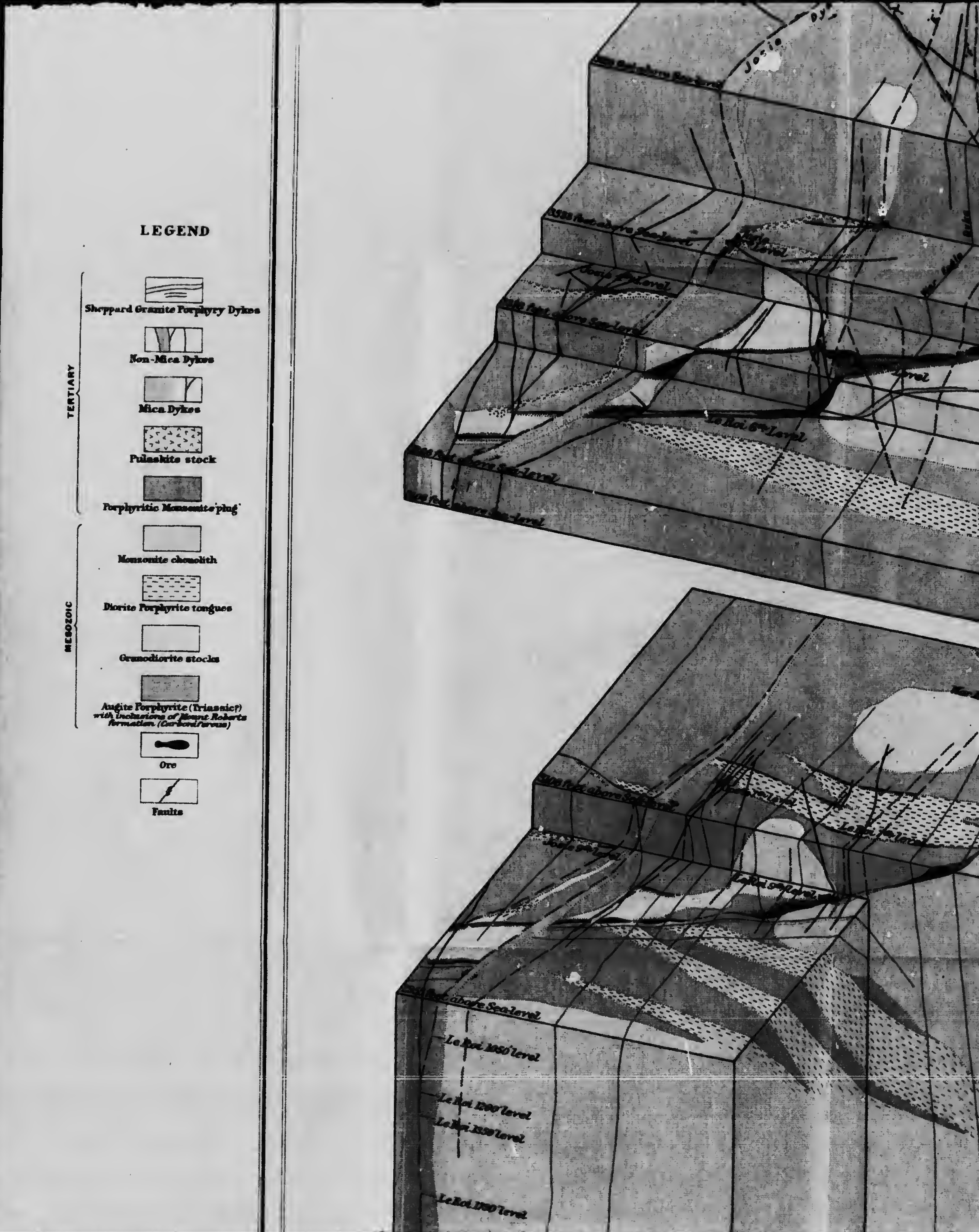
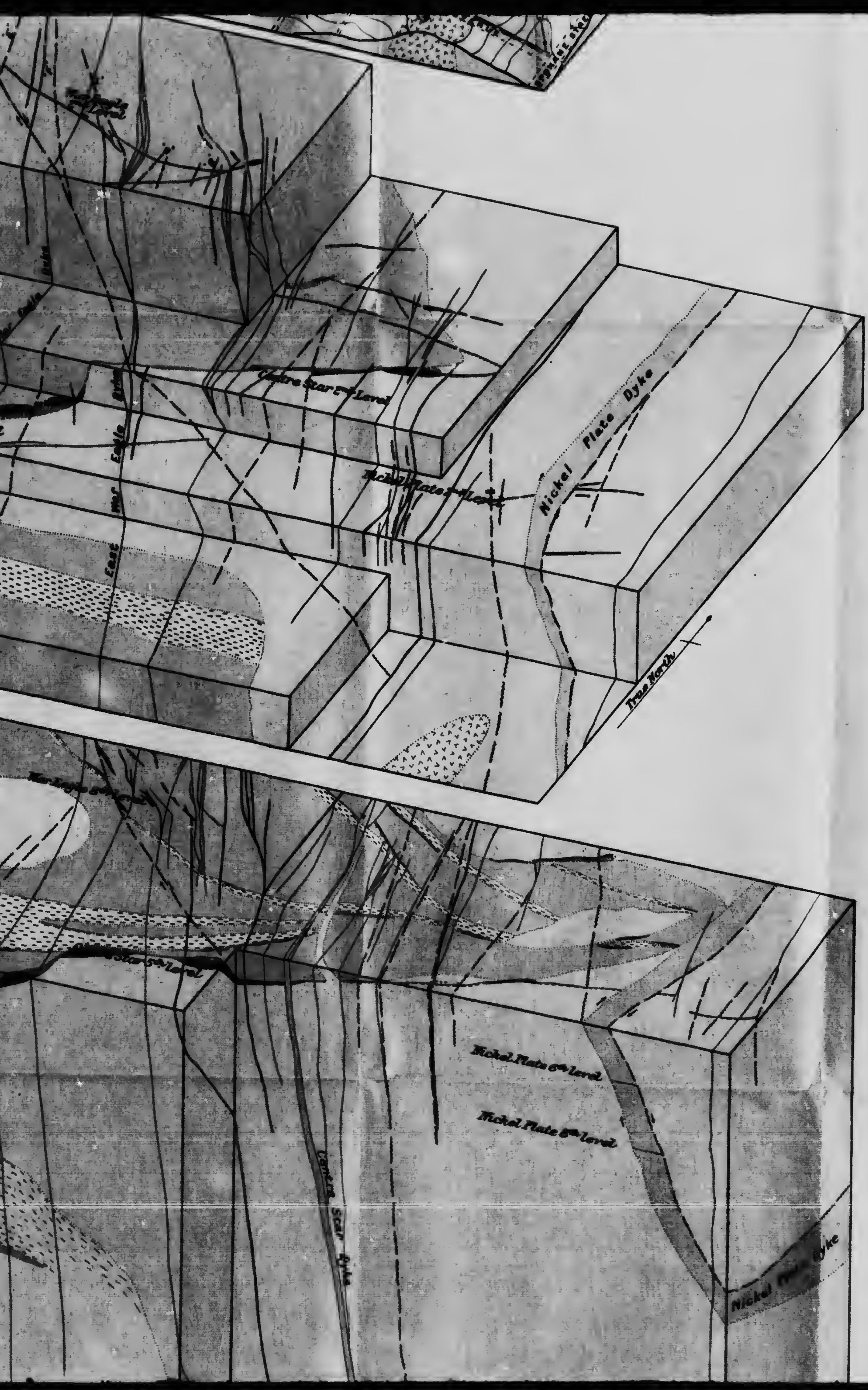
GEOLOGICAL SURVEY

OUTLINE MAP





LEGEND
TERTIARY
Sheppard Granite Porphyry Dykes
Non-Mica Dykes
Mica Dykes
Pulaskite stock
Porphyritic Monzonite 'plug'
MESOZOIC
Monzonite chonolith
Diorite Porphyrite tongues
Granodiorite stocks
Augite Porphyrite (Triassic?) with inclusions of Mount Roberts formation (Carboniferous)
Ore
Faults
Le Roi 6th Level
Le Roi 1050 level
Le Roi 1200 level
Le Roi 1350 level
Le Roi 1500 level

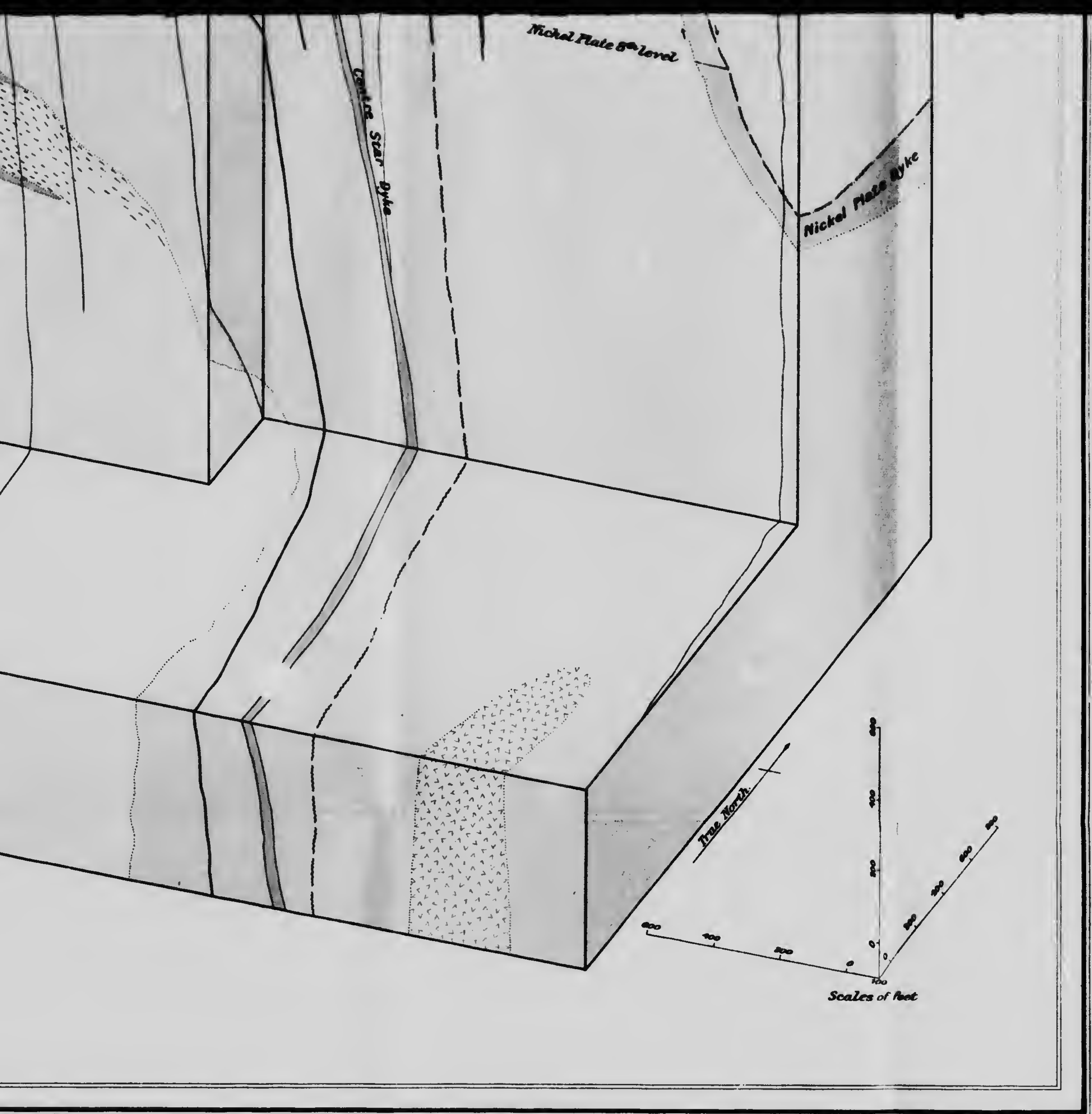


Centre Star 2nd Level
Nickel Plate Dyke
East War Eagle Dyke
True North
Nickel Plate 6th Level
Nickel Plate 8th Level
Centre Star Dyke
Nickel Plate Dyke

C.-O. Senécal, Geographer and Chief Draughtsman.
S.G. Alexander, Draughtsman.

STEREOGRAMS OF A BLOCK OF

To accompany Memoir by C.W. Drysdale



1496

MAP 146A
(Issued 1915)

K OF ORE-BEARING COUNTRY, ROSSLAND, B.C.

Stereograms and Geology by C.W. Drysdale

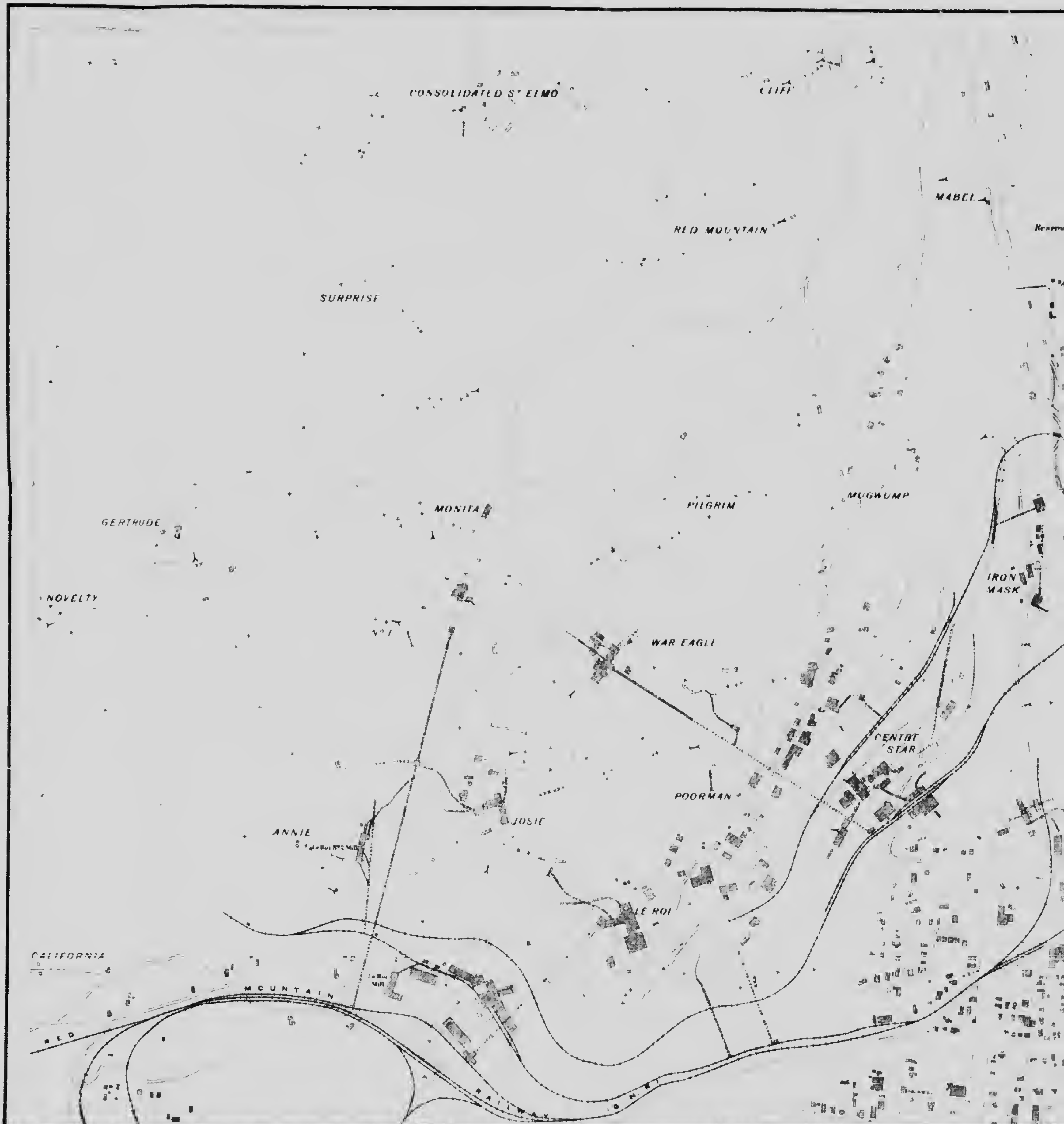
CANADA

DEPARTMENT OF MINE

GEOLOGICAL SURVEY BRANCH

Hon W Templeman Minister A P Low Deputy M
R W Brock Acting Director

1908

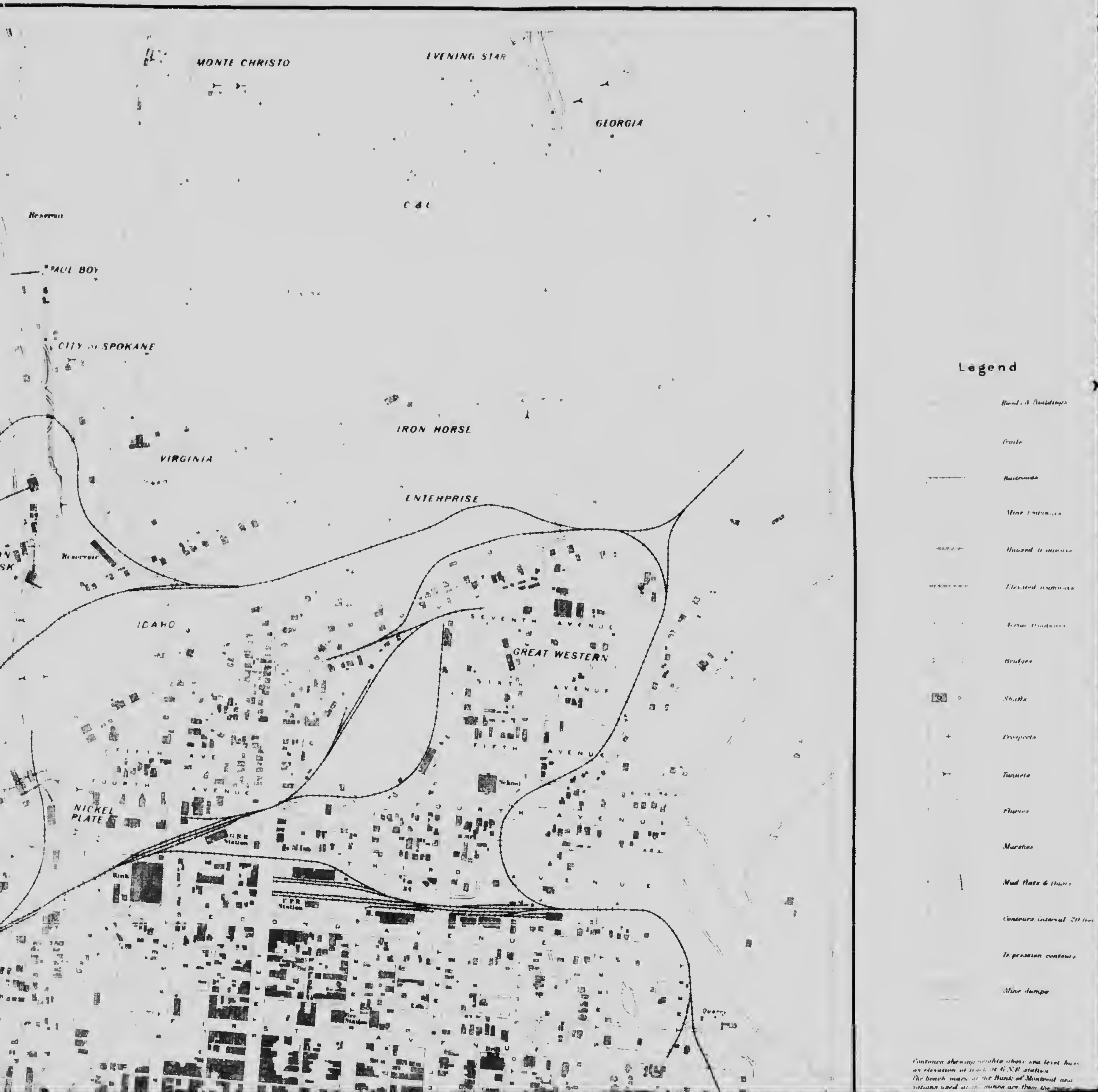


MINES

BRANCH

DEPUTY MINISTER

CTOR



C O Senecal B A Sc
A Dickison

Topographical Sheet

SPECIAL MAP of ROSS

BRITISH COLUMBIA

by

W H Boyd

Scale 400 Feet to 1 Inch $\frac{1}{4800}$

Shafts
Prospects
Tunnels
Churches
Marshes
Mud flats & dams
Contours interval 20 feet
Depression contours
Mine dumps

Magnetic declination about ... East

Surveyed in 1905 1906

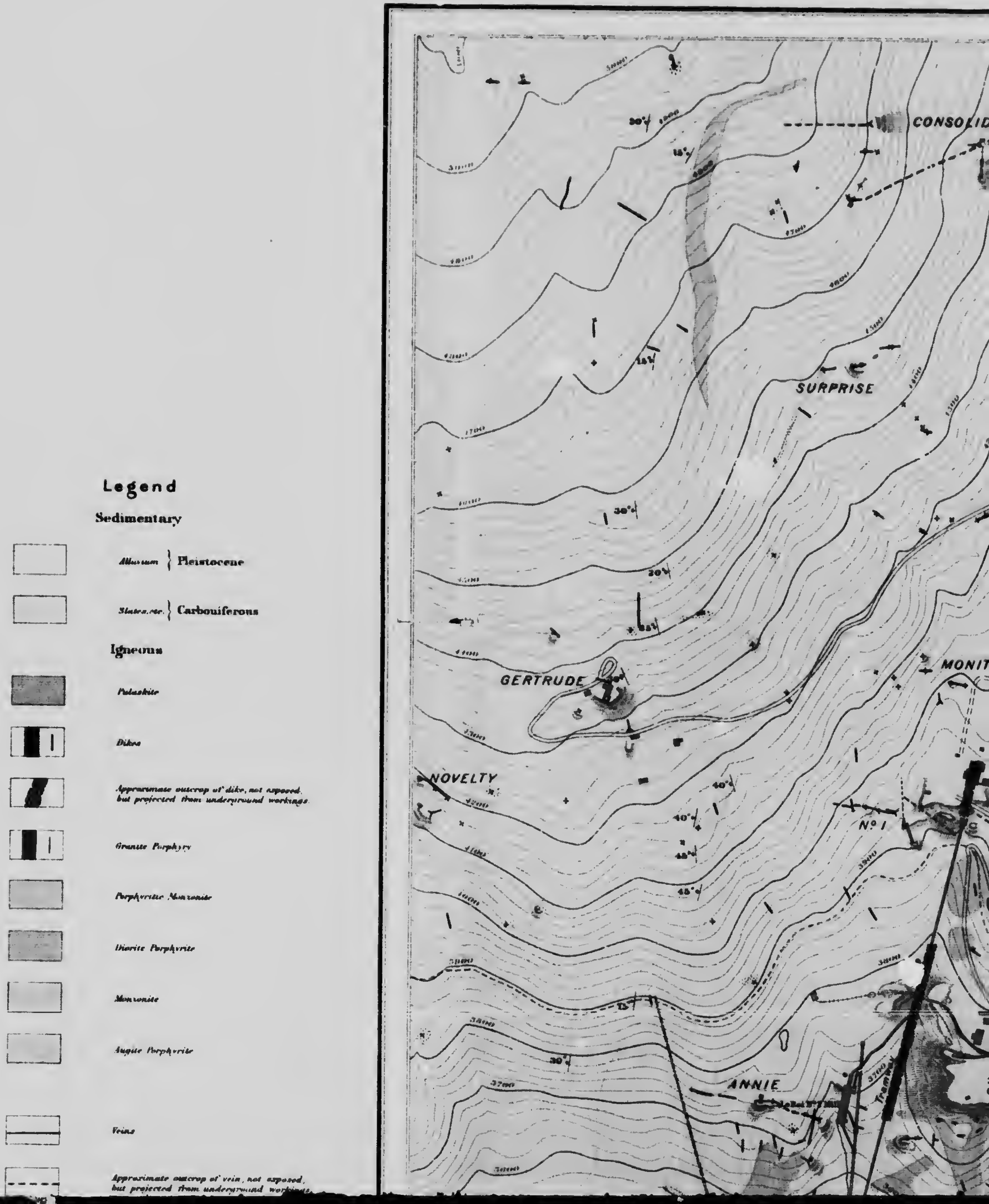
Nº 1001

Sheet

ROSSLAND

MBIA

1200 Feet


Legend
Sedimentary
Alluvium } Pleistocene
Slates, etc. } Carbouiferous
Igneous
Pulaskite
Dikes
Approximate outcrop of dike, not exposed, but projected from underground workings.
Granite Porphyry
Porphyritic Monzonite
Diorite Porphyrite
Monzonite
Augite Porphyrite
Veins
Approximate outcrop of vein, not exposed, but projected from underground workings.
SURPRISE
GERTRUDE
NOVELTY
No 1
ANNIE

CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

HON W TEMPLEMAN, MINISTER A.P. LOW, DEPUTY MINISTER
R.W. BROCK, DIRECTOR

1909

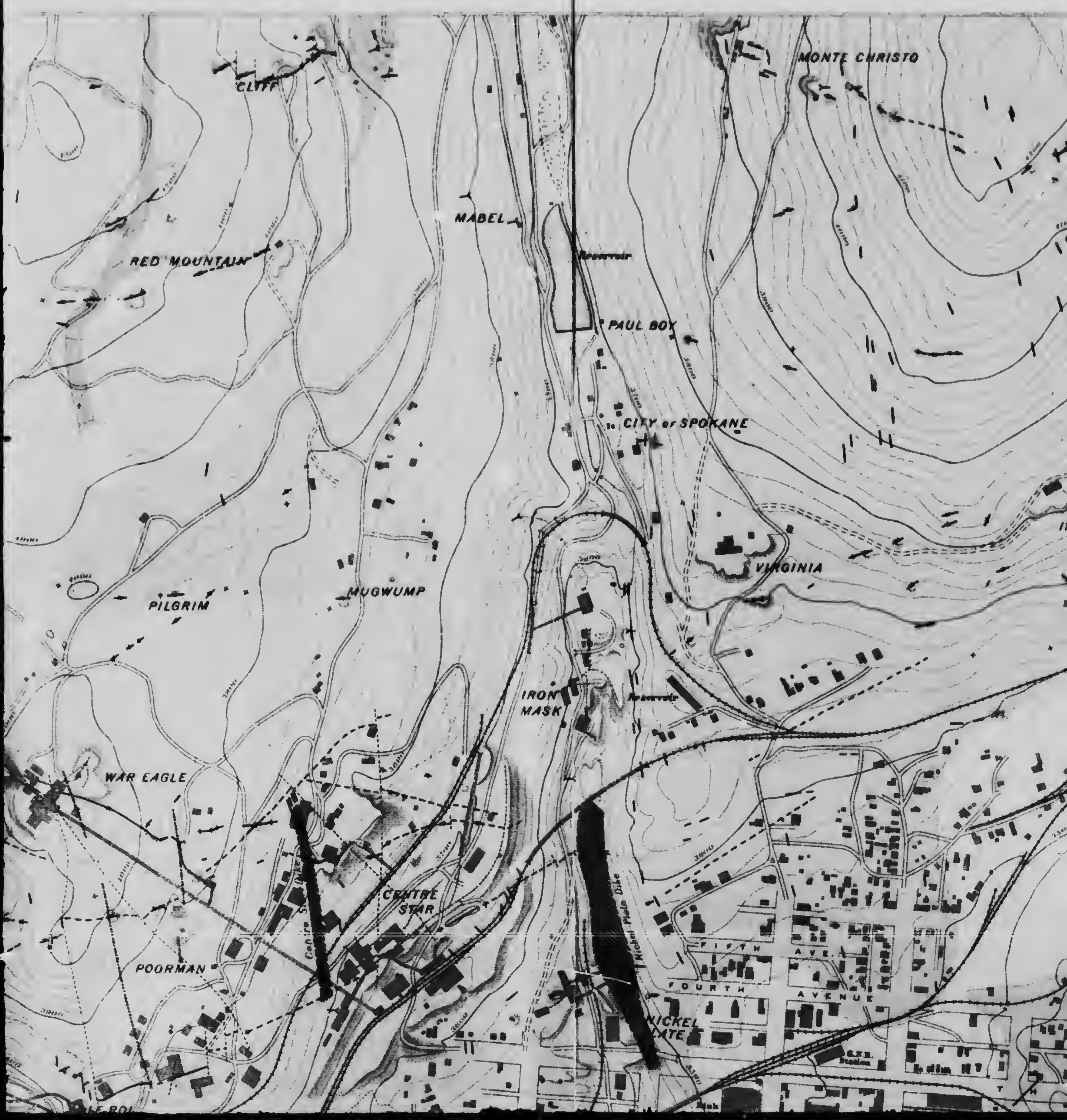
CANADA

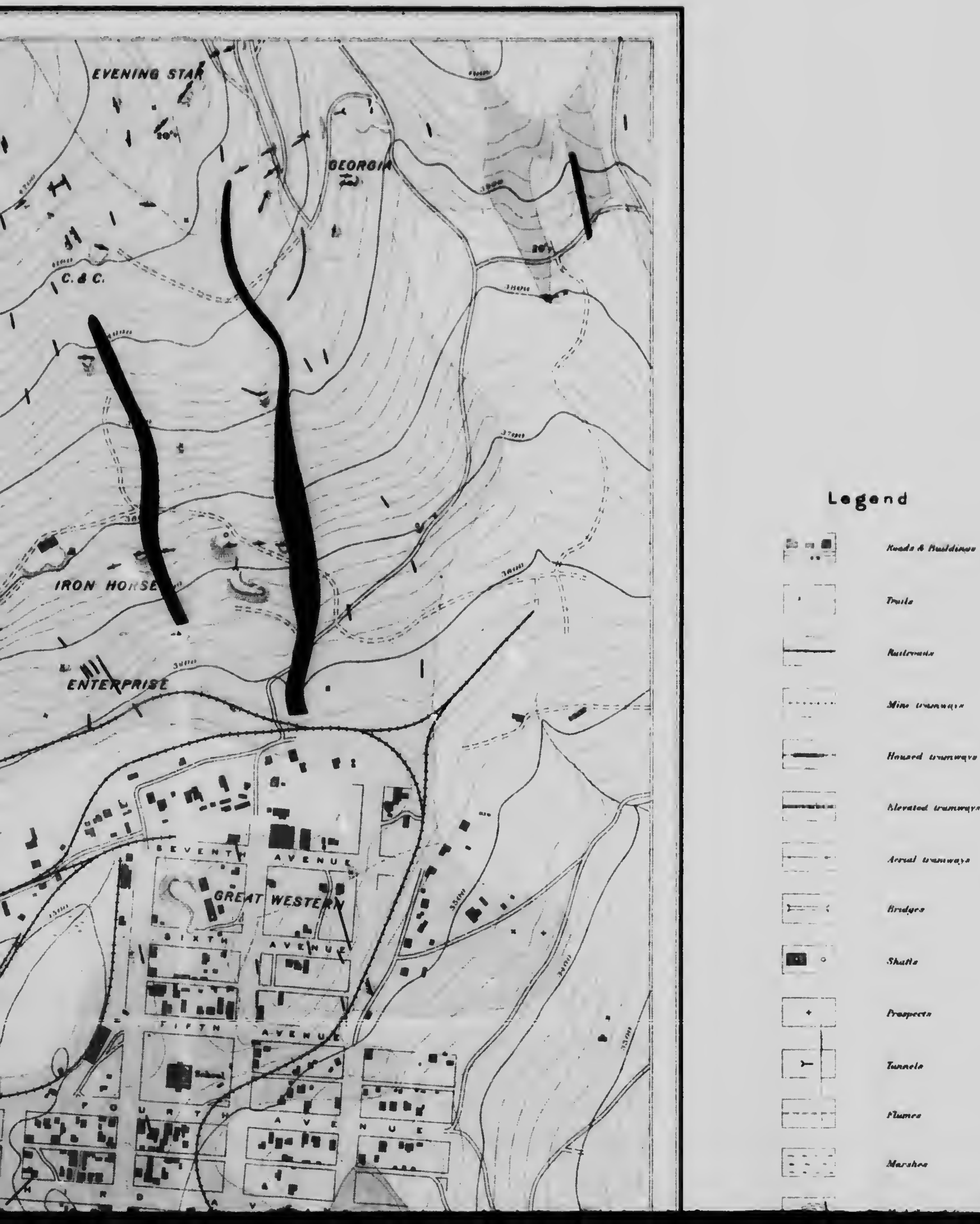
DEPARTMENT OF MINES

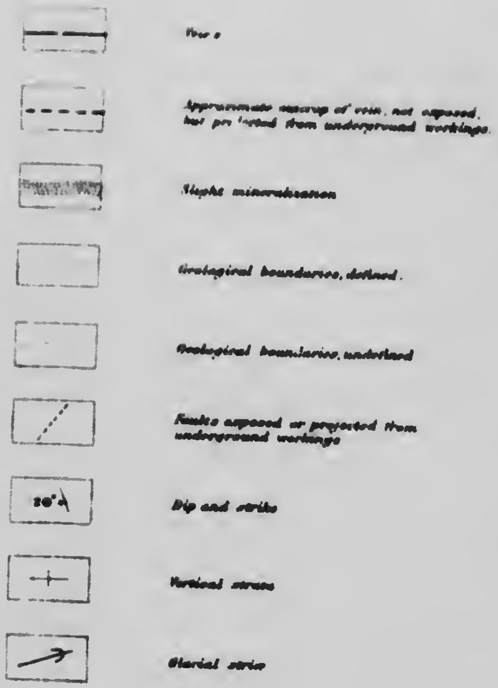
GEOLOGICAL SURVEY BRANCH

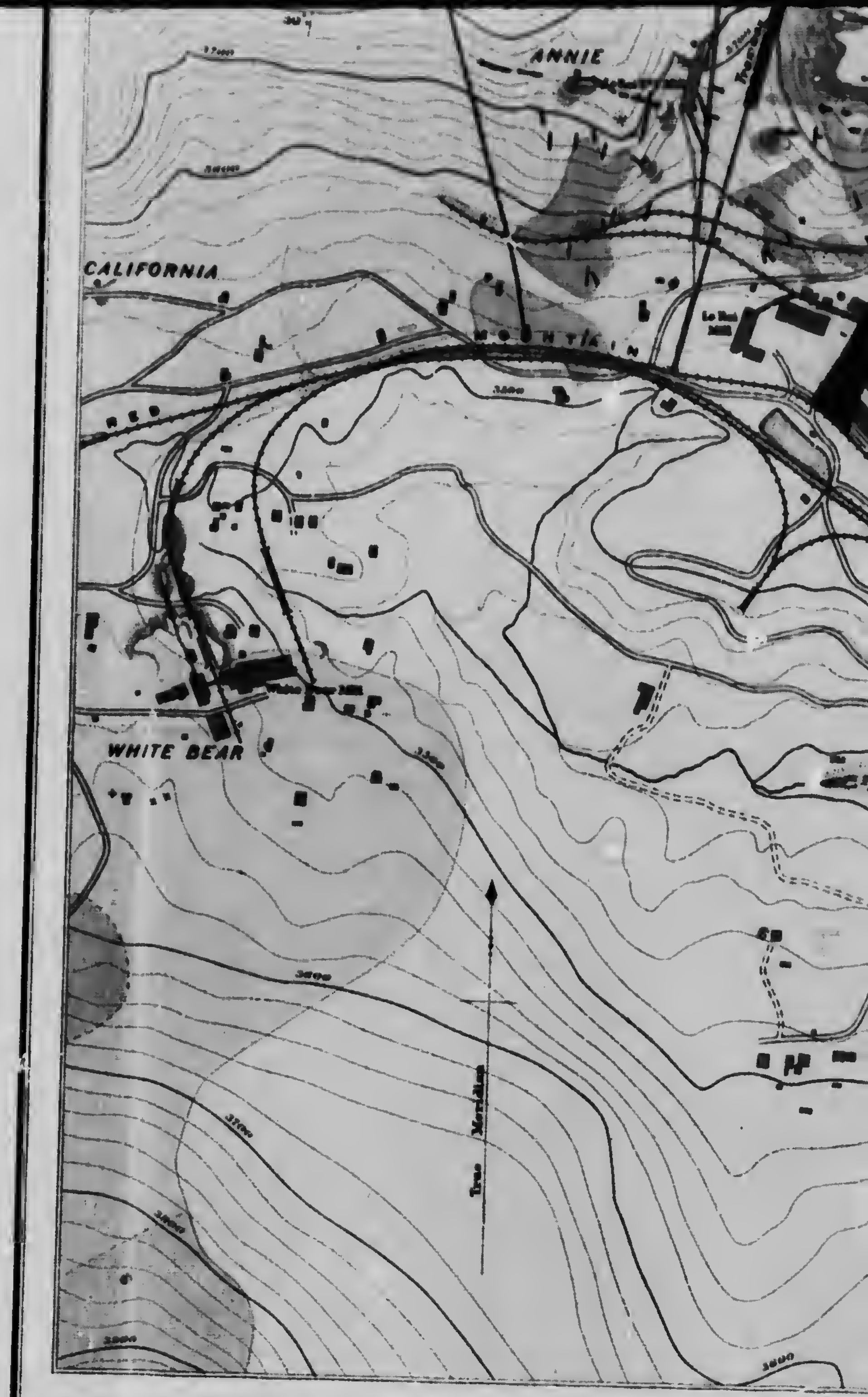
HON W TEMPLEMAN MINISTER A P LOW DEPUTY MINISTER
R W BROCK DIRECTOR

1909




EVENING STAR
GEORGIA
C. & C.
IRON HORSE
ENTERPRISE
SEVENTH AVENUE
GREAT WESTERN
SIXTH AVENUE
FIFTH AVENUE
School
FOURTH AVENUE
Legend
Roads & Buildings
Trails
Railroads
Mine tramways
Housed tramways
Elevated tramways
Aerial tramways
Bridges
Shafts
Prospects
Tunnels
Flumes
Marshes





C.O. Senécal, B.A.Sc., *Geographer & Chief Draughtsman.*
A. Dickison, *Draughtsman.*

Geological Sheet

SPECIAL MAP OF ROSSLAND

BRITISH COLUMBIA

Scale: 400 Feet to 1 Inch — 4800

Geological Sheet

SPECIAL MAP OF ROSSLAND

BRITISH COLUMBIA

Scale: 400 Feet to 1 Inch — $\frac{1}{4800}$

Feet 400 300 200 100 0 400 800 1200 Feet

Tunnels

Flumes

Marshes

Mud flats & Dams

Contours, interval 20 feet

Depression contours

Mine dumps

Contours showing heights above sea level based on elevation of track at G.N.R. station
The bench mark at the Bank of Montreal and elevations used at the mines are from the same datum

Magnetic declination about 24° East

Economic Geology by R.W. Brock.
Areal Geology by G.A. Young.
Topography by W.H. Boyd.

Nº 1002

CANA

DEPARTMENT

GEOLOGICAL SU

Hon. W. Templeman Minister,
R. W. Brock, D

Legend

Pleistocene

Mesozoic

Tertiary ?

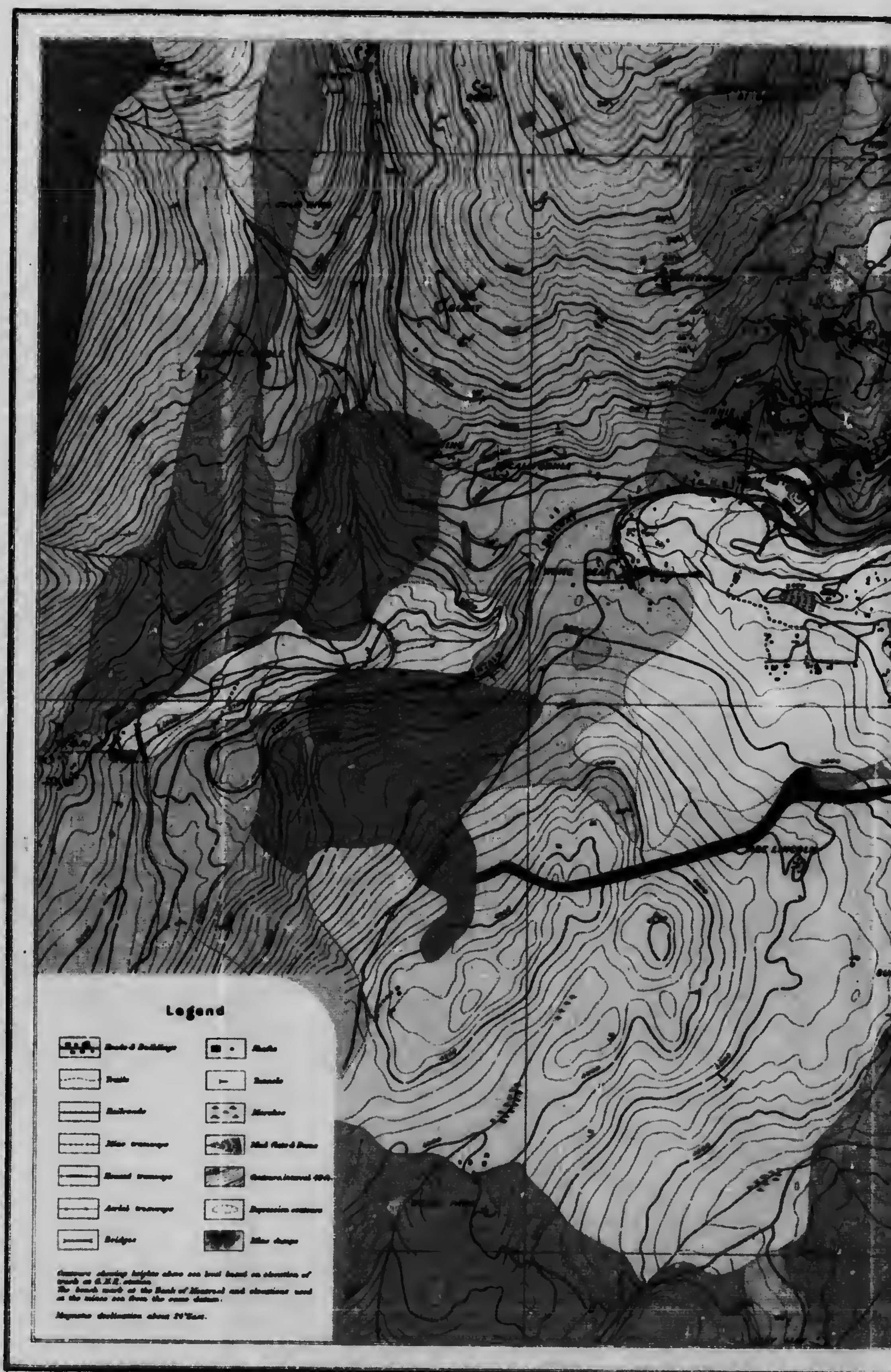
Post Jurassic ?

Jurassic ?

Triassic ?

Palæozoic

Carboniferous



Geological

ROSSLAND MI

BRITISH CO

Scale : 1200 Feet to 1

CANADA

…RTMENT OF MINES

…LOGICAL SURVEY BRANCH

…, Minister. A.P. Low, Deputy Minister; R.W. Brock, Director

Explanatory Notes

…eological Sheet

…D MINING CAMP

…ISH COLUMBIA

Economic Geology by R.W. Brock.
Areal Geology by G.A. Young.
Topography by W.H. Boyd.

Nº 1004

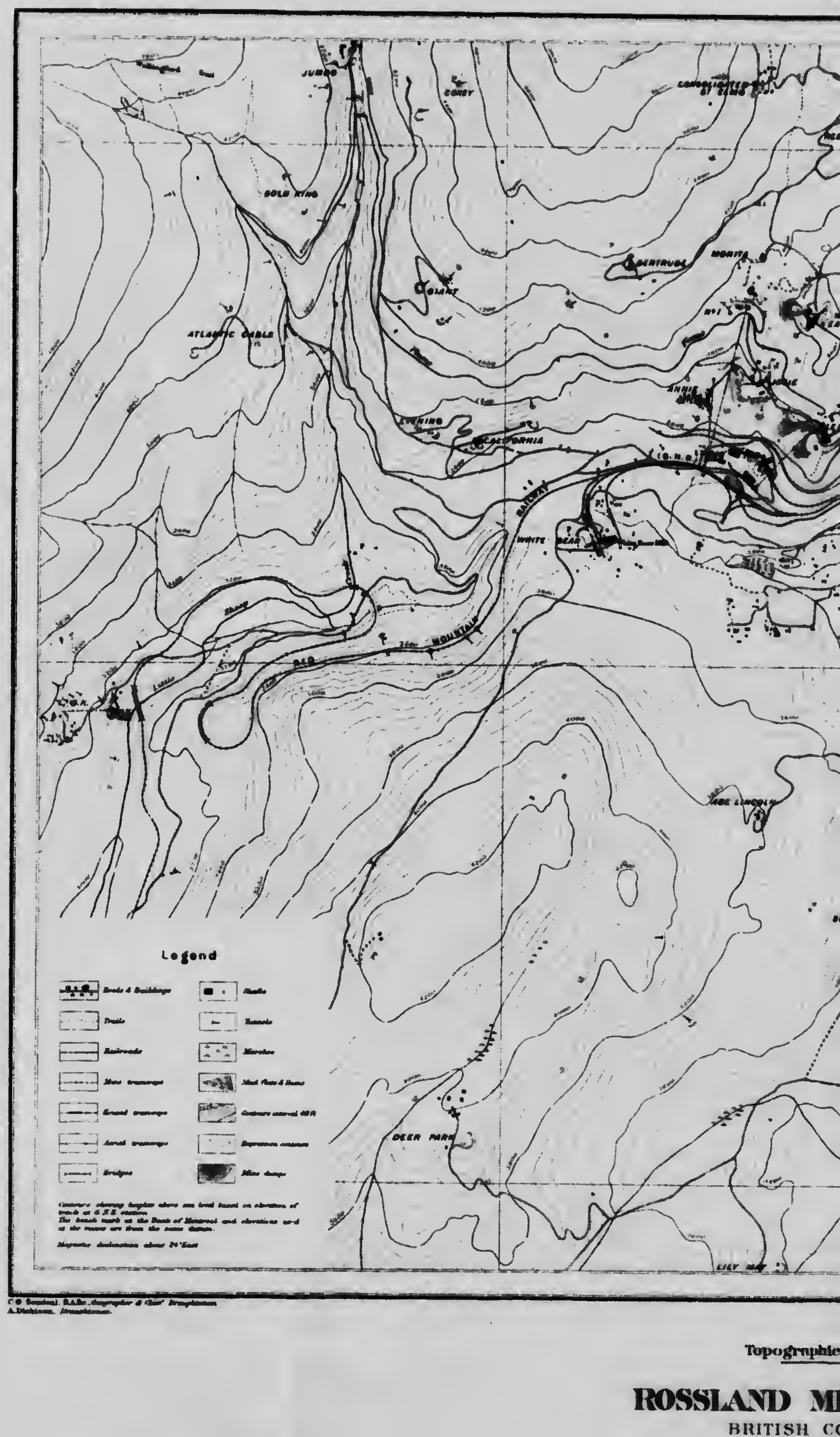
CANA

DEPARTMENT

GEOLOGICAL SU

Hon W Templeman Minister,
R W Brock, Act

190



C.O. Senécal, B.A.Sc. Geographer & Chief Draughtsman
A.Dickison, Draughtsman.

Topographic

ROSSLAND MI

BRITISH CO

by

W.H.Bo

Scale: 1200 Feet to 1

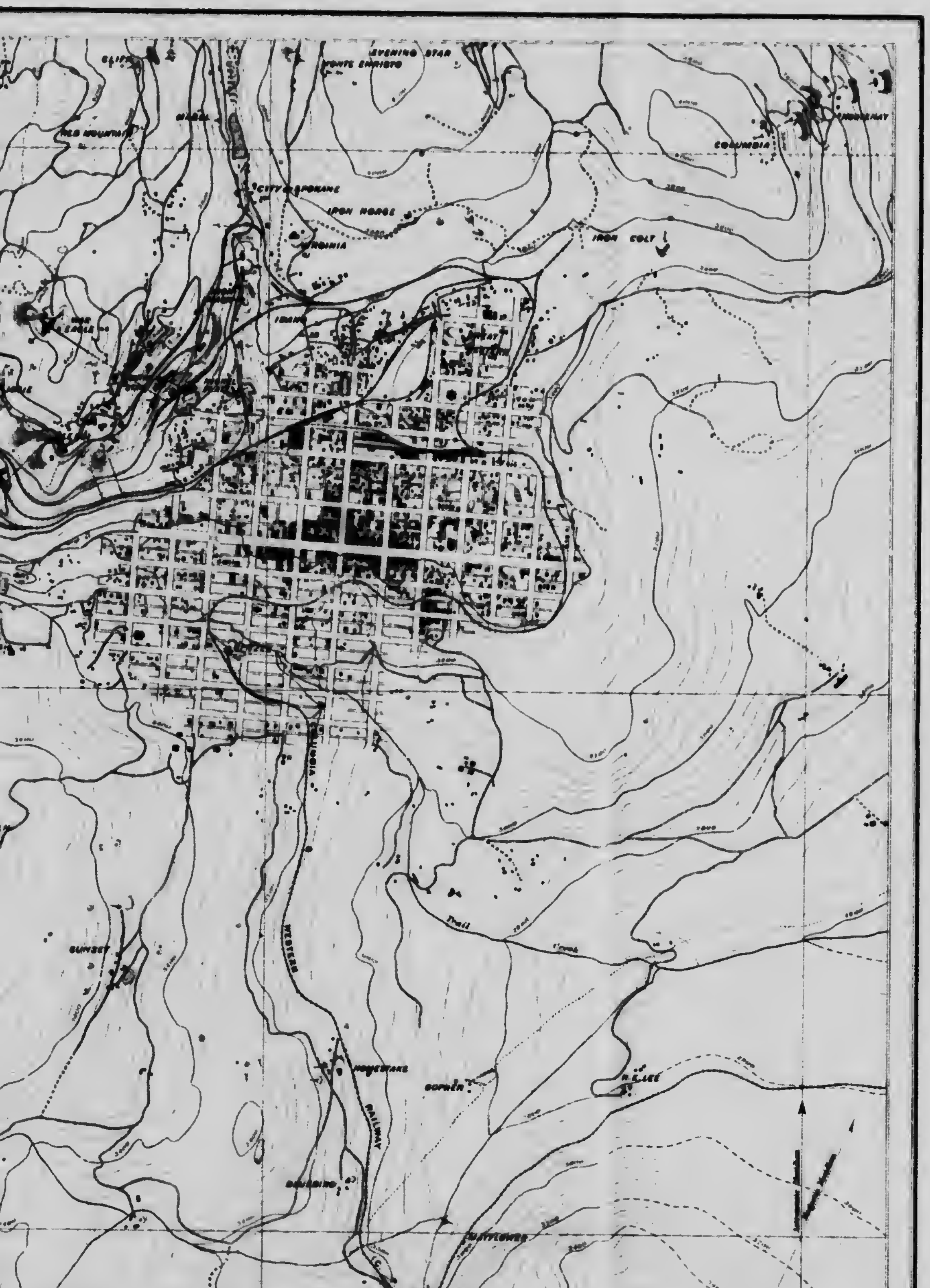
Feet 1000 500 0

CANADA

RTMENT OF MINES

LOGICAL SURVEY BRANCH

... Minister, A P Low, Deputy Minister,
W ... Acting Director



Surveyed in 1905 1906

Nº1003

pographical Sheet

D MINING CAMP

TISH COLUMBIA

by

W H Boyd

1200 Feet to 1 Inch - $\frac{1}{14,400}$