CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 132

No. 113, GEOLOGICAL SERIES

Geology and Ore Deposits of Salmon River District, British Columbia

BY
S. J. Schofield and G. Hanson

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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INTRODUCTION

The discovery of rich silver-bearing veins in Salmon River district in 1914 re-awakened interest in mining in that part of northern British Columbia. The type of ore-deposit rich in native silver—sometimes amounting to 1,000 ounces to the ton—was new to British Columbia, and it was deemed advisable to study the geological conditions surrounding the occurrence in order that prospecting for further deposits of this type might be intelligently pursued. The development in British Columbia of a mine from a prospect is usually a long and costly operation requiring an outlay of capital far beyond the means of the ordinary prospector, but the discovery of the Premier mine in Salmon River district, and the Dolly Varden mine in Alice Arm district, proved conclusively that there are deposits in British Columbia which can be made to "pay from the grass roots" and come into the category of a "poor man's proposition."

The discovery of native silver in large quantities brought the problem of secondary enrichment into a very prominent scientific position among the processes of ore-deposition in British Columbia, and this problem was studied in the field as thoroughly as possible.

Detailed geological investigation of Salmon River district, commenced in 1919 by J. J. O'Neill, was continued during the field season of 1920. The topographic base map was prepared by F. S. Falconer during the season of 1919.

Able and efficient assistance in the field was rendered in 1920 by I. M. Marshall and C. H. Crickmay. The writers wish to acknowledge courtesies received from Mr. Dale Pitt of the Premier mine. Assistance by discussion of the problems of Cordilleran geology has been freely given by Dean R. W. Brock, of the University of British Columbia.

LOCATION AND SIZE OF SALMON RIVER MAP-AREA

Salmon River district lies in northern British Columbia about 11 miles north of Stewart, which is situated at the head of Portland canal, one of the largest fiords which penetrate the Coast range (Figure 1). On the west the district adjoins the boundary between Alaska and British Columbia. The eastern boundary is formed by Bear River ridge, which trends almost north and south. The map-area is triangular and 60 square miles in area. Its southern apex is formed by the intersection of the International Boundary line and Bear River ridge, and the northern limit is an east and west line passing through mount Dilsworth in north latitude 56° 10′.

The district contains the headwaters of Salmon river, which flows southward into Portland canal at Hyder, Alaska. It is accessible by a wagon road and trail from Stewart up Salmon river, the lower 12 miles of which lies in Alaskan territory. Stewart is reached by Government steamship service from Prince Rupert and Vancouver.

HISTORY

The early history of mining in Salmon River district is intimately bound up with that of the Portland Canal district, of which it is a part. This has been summarized by R. G. McConnell[1] in the following words, "The metalliferous character of the Portland Canal mining district was first discovered by a party of prospectors in 1898, the year of the great Klondike rush. They were searching for placer deposits, but failing to find pay gravels turned their attention to prospecting for quartz. The Roosevelt and other claims on the north fork of Bitter creek were staked in 1899 and the Mountain Boy and American Girl on American creek in 1902. The Alaskan boundary at that time had not been defined, and the claims were first staked under United States laws, but were subsequently restaked and recorded in British Columbia. The Redcliff, which could hardly escape notice as the outcroppings show up prominently on the mountain side, was first staked in 1898, and has lapsed and been restaked several times, the last time in 1908."

The earliest mention of prospecting in Salmon River district is in the report of the Minister of Mines for British Columbia for 1904, where it is stated that Messrs. Harris and Rearick of Ketchikan located six claims composing the Silver Lake group, and that Dan Lindeborg located four claims on the summit of Bear River ridge between Silver Lake group on Salmon river and the American group on Bear river. In the report[2] of 1911 it is stated that the Big Missouri was also staked in 1904.

Some of the claims now owned by the Premier Gold Mining Company were staked in June, 1910, by Wm. Dilsworth and Bunting Bros., but it was not until the summer of 1914 that W. J. Rolf found high-grade ore ($500 a ton in gold and silver) on these claims. This discovery revived interest in the district and the well-known rush of 1915-1916 followed, during which all available ground was staked. Prospecting and development of these claims continued to the time the area was geologically mapped, in 1920.

PREVIOUS WORK

The first geological field work in Salmon River district was done by McConnell[3] in 1910 and 1911, and the results of this work furnish a good general description of the main geological features as well as of the numerous prospects known at that time. The Reports of the Minister of Mines of British Columbia for the years 1904, 1906, 1909, 1911, 1912, 1915, 1917, 1918, and 1919 contain good descriptions of the mining operations in the district.

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[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, 1913, p. 3.
[2] Report of Minister of Mines, British Columbia, 1911, K 73.
[3] McConnell, R. G., Geol. Surv., Can., Sum. Repts., 1910, p. 57, 1911, p. 50; Mem. 32, 1913.

It was E. E. Campbell[1] who in a paper on the "Mineral Occurrences in the Stewart District" first attributed the high silver values of the district to secondary enrichment along a series of cross fractures. His conclusions are of such value that they may be quoted:

"The general structure of the mineral zones carrying the high-grade ore is similar to that of the zones carrying the low grade. An important feature, and one which has a bearing on the high-grade ore-shoots, is shown in a series of fissures crossing the line of schistosity of the mineral-bearing schists. This cross-fissuring is most pronounced in the Premier mine, and it is along these fissure zones that some of the exceedingly rich ore is found. The extent of these rich shoots has not been determined, but sufficient development has been done to prove that the mine is one of great richness. A sample of one hundred sacks of ore taken from this mine showed the following values:

Zn	Pb	Cu	Au	Ag	Insol	SiO_2	Fe	CaO	S	Al_2O_3	MgO
3·3	1·7	0·56	6·18	148·6	75·1	64·9	7·6	1·3	8·6	6·5	1·7

Although later shipments gave higher values, this analysis affords some conception of the richness of the ore encountered in the mine. A depth of 200 feet below the surface has been attained in the zone of secondary enrichment, with no evidence of decreasing values.

The same general structure prevails on the other properties having rich secondary ores."

A good general description of the geology of the district is given by J. J. O'Neill[2] who states that the native silver is secondary and associated with a system of cross fissures. On the geological map (No. 1829) accompanying this memoir O'Neill is responsible only for the geology of the area west of Salmon River glacier. In justice to O'Neill, it may be stated that in several points concerning the geology he differs from the present authors. He considers the form of the quartz porphyry (here called the Premier sills) as a batholith, intruding the volcanic and sedimentary rocks and related in age to the Coast Range batholith. The authors of this report consider the quartz porphyry to be in the form of sills intruded parallel to the stratification of the bedded rocks and they adduce the following reasons:

(1) The top and bottom of each sill were examined closely in the field and followed for long distances. The sill-like character is apparent around the Premier mine and on the trail up Cascade creek almost to the junction of Harris creek.

(2) In one case, at least, evidence of gravity differentiation was noticed. This sill can be readily examined on the wagon road that leaves the Premier wagon road at Buntings cabin for Joker flat.

(3) Bands of tuffs of varying thickness separate the sills.

(4) The texture of the quartz porphyry is that characteristic of dykes and sills, and not that of a batholith.

Furthermore, O'Neill considers that the granodiorite mass that occurs where the Premier wagon road crosses the International Boundary occupies in Canada an area larger than shown on the accompanying geological map (No. 1829). The field facts collected by the writers of this report do not accord with this view.

[1] Campbell, E. E., Trans. Can. Min. Inst., vol. 23, 1920.
[2] Geol. Surv., Can., Sum. Rept. 1919, pt. B, p. 7 B.

Dolmage,[1] who made a close microscopic study of ore specimens furnished by Chas. Bunting, states that the native silver, as well as the other silver minerals that occur in the Premier ore, are in the main primary in character. Dolmage's conclusion cannot be considered as final since he had no opportunity to study the field relationships of the ores. The writers of this report,[2] after a careful study of the field relations, supplemented by a microscopic examination of the ores, confirm the opinion expressed by Campbell and O'Neill that the native silver as well as some of the other silver minerals is due to secondary enrichment by descending waters along a system of cross fractures.

A good description of the region in Alaska adjacent to Salmon River district is given by F. E. Wright and C. W. Wright.[3] The geology and ore-deposits are described in detail and since a greater range of geological history is recorded, the report furnishes the basis for a broader interpretation of the geology on the Canadian side.

Lewis G. Westgate[4] gives a general description of the geology and ore deposits of the region in Alaska, adjoining Salmon River district.

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[1] Dolmage, V., Can. Min. Jour., 1920.

[2] Schofield, S. J., and Hanson, G., Geol. Surv. Can., Sum. Rept. 1920, p. 6 A.

[3] Wright, F. E., and Wright, C. W., "The Ketchikan and Wrangell Mining Districts, Alaska," U.S.G.S., Bull. 347, 1908. Wright, F. E., Geol. Surv., Can., Sum. Rept., 1905, p. 46.

Westgate, Lewis G., U.S.G.S. Bull. 722 C, 1921, p. 117.

CHAPTER I

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

Regional. The Canadian Cordilleras have been divided by the Geographic Board of Canada into three main belts,[1] the Eastern, Central, and Western. The Eastern and Western belts are characterized by alpine mountain topography in contrast with the Central belt which on the whole is lower in relief and plateau-like, although in certain parts it resembles the other belts in its physiography.

The Western belt is subdivided from east to west into the Pacific system—which includes the Coast range proper—and the Insular system, the island fringe that borders the Coast range of British Columbia and southeastern Alaska. The Insular system includes Queen Charlotte mountains and Vancouver Island mountains.

The Pacific system includes the Coast mountains, Cascade mountains, and Bulkley mountains. Bulkley mountains genetically belong to the Central system and should be included in that system. In Chapter III evidence is put forward to show that the Coast mountains are of Upper Jurassic age. Bulkley mountains, on the other hand, were formed during the Laramide revolution, for they are penetrated by igneous stocks that cut Lower Cretaceous rocks, and are associated in age with the Laramide revolution.

The Pacific system has an alpine topography, characterized, especially in the northern part, by many alpine and valley glaciers and ice-caps. The central part has an average elevation of 8,000 feet. It slopes westwards to the shores of the Pacific ocean which is marked by a very intricate system of fiords, and eastwards it merges into the lower mountains of the Central belt. In the southern part, mount Garibaldi, a dormant Tertiary and Quaternary volcano, rests upon the central part of this system at the head of Howe sound.

The Pacific system is drained by numerous rivers which rise as a rule in the Central belt and pass through the Pacific system into the Pacific ocean.

Local. Salmon River area lies on the eastern slope of the Pacific system near the 56th parallel of latitude. It forms a basin-shaped depression of low relief that slopes and narrows to the south between Bear River ridge (Plate I A and I B) on the east and the high granite ranges on the west. The peaks on Bear River ridge vary in elevation from 5,000 to 6,600 feet, and elevations of over 7,000 feet are found on the granitic mountains to the west (Plates III and IV). The elevations in the depression (Plate IV) range from 2,500 to 3,500 feet, culminating in mount Dilsworth (Plate II B), 5, 500 feet, which closes the depression on the north.

[1] "Nomenclature of the Mountains of Western Canada," 1918.

Three parallel valleys trending north and south and draining to the south, occupy the depression. The easterly valley contains Long lake (Plate II A) and the headwaters of Cascade river. This river originally found an outlet through a narrow pass southeast of Slate mountain, but now flows through Long lake, into the Cascade-Harris valley, the central valley of the area. The westerly valley throughout its length in Salmon River area is occupied by the Salmon River glacier (Plate III). Big Missouri ridge, which culminates northward in mount Dilsworth, separates this valley from the Cascade valley. Slate mountain forms the divide between Long Lake valley and the main Cascade river.

The lip of this basin-shaped depression is situated near the junction of Cascade river and Harris creek, where a sharp topographic break also occurs. The depression is marked by smooth, rounded hills and northerly-trending ridges which are treeless above 3,000 feet. It is an undrained area with many lakes and swamps. In the summer patches of snow lie in the lower parts; Bear River ridge, mount Dilsworth, and the high ranges to the west are capped with ice, and numerous glaciers spread down into the valleys. Long Lake valley (Plate II A) is a treeless, snowy waste throughout the year.

The grade of the streams in the depression is comparatively low except where Cascade river cuts through the divide between Long Lake valley and Cascade creek. This part of the river is marked by cascades and falls.

Below the junction of Harris creek and Cascade river the gradient of Cascade creek greatly increases and it cascades through a canyon-like valley to join Salmon river just south of the International Boundary. The syncline which forms Slate mountain passes into a monocline just south of Slate mountain and causes the Slate Mountain ridge to disappear so that the streams that drain Bear River ridge flow directly into Cascade river. Hence, in the southern part of the area there are only the two valleys—Cascade river and Salmon river—separated by the southern extension of Big Missouri ridge. The streams in these two valleys, before they unite south of the boundary, flow through narrow, steep-walled gorges which continue as one gorge as far south as a point 11 miles from Hyder, on Portland canal. From "Elevenmile" to Portland canal Salmon river flows in a deep U-shaped valley with very precipitous walls which rise on an average 5,000 feet above the valley floor. The river itself flows in a braided course over a wide flood-plain and at high water occupies the greater part of the valley floor. The river is rapidly covering the floor with sediment and well-marked terraces so characteristic of the rivers in southern British Columbia are absent. At Hyder the debris carried down by the river is rapidly filling in the head of Portland canal. This action is supplemented by Bear river which enters the canal at Stewart 2 miles distant.

CLIMATE

The following paragraph concerning the climate in the vicinity of Stewart is due to the kindness of Mr. F. Napier Denison, superintendent in British Columbia of the Dominion Meteorological Service.

"During the period meteorological observations have been taken at Stewart, viz., from September, 1910, to the present time, January is usually the coldest month, with a mean temperature of 19 degrees F., and the warmest month is July (mean 57 degrees F.).

The heaviest precipitation occurs in the winter months and is mostly in the form of snow. The heaviest average monthly snowfall is 60 inches in December, whereas in January the fall is 58 inches, and the average total for the year is 219·58 inches, or about 18 feet. The maximum monthly snowfall was 101 inches in February, 1921, and the heaviest annual fall was 259 inches in 1921. The lowest winter temperature recorded at Stewart during the above period was 22 below zero in January, 1917, but in the surrounding district, at greater altitudes and removed from the direct influence of the sea, much lower temperatures are known to occur."

The following table is also supplied by Mr. Denison:

Meteorological Observations, at Stewart, B.C.

(*Average 1911-1921 inclusive*)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	°	°	°	°	°	°	°	°	°	°	°	°	°
Temperature	19·3	25·9	30·5	39·2	48·2	54·4	57·4	55·8	50·0	41·9	31·7	26·0	40·0
Precipitation	7·23	5·87	4·59	3·69	2·07	1·99	3·24	7·88	7·72	11·35	8·42	9·68	73·73
Snowfall	58·20	37·17	17·05	5·10	....	....	....	....	.....	.....	25·90	60·68	219·56
Number of days' precipitation	13	9	10	10	9	8	10	13	15	19	17	16	149

CHAPTER II

GENERAL GEOLOGY

The Coast Range batholith, the dominant geological feature of the Coast range of British Columbia, is the elongated narrow mass of granitic rocks which stretches from Fraser river to the southern Yukon, a distance of 1,000 miles. This composite batholith is made up of various rock types ranging from a gabbro to a granite, but the predominating type is granodiorite. The date of the main intrusion is believed to be late Jurassic. Flanking this batholith on both sides is a series of sedimentary and volcanic rocks, ranging from the Palæozoic to the Jurassic, which is older than the Coast Range batholith and is intruded by it. There is also a group of sedimentary and volcanic rocks of Cretaceous, Tertiary, and Recent periods, later in age than the main intrusion of the Coast Range batholith. The group older than the batholith is metamorphosed and impregnated by ore deposits, whereas the groups younger than it are not metamorphosed and do not contain metalliferous ore deposits to any extent, though they are important because of their coal. Included in the main batholith are numerous roof pendants of varying sizes and shapes belonging to the pre-batholithic bedded series. These inclusions are more numerous on the western side of the batholith and are mostly altered to schists. Their presence (Figure 1) gives the western border of the batholith an irregular and intricate pattern in contrast to the even-flowing contact that marks the eastern border.

A marked difference between the western and eastern contact of the Coast Range batholith is, as pointed out by F. E. and C. W. Wright,[1] the degree of metamorphism exhibited in the pre-batholithic rocks. The rocks along the eastern contact are not highly metamorphosed except in the immediate vicinity of the batholith, whereas the western contact is marked by a very wide aureole of garnetiferous schists, marbles, quartzites, and highly schistose volcanic rocks. This difference is further emphasized by the mineral contents of the ore deposits found in the two flanks of the batholith.[2] The ore-deposits along the western or Pacific belt are characterized by copper-bearing minerals, whereas the eastern or Interior belt contains deposits in which galena, tetrahedrite, and zinc blende are the principal minerals.

The Interior belt of mineralization of Salmon River district lies close to the eastern edge of the Coast Range batholith and is typical of an extensive region marginal to the batholith which stretches northwest and southeast. Before entering upon a detailed study of the geology of the district it may be well to review the geology of this whole "Interior belt" of mineralization of British Columbia. It forms a belt along the eastern flank of the Coast Range batholith. It stretches from Yukon to southern British Columbia and includes the mining districts of Keno Hill, Atlin, Unuk River, Salmon River, Alice Arm, Hazelton, Telkwa, François and Ootsa Lakes, Bridge River, and Coquihalla (Figure 1). These dis-

[1] Wright, F. E., and C. W., U.S.G.S., Bull. 347, 1908.
[2] Schofield, S. J., Trans. Can. Inst. of Min. and Met., vol. XXIV, 1921.

tricts are already known to be mineralized to a commercial degree and it is safe to predict that intervals between them will also produce commercially if transportation brings them within reasonable access.

The underlying geological features of this Interior belt are fundamentally constant. The oldest group of rocks in the belt belongs, according to fossil evidence, to the Carboniferous,[1] although older members of the Palæozoic may be present.[2] This group includes limestones, quartzites, argillites, and some volcanic rocks, and is overlain—probably unconformably—by the Porphyrite group[3] which, according to Dawson, underlies conformably the Jackass Mountain group, of Lower Cretaceous age.[4] The Porphyrite group is mainly volcanic in character. It consists of volcanic breccias, flows, tuffs, and some argillites, and exhibits the same characteristics over an area as long as the Coast range itself, since rocks similar to those mentioned above are also mentioned as occurring in the areas of Atlin, Salmon river, Alice arm, Hazelton, Ootsa and François lakes, Tatlayoko lake, Taseko lake, and Highland valley. These rocks exceed any other in area and are of most importance economically in their association with ore deposits. The age of the Porphyrite group is probably Upper Jurassic.[5] All the foregoing groups were mountain-built and intruded by the Coast Range batholith, whose age, for the most part, is placed toward the close of the Jurassic.

Scattered sporadically over all the preceding formations are small patches of Cretaceous rocks which consist mainly of conglomerates, sandstones, and shales, with—in some cases—seams of coal. These rocks rest, probably with unconformable relations, upon the older[6]. Volcanic rocks of the Tertiary and Recent periods occur in small patches along the whole of the area bordering the Coast Range batholith.

The sedimentary and volcanic rocks which form the bedrock of a large part of Salmon River district are only a small part of the above-mentioned Porphyrite group, which extends from the International Boundary at the 49th parallel along the east side of the Coast Range batholith into the Yukon. The series has been called by various names such as Porphyrite group, Hazelton formation, and Perkins group. These will be discussed in greater detail under the head of "Correlation." The rocks exposed in Salmon River area are restricted to the Mesozoic era and possibly to the Jurassic period of that era. The sedimentary and volcanic rocks are cut by the Coast Range batholith as well as by dykes and stocks associated with the main intrusion.

The formations were folded and faulted by the mountain-building forces of late Jurassic time, but they have not been highly metamorphosed except near the batholith.

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[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 57 B.
[2] Cairnes, D. D., Geol. Surv., Can., Mem. 37.
[3] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 250.
[4] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 253.
[5] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 58; ibid, 1879-80, p. 104 B.
[6] Mackenzie, J. D., Geol. Surv., Can., Sum. Rept., 1915, p. 62.
Uglow, W. L., personal communication.

Table of Formations Found in Salmon River Area

Quaternary	**Pleistocene and Recent**		**Gravels and sands** **Glacial drift**
		Unconformity	
Mesozoic	Jurassic		Lamprophyre dykes
		Intrusive Contact	
			Quartz diorite dykes
		Intrusive Contact	
			Augite-porphyrite stock
		Intrusive Contact	
		Coast Range batholith	Granodiorite
		Intrusive Contact	
		Premier sills	Quartz porphyry
		Intrusive Contact	
		Nass formation	Slates (fossiliferous), thickness 1,000+ feet
		Salmon River formation	Conglomerates, thickness 300+ feet
		Bear River formation	Agglomerates and tuffs, thickness 2,000+ feet

Base unexposed

Tabular Statement of Geological Events

Quaternary	Post-Glacial	Deposition of terminal moraine Deposition of river gravels Gradual uplift, erosion Deposition of marine clays at Elevenmile
	Glacial	Erosion—deposition of glacial drift
Tertiary	Pliocene	Erosion
	Miocene	Erosion
	Oligocene	Erosion
	Eocene	Uplift of Cretaceous peneplain, erosion
Mesozoic	Cretaceous	Erosion—probable peneplanation
	Jurassic	Intrusion of lamprophyre dykes Intrusion of quartz diorite dykes Period of mineralization Intrusion of "belt of dykes" Intrusion of augite porphyrite stock Intrusion of Coast Range batholith and accompanying dykes Orogenic movements—folding and uplift Intrusion of Premier sills Marine sedimentation—deposition of Nass formation Marine sedimentation—deposition of Salmon River formation Vulcanism—accumulation of Bear River formation

Base unexposed

BEAR RIVER FORMATION

McConnell[1] included in his Bear River formation the rocks that in this report are called the Salmon River formation. The Bear River formation is restricted to the volcanic members that form Bear River ridge, whereas the Salmon River formation includes the conglomerates that lie between the Bear River formation and the overlying slates of the Nass formation. This distinction was made to accentuate more clearly the structure of the region. The Bear River formation occupies the entire southern part of the area and is well exposed on Bear River ridge south of mount Bunting. The rocks on Bear River ridge are mainly agglomerates. They form the lower part of the formation and underlie the tuffaceous members that outcrop on the lower slopes of the ridge in the neighbourhood of the Premier mine. Younger tuffaceous members outcrop on Big Missouri ridge across Cascade creek, and continue northwards along the strike forming the crest of that ridge beyond the northern boundary of the area. A small anticlinal area outcrops on the slope of Bear river northeast of Long lake. Another area is found on the same ridge at Divide lake.

This group of rocks is almost entirely of volcanic origin and the name

[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, 1913, p. 14.

"greenstone" commonly applied to it is suitable in a general way. The lower members are largely fragmental rocks of agglomerate character. Their constituent fragments are angular, purple and green masses of andesite in an andesitic matrix. They vary in size from minute particles to pieces a foot or more across. In thin section, they show phenocrysts of a plagioclase of intermediate composition, probably an andesine, scattered through a highly altered matrix in which hornblende and plagioclase are the main constituents. The rock is highly altered and many secondary minerals such as calcite, epidote, and chlorite are present. The matrix that cements the fragments together is andesitic in composition and is more highly altered than are the fragments. In some cases it appears to be of fragmental origin; in other cases the blocks are cemented by a matrix that shows slight flow structure. In some places bands of tuff are interbanded with the agglomerate. Altogether the agglomerate is massive, uniform in composition, and very resistant to weathering agents.

The agglomerates are overlain conformably by fine-grained tuffs that form the upper part of the Bear River formation. The tuffs are massive in appearance and, as a rule, green, but purple bands occur at irregular intervals in the green. The green tuffs are dull in colour and small fragments of plagioclase feldspar can be seen in them. Under the microscope the rock is seen to be sheared and highly altered. The minerals are chiefly secondary, and consist of sericite, calcite, chlorite, quartz, altered plagioclase, rutile, pyrite, and leucoxene. The rock is penetrated by numerous veinlets of calcite. Occasionally the tuffs are mottled with green and purple patches which under the microscope are seen to be fragmental in origin, the fragments being somewhat rounded as if by water action. The purple tuff, in thin section, is found to be composed of irregular grains of quartz and highly altered plagioclase with abundant sericite.

Origin. The fragmental volcanics appear to be flows that solidified at the surface. Further movement of the flows broke up the solid crust into fragments which were engulfed in the molten mass and finally the whole solidified. At the time the flows were moving volcanic ash was settling on the mass so that the fragments are occasionally cemented by tuff. In Salmon River area the flows of lava ceased, and the tuffs were laid down—probably in water, for they are occasionally very definitely stratified. No pillow structure was seen in the flow rocks. The presence of argillites in both the agglomerate and tuff series shows that sedimentation was progressing during this period of vulcanism. The base of the Bear River formation is not exposed and the massive character of the agglomerate portion prevented any determination of its thickness. An estimate of 2,000 feet must be considered as very approximate only.

SALMON RIVER FORMATION

This formation occupies a semicircular area around the southern base of Slate mountain. The eastern edge of the mass passes under the slate exposed along the shores of Long lake and on Bear River ridge; the western edge of the area extends northward as a narrow band which passes under the glacier that caps mount Dilsworth. Another area of these rocks occupies the lower slopes of Big Missouri ridge below the Fortynine group of mineral claims.

The Salmon River formation consists mainly of fine conglomerate, bearing pebbles of the underlying volcanic rocks. Bands of argillite are interbedded in the conglomerate and a persistent bed of chert is a noticeable member. The rocks of the formation have in general a grey colour with an occasional green tinge. The study of specimens of this formation under the microscope was highly unsatisfactory because of metamorphism and shearing. In the sandstone-like member, the individual grains are not well rounded and consist of quartz, feldspar, biotite, and chlorite, giving the rock the character of a grit or arkose. In other cases the grains of the conglomerate are heterogeneous fragments of the underlying volcanics which are now composed chiefly of secondary minerals. The chert band is a fine-grained tuff consisting of small angular fragments of quartz and feldspar in a dense nearly isotropic groundmass. The thickness of the formation varies but is about 300 feet.

The Salmon River formation passes downwards by gradual transition into the tuffs of the Bear River formation. The contact is not sharp and the line between the two formations was drawn where the interbedded series of tuffs and conglomerates are about equal in thickness and importance. The upper part of the Salmon River formation in like manner gradually passes into the Nass formation by interbedding. The relationship of the Salmon River formation to the underlying and overlying formations is, therefore, one of conformity. No evidences of an unconformity were detected in the field.

NASS FORMATION

The Nass formation is well exposed on Slate mountain, the most southerly point in the sheet where the rocks of this formation are exposed, and from there the slates extend northwards and occupy, to a large extent, both slopes of Long Lake valley. Small patches of slates occur on the western slope of Big Missouri ridge. Across the Salmon River glacier, the mountains to the north of mount Lindeborg show slates of the Nass formation.

The rocks of the Nass formation are mainly argillites which, in many places—especially near the Coast Range batholith—show a slaty cleavage. Beds of sandstone and fine conglomerate occur here and there through the formation.

The formation is more than 1,000 feet thick, but the top was not exposed in the area under examination.

The contact of the Nass formation with the underlying Salmon River formation is one of gradual transition. The Nass formation is cut by the granodiorite and all younger intrusive rocks.

AGE AND CORRELATION OF THE SEDIMENTARY AND VOLCANIC SERIES WITH THE PORPHYRITE GROUP

The resemblance between the sedimentary and volcanic series exposed in Salmon River district and the Porphyrite series of Dawson is very striking, not only in lithology but also in age. This formation contains the rich silver and gold ores of the Interior mineral belt. A brief review of these rocks is, therefore, given below in order to point out their variations as well as their distribution (Figure 1).

The Porphyrite group was defined by Dawson[1], in 1875, to include "a series of rocks, chiefly feldspathic and often porphyritic, though also including diorites of varied texture. . . They are best seen about Tatlayoko lake, where they overlie unconformably the Cascade crystalline rocks, and appear to underlie the beds of the Jackass Mountain series. The whole of the rocks of this group seem to be of igneous origin, though some of them may owe the arrangement of their material to water. At the outlet of Tatlayoko lake, on the eastern side, a fine-grained, purplish feldspathic rock occurs, which is followed, in ascending order, by a great volume of pale-greenish diorite, compact but very imperfectly crystallized, and, in the arrangements of its constituents, resembling a metamorphosed fragmental rock. Two miles northward, and probably much higher in the series, a compact, dull bluish or purplish porphyrite appears. The matrix is homogeneous, and contains small glimmering feldspar crystals scattered through it. It is hardly fusible, even in thin splinters, under the blow-pipe, and is probably orthoclastic. Here also occurs a rock similar in colour to the last, but distinctly brecciated. The fragments and matrix are both porphyritic, with white feldspar crystals, and slightly calcareous. The matrix seems to have been vesicular in places, and shows irregular lines of flow, the whole having the aspect of the scoriaceous surface of a lava bed in a metamorphosed state. Half a mile from the lake up Cheshee creek, rocks of the same series, and probably overlying the last, were again found. Some beds here resemble a dull red quartzite, but on close examination are seen to be fine-grained porphyrite, in which very small whitish feldspar crystals are thickly scattered in a purplish-red matrix. Other beds, with a similar colour, have an almost earthy fracture, and appear to consist of indurated feldspathic mud, in which very few distinct crystals have been developed. A hornblende-porphyrite was also observed, forming a very compact rock, in which dark hornblende crystals, with whitish feldspar particles, are scattered in a purplish mass. Most of the rocks are here much jointed, and, in the cracks, epidote in thin films constantly appears. They are distinctly bedded in this place, and dip north 65 degrees, east 35 degrees, an attitude which would appear to place them conformably below the Jackass Mountain series of the higher parts of the mountains of the vicinity. In following the shore of the lake northward, rocks of the Porphyrite series are again found, with a similar relation to the Jackass Mountain beds, at its upper end, and probably form the greater part of the low range of hills extending to Cochin lake. They are, however, much broken and disturbed in this neighbourhood, and in some places rocks belonging to the upper series were also seen, and it is even possible that these may preponderate. In Prospect creek, 7 miles north of the lake, the strata are more than elsewhere confused and broken and are traversed by many small quartz veins. Here men employed in the railway survey found abundant 'colours' of gold in the drift."

"From the quantity of fragments of rocks referable to the Porphyrite group in the superficial deposits along the eastern slopes of the Cascade mountains, it is probable that it occurs in many places in that range. It appears extensively in the mountains on the west side of Tatlayoko lake, and, also, probably, in the flanking range between Tatlayoko and the West Homathko valley. Mr. Tiedemann, of the railway survey, has given me a number of very characteristic specimens of rocks of this series, collected between Middle and Twist lakes, on the West Homathko. Five miles from the east end of Tatla lake, beds apparently belonging to this group occur in one place, and, though not observed in contact with the micaceous rocks of this region, undoubtedly overlie them. The rocks seen are compact greyish hornblende-porphyrites, and a dull greyish-purple amygdaloidal porphyrite, in which, besides well-developed feldspar crystals, there are many small chalcedonic particles filling cavities."

[1]Dawson, G.M., Geol. Surv., Can., Rept. of Prog. 1875-76, p. 250.

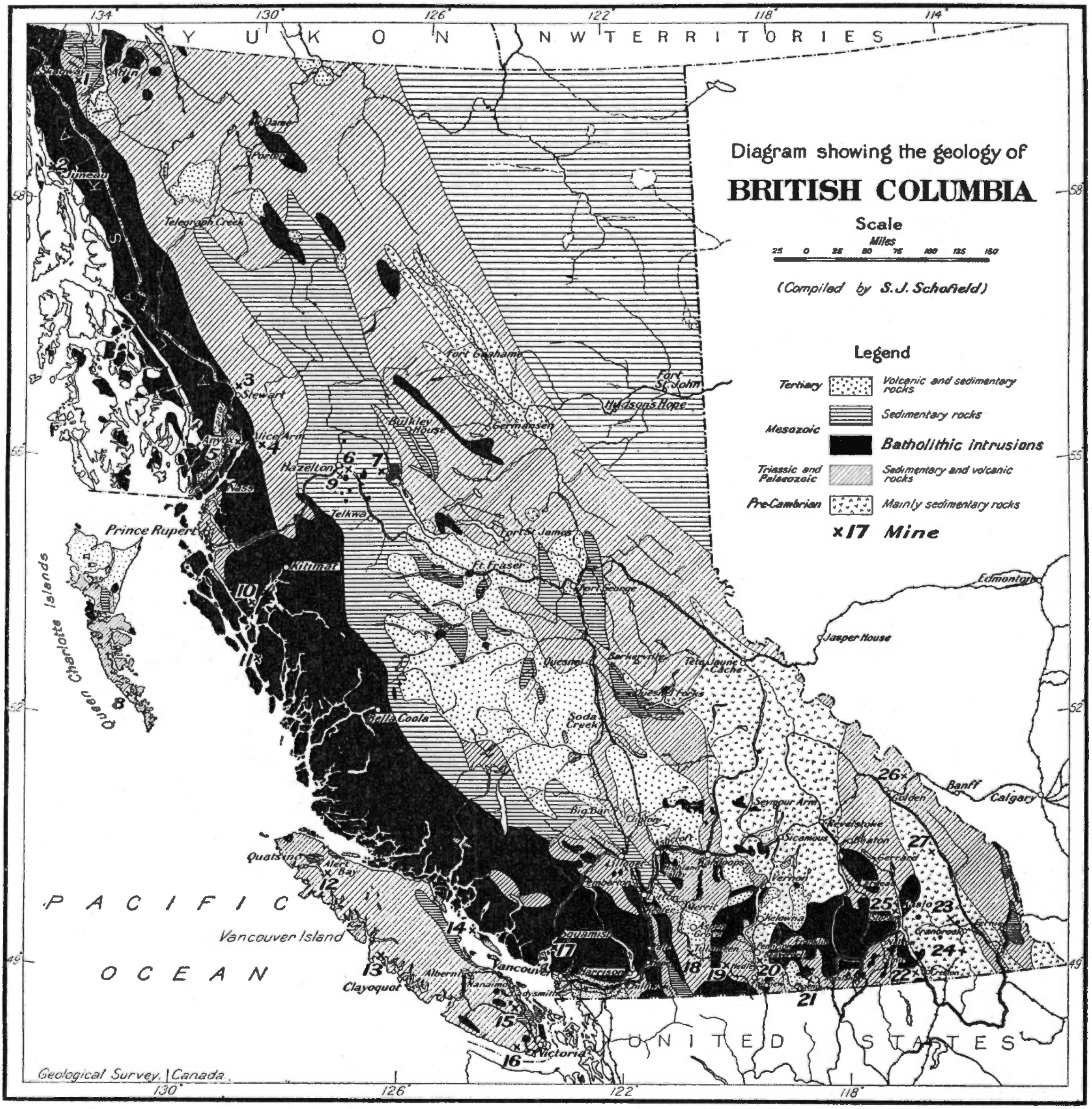

Figure 1. Diagram showing marginal relationship of Salmon River area and of various other mineralized areas in British Columbia to the Coast Range batholith. Mines located along the margins of the batholith are shown by numbers as follows: 1, Engineer. 2, Treadwell. 3, Premier. 4, Dolly Varden. 5, Anyox. 6, Silver Standard. 7, Babine Bonanza. 8, Ikeda. 9, Rocher Déboulé. 10, Drum Lummon. 11, Surf Inlet. 12, Old Sport. 13, Tidewater Copper Company. 14, Marble Bay. 15, Tyee. 16, Sunloch. 17, Britannia. 18, Tulameen. 19, Hedley. 20, Copper Mountain. 21, Phoenix. 22, Bayonne. 23, Sullivan. 24, St. Eugene. 25, Ainsworth. 26, Monarch. 27, Paradise.

"Rocks of this series also probably characterize a considerable length of the Nazko valley between the Clisbako and its mouth, and though the exposures are too few to allow any very precise definition of their area, it has been approximately represented on this map. Their relation to the Jackass Mountain beds cannot here be ascertained, the junction being covered by horizontal basalt flows. About 6 miles north of the confluence of the Clisbako, they are seen in several places, and are generally pretty typical porphyrites of bluish-grey and red colours. They are often brecciated, sometimes very coarsely, the matrix and included fragments being, however, generally almost identical in composition, and the structure of the rock masses sometimes barely apparent until weathered. In one place they were observed to dip south 22 degrees west, at angles of about 45 degrees: at another, southward <60 degrees. In many of the exposures these rocks are crumbling and rotten, and, like all the beds of this vicinity—including parts of the overlying basalt—seem to have undergone considerable change from the action of thermal springs, or steam, rendering it difficult, in many cases, to distinguish between the older and newer volcanic products. In one place, in a porphyrite with a compact red base, the feldspar crystals are represented by a soft, yellowish, granular material resulting from their decomposition. From the drift, it is probable that these porphyrites may occur largely in the mountains west of the Nazko, at this place. Farther north, though pebbles and boulders of these rocks were often found in abundance, the rocks in place were not seen, unless it be supposed that a compact diorite of imperfect crystallization, and somewhat peculiar appearance, found near Tsawhuz mountain on the trail to Fort George, belongs to this horizon."

"On the Chilcotin, the hill named Battle mountain is a remarkable mass of volcanic products, chiefly brecciated, which underlies the basaltic flows, and probably belongs here. Many varieties of igneous rocks are represented, but they are nearly all more or less typical porphyrites. In some instances the whole mass is of a uniform dull red or blue colour, and extremely compact, while in other beds the fragments included are much more varied. and they hold, besides portions of volcanic rocks of many different tints, pieces of siliceous and slaty material, apparently derived from strata of ordinary igneous origin. In most cases the fragments are angular, but in some beds many are well rounded, whether from the action of water or friction in a volcanic vent does not appear. In the lowest bed seen, which, besides showing many small fragments, is irregularly blotched or mottled with darker spots, impressions of plants are found, but are not sufficiently well characterized for determination, though there can be no doubt as to their vegetable nature. They are indicated on the surface by rusty patches, from the decomposition of pyrites which has gathered around them, and generally show parallel striation or ribbing, like that of large sedge-like leaves. They have not been derived from any of the older rocks included in the breccias, as they appear without any traces of a former matrix. A very remarkable rock seen in one place may be called a slaty hornblende porphyrite, and has probably been a fine feldspathic mud. It is bluish-grey and very fine-grained, but shows throughout small imperfect crystals of white feldspar, and scattered hornblende crystals, acicular and black. Thin splinters are easily fusible before the blow-pipe. The beds in Battle mountain dip northeastward at various angles."

"The exact position of the beds of the Porphyrite group must remain a subject for future investigation. Though they have been observed in one place to pass in apparent conformity beneath the Jackass Mountain rocks, this may merely have been the result of local accident, or folding together in the same synclinal. In some cases it may be difficult to distinguish these beds from those of the basaltic series above, but they are in general very different, for though seldom or never quartzose, they are invariably more acidic than the rocks of the great horizontal flows of the interior. I can hardly doubt that these porphyrites lie between the Lower Cache Creek and Jackass Mountain groups, but whether they should be attached to the base of the latter, or considered as a part of the former, or an independent series, cannot yet be decided."

The Jackass Mountain group[1] was determined by Dawson[2] to be Lower Cretaceous in age. The stratigraphic position of the Porphyrite group is further discussed in a later report[3] as follows:

"The most interesting and typical sections of these (Porphyrite group) rocks examined last summer are those in the vicinity of the Iltasyouco and Islaho or Salmon rivers. The

[1] Selwyn, A. R. C., Geol. Surv., Can., Rept. of Prog., 1871-72, p. 60.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 253.
[3] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 58.

rocks here seen represent those described last year on Tatlayoko lake, and although they have not been again observed in contact with the upper arenaceous and conglomerate beds of the Tatlayoko Lake sections, the discovery of fossils on the Iltasyouco river of an horizon close to, though probably lower than, that of the Jackass Mountain group, together with additional evidence tending to show the blending of the ordinary aqueous sediments of the upper part of the Jackass Mountain series with the igneous products of the Porphyrite series, leaves little room for doubt that the latter is a downward continuation of the former, and that the whole constitutes a formation, bridging to some extent the gap ordinarily found between the Cretaceous and the Jurassic."

Concerning the lithology of the Porphyrite group, which is described in some detail in the above report, Dawson says:

"The best section of the Porphyrite series obtained, was measured in the forest north of the Salmon River fall. The rocks are not continuously exposed, but are generally seen at frequent intervals. The lowest observed is a rough, feldspathic breccia, of which the paste is greyish, and holds angular and irregular fragments of compact feldspathic rock, generally of pale tints, and sometimes several inches in diameter. Occasional small, rounded pieces were also seen, which, when freshly exposed, are almost as soft as wax, but eventually become somewhat harder. Some of the more compact felsitic fragments are marked with fine, twisted lamination surfaces, in a peculiar manner. Above this is a considerable thickness of dark, blackish-grey hornblende-porphyrite, with pale-grey, imperfectly-formed feldspar crystals, and black hornblende. These, together, constitute a thickness of about 180 feet. Next in order is a dark purplish porphyritic rock, which must have been a volcanic ash of fine grain, but is now very compact. Above this is a grey-green porphyrite, with rather large glimmering crystals scarcely distinguishable in tint from the matrix. This is overlain by a fine-grained grey rock, resembling a diorite, but probably a diabase—of a type common in these rocks—above which is another bed of breccia, probably nearly 200 feet in thickness, the lower part resembling that already described; above, in some layers, the fragments become more or less perfectly rounded, as if by water action, and the matrix shows green cupreous stains. Overlying the last, 235 feet of the section is represented by porphyrites, seen in a few places only, but varying from grey to purple; those of the latter tint forming a hard, finely granular rock, in which feldspar crystals are often scarcely distinguishable. The next 240 feet shows in two places dolerite, or diabase, of the usual character; over which comes greyish compact felsite, with some hornblendic blotches, succeeded by a blackish diorite. Above the last, a thickness of 950 feet is built up—as far as the exposures allow the composition to be ascertained—of dark porphyrites and felsites, sometimes very fine-grained, with one bed, near the top, of a rather remarkable character. This appears to be a tuff, of a kind not uncommon in the Tertiary series, but here much altered. The mass, which is yellowish-grey in colour, and still somewhat porous, is traversed in all directions by irregular blackish streaks, and holds occasional compact feldspathic fragments, with small scattered pinkish feldspar crystals."

This description applies very well to the rocks in Salmon River district (Portland canal), which are correlated with Dawson's Porphyrite group.

The age of the Porphyrite group is more closely defined by Whiteaves[1] as Jurassic. His conclusion, after a full description of the genera and species collected by Dawson from the Porphyrite group is as follows: "On the whole, however, the evidence as far as it goes is in favour of the supposition that these fossils from British Columbia belong to the Lower rather than to the Upper part of the Jurassic series."

Brock[2] examined the Porphyrite group in the Eutsuk Lake district, which is adjacent to François lake, where Dawson described the Porphyrite group. The fossils collected by Brock from the group were not determin-

[1] Whiteaves, J. F., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 150.
[2] Brock, R. W., Geol. Surv., Can., Sum. Rept., 1920, p. 87 A.

ative, but do point to Upper Jurassic or Lower Cretaceous age, and increase the probability of the equivalence with Dawson's Porphyrite group and Leach's Hazelton formation.

Subsequently Whiteaves[1] modified his conclusion in favour of a later age for this group of rocks:

"The fossils collected from these porphyrites were reported upon provisionally by the writer in an appendix to Dr. Dawson's report. They were then regarded as possibly of Jurassic age, on account of their resemblance to the fossils of the so-called Jurassic rocks of the Black hills of Dakota, but are now believed to be Cretaceous."

"The collections of fossils that have been made from the Cretaceous rocks of Quatsino sound, Vancouver island, in 1878 and 1885, and at various localities off the coast or on the mainland of British Columbia between 1875 and 1888, have led to the conclusion that the *Aucella*-bearing rocks and Jackass Mountain series of that province are not older but of about the same age as the Queen Charlotte Islands formation, and that the porphyritic rocks of Siqutlat lake and Iltasyouco river are of the same age and not altered Jurassic sediments."

The correlation of the Porphyrite series with the Queen Charlotte Islands formation does not place the Porphyrite series definitely in the Cretaceous, since the lower members of the Queen Charlotte Islands formation have been determined by Mackenzie[2] to be Middle and Lower Jurassic and to be separated from the Cretaceous by a marked unconformity. Dawson and Whiteaves considered the Queen Charlotte Islands formation wholly Cretaceous. The following table taken from Mackenzie's memoir compares the two interpretations:

Present Subdivision			Dawson's Subdivision
Upper Cretaceous	Skidegate formation	Cretaceous	A. Upper shales and sandstones
	Honna formation		B. Coarse conglomerates
	Haida formation		C. Lower shales
Unconformity			
Middle Jurassic	Yakoun formation		D. Agglomerates
Lower Jurassic	Maude formation		E. Lower sandstones

McLearn, who studied the section in 1921, places the Haida and the Honna in the upper part of the Lower Cretaceous. In the above table the Yakoun formation consists chiefly of volcanic rocks and would correspond lithologically with the Porphyrite series.

North of the region examined by Dawson, Leach[3] recognizes in the Telkwa district the same series which he places in the Cretaceous, although he states that no fossils were found. No evidence is submitted to warrant this change of age of the Porphyrite group from Jurassic to Cretaceous. The rocks consist chiefly of tuffs, agglomerates, andesites,

[1] Whiteaves, J. F., Trans. Roy. Soc. Can., vol. 11, 1893, pt. 4, p. 16.
[2] Mackenzie, J. D., Geol. Surv., Can., Mem. 88, 1916, p. 11.
[3] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1906, p. 36.

and other flow rocks. Red colours predominate near the top of the series and green is characteristic of the base. The relationship of the Porphyrite group to the overlying coal-bearing series is stated in the following words:

"Immediately overlying these rocks and possibly unconformable to them, although both have been subsequently folded and faulted to such an extent that their immediate relationship to one another is somewhat doubtful, occurs a series of rocks composed chiefly of clay shales and containing a number of important coal seams. The lower member of these beds consists of a coarse loosely-cemented conglomerate, mainly composed of the underlying volcanics, in places shading into a coarse grit."

In Telkwa district also Mackenzie[1] describes the Hazelton formation as "a great mass of pyroclastic, effusive, and probably intrusive volcanic rocks," which are cut by the Coast Range batholithic rocks. The Skeena formation appears to be structurally concordant with the Hazelton formation, but "on account of the striking dissimilarity in the lithological nature of the Skeena and the Hazelton formations, the writer believes that an appreciable period of erosion took place previous to the deposition of the Skeena beds and that they rest unconformably, or at any rate, disconformably, on the Hazelton formation."

These coal-bearing rocks of Skeena River district in 1909 were called the Skeena series and on the basis of a few fossil plants referred to the Lower Cretaceous at about the horizon of the Kootenay series.

In the same report Leach[2] replaces the name Porphyrite group by the name Hazelton formation, because the great thickness of volcanics (tuffs, agglomerates, andesite flows, etc.) exposed in Telkwa district is represented in Skeena district by sediments largely of volcanic origin, but, towards the top, consisting of shales and sandstones. Dawson[3], however, in the same district, but a short distance to the west, found volcanic breccias of the Porphyrite group, as well as sandstones and argillites. Concerning the age of the Hazelton group, Leach states: "From the fossil evidence so far obtained, the upper beds of this group (sandstones and shales) appear to be equivalent to the Fernie shales of East Kootenay and Alberta and the 'Lower Shales' of the Queen Charlotte Islands series now supposed to be Jurassic." He also places the Skeena series of Lower Cretaceous age conformably upon the Hazelton series.

O'Neill[4] describes in Hazelton district the Hazelton series on the southern part of Rocher Déboulé mountains as "interbedded flows and coarse, ill-assorted tuffs or tuff-agglomerates. North of the central portion of the group, the series become more and more evenly bedded, with well-assorted material distinctly banded, and with very slight gradation from one band to the next, but all are tuffaceous in composition."

The fossil plants collected by O'Neill were reported by W. J. Wilson to indicate the very top of the Jurassic or perhaps the lowest Kootenay rocks. A determination of the marine fauna by Dr. T. W. Stanton fixes the age of this series as most probably Upper Jurassic. Concerning the

[1] Mackenzie, J. D., Geol. Surv., Can., Sum. Rept., 1915, p. 62.
[2] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1909, p. 64.
[3] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1879-80, pp. 10-13.
[4] O'Neill, J. J., Geol. Surv., Can., Mem. 110, 1919, p. 4.

stratigraphic relationship of the sedimentary part of the Hazelton series and the underlying series of crystal line and of agglomeratic tuffs, O'Neill states: "There appears to be a structural unconformity, but this was not conclusively demonstrated; however, there is a conglomerate at the base of the sediments which contains pebbles and boulders of the underlying tuffs."

In 1911 Malloch[1] made a reconnaissance from Hazelton to the Groundhog coal fields, a distance of approximately 120 miles. The direction travelled was almost due north from Hazelton and since the regional strike of rocks is northwest-southeast, the Hazelton series exposed in the Groundhog basin lies considerably to the east of those exposed at Hazelton. Malloch notes the presence of volcanic flows in the Hazelton series near Hazelton; but farther north, at Shegunia river, flow rocks cease and the Hazelton series is composed almost entirely of sandstones and shales, though the sandstones contain much tuffaceous material, and some true tuffs occur. Malloch found marine fossils near the top of the horizon, which were considered to indicate a Jurassic age. The coal-bearing group (Skeena series) is considered to form a conformable series with the underlying rocks (Hazelton series) and to be of Kootenay age.

In 1912, Malloch[2] made a detailed examination of the Groundhog coal field and gathered new fossil evidence as to the age of the Hazelton series, which is considered to be Jurassic; and of the Skeena series, about which Dr. Knowlton, who examined the plant-remains, states, "There can be no reasonable doubt as to the correctness of referring them all to the Kootenay."

To the north of the Groundhog coal field, as far as Atlin, no detailed study of the rocks belonging to the Porphyrite group has been made. At Atlin, Cairnes[3] describes the Perkins group as consisting of andesites, andesitic breccias and tuffs, diabase, and diorite, and, therefore, lithologically similar to Dawson's original Porphyrite group. The Perkins group is cut by the Coast Range batholith and is overlain by the Laberge series of Kootenay age. Cairnes correlates the Laberge series with the Porphyrite and Hazelton groups; but the Laberge series contains pebbles of Coast Range granite, whereas the Porphyrite and Hazelton groups are cut by the Coast Range granite. Therefore, it is considered best to correlate the Porphyrite group, the Hazelton group, and the Perkins group, all of which are cut by the Coast Range granite. In 1912, Cairnes[4] described the Perkins group from the Wheaton River district, Yukon, but added no new evidence as to their age and correlation.

In Taseko valley Mackenzie[5] describes the Denain formation consisting essentially of basaltic pyroclastics and flows which he tentatively assigns to the Jurassic, and correlates with Dawson's Porphyrite group.

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[1] Malloch, G. S., Geol. Surv., Can., Sum. Rept., 1911, p. 72.
[2] Malloch, G. S., Geol. Surv., Can., Sum. Rept., 1912, p. 69.
[3] Cairnes, D. D., Geol. Surv., Can., Mem. 37, 1913, p. 54.
[4] Cairnes, D. D., Geol. Surv., Can., 1912, p. 46.
[5] Mackenzie, J. D., Geol. Surv., Can., Sum. Rept., 1920, p. 42 A.

The main facts brought out in the above review are:

(1) The areas where the fossil evidence concerning the age of the Porphyrite group is most complete are those described by Dawson in the vicinity of Tatlayoko lake and by Malloch in the Groundhog coal field and in both cases a Jurassic age is indicated.

(2) No evidence is submitted by any of the workers of a structural unconformity between the Porphyrite group and the overlying Skeena series, which is Kootenay in age, although in many places a heavy conglomerate containing pebbles of the underlying Porphyrite group marks the base of the Skeena series.

(3) The Porphyrite group in the vicinity of the Coast Range batholith contains a great thickness of andesite and andesite breccia which in the east gives way to water-laid sediments consisting of sandstones and shales with some tuffs. The regional strike of the Porphyrite group is northwest-southeast, and is of Cordilleran trend. This points to a linear source of supply for the Porphyrite group in the area now occupied by the Coast Range batholith.

(4) Dawson's conclusions of 1876 that the Porphyrite group bridges the gap ordinarily found between the Jurassic and the Cretaceous is substantiated to some extent.

(5) The granodiorite of the Coast Range proper cuts the Porphyrite group, and pebbles of this granodiorite are found in the Lower Cretaceous of Fraser river[1] and in the Laberge series of Northern British Columbia and the Yukon.[2]

The presence of these pebbles in the Lower Cretaceous rocks supports the conclusion that the granodiorites of the Coast range were intruded and solidified before the Lower Cretaceous strata were deposited. This dates the intrusion of the Coast Range batholith as post-Porphyrite group and pre-Lower Cretaceous; therefore, in very late Upper Jurassic time. Hence the Porphyrite group must be older than the Lower Cretaceous beds exposed in Fraser river and in the Yukon. The Skeena series, of Kootenay age, as far as known, does not contain pebbles of the Coast Range granodiorite, but, according to Malloch, contains pebbles of blue and green chert as well as pebbles of volcanic rocks, presumably of the Porphyrite series which underlies it. The chert pebbles are evidently derived from the Cache Creek rocks which according to Malloch underlie the Hazelton rocks. This shows that the Cache Creek rocks were folded, and exposed to erosion, before and during the time that the Skeena series was deposited. This movement would correspond to the folding of the Coast range. The absence of granite pebbles in the Skeena series may indicate, either that the granodiorite was not exposed while the Skeena series was being deposited, or that the areas of Skeena rocks so far examined were not favourably located for the derivation of pebbles from the granodiorite rocks.

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[1] Dawson, G. M., Geol. Surv., Can., Sum. Rept., vol. VII, 1896, pp. 147 B–156 B.
[2] Cairnes, D. D., Geol. Surv., Can., Mem. 31, 1912.

PREMIER SILLS

Distribution. The name Premier sills is given to a series of tabular igneous bodies that were intruded along the bedding planes of the tuffs of the Bear River formation, when these tuffs were in an horizontal position. Later, the sills and tuffs were tilted into their present position and were subsequently exposed by erosion. As might be expected from the structural features of the tuffs, the sills occur in greatest abundance associated with them. They were never seen in contact with the slates and occur, presumably, only rarely with the breccias of the Bear River formation. The sills occur on the lower slopes of Premier hill as far south as the boundary, in the neighbourhood of the International group of mineral claims. From the Premier mine they swing northwesterly, cross Cascade river, and are exposed on the southern end of Big Missouri ridge near Indian lake.

Another area of the sill rock is exposed on the hill just west of Silver lake. The structural relationships show that the sill in this locality forms the axis of a northerly-striking anticline, the eroded roof of which exposes the upper part of the sill. This sill disappears to the east and north by plunging under the tuffs. The open-cuts and the tunnels on Mineral hill occur in the upper part of the sills.

The best localities for the study of the lithological character and structural relationships of the sills are on the Premier wagon road; on the road that leaves the Premier road at Bunting's cabin; in the various tunnels of the Premier mine; on the Joker trail; and in the Joker and Big Missouri tunnels at Joker flats.

Where the sills and the tuffs are highly sheared, they are difficult to distinguish in the field. No Premier sills were certainly determined on Big Missouri ridge, although they may outcrop on the lower slopes near Salmon glacier.

Owing to the dense vegetation and the thick covering of wash, it was impossible to separate the sills from the tuffs on the accompanying geological map (No. 1829).

The sills vary in thickness. No definite measurements could be made, but it is believed that they are nowhere more than 500 feet thick.

Lithology. The rock which constitutes the sills varies in texture and composition, but on the whole may be considered a granodiorite porphyry or quartz porphyry. It varies from fine grained to porphyritic. In the hand specimen it is grey relieved by pink crystals of orthoclase. Another variety of the sill rock is grey, very fine grained and brittle under the hammer.

Under the microscope the large phenocrysts of orthoclase are seen to be twinned after the carlsbad law and highly altered chiefly to sericite and calcite. Some sections show crystals of quartz as well as orthoclase. The groundmass is a fine-grained mass of secondary minerals chiefly sericite, chlorite, and calcite. Sericite is abundant in large foils. Titanite, apatite, magnetite, and pyrite are the accessory minerals. Originally the rock probably contained a good deal of acid and intermediate plagioclase. The non-porphyritic and the brittle varieties under the microscope appear to be of the same mineralogical composition, but on account of the high state of alteration of these sills it is possible to distinguish only major characteristics.

There are distinct field differences in the weathering exhibited by the different varieties. The rock near the base of the sills weathers to a soft, somewhat iron-stained mass, but becomes harder and porphyritic near the centre of the sill. The upper contact of the sill is frequently marked by the hard brittle variety which superficially shows very little evidence of weathering. Since the weathering has a close relationship to the mineralogical and chemical composition of rocks exposed to similar conditions, these differences in weathering indicate a variation in the lithology from the bottom to the top of the sills.

Age. The Premier sills are intruded in the Salmon River formation and are cut by the Coast Range granite. Their age must, therefore, lie between that of the Bear River formation and that of the Coast Range granite. Also, the sills are folded and highly metamorphosed along with the bedded rock series, and therefore, must have been intruded before the orogenic movements that folded these rocks. Evidence has been adduced in a previous chapter to show that these orogenic movements took place in Upper Jurassic time and since in all probability the Bear River formation is Upper Jurassic, the Premier sills must also be Upper Jurassic in age. Their mineralogical composition shows a general resemblance to that of the Coast Range batholith and the sills may represent the first stage of this batholith, which was intruded during the mountain-building movements. The sills, however, were intruded just prior to these movements since they are themselves affected by them.

Correlation. Sills of similar composition, structure, and age occur at the Britannia mine on Howe sound, where large deposits of copper ores are restricted to the sheared part of one of these sills, designated in that locality the Britannia sills.[1]

COAST RANGE BATHOLITH

The granodiorites of the Coast Range batholith occupy only a small part of the area. The largest mass forms the high range on the west side of Salmon River glacier, south of mount Lindeborg. Two other small areas occur along the boundary line, one on the Salmon River road up Cascade creek, the other at the most southerly point of the area on Bear River ridge. All these areas are parts of very much larger masses that form part of the Coast Range batholith to the west (*See* Figure 1).

The intrusive rocks that are classified under the general term, "granodiorite" are very variable in character. In general the granodiorite becomes more basic as the contact with the intruded rocks is approached. This feature is well shown in the numerous cuts along the road from Hyder to Elevenmile in Alaska on the way to the Premier mine. Around Hyder the granodiorite is light coloured, approaching a true granite in composition. In the neighbourhood of Elevenmile the staple rock is dark greenish-grey, and plagioclase and hornblende can be distinguished. The colour is evidently due to the great number of these horn-

[1] Schofield, S. J., Geol. Surv., Can., Sum. Rept. 1918, p. 56 B.

blende crystals. In composition it is a quartz diorite. No definite contact was seen between the light-coloured and dark-coloured types and they appeared to grade gradually into each other. To get an idea of the general or average composition of the Coast Range batholith, F. E. and C. W. Wright[1] made a study of a section across the Coast Range batholith along the line of Unuk river, Alaska, a little northwest of Salmon River district. They concluded that the average composition was that of a quartz diorite, of the type tonalite according to the usual classification.

The granodiorite cuts the rocks of the Bear River and Nass formations and the Premier sills, and is overlain by Quaternary deposits. Dykes from the main granodiorite mass penetrate these formations, and, near the contact, masses of the formations are embedded in the granodiorite. These masses are separated from the main formations by parallel dykes of the granodiorite without, in most cases, altering their strike and dip. This phenomenon can be seen in Alaskan territory just south of Elevenmile.

Age and Correlation. The Coast Range batholith has been examined along its entire boundary in a reconnaissance way, but no definite information has been gained regarding its exact age, its complexity, and its methods of intrusion. It will be seen, from the report on the fossils found in Salmon River area, that the granodiorite cuts rocks which are in all probability of Jurassic age, although they may be Lower Cretaceous. On structural grounds, the following discussion of all the information available on this problem points to an Upper Jurassic age for the main intrusion of the Coast Range batholith.

The most definite information concerning the age of the pre-batholithic rocks is given by Mackenzie[2], who found that the batholithic masses exposed on Graham island belong to the Coast Range intrusive and cut the Yakoun formation of Middle Jurassic age. The Yakoun formation is, the writer believes, the youngest group of rocks cut by the Coast Range intrusive whose age is definitely known. Numerous observers in other parts of the Coast range have recorded the intrusion of the Coast Range batholith into rocks of Carboniferous, Triassic, and Jurassic age. The stocks and small batholiths such as those exposed in the interior part of British Columbia at Hazelton, Telkwa, etc., are not included with the Coast Range batholith in this report, since they cut rocks that are definitely Cretaceous in age and are believed to belong to the time of the Laramide revolution.

The rocks which might define the upper limit in time of intrusion of the Coast Range batholith were first described by Dawson[3] on the southeastern edge of the batholith in the vicinity of Skagit river near the boundary line. The fossils found by Dawson in the series exposed on Skagit river were determined by J. F. Whiteaves as newer Mesozoic. Among them was *Aucella piochii* var. *ovata*[4] concerning which Dr. T. W. Stanton[5] states: "The typical form occurs in the lowest known beds of Knoxville (Lowermost Cretaceous). It ranges through several thousand feet of strata, and in the upper part of its range is associated with the

[1] Wright, F. E. and C. W., U.S.G.S. Bull. 347, 1908, p. 63.
[2] Mackenzie, J. D., Geol. Surv., Can., Mem. 88, p. 51.
[3] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, pt. B, p. 105.
[4] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1920, pt. A, p. 17 A.
[5] Stanton, T. W., U.S.G.S. Bull. 133, p. 44.

variety *ovata*. The latter is the predominant form at an horizon about 2,000 feet below the top of the Knoxville and above the horizon of its culmination it is gradually replaced by "*Aucella crassicollis*."

"The Aucella collected by Geo. M. Dawson on Skagit river, British Columbia, in 1877, seem to belong to *Aucella piochii* var. *ovata*."

Dawson notes the presence in these rocks of well-rounded granitic and dioritic fragments, up to 9 inches in diameter. Later Daly[1] made a more detailed study of this Paysaten series and on fossil evidence determined their age as Lower Cretaceous. The series overlies unconformably a southern extension of the Coast Range batholith, and contains pebbles of this granite. Fossil plants collected approximately 5,000 feet above the unconformity place the series in the Lower Cretaceous (Shasta). Marine fossils obtained from a higher horizon separated by about 21,000 feet of strata above the unconformity are of Lower Cretaceous (Horsetown age).

Farther north, near Lillooet, the Jackass Mountain formation occurs on the eastern flank of the Coast range, but not in contact with the Coast Range batholith itself. However, according to Dawson,[2] the Jackass Mountain rocks contain pebbles of granite and granitoid rocks derived from the Coast Range batholith exposed a few miles to the west. The age of the Jackass Mountain formation from its fossil content was "determined as Lower Cretaceous of the horizon of the Shasta group of the California geologists." T. W. Stanton[3] in a footnote concerning the fossil list of Dawson states that "This list indicates correlation with the Horsetown of California." In Northern British Columbia and the Yukon, where granites of two ages are associated with fossiliferous rocks, the stratigraphy and the palæontology have not been studied in sufficient detail to allow of definite conclusions being drawn.

On the western flank of the Coast Range batholith Dolmage[4] describes Lower Cretaceous rocks on the western coast of Vancouver island: "Fine conglomerate, interbedded with sandstone, occurs at Rafael point on Flores island and thick beds of coarser material were observed near Bajo reef on Nootka island. The pebbles of the fine conglomerate consist entirely of volcanic rocks and are obviously derived from the various members of the Vancouver group. Fairly thick beds of dark grey shale near point Estevan are lying almost flat and probably underlie the whole of the peninsula". "These rocks are only slightly folded, the strikes are all nearly parallel to the shore, i.e. north 45 degrees, to 60 degrees west, and the dips are to the southwest or seaward from 10 to 25 degrees, excepting on Grassy and One Tree islands where they steepen up to 50 degrees. They overlie the Vancouver group unconformably. Though the strike is more or less parallel to that of the Vancouver volcanics, the dip is much flatter. No rocks were found cutting these and none overlying them".

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, p. 480.
[2] Dawson, G. M., Geol. Surv., Can., Rept. of Prog. 1877–78, p. 110 B.
[3] Stanton, T. W., "Index to the Stratigraphy of North America," U.S.G.S. Prof. Paper 71, p. 626.
[4] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1920, p. 17 A.

"The age as determined from fossils collected on One Tree island just off the entrance to Kyuquot sound is Lower Cretaceous. The fossils were examined by F. H. McLearn who identified the forms. .

Aucella cf. *piochii*
Belemnites sp.
Intermediate ammonite

"The Aucella forms were sent to Dr. Stanton of the United States Geological Survey for comparison with the more complete sets of Aucella there. Dr. Stanton identified the forms as '*Aucella piochii* var. *ovata* Stanton.'"

From the note of Stanton concerning the horizon of the *Aucella piochii* var. *ovata* given above, it is seen that this fossil is the "predominant form at an horizon 2,000 feet below the top of the Knoxville."

Although these Lower Cretaceous beds were not seen in contact with the Coast Range batholith and granitic pebbles were not seen in the conglomerates, yet a strong unconformity is noted between the Vancouver volcanics and the Lower Cretaceous (Knoxville). Since mountain building and batholithic intrusion are associated, it is concluded that the batholith of the Coast range accompanied the mountain building that made possible the unconformity at the base of the Lower Cretaceous (Knoxville). Hence the batholithic intrusion took place in the Upper Jurassic. Evidence to support this conclusion is given by Mackenzie[1] from observations on Graham island, one of the Queen Charlotte islands. Here the upper part of the Lower Cretaceous is divided into the Haida and the Honna formations, the conglomerates of which contain pebbles of the granite family derived from the Coast Range batholith. Evidently the Coast Range batholith had been intruded and unroofed before the upper part of the Lower Cretaceous was laid down.

To sum up the evidence, it is clear that the Coast Range batholith intrudes the agglomerates of the Yakoun formation of Middle Jurassic age on Graham island, and pebbles of granite derived from the Coast Range batholith are present in conglomerates of Lower Cretaceous age (Knoxville) on Skagit river, which overlie the granite unconformably. The granite batholith must have been intruded and unroofed before the deposition of the Knoxville which is lowermost Cretaceous. Hence the Coast Range batholith must have been intruded during Upper Jurassic time.

AUGITE PORPHYRITE

The augite porphyrite is a stock-like mass outcropping just north of Long lake near the Spider group of mining claims (Figure 4). The area is exposed about 4,000 feet long and has a maximum width of 1,600 feet.

In hand specimens, the rock is dark grey and holocrystalline. Phenocrysts of augite can be seen embedded in a groundmass of augite and plagioclase. Under the microscope large phenocrysts of colourless augite altered along fracture and cleavage lines to uralite can be determined. Chlorite and calcite are also present. Some of the phenocrysts are entirely

[1] Mackenzie, J. D., Geol. Surv., Can., Mem. 81, 1916.

altered to a dense mass of chlorite and epidote. The feldspar, which is a plagioclase—probably andesine—is too highly altered for specific determination. The alteration products are chiefly calcite and sericite. The groundmass is medium grained and consists of partly altered, small rectangular laths of plagioclase, and a darker brownish material which consists chiefly of calcite and much sericite. Very little magnetite and an occasional crystal of apatite constitute the accessory minerals. The augite porphyrite cuts all the rocks of the bedded series and has all the structural features of a stock. This stock is cut by the quartz diorite or granodiorite dykes about one-half mile south of the portal of the Spider tunnel. It is also affected by the primary mineralization. The relationship of the augite porphyrite to the main Coast Range diorite is not known; but from the above facts, the stock is believed to be associated with the earlier phase of the Coast Range batholith.

QUARTZ DIORITE

The quartz diorite dykes are most numerous in the southern part of the area and may be examined in detail in the numerous cuts along the Premier wagon road from the boundary line to the Premier mine. On the accompanying geological map (No. 1829) they are called granite dykes as granite was used as a field name for the group of intrusives; but microscopic examination of the rocks subsequent to the compilation of the map showed that the dykes consist of quartz diorite. In the field they are remarkable for their continuity in one general direction and for their persistent northwesterly strike. They vary in width from a few inches to 1,000 feet.

The rocks of these dykes resemble granites or granodiorites in colour and appearance. In the hand specimen feldspar, usually plagioclase, is abundant. Under the microscope the rock is holocrystalline and slightly porphyritic. Plagioclase intermediate to acid in composition is greatly altered, chiefly to sericite and calcite. The coloured constituent is usually chlorite, which probably has resulted from the alteration of biotite or hornblende. Quartz is present in small amount. The accessory minerals are apatite in long slender crystals and abundant magnetite. The marginal phase of these dykes is distinctly porphyritic, the phenocrysts being plagioclase, altered chiefly in the central part of the crystals to epidote and some calcite. Epidote is not found in the groundmass. The groundmass is fine grained, shows flow structure, and consists almost entirely of plagioclase and quartz. Some of these dykes show orthoclase, and thus grade into the granodiorites.

The relative age of these dykes is difficult to determine. They cut the quartz porphyry sills, the different members of the bedded series, and the augite porphyrite stock. They are cut by the lamprophyre dykes, which in one case at least (on the Joker trail) cut the primary ore deposits, and thus appear to be among the youngest intrusives in the region.

THE BELT OF DYKES

Under the caption "belt of dykes" is included a large number of dyke rocks of various types ranging from diorites to quartz porphyries, which cross the centre of the Salmon River region in a northwesterly direction. The dykes are too numerous and in many cases too small to be mapped separately.

These dykes cut all the members of the bedded series. That they are of different ages is seen from the fact that they cross one another and some of them cut the primary mineral deposits, whereas others are affected by the mineralization. They are considered to be almost contemporaneous with the mineralizing solutions.

LAMPROPHYRE DYKES

The lamprophyre dykes are from a few inches to several feet in thickness. They occur in the Premier tunnels, in the tunnels and open-cuts of the Mineral Hill, and in the Joker tunnel, but were not seen on Big Missouri ridge. The general strike everywhere is north 60 degrees west with a southerly dip of 50 degrees.

In hand specimens these rocks are fairly even in grain and dark grey, darker than the coarse granodiorite or quartz diorite dykes, and very little can be determined except the presence of hornblende and quartz. Microscopically they are characterized by a large content of feldspar in long laths, and some quartz. The feldspar could not always be identified exactly, but in most cases it is an oligoclase, andesine, or an albite-oligoclase. Orthoclase is not common. The coloured constituents are usually highly altered, but hornblende is common in most of these dykes. The alteration products noticed are sericite, chlorite, and epidote; the accessory minerals are magnetite, titanite, and apatite.

The lamprophyre dykes cut the bedded rocks, the quartz diorite, and the augite porphyrite. They are also more recent than the primary mineral deposits and are considered to be the youngest intrusives in Salmon River area. Their contact relationships with the primary mineral deposits can be seen in the Premier mine (Ladder tunnel) and in the surface strippings of the Mineral Hill and Big Missouri claims. In the absence of any contrary field evidence they may be considered to be associated with the closing stages of the Coast Range batholith of Upper Jurassic age.

SUPERFICIAL DEPOSITS

PLEISTOCENE

The greater part of Salmon River region, especially the lower slopes, is covered with glacial drift of considerable thickness. Glacial erratics are very common.

POST PLEISTOCENE

South of the boundary line near Elevenmile, Alaska, is a series of stratified sands and clays about 450 feet above the sea. These sands and clays are evenly bedded and rest upon the glacial drift. Pebbles and boulders are scattered sporadically throughout these deposits. McConnell[1] found similar stratified clays and sands at an elevation of 500 feet above sea-level at Bear lake on Bear river which enters Portland canal at Stewart, B.C. This occurrence indicates post-glacial elevation of at least 500 feet.

RECENT

Deposits of sands and gravel are being made in the various lakes, and especially at the head of Long lake. Terminal moraines are being formed at the edges of glaciers, which are numerous throughout the area.

[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 22.

CHAPTER III

GEOLOGICAL HISTORY

The Jurassic rocks exposed in Salmon River area form part of a great geosynclinal of sedimentary and volcanic rocks that once occupied the whole of British Columbia and Alberta and extended at least as far east as Moosejaw. The eastern and western boundaries of this huge basin are conjectural, but there is evidence to show that the western margin lay beyond the present coast-line of British Columbia and Washington; the eastern border was between Moosejaw and the Precambrian rocks of the Canadian shield. Sedimentation has been going on almost without interruption at least since Lower Palæozoic time throughout the whole basin, and in the region of Selkirk and Rocky mountains it was active. Also vulcanism played a leading rôle in the area now occupied by Columbia range, Interior plateau, and Coast mountains. The old land mass which formed the western margin of this geosyncline is now covered by the Pacific ocean.

The orogenic movements that took place in Upper Jurassic time compressed the sedimentary and volcanic rocks into mountain folds at least in two main parts of this geosyncline—the area occupied by the present Coast and Vancouver ranges and the area occupied by Purcell and Selkirk mountains and their extension southerly in Idaho and Montana. These two great areas of folding are arranged *en échelon* in conformity with the general results of orogenic movements. The portions of the geosyncline not included in this folding were, apparently, not greatly affected, since no structural unconformity exists between the Jurassic and the Cretaceous in these areas. The folding permitted the intrusion of vast quantities of granitic material the unroofed parts of which now constitute the Coast Range batholith in the Coast range, and the West Kootenay and other large intrusions in the Selkirk and Purcell ranges.

Since the Cretaceous sediments occur in three main belts separated by highlands of Jurassic age, it can be seen that the present distribution of the mountain chains, except the Rockies system, has been outlined before the close of the Jurassic period. The western Jurassic highland occupied the site of the present Coast and Vancouver ranges; the eastern Jurassic highland was situated just west of the site of the Rockies system. It is believed that the old land out in the Pacific may have existed until the Tertiary period, when it finally was depressed beneath the ocean. Separating these two Jurassic highlands was an interior basin now occupied in great part by the Interior plateau. After the building of these Jurassic mountains they were subjected to erosion, the products of which may be seen in the Cretaceous rocks that occur along the Pacific coast on Vancouver and Queen Charlotte islands, in the Interior Plateau region, and in the Rocky mountains and Great

Plains region. The granitic pebbles that occur in the Cretaceous formations in the three regions mentioned above prove that the two Jurassic highlands were eroded to such an extent that their granitic cores were at that time unroofed.

Erosion and sedimentation continued almost without interruption until the Laramide revolution in early Tertiary time, when the Cretaceous areas of sedimentation were mountain built, producing mountains for the first time in the Interior plateau, the Rockies system formed, and the Great Plains raised out of the sea. (This mountain building was accompanied by small granitic intrusions.) During this period of mountain building, the Coast range and the Selkirks and Purcells, which had been peneplanated, were re-elevated. The old land in the Pacific at the same time was depressed beneath the ocean.

Erosion recommenced with uneven vigour, accompanied by sedimentation and vulcanism in restricted areas, and continued throughout the Tertiary. During the Middle Tertiary period mountain building of minor importance accompanied by uplift occurred. Some igneous intrusion accompanied these orogenic movements. Glaciation was almost universal in British Columbia throughout the Pleistocene.

JURASSIC RECORD

No rocks older than Mesozoic are exposed in Salmon River area or, indeed, anywhere in its vicinity, and the only rocks later than the Mesozoic are the Pleistocene and Recent deposits. From such a meagre record it is almost impossible to decipher the geological record exposed within the map-area.

Bear River Epoch

The earliest record is one of vulcanism, and from observations on the character of the rocks exposed it is clear that the first activity produced great lava flows whose surface cooled or froze only to be broken up by further movement and engulfed in the moving mass. From the nature of some of the matrix which cements the blocks, it can be concluded that materials of ash-like character were being deposited on the moving lava floods. In Salmon River area, a maximum of 2,000 feet of this material can be seen and the base is not exposed. Although so thick the time for its accumulation was comparatively short as compared with the time necessary for the accumulation of similar thickness of marine sediments. The closing stages of the Bear River epoch were marked by a cessation of lava floods and a predominance of ash accumulation. No pillow lava was seen, but since the tuffs show almost perfect sorting and stratification, the lava must have collected near sea-level.

Salmon River Epoch

The volcanic activity so prominent during the preceding epoch had almost ceased when the Salmon River epoch opened, since volcanic rocks form a very small part of the materials accumulated during this epoch. Fine conglomerates, evidently collected in shallow water, are the prevailing rocks.

Nass Epoch

The sea during this epoch resumed normal deposition of muds which later changed into the argillites and slates of the Nass formation. The presence of marine fossils at the base of the formation points to marine deposition. The age of the fossils is probably Jurassic.

Irruptive Activity

The igneous record conforms almost perfectly to the normal cycle[1] which constitutes the three phases: volcanic, plutonic, and phase of minor intrusions. The volcanic phase, during the Bear River epoch, described above, is linked very closely with the plutonic record. In Salmon River area the intrusion of the Premier sills prior to the time of igneous intrusion and orogenic movements complicates the normal cycle in that a minor intrusion preceded the plutonic phase. This is true in other parts of the Cordillera and was especially noted in the Britannia map-area.[2] The Premier sills were intruded prior to the orogenic movements of the region since they have been folded along with the surrounding tuffs. Moreover, the sills are stratified according to density which could occur only if they had cooled in an horizontal position.

After the intrusion of the Premier sills sedimentation was brought to a close by a great orogenic revolution which took place during Upper Jurassic time. During this revolution the accumulation of volcanic and sedimentary materials was folded and rose out of the sea on a series of anticlines and synclines, striking in a northwesterly direction. Deep down in the core of the range, vast quantities of granodiorite magma constituting the plutonic stage of the normal cycle were intruded by magmatic stoping and by forcing the sedimentary rocks upwards and outwards from the igneous mass. The last phase—the phase of minor intrusions—is represented by the great number of granodiorite, quartz porphyry, diorite, and aplite dykes, as well as by the small intrusion of augite porphyrite seen in Salmon River area.

The ore deposits of Salmon River area were formed during the period of the injection of the minor intrusives, since some of these are impregnated by mineral veins, and others cut the primary ore deposits.

CRETACEOUS RECORD

The Cretaceous period in this region was one of erosion in which the Coast range was worn down sufficiently to expose the Coast Range granodiorite over large areas and to reduce the rugged mountains to a condition of peneplanation. The products of erosion may be seen in the great thickness of Cretaceous sediments now exposed in the interior of British Columbia and along the Pacific coast and islands.

TERTIARY RECORD

The Tertiary record was also one of erosion after a rejuvenation of the Coast range at the beginning of that period. During Tertiary time most of the present valleys of the Coast range were excavated.

[1] Harker, A., "The Natural History of Igneous Rocks," p. 25.
[2] Schofield, S. J., Geol. Surv., Can., Sum. Rept. 1918.

QUATERNARY RECORD

The Quaternary period was marked by refrigeration and glaciation, conditions which still linger with constantly diminishing intensity in these latitudes. Ice caps still cover some of the hills such as mount Dilsworth (Plates I and II) and great glaciers such as the Salmon River glacier (Plate III) slowly move through the valleys. Following the maximum period of glaciation the region must have been depressed since marine silts can be seen as high as 400 feet in the Salmon valley just above Elevenmile. Subsequently came an uplift which raised the land and caused the sea to retreat to its present position, leaving the stratified silts in their present position. This uplift is also marked by the erosion of the first glacial gorge of Salmon river above Elevenmile and the filling up of Salmon valley by stream gravels furnished by the erosive action of the Salmon River glacier. In contrast to the valleys of southern British Columbia, which are actively eroding their channels and giving rise to well-marked terraces, the rivers of northern British Columbia, such as Salmon river, are depositing material and filling up the valleys so that no terraces are present. The filling up of these valleys causes the rivers to meander from side to side over the valley floor, making the building of permanent roads difficult.

CHAPTER IV

STRUCTURAL GEOLOGY

REGIONAL

The structural geology of Salmon River area is only a small detail of that of the Coast range. The dominant feature of the Coast range is its core, the Coast Range batholith. This elongated batholith trends northwesterly and along its flanks occur folded and faulted pre-batholithic rocks.

The stratified series on the eastern side of the batholith are in tightly folded anticlines and synclines that strike in a general northwest-southeast direction. These folds have been described and figured by Dawson.[1] The region he describes has been subject to at least two main periods of mountain building, one in the Upper Jurassic, and the other in early Tertiary (Laramide), and it is difficult to determine to which period the folding belongs. However, where the Jurassic and Cretaceous rocks are in contact the history of the folding can be to some extent deciphered. In some cases the Lower Cretaceous rocks rest with a structural unconformity on the Jurassic, and in these cases the Jurassic rocks have been folded before the Cretaceous rocks were laid down. In other cases the Jurassic and Cretaceous rocks appear to be conformable, which indicates an absence of Upper Jurassic movements in this area. Hence it seems that the folding near the Coast Range batholith was almost entirely of Upper Jurassic age, but, farther away, in the area unaffected by these movements, where the Jurassic and Cretaceous sediments are conformable, the folding belongs to the Laramide revolution. Between these two areas, the folds may be due to both movements.

On the west side of the batholith, on Vancouver and Queen Charlotte islands, the Cretaceous[2] rocks rest unconformably on the underlying Jurassic and Triassic rocks[3] which are folded into northwest-striking anticlines and synclines, whereas the Cretaceous rocks show very light folding. Northward, in southeastern Alaska and westward across the Coast Range batholith from the Salmon River area, Chapin[4] described the stratified rocks as being compressed into truncated isoclinal folds, and folds overturned towards the west.

All observers, therefore, agree that the dominant structure of the pre-batholithic rocks consists of northwesterly striking anticlines and synclines, and in some cases of overturned folds. The stratified rocks "flanking the Coast Range batholiths are folded more closely near the batholith and more openly at a distance, so that, though their general trend is parallel to the coast, their dip is extremely variable, ranging from northeasterly to southwesterly at all angles."[5]

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1875-76, p. 233; 1876-77.
[2] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912.
[3] Mackenzie, J. D., Geol. Surv., Can., Mem. 88, 1915.
[4] Chapin, Theodore, U.S.G.S. Prof. Paper 120, 1918, p. 83.
[5] Wright, F. E., and Wright, C. W., U.S.G.S. Bull. 347, 1908, p. 62.

LOCAL

Salmon River area, in harmony with the other parts of the Coast range, has dominantly a folded structure, the folds trending in a northwesterly direction.

Slate mountain consists of a shallow syncline, the axis of which is composed of Nass argillites. The syncline pitches towards the northwest. Southward along the ridge on which the Premier mine is located, the syncline dies out and is replaced by a westerly dipping monocline composed of rocks of the Bear River formation intruded by the Premier sills. The dip of the formation corresponds to the slope of the Premier hill, and consequently the boundaries of the Premier sills are too irregular and sinuous to be separated from the Bear River formation on the geological map. A small map of the region near the Premier mine (Figure 5) shows this complexity of geology. A small, northwesterly striking anticline, a little north of Long lake, the axis of which has been eroded sufficiently to expose the rocks of the Salmon River formation, is succeeded by a syncline striking in the same direction, whose axis is composed of Nass argillites. This syncline is followed by an anticline, the southwestern limits of which lie west of the map-area. The valley of Harris creek is occupied by an anticline of rocks of the Bear River formation intruded by one of the Premier sills. The axis of the anticline along the hill south of Hog lake is composed almost entirely of one of these sills, from which the overlying rocks have been eroded. Big Missouri ridge is composed of an anticline of the rocks of the Bear River formation. The anticline is slightly overturned to the west so that the argillites of the Nass River formation outcrop along the foot of the ridge along Salmon River glacier. Small normal faults were noticed in the tunnels of the Premier mine and on the surface of the Silver Crest claims.

CHAPTER V

ECONOMIC GEOLOGY

The attention of the mining public at the present time is directed towards the Salmon River district, where the Premier mine is rapidly developing into a large producer of high-grade ore. Although some of the claims now constituting the Premier group were staked in 1910, no rich ore was developed until 1914. Since that date the Premier, under the efficient management of Mr. Dale Pitt, has reached a daily output of 500 tons and has large ore reserves blocked out. The importance of this development can at this date be hardly estimated. The geological conditions which surround the Premier extend hundreds of miles north and south, along the eastern flank of the Coast Range batholith, and it is most probable that other properties similar to the Premier will be discovered in this large unprospected area. Keno Hill in the Yukon, the Engineer mine of Atlin, and the Dolly Varden mine of Alice Arm, are other properties in this great belt of mineralization. The occurrence of such high-grade ore as occurs in the Premier mine proves conclusively that there are ore-bodies in British Columbia that can be made to pay from the outcrop.

CLASSIFICATION OF THE MINERAL DEPOSITS

The ore-deposits fall into three main groups:

A low grade, complex, siliceous type, with values in the base metals, copper, lead, and zinc.
Province, Big Missouri, Hercules, Forty-nine (some ore-bodies).

A silver-gold type rich in gold and silver minerals, including native silver, tetrahedrite, pyrargyrite, freibergite, argentite.
Premier, Silver Tip, certain ore-bodies in the Forty-nine, Big Missouri, and Mineral Hill.

A pyritic siliceous type with high gold values (an ore-body in the Premier).

GEOLOGICAL OCCURRENCE OF ORE DEPOSITS

Most of the ore-bodies are associated with the quartz porphyry sills at their intrusive contact with the tuffs of the Bear River formation. On the geological map (No. 1829) the sills were not separated from the tuffs, so that most of the area mapped as being underlain by the Bear River formation may be considered worthy of attention.

The most favourable geological conditions for the occurrence of ore in Salmon River area appear to be found at the following places:

At the contact of the quartz porphyry with the tuffs.
In certain beds of the tuff and tuffaceous conglomerate.
In the quartz porphyry sills.

The slates, although mineralized in some cases, do not appear favourable for the deposition of commercial ore-bodies.

MINERALOGY OF ORE DEPOSITS

Ore and gangue minerals only are included in the following description of the minerals of the Salmon River district. The order of arrangement follows Dana's classification.

Native elements	Gold, silver
Sulphides	Argentite, galena, sphalerite, covellite, pyrrhotite, bornite, chalcopyrite, pyrite
Sulpho-salts	Pyrargyrite, tetrahedrite, freibergite, polybasite
Oxides	Quartz, limonite
Oxygen salts	Calcite, malachite

Native Elements

Gold (*Au*). Nearly all the mineral deposits in the area contain low values in gold, and some of the ore in the Premier mine carries several ounces to the ton. The metal occurs chiefly as native gold associated with sulphides.

Native silver (*Ag*) is found in the Premier, Spider, Silver Tip, and other properties. It mostly occurs in leaves or plates, nuggets, and wire forms. The nuggets and plates of the metal are rarely pure. They contain, as a rule, freibergite, polybasite, or sphalerite, which have been partly replaced. The metal is also found associated with ruby silver. Native silver is very plentiful in the Premier ore, but is of local occurrence only and not disseminated throughout the deposit. Native silver was the last ore mineral to be deposited and is believed to be secondary.

Sulphides

Argentite (Ag_2S) is uncommon in the district. It is present in small quantities in the Premier ore and perhaps in that of a few of the other properties.

Galena (PbS) is found in every mineral deposit examined in the district. The galena in the district is most commonly of medium grain. Fine-grained, steely galena is not common, nor is the mineral very coarsely crystallized at any place. It is found evenly distributed throughout the ore-bodies and carries average values in silver.

Sphalerite (ZnS) is of widespread occurrence. In the Premier mine it is occasionally well crystallized and is not intimately intergrown with chalcopyrite, as it is in the base metal properties in the district. In some of the properties the zinc blende has a high iron content and is quite black. In the Premier mine it is usually resinous and yellowish brown.

Covellite (CuS) is rare in the district. A few small particles were seen in ore specimens from the Silver Tip.

Pyrrhotite (Fe_5S_6). Small amounts of pyrrhotite are present in a few of the low-grade mineral deposits.

Bornite (Cu_5FeS_4) in small particles associated with covellite was found in ore specimens from the Silver Tip.

Chalcopyrite ($CuFeS_2$) is usually associated with pyrite, sphalerite, and galena, and is abundant. It is usually massive, but on the Lake Shore property imperfect crystals were seen. Here the sulphide crystallized at the same time as quartz in quartz druses. In most of the properties chalcopyrite is intimately intergrown with sphalerite. Chalcopyrite, sphalerite, and galena are of about equal abundance in the district.

Pyrite (FeS_2) is the most abundant and widespread mineral in the district. It is usually rather finely crystallized in cube form. It is fairly common in the country rock near mineral deposits as well as in the deposits themselves. In the heavy sulphide ore-body in No. 2 tunnel of the Premier mine pyrite is apparently an important carrier of gold; in the other properties it carries only low values in gold.

Sulpho-Salts

Pyrargyrite (Ag_3SbS_3) (*Ruby Silver*). Pyrargyrite is not common except in the Premier mine, where it is one of the important ore minerals. It occurs chiefly in irregular blotches and narrow discontinuous veinlets less than a quarter of an inch in thickness, in a gangue of quartz. It is rare in the heavy sulphide ore. The ruby silver is mostly associated with native silver and a little polybasite and, occasionally, with tetrahedrite. It was formed prior to the native silver, but later than the other sulphides. Ruby silver is usually a secondary mineral in other districts. In this district it is associated with secondary minerals, was deposited much later than the known primary minerals, and is found chiefly in fractured vein material near shear zones and faults carrying surface waters. It is believed to be in large part secondary.

Tetrahedrite ($Cu_8Sb_2S_7$) and *Freibergite* ($(CuAg)_8\ Sb_2S_7$). The copper sulphantimonide is found in the Premier, Spider, Silver Tip, Mineral Hill, Forty-nine, and other properties. Wherever it is present the ore carries good values in silver. Most of this material is freibergite. It is commonly associated with galena and sphalerite. Freibergite and galena are the two important primary silver-bearing minerals in the district.

Polybasite (Ag_9SbS_6) is rare and was seen only in a few specimens from the Premier mine. It is mostly associated with native silver. The polybasite in the Premier mine is probably secondary.

Stephanite (Ag_5SbS_4) was not found in any of the specimens examined by the writer, but it has been recorded.[1]

Oxides

Quartz (SiO_2) is the common gangue mineral in all the vein deposits in the district. In most of the veins it is milky white and glassy, but in some deposits there are numerous druses of clear quartz. The mineral is mainly of medium grain and is rarely coarsely crystalline. It does not as a rule carry commercial values in gold.

Limonite ($2Fe_2O_33H_2O$) is abundant in the oxidized material at the surface of all the base metal deposits. In the Premier mine it is present in faults and shear zones as deep as the workings extend.

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[1] Dolmage, V., "High Grade Ores of the Stewart District, British Columbia," Can. Min. Jour., vol. 41, 1920.

Carbonates

Calcite (*$CaCO_3$*). Next to quartz, calcite is the most important gangue mineral. It is not abundant, though present in most of the mineral deposits of the district. In some places it is intergrown with quartz, in other places it was deposited later and is present in veinlets cutting the quartz gangue and country rock. Calcite is a common alteration product in the country rock.

Malachite ($CuCO_3Cu\ (OH)_2$) is rare. Very small amounts are present at the surface of some of the deposits.

Silicates

Numerous silicate minerals are present in the district as ordinary constituents of the country rock. They do not form a part of the ore deposits and will not be enumerated here. Sericite (potassium-aluminum silicate containing combined water) is the typical alteration product in the wall rocks of the ore deposits. Chlorite (magnesium-iron-aluminum silicate containing combined water) is fairly common associated with sericite in the wall rocks. Vermicular chlorite is present but rare.

SECONDARY ENRICHMENT

Secondary ores in various districts in northern British Columbia and southeastern Alaska have been described,[1] and the probability of secondary enrichment of the high-grade silver ores of northern British Columbia has recently received a great deal of attention. The nature of the ore at the Premier and Dolly Varden mines will now be discussed briefly.

The terms "primary" and "secondary" have been used with different meanings by various writers on ore deposits. Nearly all, however, apply the term "primary" to ore-bodies whose chemical and mineralogical composition has not been changed by superficial agencies, and "secondary" to ore-bodies that have resulted through the action of superficial agencies.

When mineral deposits are exposed to weathering the compounds which are unstable under these conditions are decomposed and soluble salts and stable secondary minerals are formed. These soluble salts may move downward, react with minerals below, and form other secondary minerals. In the change from oxidizing conditions at or near the surface to relatively reducing conditions below, solutions may deposit part or all of their metal content. Secondary minerals may result from other reactions. In general the process of secondary enrichment takes place in three steps:

Decomposition of primary minerals.
Transportation, usually in solution.
Deposition in concentrated form.

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[1] Campbell, E. E., "Mineral Occurrences in the Stewart Region." Trans. Can. Min. Inst., 1920, pp. 391-395.
Cockfield, W. E., "Mayo Area, Yukon." Geol. Surv., Can., Sum. Rept., pt. B, 1918, pp. 1-15.
Wright, C. W., "Geology ond Ore Deposits of Copper Mountain and Kasaan Peninsula, Alaska." U.S.G.S. Prof. Paper 1915, p. 56.
Wright, F. E., "The Unuk River Mining Region of British Columbia." Geol. Surv., Can., Sum. Rept. 1905, pp. 46-53.

Secondary Enrichment at the Premier Mine

GEOLOGICAL EVIDENCE

If a high-grade ore is related in position to the present surface it is probably related to it in origin. If there has been considerable erosion since the deposition of the primary ore, it is all the more likely that the ores now confined to a zone near the surface are of surface origin. This point was brought out by Ransome[1] in 1910. The primary ore of the Premier mine was deposited in late Jurassic time. It was formed at a considerable depth below the surface and erosion has been extensive since the Jurassic; hence there should not be any uniform relation to the present surface. Mining has not yet reached the low-grade ores under the high-grade ores, but although the gold values will probably persist, it is likely that the values in silver will decrease rapidly a few hundred feet below the surface.

The ore-bodies are cut by numerous fractures and faults transverse to the strike of the vein. The high-grade silver ore is found in, or very close to, these fractures. High silver values are not found in the unfractured vein matter. The fractures are younger than the primary ore; consequently, to explain the relation between the faults and rich ore, a second period of mineralization is postulated. The apparent source of the mineralization is the primary ore. A second period of primary mineralization is unlikely. If this late mineralization were primary the whole fracture or fault plane should be mineralized. This is not the case. Only the original vein carries ore and the vein is high grade where it is crossed by fractures. It seems obvious that the faults and fractures were simply channels for the downward-moving surface solutions.

MINERALOGICAL EVIDENCE

The space between the walls of the fractures and faults is filled chiefly with sheared and brecciated country rock, vein matter, and ore. A good deal of surface water finds its way along these faults into the tunnels. Limonite is abundant in the crushed rock along the fault planes. Native silver and silver sulphantimonides are also present.

The metallic minerals found in the Premier ore are pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, freibergite, polybasite, pyrargyrite, argentite, native silver, and limonite. Native gold and stephanite have been recorded by Dolmage. The presence of limonite in the fractures furnishes undoubted evidence that oxidizing solutions have moved downward along the fractures. Native silver in sulphide deposits is nearly always secondary. Pyrargyrite, polybasite, and stephanite are usually secondary. Argentite is usually secondary.[2] These are the minerals that make up the rich silver ore at the Premier mine. It is clear that some secondary action is necessary in order to deposit the limonite, and it is probable that the silver minerals were deposited in the same general period and by the same process.

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[1] Ransome, F. L., Econ. Geol., vol. 5, pp. 205–220.
[2] Emmons, W. H., "The Enrichment of Ore Deposits." U.S.G.S. Bull. 625, 1917, pp. 261, 270, 274.

TEXTURAL EVIDENCE

The native silver, and, to a less extent, the ruby silver, occurs in small irregular cracks in the rock and ore in and near the fault planes. Small vugs are found in the ore, and these contain native silver in nugget and wirę form. Native silver was not seen in the unfractured vein material. The texture is similar to that of most secondary ore deposits.

No conclusive evidence in regard to the nature of the Premier ore was obtained from the metallographic study itself. It is clear that the native silver was deposited later than the other ore minerals, and that it has to some extent replaced other minerals. This fact, however, combined with the facts previously cited, helps to substantiate the theory of secondary enrichment.

Dolmage believes that secondary enrichment has played a very minor role in the concentration of the rich ores in the Premier mine[1]. He had not visited the field, however, but based his conclusions on a careful metallographic examination of ore specimens.

The minerals polybasite and argentite were deposited later than the other ore minerals, except pyrargyrite and native silver. The native metal is later than all the other ore minerals. The replacement veinlets and areas of the metal commonly contain remnants of the minerals replaced, which are chiefly polybasite, freibergite, and sphalerite.

Secondary Enrichment at The Dolly Varden Mine

The Dolly Varden mine is situated about 17 miles up Kitsault river from Alice Arm. Two weeks during September, 1920, were spent at this mine, but it will not be discussed fully here, since it closely resembles the Premier in geology, mineralogy, and structure of the ore. The origin of the high-grade silver ores will, however, be discussed briefly.

The upper workings of the mine are 1,850 feet above sea-level. Ore has been extracted to a depth of approximately 250 feet and development extends to a greater depth. The ore is a heavy sulphide and lies at the contact between a red tuff hanging-wall and a green tuff foot-wall. The terms red and green tuff are used locally to designate the red and green volcanic rocks in the area. Tuffs and breccias are present in the series, as well as andesitic flows. The ore deposit has been fractured and cut by transverse faults.

The writers wish to express their indebtedness to the men in charge of the Dolly Varden, and in particular to C. B. North, the general manager, for detailed information as to the nature of the ore taken from the different levels, etc.

GEOLOGICAL EVIDENCE

The geological evidence favouring the theory that the ore is secondary is particularly strong at the Dolly Varden. The high-grade ore is concentrated within 250 feet of the surface. The primary ore was deposited in late Jurassic time, and since then erosion has removed a thick rock cover. It is very unlikely that the ore would show such a marked relation to the present surface if it were primary.

[1] Op. cit., p. 457.

Relations similar to those in the Premier are found between the ore-bodies and faults. The hanging-wall of the ore-shoots is smooth and covered with gouge; and ore ceases abruptly against this wall. Along the foot-wall there is a gradual change from ore to country rock. Faults striking approximately at right angles to their trend have offset the ore-shoots for over 150 feet in some instances. The rich silver ore is concentrated near the hanging-wall and near the cross faults. The transverse faults and also the hanging-wall of the vein in the Dolly Varden are admirable channels for downward-moving solutions.

MINERALOGICAL EVIDENCE

The mineralogy is very similar to that at the Premier. The chief difference is the lack of gold at the Dolly Varden. The same evidence of downward movement of surface water is observed, i.e., the presence of water and limonite in the faults. The ore minerals identified in polished specimens are pyrite, sphalerite, galena, pearcite, pyrargyrite, argentite, and native silver. Chalcopyrite and tetrahedrite are rare. In the primary ore the silver values are apparently contained in galena and tetrahedrite.

TEXTURAL EVIDENCE

The texture of the ore is much like that at the Premier, but almost all the native silver is found in irregular veinlets in the fractured vein matter. Nuggets are rare. Native silver is later than the other minerals and replaces them. In the upper workings native silver occurred in thick plates and leaves; lower down the plates were thinner, and 200 feet below the surface only very thin leaves and wires of the metal were found. In the lower workings ruby silver and argentite were found only in small fractures but near the surface these minerals were more abundant and occurred in irregular blotches and numerous small blebs. Near the surface replacement has been more extensive than at depth.[1]

Conclusions

It is believed that at the Dolly Varden the pearcite, pyrargyrite, native silver, and some of the argentite are secondary.

It is probable that at the Premier the values in gold will continue to greater depths than the values in silver.

Mining has not reached a sufficient depth at the Premier to furnish conclusive evidence of secondary enrichment.

The native silver, polybasite, pyrargyrite, and some of the argentite at the Premier are probably secondary.

Convincing data in regard to the nature of the ore must come from field work. Conclusive evidence cannot always be obtained from the texture, structure, or order of crystallization of the ore minerals studied in the laboratory.

[1] For a more complete discussion of the Dolly Varden mine, the reader is referred to a paper by Mr. Hanson in the Bull. of the Can. Inst. of Min. and Metal., August, 1922.

The following points are good evidence of secondary enrichment:

(1) A close relation between the ore and the surface, particularly when considerable erosion has taken place after the deposition of the primary ore.
(2) The localization of ore to the vicinity of channels where surface waters find their way downward.
(3) The presence of undoubted secondary minerals.

AGE OF DEPOSITS

In the absence of any evidence to the contrary, the ore deposits of Salmon River area are believed to belong to one period of mineralization. In the description of the general geology it is shown that the period of ore deposition was later than the various members of the bedded series as well as the quartz porphyry of the Premier sills, since ore-bodies are found replacing these rocks. In studying the age relationships of the primary ore deposits and the various dyke series, it was found that primary mineralization affected the augite porphyrite stock and some of the quartz porphyry dykes belonging to the "belt of dykes," but that the ore-bodies were cut by dykes of quartz-diorite, lamprophyre, and some of the dykes belonging to the "belt of dykes." In Salmon River area there are no mineral deposits in the main Coast Range batholith, but in the neighbouring region of Alaska, Westgate[1] has described ore deposits occurring in shear zones in that batholith.

The following table shows the order and period of mineralization of these events:

(1) Bedded series.
(2) Premier sills.
(3) Coast Range batholith.
(4) Augite porphyrite stock.
(5) Belt of dykes and mineralization.
(6) Augite diorite dykes.
(7) Lamprophyre dykes.

The belt of dykes and the period of primary mineralization are grouped together because, in some cases, the dykes which make up this belt are affected by the mineralizing solutions and, in other cases, the dykes cut the primary ore-bodies. The relative position of the augite-porphyrite stock and the Coast Range batholith is unknown since they were not seen in contact.

The exact age of the deposits of Salmon River area is indeterminable from the meagre information at hand. The period of mineralization is associated with the period of dyke intrusion, which is believed to belong to the closing stages of the Coast Range batholith intrusion. This period of intrusion is placed in the Upper Jurassic from evidence which has been presented in Chapter III, so that the age of mineralization is considered to be Upper Jurassic and correlated with the great period of mineralization which is largely responsible for the formation of most of the ore deposits of the producing mines in British Columbia.[2]

[1] Westgate, L. G., U.S.G.S., Bull. 722 C, 1921, pp. 134–140.
[2] Schofield, S. J., Trans. Can. Min. Inst., vol. 21, 1918; vol. 24, 1921.

ORIGIN OF THE ORES

Ore-bearing solutions emanating from the granite during the final stages of cooling entered the fissures and shear zones and at favourable localities formed ore-bodies of commercial size. The ore-bearing solutions which formed the ore-bodies on Big Missouri ridge evidently spread laterally along favourable horizons in the tuffs and tuff conglomerates. In other cases, as at the Premier mine, the ore-bearing solutions found the sheared contact between the quartz porphyry sills and the tuffs a favourable place for ore deposition.

A period of faulting followed the above period of primary mineralization. Subsequently, processes of secondary enrichment concentrated the ores carrying high silver values in the neighbourhood of the fault fissures.

DESCRIPTION OF MINES AND PROSPECTS

Claims on Big Missouri Ridge

The claims on Big Missouri ridge form a unit in Salmon River district. Geologically and mineralogically the ore deposits are very similar. Big Missouri ridge stretches from the International Boundary northwards and culminates in mount Dilsworth. The ridge consists of an anticline, probably slightly overturned to the west, of rocks belonging to the bedded series except the agglomerates. The rocks on the southern part of the ridge consist of tuffs intruded by quartz-porphyry sills of the Premier type. Going northward younger rocks of the bedded series appear, the axis of the ridge being composed of altered tuffs of the Bear River formation and fine conglomerates of the Salmon River formation, all highly metamorphosed by shearing. Quartz porphyry was not with certainty identified farther north than the Province claim, but from structural reasons it is believed to occur at no great depth below the surface.

The above-mentioned anticline has been greatly eroded and in such a way that the western slope of Big Missouri ridge is steeper than the dip of the rocks composing it. This causes the edges of the strata to outcrop in long bands on the western slope of the ridge and the younger strata to form the crest of the ridge.

North of the Hercules, Big Missouri ridge is cut by the "belt of dykes."

The mineralization on the Big Missouri is of two types: (1) replacement and impregnation of favourable beds in the tuffs and fine conglomerates. These deposits constitute what are known as the complex siliceous ores which consist of a fine-grained mixture of galena, zinc blende, chalcopyrite, and pyrite in a quartz gangue. From Big Missouri ridge these deposits can be clearly seen as wide, almost parallel bands of brownish colour running along the western slope of the ridge and gradually pitching down hill towards the glacier. These mineralized bands dip towards the glacier, and since the slope of the hills is greater than the dip of the mineralized zones, the continuation of these zones is up the hill and not down, as is usual with veins. A vertical drill hole on the top of the ridge would probably crosscut all the mineralized zones and if deep enough would intersect the tuff-quartz-porphyry contact exposed around Mineral hill at Joker flats. There is a possibility for ore at this contract on the Big

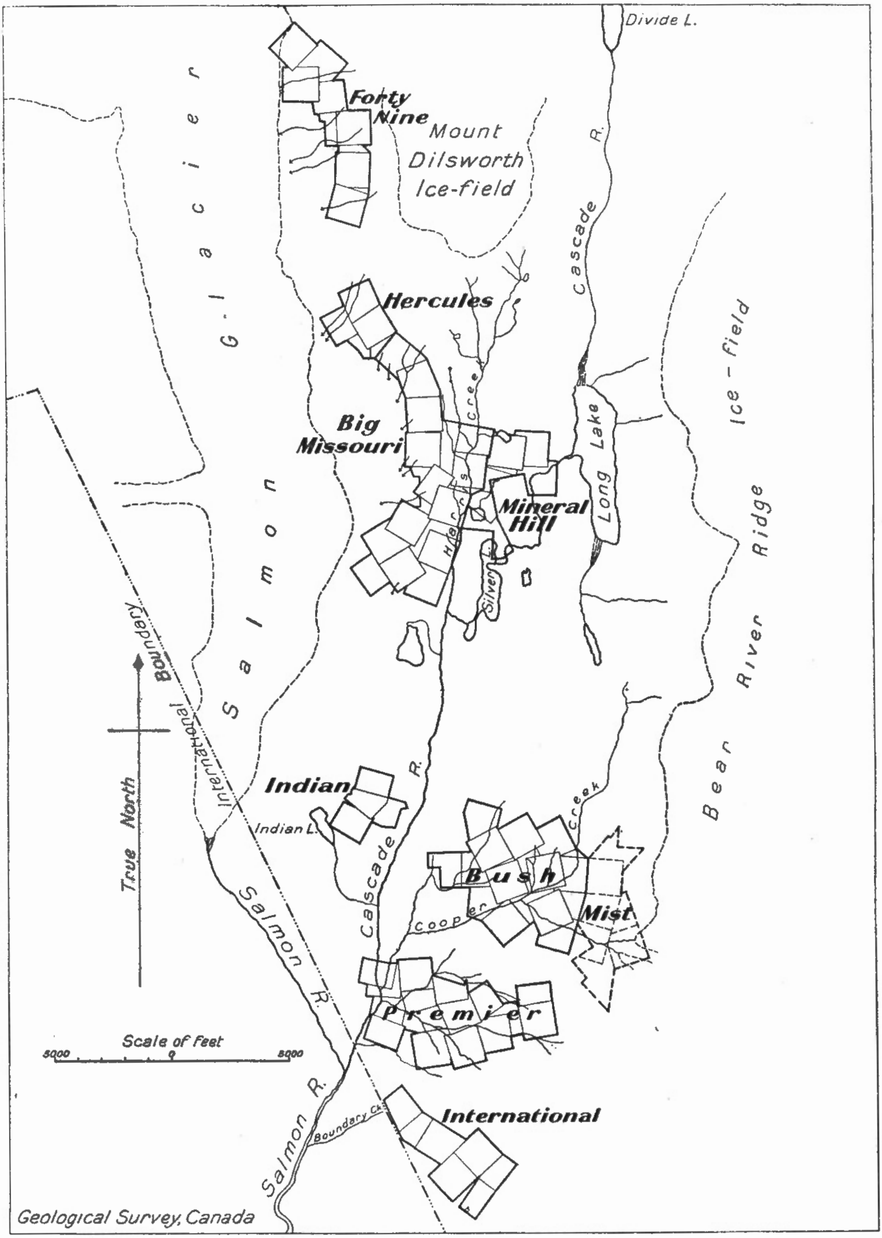


Figure 2. Diagram showing position of the groups of mineral claims in Salmon River area, Cassiar district, British Columbia.

Missouri ridge. (2) Fissure veins, as on the Hercules, which cut the bedded formations and contain shipping amounts of galena with some zinc blende.

The groups of claims from south to north along the ridge are: Indian, Big Missouri, Hercules, and the Forty-nine (*See* Figure 2). In addition to these groups there are many other individual claims.

INDIAN MINES, LTD.

There are four Crown-granted claims in this group. Development consists of a number of open-cuts and strippings, and about 400 feet of tunnel. The group is located on the Cascade Creek slope near the south end of Big Missouri ridge. The main tunnel is 2,200 feet above sea-level. The country rock in the immediate vicinity of the ore-body is a quartz porphyry of the Premier type which intrudes tuffs and tuff-conglomerates. Lamprophyre dykes are present intrusive in the porphyry. The ore occurs in a sheared and brecciated zone which follows closely a lamprophyre dyke. The zone is of variable width and is mineralized with quartz, pyrite, sphalerite, galena, and chalcopyrite. In several places in the zone bodies of solid sulphide up to 15 feet occur, consisting chiefly of galena and sphalerite. The main tunnel has been driven for 400 feet along this mineralized zone and exposes three ore-bodies, the same probably that were developed on the surface by open-cuts. The two ore-bodies first encountered in the tunnel are very siliceous and do not carry very heavy sulphide mineralization. The ore-body exposed in the face of the tunnel shows very heavy sulphide mineralization for a width of over 15 feet.

BIG MISSOURI GROUP

The Big Missouri group is situated on the summit and on both flanks of Big Missouri ridge about 20 miles from Stewart and consists of sixteen full claims and four fractions. It is owned by Dan and Andy Lindeborg and the Stevenson and Proudfoot estates. The claims are easily reached by road and trail.

Big Missouri Claim. This claim is situated at the southern end of the Big Missouri group, on the western slope just above Salmon glacier. From a distance, the whole side of the hill appears mineralized, the brown iron capping being plainly visible. In addition the large talus slopes composed of iron stained rock make the hillside very conspicuous.

The claim is underlain by highly sheared tuffs of the Bear River formation, which have been selectively impregnated by pyrite, galena, and zinc blende, forming a large deposit of very low-grade complex ore. The workings consist of a couple of short tunnels.

Province Claim. This claim is situated partly on the summit and partly on the western slope of Big Missouri ridge in a northwesterly direction from Joker flats. It is one of the central claims of the group.

The claim is underlain by highly sheared tuffs of the Bear River formation and fine conglomerates of the Salmon River formation, all highly sheared and metamorphosed. On the western slope of the ridge these bedded rocks dip at a low angle to the west and strike northerly along the ridge. On the lower slopes of the hill a highly sheared rock resembling the quartz porphyry of the Premier sills was seen, but was not identified with certainty. It is intrusive into highly altered tuffs.

The ore zones on the claim are certain bands of the tuffs, and the fine conglomerates which have been impregnated with pyrite, zinc blende, galena, chalcopyrite, and quartz. The deposit is opened up by many open-cuts, strippings, and short tunnels.

E. Pluribus. This claim, one of the Big Missouri group, lies just above Joker flats, on both sides of Harris creek, which flows southwards along the eastern base of Big Missouri ridge.

The part of the claim on the west side of Silver creek is underlain by highly sheared tuffs of the Bear River formation. On the eastern side of Harris creek quartz porphyry of the Premier type is exposed and evidently forms the upper part of one of these sills, which has been exposed by erosion. The contact between the tuffs and the sills is covered by the wash of Harris creek. The sill to the north passes under the tuffs with an intrusive contact. The quartz porphyry is cut by a series of lamprophyre dykes which strike in the same general direction, north 60 degrees west. These dykes also cut the primary ore-bodies and can be seen in the strippings and in the tunnels.

Development work had not gone far enough in 1920 to permit of the determination of the character of the ore-bodies, so that only a general statement can be given. The ore-bodies exposed appear to be remnants of ore-bodies which at one time occurred along the contact of the quartz porphyry and the tuffs in a manner similar to that in the Premier. Erosion has removed the tuffs and most of the ore-bodies and exposed the quartz porphyry. Extension of these ore-bodies should be looked for along the present contact that underlies Harris creek on the E. Pluribus, and in the depression on the Mineral Hill fraction.

The ore-bodies are of two kinds: low grade, consisting of zinc blende and galena with low gold and silver values; and bodies, probably of secondary origin, which are associated with faults and slips in the bedrock where they intersect the veins. The ores in the latter variety consist of argentite and tetrahedrite, variable amounts of ruby silver, and native silver. The workings consist of a series of open-cuts and one tunnel about 350 feet long.

HERCULES GROUP

The Hercules group adjoins the Big Missouri group on the north and consists of five claims: Glacier, Martha Ellen, Cornelius, Empire, and Leckie Fraction. The trail to Forty-nine passes through this group, and, therefore, it is easily accessible by road and trail from Stewart.

The group is underlain by a series of tuffs belonging to the Bear River formation which dip at a low angle to the west and strike in a northerly direction. The primary mineral deposits consist of a mineralized zone which crosses irregularly the property from north to south (Figure 3), and a fissure vein which cuts the formation. An augite-diorite dyke cuts northwesterly across the bedded rocks and the mineralized zone.

The mineralized zone consists of a bed of tuffs impregnated by disseminated pyrite, zinc blende, and galena in a quartz gangue. The fissure vein strikes northeasterly across the mineralized zone. The ore consists mainly of galena with some zinc blende and pyrite in a quartz gangue. The workings consist of a tunnel, a shaft, and many open-cuts.

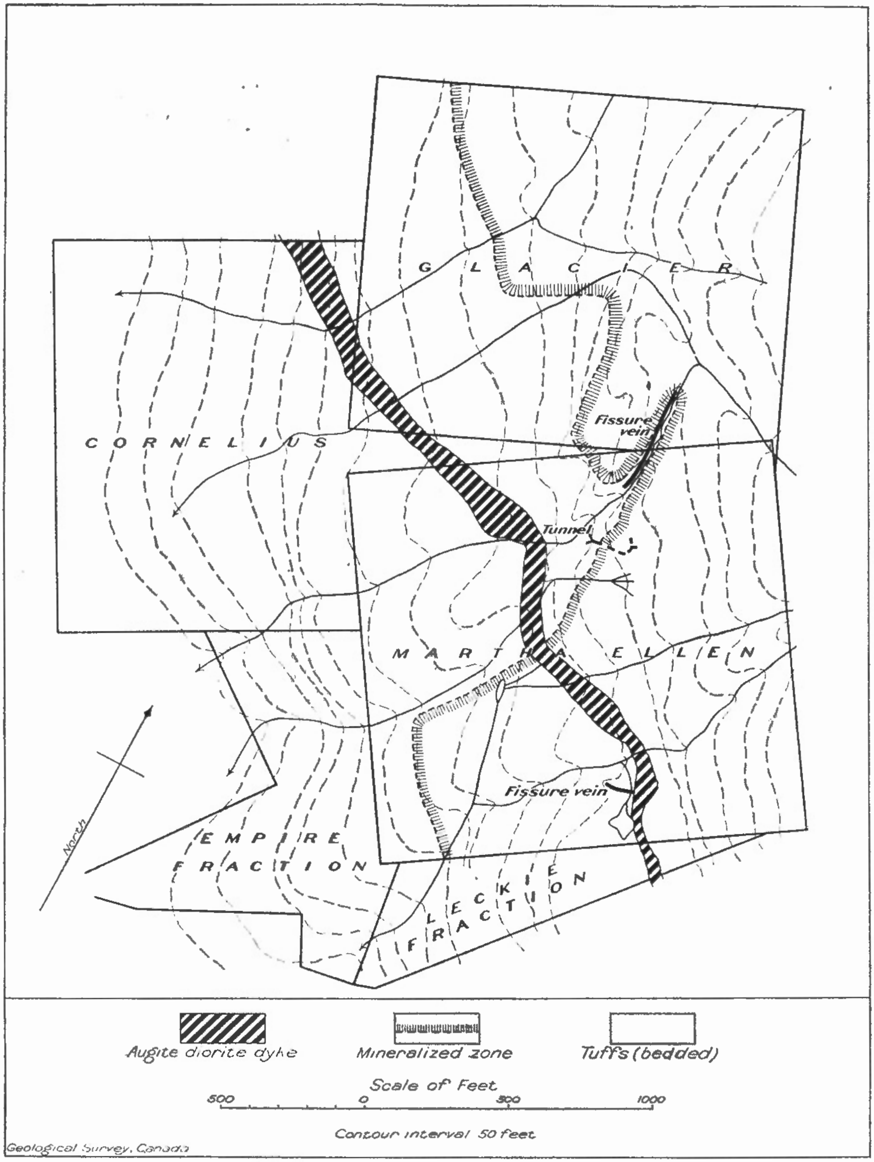


Figure 3. Diagram showing geology of the Hercules mineral claims, Salmon River area, Cassiar district, British Columbia. (*See also* Figure 2.)

FORTY-NINE GROUP

This group consisting of nine claims is controlled by the Forty-nine Mining Company, Limited, of Vancouver. It is situated on the western slope of mount Dilsworth above Salmon River glacier and is accessible by a trail through the Hercules and Big Missouri to the Premier wagon road.

The claims are underlain mainly by the highly altered fine conglomerates of the Salmon River formation, which dip to the west and strike northerly almost parallel to the slope of the hill.

There are two ore zones which are beds of the fine conglomerate impregnated with sulphides of iron, lead, and zinc. Their outcrop is about 75 feet wide and they are separated by barren ground about 200 feet wide. These two zones are joined by cross veins that contain stringers of ore. In some places faulting has somewhat offset these zones.

The property was closed down at the time of the writers' visit, and very little information could be obtained concerning the values. G. A. Clothier,[1] Provincial Mining Engineer for this district, in his report on the Forty-nine group states:

"The first work was on the Forty-nine claim on which an open-cut was run across a cropping for 20 feet, showing ore for that width, of which 8 feet was of better grade, but the whole averaging $3.20 in gold and 19 ounces silver to the ton. On the foot-wall of this vein there is a 25-foot dyke, which must lie within the vein, as a later open-cut on its south side exposed an additional 6½ feet of ore, assaying 80 cents in gold and 65·6 ounces silver to the ton. This has always been considered the main vein."

"Open-cuts above this cut exposed two smaller veins—one 2 feet wide assaying 72·6 ounces silver a ton, and another 10 feet wide assaying $1.20 in gold and 6 ounces silver to the ton."

"Southwest of the big cut, a width of 20 feet of broken-up quartz has been exposed by an open-cut, from which sorted ore assayed $6.40 in gold and 29·8 ounces silver to the ton. There has been no work done farther north, but the surface gives every reason to believe that extensive ore-bodies will be found when the ground is explored."

"A tunnel was started at an elevation of 4,100 feet on the main vein exposed on the surface by the old cuts. This had been driven over a hundred feet, cutting diagonally across a milling grade of ore in which are streaks of high grade."

In 1920 this tunnel had been driven underneath the high-grade ore exposed in the open-cuts above. The high-grade ore had been taken out from the foot-wall of the dyke exposed both on the surface and in the tunnel and it is reported that the ore consists of silver sulphides and native silver in a quartz gangue.

Mineral Hill Mines, Limited

This company's holdings consist of seven mineral claims situated just north of Joker flats at Hog lake. The Mineral Hill group adjoins the E. Pluribus and Laura claims of the Big Missouri group.

The geology of this group is similar to that of the E. Pluribus, in that the central quartz-porphyry mass protrudes through altered tuffs. The contact between this intrusive quartz porphyry, which is of the Premier type, and the tuffs lies in the depression on the Mineral Hill claims, trends northerly and then swings around to the northeast and joins the western contact which underlies Harris creek.

[1] Clothier, G. A., Report of Minister of Mines, B.C., 1912.

The surface cuts on the Mineral Hill group expose some high grade ore (pyrite, zinc blende, galena, argentite, and a little chalcopyrite), but no large body has as yet been uncovered. The long tunnel (Joker tunnel) which was driven beneath the surface croppings in quartz porphyry did not yield satisfactory results. The ore consists of pyrite, argentite, and native silver in quartz gangue.

The structure, as stated under the description of the E. Pluribus, is an anticline, the eastern limit of which occurs on the Mineral Hill and the western limit on the Big Missouri. The occurrence of the ore-bodies at the Premier between the tuffs and the quartz porphyry lends support to the idea that the ores now exposed in the strippings on the Mineral Hill group are remnants of larger ore-bodies which at one time occurred at or near the contact of the quartz porphyry and the tuffs. The axis of the anticline has been eroded to such an extent that the tuffs and contact ore-bodies have all been removed except the ore now seen in the strippings. The contact which lies under the drift-covered depression on the Mineral Hill claim and its extension north and south is worthy of attention. The workings consist of numerous open-cuts and a couple of tunnels.

Spider

The Spider group (*See* Figures 2 and 4) consists of three claims—Spider, Spider No. 2, and Spider No. 3. It is situated in Long Lake valley about three-quarters of a mile north of Long lake on the eastern side of the valley. They were owned by Bill Hamilton and Charlie Larson of Stewart and, at the time the property was visited, this group was under bond to a Belgian exploration company and was being developed under the direction of W. A. Meloche.

The country rock of this group is mainly the augite porphyrite which has intruded the slates of the Nass formation and the tuffs of the Salmon River formation. North of the creek which flows past the Spider camp, the augite porphyrite can be seen to be intrusive in the slates. Small inclusions of slate occur within the augite porphyrite. Near the intersection of the quartz vein and the main shear zone occurs a lamprophyre dyke intrusive in the augite porphyrite and cutting the quartz vein. The shear zone cuts the dyke and the quartz porphyry at the place mentioned. South of the claims, an augite-diorite dyke cuts the augite porphyrite, and masses of tuff are included in the augite porphyrite.

There are two intersecting fissures on the property. One is occupied by a quartz vein 10 to 20 feet wide, striking north 20 degrees west with a vertical dip. The surface on the Spider claims is devoid of vegetation, and the quartz vein could be followed a long distance along the outcrop. The other fissure is a shear zone which cuts both the quartz veins as well as the lamprophyre dyke. The direction of the shear zone at the point of intersection is north 55 degrees west with a dip of 70 degrees to the south. The shear zone followed by the tunnel may be a continuation of this shear zone.

The quartz vein is not visibly mineralized except where it is associated with inclusions of the slates in the augite porphyrite.

This association was noticed in several places. The ore at these points consists of galena, zinc blende, chalcopyrite, and pyrite in a quartz gangue.

The shear zone which is being explored by an adit tunnel strikes at this point north 45 degrees west and at the face of the tunnel dips 60 degrees to the south. It is mineralized at irregular intervals by galena, zinc blende, and some chalcopyrite in a quartz gangue. Native silver is present in the open spaces and in cracks in the ore. At the intersection of the quartz vein and the shear zone is a lens of galena with a little zinc blende on the hanging-wall of the shear zone. The gangue is quartz. The mine workings consist of an adit tunnel and some surface strippings.

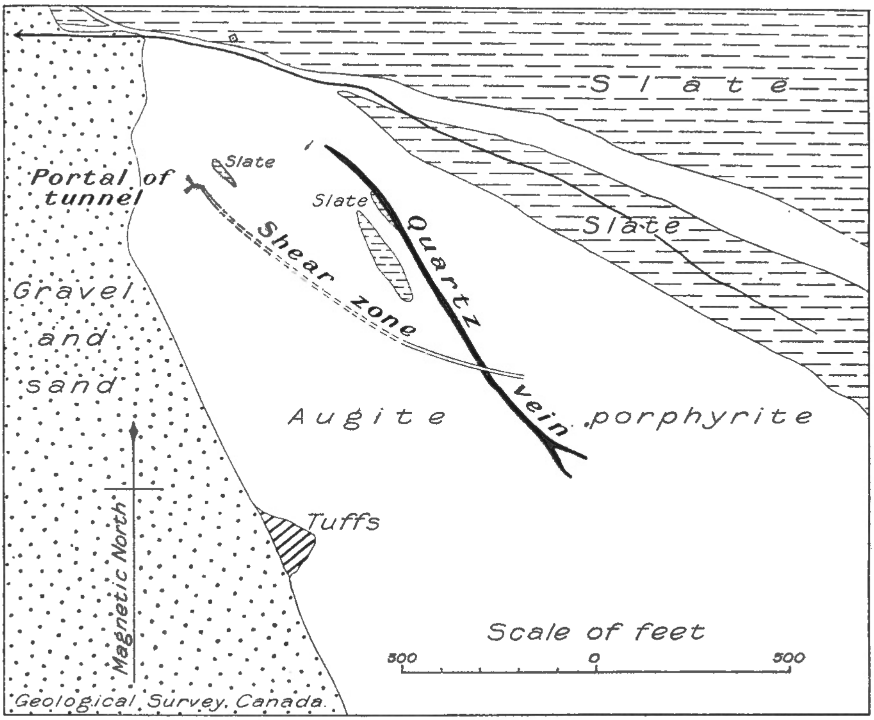


Figure 4. Diagram showing geology in vicinity of Spider group of claims, Salmon River area, Cassiar district, British Columbia.

Premier Gold Mining Company

The property of the Premier Gold Mining Company is situated on the western slope of Bear River ridge on Cascade river just north of the International Boundary. It is easily accessible by wagon road from Stewart and Hyder.

History. A brief history of the property controlled by the company is given by G. A. Clothier[1] as follows:

"This company was incorporated early this year and is a reorganization of the former Salmon-Bear River Mining Company, Limited. The holdings now consist of seventeen claims and fractions, as follows: Essington, Rupert, Simpson, Picton, Cascade Falls, No. 4 and No. 8, Dolly Fraction, Trites Fraction, and Pat Fraction, which are the claims of the original company, and the remaining claims, Forks, Cascade Forks No. 1 to No. 6 inclusive, and Wood Fraction, being a later purchase from Bunting Bros. . . . I might state that three years ago the property was bonded by R. K. Neill, of Spokane, Wash., associated with whom were Trites, Wood, and Wilson, of Fernie. It had been previously explored by New York people with unsatisfactory results. Under the management of Mr. Neill, work was started in the upper tunnel, and in a comparatively short distance the shoot of high-grade gold-silver ore was struck which has since brought the property and district into prominence."

"This fall (1919) the American Smelting and Refining Company acquired an interest in the property after exhaustive examinations by its engineers."

Mr. Dale Pitt is at present general manager of the Premier Gold Mining Company.

Production. Through the courtesy of Mr. W. Fleet Robertson, Provincial Mineralogist of British Columbia, the output of the Premier is given below.

Year	Ore produced in tons	Total gross contents per lot without smelter deduction	
		Oz. gold	Oz. silver
1916	10	not shipped	
1917	Several hundred tons	no shipments	
1918	26	182	2,268
1919	488	3,209	108,285
1920	799	2,283	77,180
1921	18,750 (concentrates and crude ore shipped, 5,007)	35,147	1,136,249

Surface Geology. The areal geology around the Premier mine is difficult to map, both on account of the extremely heavy covering of drift and vegetation, and of the metamorphism which the rocks have suffered, especially near the ore-bodies.

In general, the area (Figure 5) is underlain by a series of greenish or purplish tuffs, usually very fine grained and intruded along their bedding planes by sills (Premier sills) of quartz porphyry. The tuffs are the younger members of the Bear River formation. Near the Premier mine the strike is very variable, ranging from north 80 degrees east to almost north and south. The general dip of the series is westerly and southwesterly at angles of from 45 to 70 degrees and corresponds in general to the slope of the hillside. The rocks are highly sheared, especially near the ore-bodies which in general are located at or near the contact of the quartz porphyry sills and the tuffs.[2] Cutting the above-mentioned rocks is a series of wide,

[1] Clothier, G. A., Rept. of Minister of Mines, B.C., 1919.

[2] This statement is based entirely on the exposures in No. 1 tunnel, the only tunnel in which the ore-bodies were exposed at the time of examination (September, 1920). (Figure 6.)

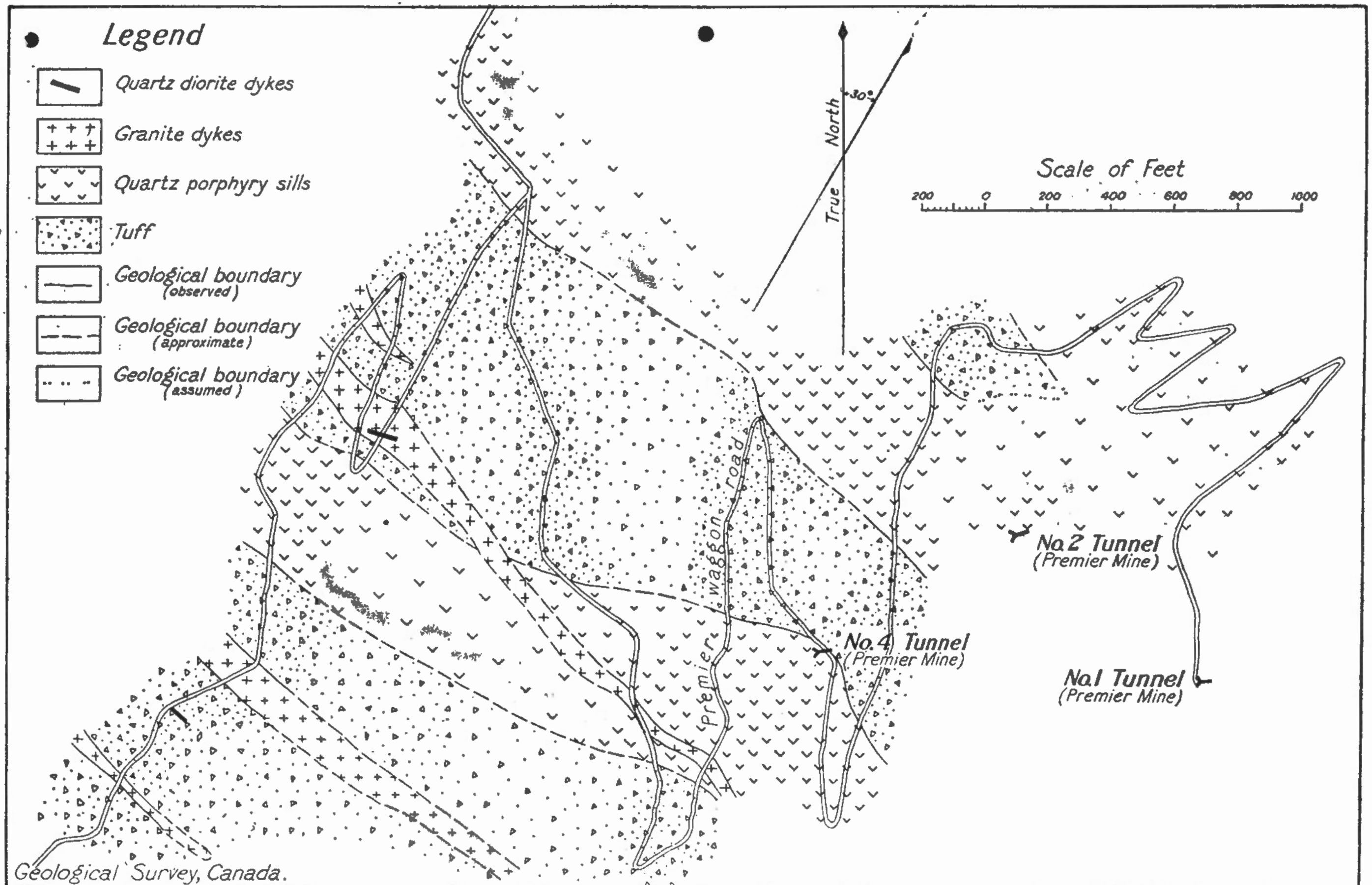


Figure 5. Diagram showing areal geology in vicinity of Premier mine.

light-coloured dykes resembling a granite in appearance but which on microscopic examination prove to be quartz diorite. They strike northwesterly and may be examined on the Premier wagon road at many points indicated on the accompanying geological map as "J 6." These dykes have been found cutting the primary ore-bodies in other properties in the district. The youngest intrusives in the Premier are the lamprophyre dykes which cut both the augite-diorite dykes and the primary ore-bodies. They may be seen in all the Premier tunnels; and in the Ladder tunnel one of these dykes cuts the ore. They are usually narrow and dark in colour. Covering all these rocks unconformably is a thick layer of unsorted sand, gravel, and boulders of varying thicknesses.

Underground Geology. Ore-bodies of the silver-gold type at the time the property was examined (September, 1920) were exposed only in No. 1 tunnel (Figure 6). The general trend of the ore-bodies is north 80 degrees east and the dip is northerly at angles of 70 to 80 degrees. They occur at or near the contact of a quartz-porphyry sill and tuffs, both highly sheared and metamorphosed in the immediate vicinity of the ore-bodies. In general the mineralization has penetrated, and in part replaced, the wall-rock on both sides of the ore-body and the walls of the ore-bodies are, therefore, not clean.

The minerals which have been identified are pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, freibergite, polybasite, pyrargyrite (ruby silver), argentite, and native silver. Stephanite and native gold have been recorded.[1] The predominant gangue mineral is quartz. Most of the ore is a heavy sulphide, but some of it consists of quartz with isolated patches of sphalerite, tetrahedrite, and silver minerals. The wall-rocks have been extensively silicified.

Dolmage, from an examination of specimens of the ore, believes that secondary enrichment has played a very minor role in the concentration of the rich ores in the Premier mine, but E. E. Campbell,[2] J. J. O'Neill,[3] and the writers of this report from evidence in the field consider that most of the native silver, as well as some of the other silver minerals, such as pyrargyrite, are of secondary origin (*See* previous sections of this chapter).

The ore-bearing zone is crossed almost at right angles by faults that have displaced portions of the ore-bodies, so that the vein appears irregular and broken. The first ore-body encountered in No. 1 tunnel is exposed in No. 1 stope at the contact of the quartz porphyry and the tuffs, about 210 feet from the portal. At this point a cross-cut (No. 3) has been driven to the south for about 100 feet, at the end of which is ore which may prove to be a parallel ore-shoot in the sheared quartz porphyry. No. 1 ore-body is about 60 feet long with an average width of 8 feet. It dips to the north at an angle of about 80 degrees. Between No. 4 cross cut, which is 290 feet from the portal and No. 5 cross cut, 50 feet farther on, the main tunnel is driven in tuffs, and no ore was encountered between these points. However, 40 feet to the south of the main tunnel another drift, parallel to the main tunnel, exposed ore in No. 4 stope. This ore occurs at the contact of the tuff and the quartz porphyry, and is possibly the faulted part of the ore exposed in No. 1 stope in the main tunnel. A well-marked fault is seen

[1] Dolmage, V., Can. Min. Jour., vol. 41, No. 22, 1920, p. 454.
[2] Campbell, E. E., Trans. Can. Min. Inst., vol. 23, 1920, p. 394.
[3] O'Neill, J. J., Geol. Surv., Can., Sum. Rept. 1919, p. 7 B.

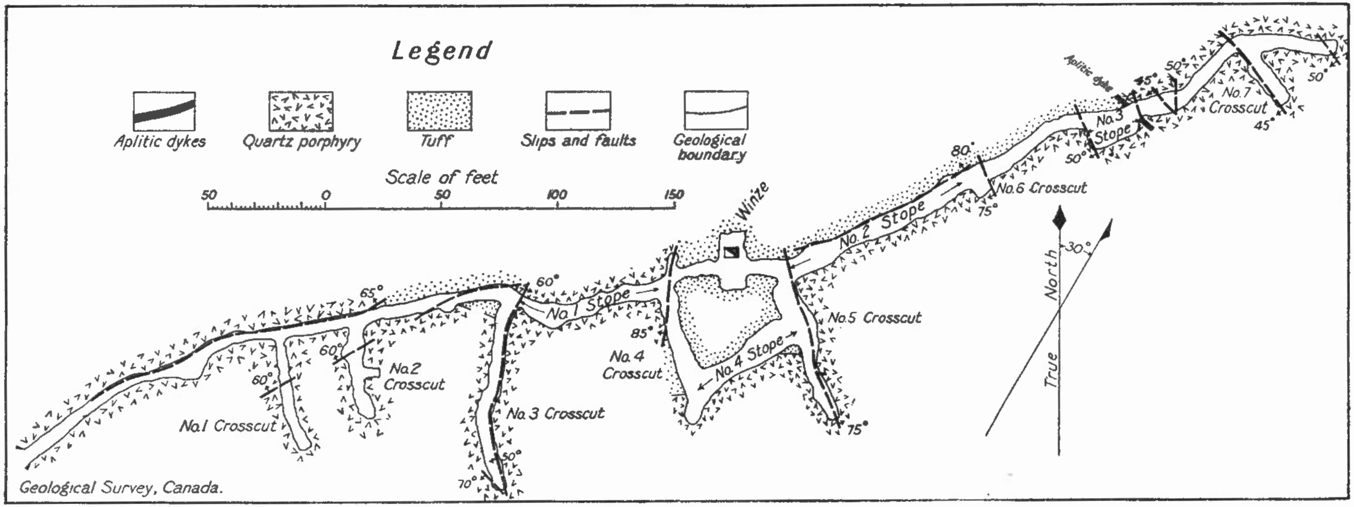


Figure 6. Diagram showing geology of No. 1 tunnel (September, 1920), Premier Gold Mining Co. Limited, Salmon River area, Cassiar district, British Columbia.

along No. 4 cross cut. Another fault occurs along No. 5 cross cut, but the horizontal movement appears to have been less than that along the fault seen in No. 4 crosscut. In the main tunnel where it intersects crosscut No. 5, 340 feet from the portal, another ore-body (No. 2 stope) is encountered at the contact of the tuffs and the quartz porphyry. This ore-body is about 60 feet long and dips 85 degrees to the north. It has an average width of 8 feet. From No. 2 stope to No. 3 stope, a distance of 65 feet, no ore is encountered, although the tunnel is driven along the contact of the tuff and the quartz porphyry. In No. 3 stope, high-grade ore was met and it seems apparent that the ore-bodies exposed in No. 2 and No. 3 stopes occur on the main vein but are separated at the tunnel level by a block of barren ground. From No. 3 stope to the end of the tunnel the country rock is unsheared quartz porphyry cut by numerous slips. Hence the tuff-quartz porphyry contact lies to the north of the tunnel.

Tunnel No. 2 was driven approximately 250 feet below tunnel No. 1 and at the time of the examination the ore-bodies exposed in No. 1 tunnel were not encountered. But another ore-body composed mainly of pyrite in a quartz gangue was exposed. The size and structural features of this ore-body could not be determined owing to the development work being insufficient. It lies entirely within quartz porphyry and is associated with a wide sheared zone whose strike is north 30 degrees west. This ore-body is reported to carry good gold values.

No. 3 tunnel, about 80 feet long, is 170 feet below No. 2. No ore was exposed, in fact it followed a lamprophyre dyke about 8 feet wide having a strike of north 36 degrees west.

No. 4 tunnel, about 550 feet long, is 250 feet below No. 3 and at the time of examination was being rapidly extended to encounter the ore-bodies exposed in No. 1. It affords a good opportunity to study the structural relationships of the tuffs, the quartz porphyry, and the lamprophyre dykes. The strike of the contact between the quartz porphyry and the tuff was north 20 degrees west with a dip of 60 degrees to the southwest.

The following account of development at the Premier during 1921 is by G. A. Clothier:[1]

"This company has this year accomplished a great deal in all the departments, mining, milling, surface equipment, and transportation, and the property has now reached the stage where there should be no more serious handicaps to interfere with maximum production. With the completion of the tramway from the mine to the beach the greatest difficulties have been overcome. Mining for the year consists of extensive development-work, about 4,000 feet on all three working-levels. On the No. 1 level, at 2,000 feet elevation, the south vein was located by diamond-drilling, crosscuts run from the No. 1 tunnel, and the south stope opened up. It shows a length on this level of about 200 feet of the same lenticular character as the north vein and with like enrichments along the fault-seams. The greater portion of the ore shipped last winter and this summer, amounting to over 4,000 tons, was taken from below the No. 1 level on the north vein and above the No. 1 level on the south vein. On the No. 2 level, 1,650 feet elevation, a long crosscut and drift picked up the south vein and the stope is now being opened up above this level. The south vein on this and No. 1 levels is supplying all the ore to the concentrator, over 100 tons a day, and considerable shipping-ore as well, found along the cross-slips. The No. 4 level, 1,325 feet elevation, has been driven ahead from the face of the old Plate

[1] Clothier, G. A., Rept. of Minister of Mines, B.C., 1921, p. G 69.

tunnel, and at the time I was at the property (January 1, 1922) had about 200 feet to go before it was expected to encounter the south vein. When this vein is opened up it will prove the ore-shoot to a depth of about 700 feet below the surface, and should the values hold as good as the upper levels will mean several millions of dollars' worth of probable ore. When both veins are raised on from the No. 4 level and the ore blocked out and "in sight," then a fair estimate can be made of the value of the ore. It has just been reported in the press that there is $80,000,000 worth of ore in sight, which may prove true, but is an absurd statement to make at the present stage of development."

"Diamond-drilling was being done on the No. 4 level and one or two drills have been in operation all year, totalling 6,800 feet of drilling. A raise has been put through from the fourth to the second level and equipped with a hoist and cage for a thoroughfare from the No. 4 camp to the upper camp, where the main office is located."

"Surface improvements and equipment at the upper camp include new buildings for hospital, residences, bunk-house, and improvements and additions to the old ones; change-house, using open cages in which men hang their clothes, hoist them to the ceiling out of reach, and lock them when not in use, doing away with the old locker system; mine warehouse and office, etc. At No. 4 camp, at the mouth of the No. 4 or main working-level, much construction has been done and a great deal of equipment installed; a new bunk-house, with up-to-date accommodation; snow-shed; concentrator; upper terminal tramway; blacksmith shop, equipped with machine-drill sharpener and oil-burner for heating steel; compressor building, housing two 150-horse-power Fairbanks-Morse semi-Diesel engines, compressors, lighting plant, and well-equipped machine-shop. An auxiliary, consisting of two 150-horse-power Fairbanks-Morse semi-Diesel engines, has also been added to the power plant."

"Transportation from the dock to the mine, a distance of about 15 miles, has been the greatest handicap to the development of the property. It was, therefore, decided to install a tramway, and work was started this spring as soon as weather conditions would permit. The contract was let to the Riblet Tramway Company, Spokane, Wash., and that this company was able to complete it and have it in operation for January 1, 1922, is a very creditable piece of work. It is 11½ miles in length in four sections or with three angle-stations, and with a tension tower on an average of about every 4,000 feet. The difference in elevation between the upper terminal at No. 4 level of the mine and the lower terminal at the dock is about 1,325 feet. The power required to operate it is a 50-horse-power motor geared to the bull-wheel at the upper terminal. There are one hundred and fifty-three towers in the entire distance. There are 120 buckets being used at present of 800 pounds capacity each, and as it takes less than two hours for a bucket to travel the 11½ miles, it means a bucket dumped every two minutes, giving a capacity, at full speed, of about 12 tons an hour, which will be cut down somewhat when handling return freight."

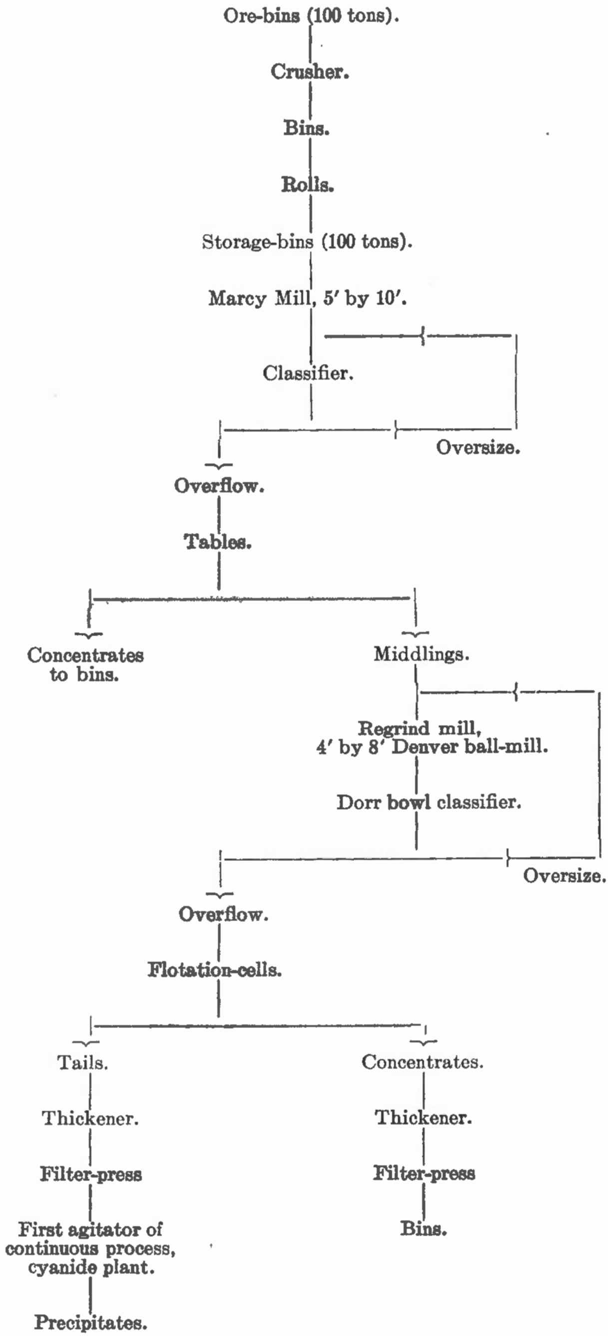
"The mill was started in July and has been running continuously, except for minor close-downs for repairs and alterations. On account of the complex nature of the mill-feed, especially its variations in silver-sulphide contents, its treatment has presented many complications and necessitated some small alterations in the mill from the original flow-sheet."

"The mill was designed for treating 100 tons of feed in twenty-four hours, but has been running over capacity and producing from 20 to 30 tons of concentrates a day."

"The ore-bunkers at the lower terminal have a capacity of 1,500 tons and are so arranged that boats are loaded directly from them by means of a travelling belt. They are housed in a three-story building 300 feet long. The lower floor on the dock-level is used as a warehouse and storage and also contains the loading belt. The next floor is a warehouse, and the top floor is the lower terminal of the tramway and, therefore, the dumping and loading floor. A small hoist and incline truckway have been arranged for taking freight from the dock-level to the second or top floors. A heating plant will be installed for the double purpose of keeping perishable supplies and the ore from freezing in the bunkers."

"I understand that all adjustments have been made on the tramway and that it is now working perfectly, delivering about 100 tons of ore a day. Its necessity can be appreciated when it is realized that the company has been using from forty to sixty horses and two 5-ton caterpillar tractors for hauling throughout the year, and has handled upwards of 6,000 tons of freight from the dock to the mine over the wagon-road."

" *Flow-sheet of Premier Mill, Salmon River, Portland Canal*



"The shipments from the mine this year amounted to 4,356 tons of ore, and from the concentrator 1,000 tons of concentrates and about 9,000 pounds of precipitates from the cyanide plant, the total production yielding 35,000 ounces of silver, valued at $1,400,000."

"The perfected facilities for handling ore now from the mine to the dock should greatly increase shipments in the future, and will probably enable the company to ship a medium-grade ore, such as their siliceous gold ore, or ore not too high in silver values but too good for mill-feed, to the Granby smelter at Anyox."

"Credit is due the energy and efficiency of the general manager, Dale L. Pitt, and assistant manager, Bert F. Smith, for the progress made in the past two years and for the very capable organization they have built up."

International Group

The group consists of eight claims, the property of Pat Daly and associates, of Stewart, B.C. The claims adjoin the International Boundary on the south and are easily accessible by a trail from the Premier wagon road at Elevenmile, Alaska. The camp is about 2,000 feet above the sea.

The claims are underlain by a series of green tuffs of the Bear River formation cut by quartz porphyry sills of the Premier type. The whole series strike about north and south and dip about 45 degrees to the south, an angle which corresponds to the slope of the hill. The strippings on the creek to the south of the tunnel are at the contact of the tuffs and the quartz porphyry where stringers of ore consisting of pyrite and galena in a quartz gangue occur. The quartz porphyry is not sheared. A tunnel 93 feet long was being driven to cut some ore exposed on the surface, but in 1920 when the examination was made it had not reached the required point. The tunnel was entirely in a fine-grained green tuff.

CHAPTER VI

SUMMARY AND CONCLUSIONS

GENERAL GEOLOGY

The bedded rocks of Salmon River area are of the Mesozoic era and possibly of the Jurassic period of that era. They comprise the following formations:

Bear River Formation

This group of rocks is almost entirely volcanic in origin and the name "greenstone," commonly applied to it, is very applicable in a general way. The lower members of the formation consist largely of fragmental rocks of agglomerate character, the fragments being irregular purple and green masses of andesitic composition. These agglomerates are succeeded by tuffaceous or ash rocks, mostly green, but in part alternating with purple-coloured members. The total thickness can not be given, since the base is not exposed.

Salmon River Formation

This formation overlies conformably the Bear River formation. McConnell[1] included, in his Bear River formation, the rocks here grouped under the Salmon River formation. It consists mainly of a conglomerate, with pebbles composed of fragments of the underlying volcanic rocks. The thickness of the formation is approximately 300 feet.

Nass Formation

The passage from the underlying Salmon River formation is transitional in character, the conglomerates and the slates being interbedded near the base. The dominant rock is a black argillite with some interbands of clastic material resembling sandstone. The argillites are locally called slates. Fossils collected from the conglomerates at the base include *Trigonia, Belemnites, Pecten* (*Entolium*), *Gryphœa,* and *Cucullœa* of undescribed species. McLearn considers that the fossils probably indicate a Jurassic age; but the evidence is not conclusive.

Premier Sills

These are tabular masses of quartz porphyry intruded between the bedding planes of the tuffs of the Bear River formation. Their maximum thickness is in the neighbourhood of 1,300-feet. The rock is grey, massive, and in hand-specimens shows in some cases phenocrysts of orthoclase and small, irregular masses of quartz in a fine-grained groundmass. The sills

[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 14.

were intruded prior to the mountain-building, and, therefore, while the tuffs were horizontal. Since the time of intrusion, they have been subjected to folding along with the containing rocks, and now occupy varying positions which deviate from the horizontal.

Coast Range Batholith

The district borders the Coast Range batholith on the east. The batholith is composed largely of granodiorite, a greyish white rock of "pepper and salt appearance," consisting of plagioclase and hornblende with some orthoclase usually as phenocrysts. The hornblende is in many cases accompanied by biotite. Quartz is present in varying amounts. The rocks of the batholith include both granites and gabbros.

Augite Porphyrite

This rock outcrops as a stock on the Spider mining claim and is a dark-coloured member of the Coast Range batholith. In the hand-specimen, phenocrysts of augite can be distinguished in a fine-grained groundmass. This rock definitely cuts the argillites of the Nass formation and is itself cut by granite dykes and is affected by mineralizing solutions.

Granite Dykes

The dykes (quartz diorite) included in this group belong to the diorite family and vary from a coarse-grained diorite to a quartz porphyry. They are very numerous, especially in the northern part of the district where they have been grouped and mapped under the name "belt of dykes." Although belonging to the same general period of intrusion, they are of different ages, since in places they intersect one another, and some are affected by mineralizing solutions and some are not. They vary in width from a few inches to 50 feet and can be traced in some cases a long distance along the strike.

Pleistocene

The Pleistocene is represented by drift and fluvioglacial deposits.

Post-Pleistocene

About 2 miles south of the International Boundary in Alaska, stratified sands and bluish-coloured clays overlie the glacial drift and, therefore, are post-glacial. They occur about 350 feet above the sea. They may be correlated with the fossiliferous post-glacial clays found by McConnell[1] on Bear river 10 miles from tide-water, at an elevation of about 450 feet above sea-level.

The present streams, all of which have their origin in glaciers, are depositing great quantities of gravel along their courses. The valleys, such as those of Salmon and Bear rivers, are being filled up or aggraded, so that the absence of river terraces is a noticeable feature in contrast to the river valleys of southern British Columbia.

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[1] McConnell, R. G., Geol. Surv., Can., Mem. 38, p. 22.

ECONOMIC GEOLOGY

In the mines of Salmon River area, the values up to the present have been mainly in silver and gold, although many of the deposits contain economic quantities of galena, zinc blende, chalcopyrite, and pyrite in a quartz gangue, which constitute what is known as a complex siliceous ore.

The mineralization of the district is associated with the closing stages of the Coast Range igneous activity[1]—that period which has been so important in commercial ore deposition in British Columbia.

As already stated, the ore deposits are of three main types: (1) base metal type; (2) silver-gold type; (3) gold type.

Base Metal Type

The usual mode of occurrence of this type is that of replacement and dissemination in certain beds of tuffs and tuffaceous conglomerates, although veins occur containing the base metals. The deposits are roughly tabular, since they correspond in strike and dip with the beds with which they are associated. In Big Missouri ridge, these beds strike along the ridge and dip at a low angle to the west and since the slope of the hillside down to the Salmon River glacier is steeper than the dip of the tuffaceous beds, the mineralized zones form long, linear outcrops on Big Missouri ridge. These weathered outcrops, coloured brown by the presence of limonite, are a marked feature of the ridge.

The minerals present in these bands are pyrite, chalcopyrite, sphalerite, and galena in a gangue of quartz. Nearly all the examples of this type occur on Big Missouri ridge. The groups of claims from south to north are as follows: Indian, Big Missouri, Hercules, and Forty-nine, all of which contain mineral deposits similar to the description given above.

The alteration or metamorphism of the rocks on Big Missouri ridge makes their determination very difficult, if not impossible in many cases, so that the contact between the quartz porphyry and the tuffs was not definitely recognized, and it is certain that over the greater part of Big Missouri ridge this contact is buried underneath the tuffs and the tuffaceous conglomerates.

Silver-Gold Type

The ores of this type occur in veins and vein-like replacements in quartz porphyry and at the contact of the porphyry and the tuffs. The large ore-chutes are lenticular. The minerals present are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, freibergite, pyrargyrite and other sulph-antimonides and sulph-arsenides, native silver, and gold. The gangue is rather abundant and is almost entirely quartz. The ore-bodies of the Premier mine belong to this type.

The native silver is found almost entirely associated with faults and shear zones and was not seen in the unfractured vein material. In addition the fractures show a strong downward movement of water and contain considerable amounts of limonite. The silver occurs as thin leaves or

[1] Schofield, S. J., Proc. Can. Min. Inst., 1918, p. 202; 1920.

plates filling small cracks in the ore. Some occurs in hair-like forms (wire silver) and nuggets in small quartz druses. The localization of the silver to the immediate vicinity of the fractures points to a secondary origin for the native silver, or, in other words, the native silver is due to secondary enrichment.

Metallographic study of specimens obtained during the examination of the mine shows that the native silver occurs in minute veinlets cutting and replacing the other minerals and giving a structure which has been accepted, in large measure, as one due to secondary enrichment. Evidence in regard to the pyrargyrite and argentite is not so striking. Probably, however, these minerals are in large measure of secondary origin. It is believed that the silver in the primary ore is carried chiefly in the galena and tetrahedrite and that the values in gold are not affected by secondary enrichment.

Gold Type

A single ore-body in No. 2 tunnel of the Premier mine is of this type. It is a siliceous, heavy-sulphide deposit. Quartz and pyrite are the predominant minerals. Small quantities of chalcopyrite, sphalerite, and galena are present. Assays show high values in gold but practically no silver.

GENERAL CONCLUSIONS

The ore deposits fall into three main groups:

(a) A low-grade, complex type, with values in the base metals, copper, lead, and zinc (Big Missouri, Hercules, Forty-nine, etc.)
(b) A type rich in silver minerals, including tetrahedrite, freibergite, pyrargyrite, argentite, and in some cases native silver. (Premier, Silver Tip, certain ore-bodies in Forty-nine, Big Missouri, and Mineral Hill.)
(c) A pyritic siliceous type, with high gold values. (An ore-body in Premier mine.)

The most favourable associations for the occurrence of ore are as follows:

(a) In the quartz porphyry.
(b) At the contact of the quartz porphyry with the tuffs.
(c) In certain beds of the tuffaceous conglomerate.

The slates in general do not appear favourable for the deposition of ore.

The sulphides rich in silver, such as tetrahedrite, freibergite, argentite, and some of the pyrargyrite are considered to be of primary origin and will continue in depth.

The native silver is considered to be of secondary origin.

CHAPTER VII

Ore Deposits of British Columbia

By S. J. Schofield

GENERAL STATEMENT

Fifty years ago the Geological Survey began investigations into the geology and ore deposits of British Columbia.[1] It has been a half century of achievement and the purpose of this chapter is to examine rather closely the results obtained and to draw any conclusions that may be possible from the facts gathered during these extended researches. In doing so, the danger of generalization is fully realized, yet if well directed progress is to be made in the future generalizations are necessary.

Reviewing the advance made in economic geology in British Columbia, the work may be classified in a general way in two main periods.

EXPLORATORY PERIOD

The exploratory period, dating from 1871 to 1905, is that period made famous by the explorations of Richardson, Selwyn, Dawson, McConnell, Bauerman, Brock, and others who outlined the general features of the mineral belts of British Columbia. Upon this foundation all the later workers have grouped their superstructures.

The coal fields of British Columbia were outlined, and the quality of the various seams carefully investigated.

It is customary to speak of the great mineral belts that parallel the two flanks of the Coast range, and of those that surround the batholiths of West Kootenay and occur in the Interior plateau. These belts are pointed out in almost every report on British Columbia as the finest field for the prospector. It is due to the intelligence of these pioneers that these belts were accurately defined and their future value predicted. Modern development has amply justified these predictions.

Subsequent to, and largely because of, the labour of these men, a great mining industry has developed and there are enough good prospects in sight to warrant the statement that the industry will grow with an ever increasing speed. To avoid the cumbersome phraseology generally employed in referring to the mineral belts of British Columbia, special names are here applied to them. There are two main mineral belts in British Columbia separated from each other by an elongated and curved area of granite batholiths belonging mainly to the early part of the Mesozoic era. This mass includes the Coast Range batholith and the majority of the

[1] Schofield, S. J., Trans. Can. Inst. of Min. and Met., vol. 21, 1918, pp. 422-427; vol. 24, 1921.

batholiths occurring in the southern part of British Columbia. The belt which follows along the Pacific coast, including the island fringe on the western side of the Coast Range batholith, may be called the Pacific mineral belt; that along the eastern side of the same batholith, the Interior mineral belt. It will be remarked that the two belts differ in the mineralogical composition of their ore-bodies. The ore deposits of the Pacific belt are sought mainly for their copper content; those of the Interior belt are sought mainly for their gold, silver, and lead content. It is only necessary to mention Anyox, Marble bay, Quatsino sound, Sunloch, and Britannia of the Pacific belt, and Salmon river, Premier mine, Bear river, Alice Arm, Dolly Varden mine, Hazelton (excepting Rocher Déboulé), and the deposits in the Ootsa Lake and Whitesail Lake areas to be convinced of the truth of the above statement. The Pacific and Interior mineral belts strike in a northwesterly direction parallel to the coast, but in the neighbourhood of Vancouver, they turn eastward, conforming in general with the contact of the batholiths of southern British Columbia. To avoid confusion, it is suggested that the northerly belt be called the Kootenay belt and the southern one the Boundary belt. The metal characteristic of the Pacific belt predominates also in its easterly extension, the Boundary belt; the same statement holds true for the Interior belt in its easterly extension, the Kootenay belt. The two belts merge into one in the area bordering the southern part of Kootenay lake. The Boundary belt includes Highland valley, Copper mountain, Phoenix, Deadwood, and Rossland, and the Kootenay belt embraces Ainsworth, East Kootenay (Sullivan, North Star, St. Eugene), Slocan, Lardeau, Revelstoke, and Stump Lake mineralized areas.

The reason for the separate occurrence of copper on the one border and of gold, silver, and lead on the other border of the great complex of igneous intrusions is not at once apparent. A fact that may throw some light on the subject is that the copper ore deposits are not confined to true fissure veins, but resemble impregnations of the country rock by minerals such as pyrite, pyrrhotite, chalcopyrite, which indicate conditions of high temperature and pressure, even bordering on those of contact deposits, whereas the gold-silver and silver-lead deposits are usually, though not always, associated with fissure veins filled under conditions of a moderate temperature and pressure, the gold-silver being characterized by the presence of such minerals as gold, silver, argentite, pyrargyrite, etc., in a quartz gangue and the silver-lead by galena, zinc blende, tetrahedrite in a gangue of calcite, siderite, and sometimes quartz. Where the Boundary belt and the Kootenay belt merge minerals such as garnet, hornblende, and pyrrhotite occur in the deposite of the Kootenay belt—as in the Sullivan, St. Eugene, and Bluebell mines. In the Slocan and Ainsworth districts of the Kootenay belt, the ore-bodies that occur away from the contact of the roof rocks have less high temperature minerals than those that occur close to the contact.

Not only is there a contrast between the ore deposits on the two sides of these batholithic masses, but also a contrast in the degree of metamorphism exhibited by the pre-batholithic rocks. This has been remarked by F. E. and C. W. Wright,[1] who say:

[1] Wright, F. E., and C. W., U.S.G.S. Bull. 347, 1908, p. 66.

"Although the strata directly above the massifs have long since been removed by erosion, an observer approaching the contacts from the southwest finds that distinct changes in the sedimentary rocks are generally noticeable, especially in the southern portion of southeastern Alaska. The prevailing argillites become more visibly crystalline and at many points, especially in the Wrangell district, new minerals, andalusite and staurolite, occur. From the coast of Behm canal to the western contact of the Coast Range massif, the invaded sedimentary rocks change from slates and argillites to phyllites and mica schists and in some places near the contact to gneiss. The many types of hornfels are rare and spotted schists do not form an integral part of the complex. The strata are intensely folded and were undoubtedly deeply buried at the time of the granitic invasion. Deep-seated metamorphic forces were already active and had undoubtedly heated and altered the rocks to such an extent that the granitic intrusion did not disturb their equilibrium greatly; its chief effect being to accentuate the processes of crystallization already in force and to increase their power rather than to replace them by others."

"The character of the invaded sedimentaries east of the inland border of the granite is noticeably different. The slates and sandstones are less altered and typical schists and sandstones are rare. Folding and particularly faulting are common and characteristic of the entire complex. The granite contact is sharp and frequently traverses the bedding planes of the intruded strata. Although its general trend is parallel to the Coast range, the actual line of contact exposed in the Unuk River section undulates locally and crosscuts the strata at variable angles."

The metamorphic effects of the Coast Range batholith along its western and eastern flanks described above from the Ketchikan district is characteristic of this batholith in British Columbia to the south.

Another explanation—the one favoured by the author—for the varying intensity of metamorphism of the two flanks may be given. It is well known that the roof of a batholith is always intensely metamorphosed by the ascending hot solutions from the underlying molten magma. On the other hand the deeper and more vertical contacts do not show contact metamorphism to the same degree, not only as regards intensity but also as regards areal extent.[1] If the batholith and the intruded rocks are exposed in a plane normal to the vertical axial plane of the batholith, the plane would consist of a core of granite surrounded by a contact zone of approximately the same width. On the other hand if the batholith and the intruded rocks are cut obliquely, the roof rocks will be preserved higher up on the low side, whereas on the high side the highly metamorphosed roof rocks will be entirely removed and the contact will be undulating and fairly even. The contact metamorphic zone will be very narrow on the high side and very wide and irregular on the low side. In addition, the low side will be marked by many roof pendants of all sizes, whereas the high side will be almost free from them. Examination shows that the two sides of the Coast Range batholith correspond to the above distribution, as can be seen by the following table:

Eastern Flank	*Western Flank*
(1) Smooth flowing contact	(1) Very irregular contact
(2) Few roof pendants	(2) Many roof pendants
(3) Very narrow metamorphic zone	(3) Wide metamorphic zone
(4) Slates, sandstones, and tuffs characteristic	(4) Schists and gneisses characteristic
(5) Moderate temperature conditions	(5) High temperature conditions
(6) Gold-silver and silver-lead deposits of medium temperature and pressure.	(6) Copper deposits of high temperature and pressure.

(7) Intruded rocks of roof type, gneisses, and schists reach the same elevation as the unaltered rocks along the steeply pitching contact.

[1] Schofield, S. J., Geol. Surv., Can., Mem. 76, 1915, p. 83.

These facts show that erosion on the western side of the Coast Range batholith has not entirely removed the roof rocks, and that the contact between the batholith and these rocks is almost flat. This conclusion is supported by the presence of a large number of roof pendants and the very irregular contact between the granite and the intruded rocks. On the eastern flank, however, erosion has exposed a deeper portion of the batholith, the roof being entirely removed, so that the margin of the batholith plunges very steeply beneath the intruded rocks. Also, the contact is smoothly undulating and the roof pendants are absent.

This points either to greater uplift on the eastern side of the batholith or to a depression on the western flank. The depression seems to be the more probable, since the western coast of British Columbia and southeastern Alaska has all the aspects of a depressed coast that protected the western flank from deep erosion.

It follows that, in the wide metamorphic zone on the western flank, ore deposits of high temperature and pressure would be characteristic, but on the eastern flank a few ore deposits of high temperature and pressure might occur along the immediate contact of the granite. Owing, however, to the very low conductivity of rocks, the zone for these deposits would be very narrow and would rapidly give way to ore deposits characterized by minerals of medium temperature and pressure. The deposits of the latter variety on the western flank are covered by the waters of the Pacific ocean.

SECOND PERIOD

The second period, which may be called the period of intensive study of the above-mentioned mineral belts, has occupied the years from 1905 to 1921. The problem to which the greatest attention has been devoted consists in determining the cause of the localization of ore-shoots in these mineralized belts. This brings the investigation in touch, commercially, with the mining industry. The results obtained are of such importance that a generalized statement of the facts is given.

In general, the ore deposits of British Columbia are of primary origin, that is, they have not suffered enrichment to any great extent. This is in marked contrast with the majority of the ore deposits of the western United States, especially those of the desert regions of Wyoming, Utah, Nevada, Arizona, and Texas. Certain exceptions to this will at once be called to mind. The native silver of Salmon River and Alice Arm districts have certain structural characteristics that suggest a zone of secondary enrichment. The native silver in the upper workings of the ore deposits at Ainsworth is also due to secondary processes. These occurrences, although highly important, are the exception rather than the rule in British Columbia.

In Canada, the localization of ore-shoots of commercial importance is in the main due to two features that have been neglected to a large extent in looking for new ore-bodies and in the development of those already known.

These features are: chemical and physical properties of the rocks that come under that branch of geology known as petrology; structures, that is, folding and faulting, which belong to the field of structural geology.

Petrology

The most favourable rocks for the location of ore-shoots in commercial quantities may be listed in approximate order of merit as follows:

LIMESTONES

Bluebell, Florence, Silver-Hoard, No. 1, Krao, Skyline, Cork-Province, Monarch, Deadwood, Phoenix, Hedley, Marble Bay, Quatsino Sound (Old Sport).

GRANITE FAMILY (Monzonite, Granodiorite)

Rocher Déboulé, Molly Gibson, Rossland (some ore-shoots), Copper Mountain, Emma, Drum Lummon, Surf Inlet.

DIORITE-GABBRO FAMILY

Britannia............quartz-porphyry (now chlorite schist)
Anyox..............diorite porphyry
Ty e...............quartz porphyry (now sericite schist)
Sunloch.............gabbro
Rossland............diorite and augite porphyrite (some ore-shoots)
Premier.............quartz porphyry (some ore-shoots)
Silver King.........diorite porphyry and quartz porphyry

VOLCANIC TUFF

Highland mine, Dolly Varden, Premier (some ore-shoots), Silver Standard, Florence (some ore-shoots).

QUARTZITES

Sullivan, St. Eugene, North Star, Society Girl, Spokane Trinket.

SLATES

Slocan Star (Silver Standard), Standard, Richmond Eureka, Rambler, Cariboo, Whitewater, Lucky Jim, Surprise, Van Roi, Noble Five, etc.

From this brief review of the ore deposits, it can be seen that the favourite associated rocks are the stratified or bedded rocks, such as limestones, shales, quartzites, and tuffs, although the commercial values of the ores derived from these rocks may not equal that derived from the intrusive or igneous type. The ore-shoots conform in great measure to the recognized rule that the copper ores favour the basic igneous rocks. But there are many exceptions, especially among the porphyry copper ores of the United States. Another and a very striking feature is the large number of rock types that contain valuable ore-shoots. These types are limestone, slate, quartzite, tuffs, granite family, and diorite-gabbro family. They are all very common rocks and every mining engineer and prospector should bear this point in mind when studying any district in the above-mentioned mineral belts. It must not be assumed that commercial ores are necessarily absent in any other rock types, but the results of investigation by many workers, covering a period of twenty years, certainly show clearly that the greatest possibilities lie in the rocks indicated.

Influence of Structures

The influence of folds and faults upon the localization of ore-shoots is not so clearly defined nor so evident. Minor structures which influence ore deposition occur in nearly all ore deposits, although the influence of rock type may be the predominant one.

The most pronounced effect of major structures on ore deposition that has come to light in British Columbia, is exhibited in the Britannia mine. Here the commercial ore-bodies are restricted to large, steeply dipping folds of which, up to the present, three have been discovered. The folds occur in sheared quartz porphyry, and the folding caused incipient or potential openings on the axes of the folds, furnishing favourable channels for the ore-bearing solutions. The recognition of this association of folds and ore-bodies in the structural geology of the district proved of great value in the exploration of the property. In this case, the fact that the large ore-shoots are restricted to the quartz porphyry must not be overlooked, and hence in the Britannia mine there is a combination of the two factors, the influence of the host rock as well as structure to be considered.

Another illustration of the effect of structure[1] on the location of ore-shoots is seen in the old Tyee mine on Vancouver island, where the ore occurs in the southern limb of a closed syncline formed of schists derived from the metamorphism of the Sicker sediments and Tyee quartz porphyry. The circulation of the ore-bearing solutions was doubtless controlled largely by the schistose zone and confining walls of the Sicker porphyry, and partly by the pitching synclinal troughs, in one of which the ore-body was formed, largely by replacement.

The subject of structural geology must not be left without dealing with faulting. It has been noted by Campbell, O'Neill, the writer, and others[2] that the high-grade silver ores of northern British Columbia are associated with cross fractures that in most cases are faults with considerable throw. They divide the mineral zone into blocks which have moved relatively to one another. Along these fractures which controlled the location of the descending solutions, native silver has been deposited as a secondary enrichment.

Metallogenic Epochs in British Columbia

In all the above discussion attention is drawn to the influence of the host rocks and their structure in the localization of ore-shoots. There remains for consideration the source of the ore-bearing solutions that gave rise to the deposition of the ore itself, either in bodies of commercial, or in small disseminated bodies of no commercial, value at the present time.

In 1918, at the meeting of the Canadian Mining Institute in Montreal, it was pointed out by the writer that the commercial ore deposits of British Columbia, from the evidence that has been collected by many observers over a period of twenty years, were formed mainly from solutions

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[1] Clapp, C. H., Geol. Surv., Can., Mem. 96, 1917, p. 389.
[2] Campbell, E. E., Trans. Can. Min. Inst., vol. 23, 1920, p. 394.
O'Neill, J. J., Geol. Surv., Can., Sum. Rept. 1919, p. 713.
Schofield, S. J., and Hanson, George, Geol. Surv., Can., Sum. Rept. 1920, pt. 6 A.

derived from the granodiorite intrusions of Mesozoic age; to be more exact, probably of Upper Jurassic age. Later work has supported this view with one exception, that of the Sunloch property on Vancouver island where the ores are associated with the Sooke gabbro of Tertiary age.[1] The Jurassic intrusions compose the Coast Range batholith and the majority of the granite intrusions of the Kootenays.

The value of this generalization is evident, for it explains why the great mineral belts of British Columbia are distributed in certain well-defined regions. It also shows the value of grouping igneous intrusions according to age, a system which has been followed as far as possible in the geological maps issued by the Geological Survey.

The accompanying map (No. 1829) shows many small stock-like masses on the eastern side of the Coast Range batholith in the Interior Plateau region extending from the Yukon to the International Boundary line at the 49th parallel. A great many of these stocks cut Lower Cretaceous rocks that were folded and faulted during the Laramide revolution. The mid-Tertiary lavas rest unconformably on the eroded surface of some of these stocks. They are, therefore, later in age than the Coast Range batholith which is overlain unconformably by Lower Cretaceous rocks. There is no record of mountain building and igneous intrusion between the Upper Jurassic and the Laramide revolution, and it is, therefore, concluded that some of these stocks belong to the Laramide revolution, which took place probably in Eocene time. The ore deposits associated with these intrusions are considered to belong to the Eocene period.

The interior country in certain districts was affected by the three periods of igneous intrusion, Upper Jurassic, Eocene, and Oligocene, and it is difficult in all cases to date exactly the age of mineralization in that region. However, the intrusions of Upper Jurassic age comprise greyish-white diorites and granodiorites, sometimes characterized by large phenocrysts of orthoclase, whereas the Tertiary intrusives are as a rule true granites and syenites of pink colour. This fact has been pointed out by Daly[2] along the International Boundary line and by Brock[3] in the Eutsuk and François Lake regions. This evidence as to the age of the various intrusives must, of course, be used with discretion.

It may be of interest in this connexion to examine the geological history of British Columbia and to indicate the different epochs during which mineralization took place. The following is a synopsis of the different geological periods represented in British Columbia showing the periods of mineralization.

Deposits Dependent Upon the Eruption of Igneous Rocks

Recent	
Pleistocene	
Pliocene	*Mercury ores*, Kamloops, etc.
Miocene	*Copper ores*, Boundary district
Oligocene	*Copper ores*, Sunloch property
Eocene	*Lead ores*, Monarch mine, Field; Hazelton
Cretaceous	

[1] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1919, p. 120 B.
[2] Daly, R. A., Geol. Surv., Can., Mem. 36, 1912, p. 425.
[3] Brock, R. W., Geol. Surv., Can., Sum. Rept. 1920, p. 81 A.

Jurassic	*Copper ores*, Anyox, Britannia, Marble Bay, Copper mountain, Rossland, etc. *Silver lead ores*, Salmon River, Alice Arm, Monarch mine, Lardeau, Slocan, Ainsworth, East Kootenay, etc. *Gold ores*, Bridge river, Coquihalla *Iron ores* (magnetites), Vancouver island, Coast, etc. *Platinum*, Tulameen
Carboniferous	
Devonian	
Silurian	
Ordovician	
Cambrian	
Beltian	*Copper ores*, East Kootenay
Shuswap	

Deposits Produced by Mechanical and Chemical Processes of Concentration

Recent	*Iron ores* (limonites), Taseko lake, Skeena river, Squamish. *Hydromagnesite deposits*, Interior plateau *Epsomite deposits*, Interior plateau *Placer gold*, Cariboo, Fraser, North Thompson, East Kootenay, etc. *Placer platinum*, Tulameen *Manganese, Wad*, Kaslo
Pleistocene	
Pliocene	*Silver Ores* (secondary), Alice Arm, Dolly Varden, Salmon River, Premier, East Kootenay, Slocan, Beaverdell, Ainsworth, Boundary, etc. *Placer Gold*, Cariboo, Atlin, etc.
Miocene	
Oligocene	*Copper ores* (secondary), Boundary district
Eocene	
Cretaceous	
Jurassic	
Triassic	
Carboniferous	
Devonian	
Silurian	
Ordovician	
Cambrian	
Beltian	*Iron ores* (hematite), East Kootenay
Shuswap	

DEPOSITS DEPENDENT UPON THE ERUPTION OF IGNEOUS ROCKS

Precambrian

The oldest traces of mineralization in British Columbia occur in East Kootenay[1] where the country is underlain to a large extent by quartzites of Precambrian age. Intruded parallel to the bedding planes of the quartzites are numerous sills of gabbro which contain segregations of more quartzose material containing chalcopyrite. Since these sills are related to the Purcell lava of Precambrian age and since the ore occurs only in the sills, it is concluded that the mineralization is Precambrian. It may be of

[1] Schofield, S. J., Geol. Surv., Can., Mem. 76, 1915, p. 140.

interest in a general way to point out that they bear a strong resemblance not only in age and lithology, but also in structure, to the sills of Sudbury and Cobalt. Traces of cobalt and nickel have been found also in the Purcell sills of East Kootenay.

Jurassic

A long period of time, embracing the whole of the Palæozoic and the Triassic, intervenes between the Precambrian and the Jurassic; nevertheless, there are no primary ore deposits associated with rocks of any of the intervening periods. Not until the closing stages of the Jurassic itself is mineralization again recorded, but as if to make up for lost time, it gave ore deposits abundantly. It is only necessary to review the producing mines of British Columbia, to see that they probably are all linked with the closing stages of the intrusion of the igneous rocks of the Jurassic period which produced the Coast Range batholith and most of the batholiths of the interior of British Columbia—Anyox, Marble Bay, Tyee, Britannia, Coquihalla, Copper Mountain, Nickel Plate, Deadwood, Phoenix, Rossland, East Kootenay, Ainsworth Slocan, Lardeau, Bridge River, Alice Arm, and Salmon River, to say nothing of the vast number of prospects, some of which must be developed if the mining industry of British Columbia is to prosper.

Oligocene

The next period of mineralization is that of the Oligocene, of the Tertiary. As far as present knowledge goes, the one deposit belonging to this period without any doubt is the Sunloch on Vancouver island,[1] which mining men say will soon be a producing copper property on a large scale. It occurs in a shear zone in gabbro of Oligocene age.

Pliocene

The age of the mercury deposits which occur in several places throughout British Columbia is doubtful, but all observers place it in the Tertiary. In the Kamloops district, Camsell[2] says they are associated with late Tertiary lavas, in fact some deposits occur in late Miocene lavas which had been faulted and brecciated. Dolmage,[3] who studied the deposits on the western coast of Vancouver island, on indirect evidence, places them in late Tertiary.

DEPOSITS PRODUCED BY MECHANICAL AND CHEMICAL PROCESSES OF CONCENTRATION

The separation of these two groups of deposits is thoroughly grounded on the basis of genesis. The first group, formed during the periods of igneous intrusion, is the source from which the second group of deposits was formed by the concentration of certain minerals by the agencies of weathering, erosion, and deposition either mechanically or from solution.

[1] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1919, p. 20 B.
[2] Camsell, C., Geol. Surv., Can., Sum. Rept. 1918, p. 17 B.
[3] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1919, p. 18 B.

Precambrian

The oldest mineralization so far discovered is seen in the bedded iron deposits in the Purcell series of Precambrian age near Kitchener.[1] They consist of layers or strata of hematite interbedded with the argillaceous quartzites. These layers are believed to be of sedimentary origin and to be derived from the weathering of a still older Precambrian terrane which furnished the iron probably as a limonite, in a similar way to the limonite forming today in the lakes in the province of Quebec and elsewhere. The limonite was later changed to hematite by pressure.

Pliocene

The preglacial gravels of the Cariboo[2] are assigned to this period. Most of the gold from the Cariboo was mined from these gravels derived by the processes of erosion from the underlying bedrock which contained stringers of gold-bearing quartz. The gold-bearing gravels are preglacial and probably Pliocene, a period represented in British Columbia by great erosion.

Recent

The Recent mineral deposits include those which have been formed since the withdrawal of the ice in the Pleistocene period and the present day. In fact several of the deposits mentioned below are in the process of formation at the present time.

Placer Gold. The gold-bearing gravels and sands which occur along nearly every river in British Columbia, including the Fraser, North Thompson, the rivers of Cariboo, Atlin, East Kootenay, and others, are post-Pleistocene in age. It is very probable according to many observers that these gravels have been derived from the post-glacial streams.

Hydromagnesite and Epsomite Deposits. These deposits occur in Cariboo district and near the International Boundary in southern British Columbia, and occur in basin-shaped depressions in the glacial drift. The materials are dissolved from the surrounding rocks and carried by underground channels and deposited in the basins by evaporation.

Sodium Carbonate. Also occurs in saline lakes in the neighbourhood of Clinton, B.C. These lakes are presumed by Reinecke[3] to be fed from underground springs and the soda to be derived from hot waters ascending from below and connected with the volcanic activity that caused the extrusion of the Tertiary basalts.

Iron Ores. The iron ores of this period are limonites and occur as surface deposits. The typical examples are, the limonites of Taseko lake,[4] Skeena river,[5] and Squamish. These ores have been derived from the surrounding rocks by weathering and have been deposited on the hillside. Most of the deposits are in active formation today.

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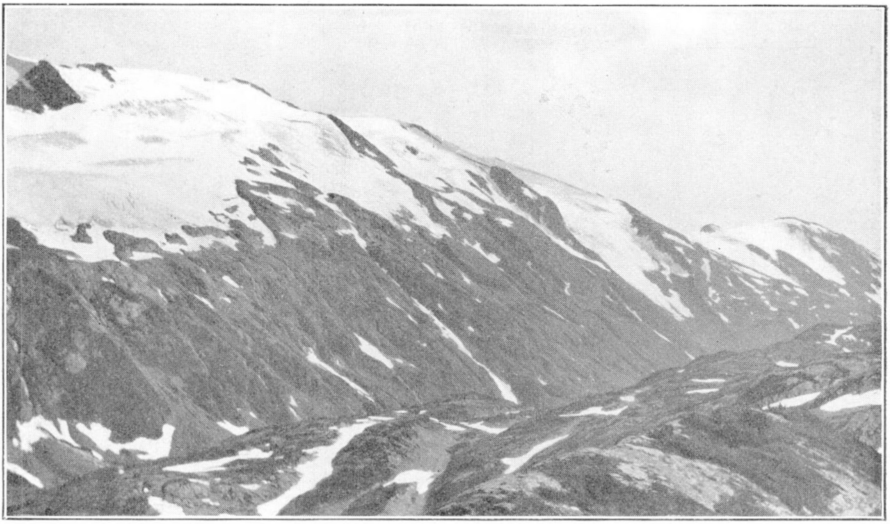
[1] Blakemore, W., Trans. Can. Min. Inst., vol. 5, 1902, pp. 76-80.
[2] Bowman, A., Geol. Surv., Can., Ann. Rept. 1887-8, p. 17 C.
MacKay, B. R., Geol. Surv., Can., Sum. Rept., 1918, p. 39 B.
Johnston, W. A., Trans. Can. Inst. of Min. and Met., vol. 25, 1922.
[3] Reinecke, L., Geol. Surv., Can., Mem. 118, 1920, p. 63.
[4] Mackenzie, J. D., Geol. Surv., Can., Sum. Rept., 1920, pp. 42 A-70 A.
[5] Mackenzie, J. D., Geol. Surv., Can., Sum. Rept. 1915, p. 62.

SECONDARY ENRICHMENT

Secondary enrichment is the term generally used for the enrichment that certain ore-bodies have undergone by the deposition of minerals which have been dissolved from the zone of oxidation and deposited by descending solutions either above or below the groundwater level. Although the process in British Columbia is widespread and has been recorded by many investigators, it has only recently attracted attention by the occurrence of native silver in the Salmon River and Alice Arm mining camps. The idea has been largely developed in the United States where secondary enrichment has made bonanzas out of originally low-grade primary ores, especially in the desert regions of Arizona, Texas, New Mexico, Utah, Wyoming, Nevada, California, and several other states.

Brock was the first geologist to describe secondary enrichment in British Columbia. He observed the results of such action in the Boundary district in 1901, at the King Solomon and Copper Camp, where the oxidized, enriched, and primary ore zones are clearly defined. Later, LeRoy noted it at the Hewitt mine in the Slocan, Reinecke in Beaverdell, Drysdale at Ymir, O'Neill in the Salmon river, and the writer at the North Star and Society Girl mines in East Kootenay and several properties at Ainsworth. It is very probable that the native silver at Alice Arm is also of secondary origin. In the description of these occurrences, it is remarked how frequently these enriched ore-shoots are associated with cross-fractures or faults, which cut or displace the original ore-bodies. Descending solutions following down these fractures dissolved the copper and silver from the zone above the groundwater level and deposited it in the vein below. In most of these veins in British Columbia, the oxidized, and some of the enriched, portions have been eroded away leaving the roots of the zones of secondary enrichment.

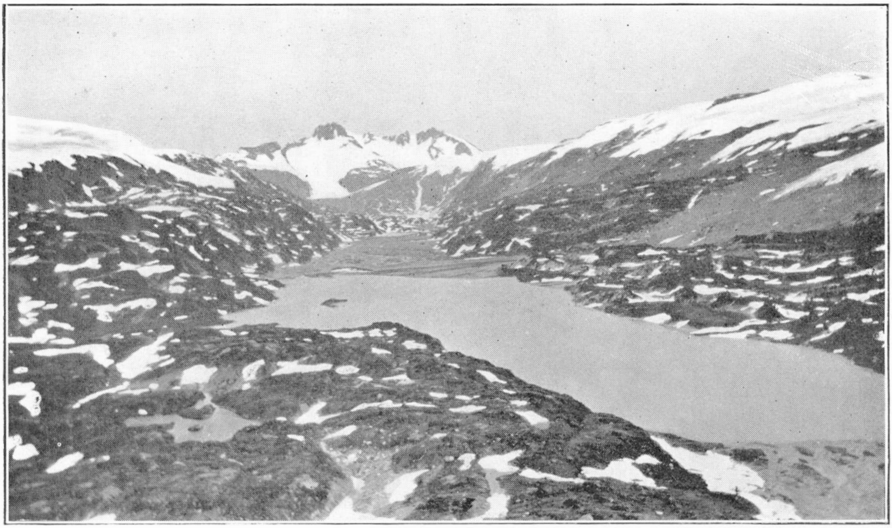
Enrichment by descending solutions is favoured by rapid erosion in a rising country, for these conditions bring new zones within the influence of the agencies of oxidation and erosion and at the same time lower the groundwater level below which enrichment is produced under its most favourable circumstances. In reviewing the geological history of British Columbia, it is found that the Miocene and Pliocene were periods of prolonged erosion interrupted by intervals of slow uplift, so that secondary enrichment was possible during these periods. Glaciation in the Pleistocene very probably removed the oxidized zones as well as some of the zones of secondary enrichment producing the conditions existing today. The greatest depth at which secondary enrichment is reported is about 500 feet below the surface.



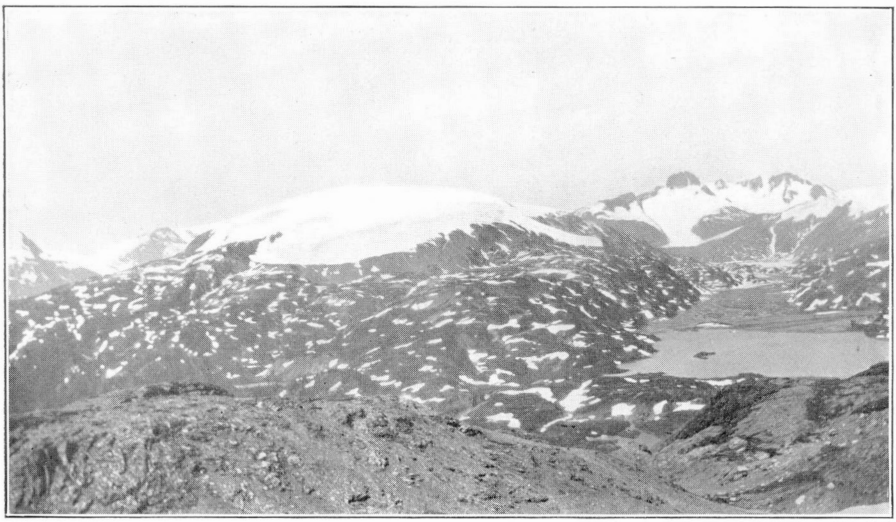
A. Bear River ridge, looking southeast from Slate mountain. (Pages 5, 32.)

B. Bear River ridge, looking east from Slate mountain. (Pages 5, 32.)

PLATE II



A. Long Lake valley, from Slate mountain. (Pages 6, 32.)

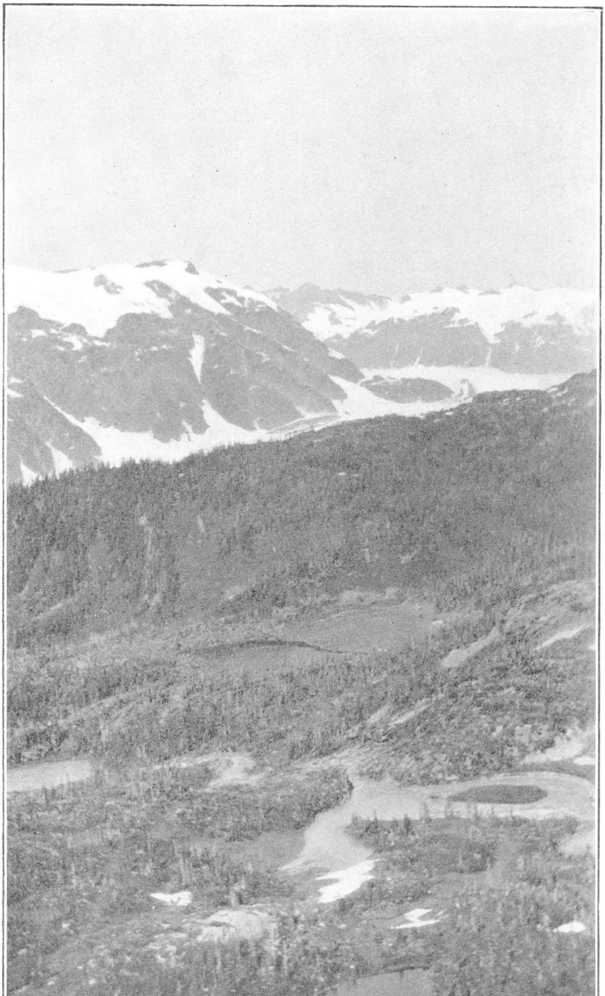


B. Mount Dilsworth, from Slate mountain. (Pages 5, 32.)

PLATE III

Main Coast range, across Salmon River glacier from Big Missouri ridge in neighbourhood of the Hercules claim. (Pages 5, 6, 32.)

PLATE IV



Joker flats and Big Missouri ridge, looking northwest to main Coast range. (Page 5.)

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