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Geology and Mineral Deposits of the Bridge River Map-area, British Columbia

BY

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Geology and Mineral Deposits of the Bridge River Map-area, British Columbia

CHAPTER I

INTRODUCTION

"The geology of the Bridge River map-area, embracing as it does the transition belt of mountains connecting the rugged and little explored Coast mountains with the much travelled Interior plateau, forms an important link in the trans-cordilleran structure section through the province of British Columbia".[1]

Ever since the year 1858, when the first placer gold was recovered from the lower stretches of Bridge river, and a few hardy prospectors commenced their perilous work of exploring the rock-bound canyons and gorges of this region, much interest has been aroused in the geology and mineral resources of the district. The early prospectors found not only coarse and fine gold, but also 'float' of cinnabar, copper, platinum, and other minerals, which, however, were not so important to them at the time as the native gold. The majority of these pioneers were former California placer-miners and possessed little knowledge of prospecting for ore deposits other than gold placers. A few, however, discovered gold quartz of a free-milling character, and in time prospecting for placers gave place to the searching for auriferous quartz veins and in recent years for other metalliferous deposits.

The geological work of G. M. Dawson in the late eighties and early nineties of the past century did not include the investigation of the mountains west of Fraser river, and comparatively little has been published by the Geological Survey until recently[2] concerning the geology and latent mineral resources of the Bridge River map-area.

On account of the geographical situation of the region, far removed from good facilities for transportation, the miners have from necessity almost entirely confined their attention to the production of gold. Up to the year 1911 practically all the gold-quartz deposits were held by individual owners with small capital, who were able to mine only the richest ore and treat it with primitive home-made arrastres. This tedious method of treatment gave a low recovery of gold values, so that the total production of gold from this source was very small. It is hoped that with future amalgamation of interests, much systematic development work will be undertaken, and sufficient ore blocked out to keep a large mill in continuous operation for many years. Considerable tracts of promising terri-

[1] Quoted from manuscript of C. W. Drysdale.
[2] Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, pp. 111-115.
Bateman, A. M. " " " 1912, pp. 177-210.
Drysdale, C. W. " " " 1915, pp. 75-85.
" " " " " 1916, pp. 45-53.

tory still remain unprospected for gold, and certain belts, as indicated on the geologic map, might advantageously be searched for platinum, diamonds, cinnabar, antimony, and possibly some of the higher priced non-metalliferous deposits such as magnesite, talc, and asbestos.

It is well known that certain mineral deposits are closely associated with certain diagnostic rock formations throughout the Western Cordilleras.[1] Many of the mineral-bearing formations and geological conditions existent in California and other western states of America, which have been more thoroughly prospected, are present in British Columbia, so that the Coast mountains and the Interior plateau of British Columbia afford a promising field for systematic prospecting and mine development. But many difficulties will have to be overcome, close attention will have to be paid to the structure and origin of the deposits, and operative companies will do well to employ mining engineers who have gained experience in the opening up of similar deposits elsewhere.

In this volume an inventory is given of the various types of known deposits within the map-area, their occurrence, value, origin, and the possibilities of finding new mineral occurrences. The general geology and physiography of the region is dealt with concisely, the economic geology at greater length.

FIELD WORK AND ACKNOWLEDGMENTS

The main part of the field season of 1919 and two months of the season of 1920 were spent by the writer in geologically mapping the Bridge River map-area, in which work he was ably assisted by Massey Baker, Percy G. Dobson, and George Farmer. The work was done under the direction of Charles Camsell, and in 1920 the writer had the advantage of discussing the geologic problems in the field with J. D. MacKenzie. The accompanying topographic map (No. 1708) was prepared by W. E. Lawson[2] and E. E. Freeland[3] of the topographic division.

The latter part of the field season of 1919 was spent in visiting the gold-quartz deposits of Grass Valley and Nevada City, California, for the purpose of comparing them with the analogous deposits of the Bridge River map-area.

Mine managers, prospectors, and residents of the district extended most cordial co-operation and many courtesies which are gratefully acknowledged.

For helpful suggestions in the compilation of this memoir, especial thanks are due to Professors Charles Schuchert, Alan M. B. Bateman, and Adolph Knopf of the geological faculty of Yale University. The writer wishes also to acknowledge the help received from the notes and partly completed manuscript of the late C. W. Drysdale.

LOCATION OF AREA

The location of Bridge River map-area is shown in the accompanying index map (Figure 1). It includes about 600 square miles of rugged Coast Mountains country, and a small part of the Fraser plateau, between latitudes 50°40′ and 51°05′ and longitudes 122 degrees west and 123 degrees west.

The most important locality within its limits is the Cadwallader Creek belt, where mining operations were being carried on while the field work was being done.

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[1] Lindgren, W., "Metallogenic Epochs." Econ. Geol., vol. IV, p. 409, 1909.
[2] Lawson, W. E., Geol. Surv., Can., Sum. Rept., 1912, p. 418.
[3] Freeland, E. E., " " " 1912, p. 335.

MEANS OF COMMUNICATION

Access to the district is by means of pack trails, and in part by railway and wagon road from Lillooet. Lillooet, one of the oldest towns and distributing points in the interior of British Columbia, is situated about 25 miles southeast of the map-area on a high terrace overlooking Fraser river. The route most used from Lillooet is via the Pacific Great Eastern railway;[1] to Mission station on Seton lake, thence by horse or wagon, or even by motor car (although the heavy grade over Mission mountain is an obstacle) over the divide to the valley of Bridge river. The wagon road continues along Bridge river and Cadwallader creek as far as the Pioneer mine. In the summer the weekly mail stage carries passengers, making the return journey from Mission station in two days. Another, a less travelled but far shorter route to the principal mines, is by way of McGillivray creek. The trail leaves the railway where the creek empties into Anderson lake, and runs up the east side of the creek valley over McGillivray mountain, into Cadwallader Creek valley. It is possible to take a pack train along this trail, although difficulties may be encountered.

Railway connexion with Vancouver and Clinton is now afforded by the recently constructed Pacific Great Eastern railway. Good automobile roads connect Lillooet with Lytton (45 miles down the Fraser valley) and with Ashcroft (60 miles distant) on the Canadian Pacific railway, as well as with Clinton and other points along the Cariboo road.

HISTORY AND DEVELOPMENT

The history of mining in the Bridge River district commences in 1858, when placer miners, chiefly from California, who possessed little knowledge of lode mining, prospected the region, and recovered placer gold from the bed of Bridge river, near its confluence with the Fraser. Their diggings extended from this discovery for 10 miles up the Fraser, above which gold appears to be absent from the gravels. The following season (1859) a discovery was made at Gun creek, which enters Bridge river about 50 miles above its confluence with the Fraser. Five Gun Creek placer claims yielded \$6 to \$15 a man a day for a while.

Good diggings were found on Tyaughton (pronounced Tyaxon) creek, about 4 miles above its mouth, but none were discovered above Tyaughton lake. The best claims were located along the lower part of Bridge river, below Deep canyon and Horseshoe bend. Mining operations were carried on from the middle of March to the middle of November, although the richest deposits were most frequently found early and late in the summer when the water was lowest. The Californian miners were followed by Chinese, and during the seventies and eighties there were more Chinese than white placer miners in the region. It is reported that in 1866 twelve Chinese miners recovered \$66,000 worth of gold by wing-damming.

[1] The old trail built by the Royal Engineers along the north shore of Anderson and Seton lakes, has been partly obliterated by the grade of the Pacific Great Eastern railway, and, therefore, it is difficult, but by no means impossible, to take a pack train from Lillooet to Mission and to Anderson lake.

The Lillooet Indians also did their share of placer mining, mainly on the bars of Bridge river and on parts of the Fraser where the gold was coarse. They used the rocker, saving the gold by means of a blanket or gunny sack in the bottom of the rocker. They often found very rich pockets amongst the rocks, where neither the whites nor the Chinese looked for gold. One Indian in particular, known as Hunter Jack, became renowned in the Bridge River district for his ability to find rich pockets of coarse gold. He and his son are said to have recovered gold for a short time at the rate of $1,000 a day.

In 1882 the gravels of the South Fork of Bridge river (now called Hurley river) were found to be auriferous, and for a while extensive operations were carried on, yielding fair returns. Four years later gold was found also on Cadwallader creek, a tributary of Hurley river, and the simultaneous discovery of rich placers on Cayoosh creek, near Lillooet, caused a striking increase in the gold production of the region (*See* page 6). These discoveries diverted interest for a time from the Bridge River valley and led to the finding of the gold-quartz veins which were the source of the gold of the Cayoosh Creek placers. Up to this time little or no attention had been paid to the source of the gold, and these new discoveries initiated interest in the prospecting for gold-quartz veins near Cadwallader creek and Hurley river. It was not, however, until 1896 that such veins were found by Owen Williams and John R. Williams, who located the Forty Thieves group of claims on the east bank of Hurley river, just below the mouth of Cadwallader creek. In the next few years most of the important claims now located were staked, the majority of these being confined to the diorite belt on the right bank of Cadwallader creek (Map 1882). An inventory of these claims, together with the dates of location, the names of the locators, and the present owners, follows.

Crown-granted Mineral Claims in Lillooet Mining Division Situated at and near Cadwallader Creek

Name of claim	Area	Names of locators	Date of location	Present owners
	Acres			
Berta	50·59	C. A. Phair	3 July, 1897	C.A . Phair.
Ural	51·85	John R. Williams	2 July, 1896	J. Marshall estate. R. B. Skinner estate.
Forty Thieves	47·39	John Marshall	2 July, 1896	
Elephant	51·33	Paul Santini	2 July, 1896	
Why Not	51·36	Will Haylmore	16 June, 1897	A. McDonald, W. H. Slipper, Paul Santini.
Trio	44·66	Joseph DeShields	2 Sept., 1897	Alpha Bell Gold Quartz Mining Co., Limited.
Ida May	45·71	Nat. Coughlan	31 Aug., 1897	
Nellie Fraction	1·14	H. M. Keefer	10 June, 1898	
Mary Fraction	35·21	Fritz Cirkel	10 June, 1898	
Hiram	42·35	William McDonald	24 Aug., 1897	William H. Keary, W. G. McQuarrie.
Copeland	24·61	Joseph Copeland	24 Aug., 1897	
Alhambra	24·65	F. O. Richardson	28 Aug., 1897	Estate of Milton Rathbun.
Nighthawk	28·25	Thomas Dunn	28 Aug., 1897	
Lurgan Frac. No. 1	3·62	Isabella Cherry	28 Feb., 1900	
Lurgan Frac. No. 2	8·55	Will Haylmore	5 Oct., 1900	
Metropolitan	32·80	Chas. M. Glenn	12 Oct., 1897	
Cosmopolitan	40·34	F. O. Richardson	28 Aug., 1897	Paul Santini.
Little Joe	51·65	Henry Cargile	28 Aug. 1897	Coronation Mines, Limited.
White Crow	42·64	James Barnes	4 Sept., 1897	
Bend 'Or Fraction	5·58	J. M. McKinnon	17 April, 1898	
Jim Crow Fraction	0·90	William Robertson	20 Sept., 1898	
Delighted	26·22	Alice DeShields	28 Aug. 1897	
Countless	44·30	Michael Gaynor	1 Sept., 1897	
Pioneer	51·14	William Allen	6 Sept., 1897	
Union Jack Fraction	9·25	Arthur F. Noel	23 April, 1898	Andrew Ferguson, Adolph Williams.
Great Fox	51·65	Louis Mandeville	10 July, 1898	
Emmadale	44·00	Joseph Russell	16 Aug., 1903	Lorne Amalgamated Mines Co. Limited.
Corasand	41·27	Maria J. Martley	9 July, 1899	
Lorne	50·25	William Young	4 July, 1897	
Golden King	45·44	Nathaniel Coughlan	4 July, 1897	
Marquis	24·50	John R. Williams	4 July, 1897	
Woodchuck	38·20	Ervin J. Taylor	30 July, 1897	
Telephone	28·70	Ervin J. Taylor	12 Oct., 1899	
Wood Duck	24·58	L. G. Burns	6 Oct., 1897	
McKinley	23·85	George Breedon	9 Sept., 1897	A. McDonald, Paul Santini.
Blackbird	37·70	William Young	19 Aug., 1897	Geo. A. Kirk, Arthur J. O'Reilly.
Maud S. Fraction	30·50	Thomas P. Reed	20 Sept., 1897	Thomas P. Reed, Samuel Gibbs, Harvey A. Christie.
Nellie	39·50	Arthur Thiverge	20 Nov., 1902	Mark R. Eagleson Estate.
Whip-poor-will	44·00	Mark R. Eagleson	7 Aug., 1903	
Duke	19·00	Ernest Ostrander	3 Oct., 1899	
Royal	23·70	Alymor Richey	30 Sept., 1899	
LeRoy	39·00	Harley Ostrander	13 Oct., 1897	

Owing to lack of transportation facilities, development in the Cadwallader Creek gold belt progressed but slowly. All mining equipment had to be transported 70 miles by pack horses, and up to the present time this drawback has only been partly removed by the building of the present wagon road, because of the heavy grade on Mission mountain. Because of these difficulties most of the mining operators contented themselves with building old-fashioned arrastres, the materials for which could be obtained close at hand, and the motive power from adjacent creeks.

By this crude method of treatment it is estimated that gold to the amount of $50,000 was extracted from two of the properties, the Lorne[1] and the Woodchuck. This arrastre was replaced in 1902 by a 5-stamp mill. The total production of the gold-quartz properties on Cadwallader creek has been placed at approximately $350,000.

The accompanying table illustrates the manner in which the gold production of the Lillooet Mining Division has fluctuated from the year of discovery to 1918.

Table of Gold Production, Lillooet Mining Division

	$		$
1874	55,000	1899	58,590
1875	50,000	1900	30,750
1876	25,000	1901	20,000
1877	25,000	1902	31,425
1879	40,000	1903	31,275
1880	63,900	1904	34,550
1881	39,000	1905	32,585
1882	54,300	1906	20,300
1883	68,000	1907	15,100
1884	107,935	1908	13,780
1885	94,700	1909	16,675
1886	132,000	1910	9,800
1887	106,000	1911	6,450
1888	90,160	1912	5,000
1889	60,350	1913	30,275
1890	71,450	1914	7,775
1891	52,500	1915	8,600
1892	39,750	1916	59,250
1893	51,375	1917	69,900
1894	39,250	1918	51,100
1895	40,650		
1896	33,650		
1897	39,850		
1898	35,500	Total	$1,968,500

PREVIOUS WORK

In the autumn of 1910, W. Fleet Robertson[2], Provincial Mineralogist[3] visited the Bridge River district, and in the summer of 1913 W. M. Brewer examined and reported on it in more detail for the Provincial Bureau of Mines. In 1911 Charles Camsell[4], Geological Survey, made a brief reconnaisance trip through the district, with a view to planning detailed topographical and geological work. In 1912, A. M. Bateman[5] commenced the detailed examination of the area, paying particular attention to the Cadwallader Creek gold belt. His explorations extended to the west of the present map-area as far as Chilko lake. In 1915, C. W. Drysdale[6] made a geological survey of the map-area, but owing to his untimely death in 1917, the results of his work were not published. G. M. Dawson[7], in his report on "The Kamloops Map Sheet," described the geology of the vicinity of Lillooet, including the mouth of Bridge river, but did not deal with the country farther west.

[1] The Provincial Bureau of Mines reported that the arrastre on the Lorne group recovered $6,000 in seventy-six working days.
[2] Rept., Minister of Mines, B.C., 1910, pp. 134-148.
[3] Rept., Minister of Mines, B.C., 1913, pp. 246-273.
[4] Geol. Surv., Can., Sum. Rept., 1911, pp. 111-115.
[5] Geol. Surv., Can., Sum. Rept., 1912, pp. 180-210.
[6] Geol. Surv., Can., Sum. Rept., 1915, pp. 75-85.
[7] Geol. Surv., Can., Ann. Rept., vol. vii, 1894, pp. 3-247 B.

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CHAPTER II

GENERAL CHARACTER OF THE REGION

REGIONAL TOPOGRAPHIC FEATURES

In southern British Columbia between the forty-ninth and fifty-fifth parallels of latitude the Canadian Cordilleras[1] may be divided into three main physiographic provinces trending in a general north-northwest to northwest direction, parallel to the Pacific coast. The Western belt is made up of rather compact mountainous units along the Pacific coast, the Central belt is a lower and relatively flatter region, and the Eastern belt is characterized by a broad belt of mountains and foothills which, merge into the prairies of Alberta. The Western belt is composed of the Insular and Pacific systems, the Central belt includes the Interior, Columbia, and the Cassiar systems, and the Eastern belt is made up of the Rockies system. These systems are in turn divided into plateau and mountainous units.

The present work is limited in its scope to the transition belt between the Western and the Central belts, or, more particularly to the eastern flank of the Coast mountains,[2] near the fifty-first parallel of latitude; and the less rugged transition mountain range connecting the Coast mountains with the part of the Interior system known as the Fraser plateau (Figure 1).

The Coast mountains fringe the Pacific coast, extending from the Cascade mountains, which end at Fraser river near the International Boundary, for 900 miles northward to Alaska. They vary in width from 100 miles in the south to less than 50 miles in the north, and are bounded on the east by the Interior, Cassiar, and Yukon systems, and on the west by the partly submerged Pacific Coast downfold,[3] or the Coastal trench, which separates it from the Insular system of mountains.

The topography of the Coast mountains is much broken, presenting to the eye a confused mass of rugged, snow-clad peaks and serrated ridges rising to heights of 8,000 to 9,000 feet above sea-level (Plate I). To a casual observer from the valleys there appears to be a great disproportion to the mountains, the nearest ones seeming to be fo greatly varying heights and sizes, and vastly greater than those in the background; but a view from a higher altitude discloses a certain uniformity of summit level, although certain peaks tower several hundred feet above the general level (Plate II A).

[1] The Canadian Cordilleras comprise the entire group of mountain systems in British Columbia and Yukon.

[2] The Coast mountains were first named by Dawson, who called them the "Coast range," in order to differentiate the granite-schist mountains on the British Columbian seaboard from the lava-built Cascades on Columbia river. It has, however, become more and more evident, as Daly has shown in his works on the "Canadian Cordillera at the 49th Parallel," that rock-composition can never rival crest uniformity as a primary principle in grouping the western mountains.

[3] The Pacific Coast downfold (Bailey Willis, Folio No. 54, U.S.G.S., 1898) extends from Queen Charlotte islands to the gulf of California. It is bounded on the east by the Pacific system (Cascade, Coast, and Bulkley mountains) and the Sierra Nevadas. To the west of it lie the Insular system (St. Elias, Queen Charlotte, and Vancouver Island mountains), the Olympic and Klamath mountains, and the Coast range of California. The name "Coastal Trench" has been approved for it recently by the Geographic Board of Canada.

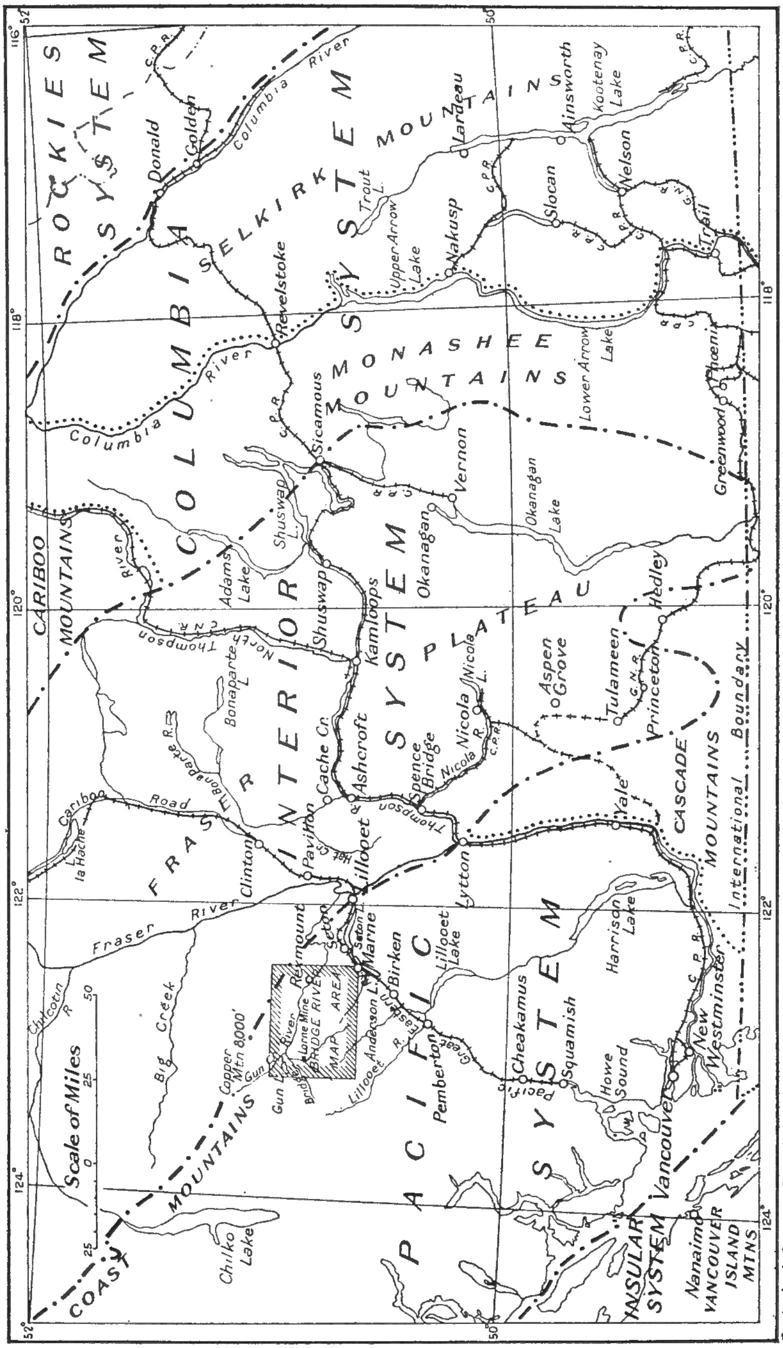

Figure 1. Index map showing location of Bridge River map-area, Lillooet district, B.C.

Extensive snow or névé fields support numerous glaciers which vary in size from small cliff-glaciers to valley glaciers, and which are usually on the northern slopes of the mountains. All the topographic forms characteristic of intensely glaciated mountains form prominent features of the landscape. The valleys are sharply incised. The steeper slopes are bare or support a few stunted trees. With a lessening of the declivity, the forest growth increases until the gentler slopes and valleys are densely timbered.

The drainage is mainly transverse, most of the major streams flowing southwesterly into the Pacific ocean through a series of fiords or deep indentations of the coast-line, or northeasterly toward the plateaus of the Interior system. Subsequent drainage in which the rivers owe their courses to underlying rock structure is more common on the eastern foothills of the range.

The Interior system of plateaus is over 500 miles long, extending from south of the International Boundary northward to the Cassiar Mountain system. In width it varies from 35 miles at the forty-ninth parallel to a maximum of about 235 miles at the fifty-fourth parallel. The region consists essentially of areas of rolling upland, separated by deep valley trenches. Unlike other units of the Cordilleras, the boundaries of the system are not everywhere well defined, and in places the uplands seem to rise to meet the mountains.[1] To the west of it lie the Cascade and Coast mountains, and to the east the Columbia system; on the north it is bounded by a group of irregular ranges including Babine mountains, which lie between the Coast mountains and the Rockies system, and to the south it ends in wedge-shaped form against the Hozameen, Skagit, and Okanagan ranges of the Cascade mountains, and the Colville mountains of the Columbia system.

In the southern part of the Interior system the uplands rise from 4,000 to 6,000 feet above sea-level. Towards the north they decrease in general elevation. The main valleys lie from a few hundred to more than 4,000 feet below the upland surface, above which a few rugged hills rise several hundred feet.

The drainage of the plateaus is principally west into the Pacific by way of Fraser and Thompson rivers. A portion of the northern region drains into Skeena river. The southern part is drained by the Similkameen, Okanagan, and Kettle rivers, tributaries of Columbia river.

The Plateau areas are in large part sparsely wooded and underlain by Tertiary volcanics, and the steep-walled narrow valleys are generally floored with fertile river terraces.

LOCAL TOPOGRAPHIC FEATURES

The Bridge River map-area lies on the eastern flank of the Coast mountains, its northeastern corner forming a part of the transition belt of more subdued mountains separating the Coast mountains proper from the plateaus of the Interior system of British Columbia. Within this area are three main mountain units all trending northwest and southeast, and known from north to south as the Shulaps, Bendor, and Cadwallader mountains respectively.[2] They are surmounted by rugged, snow-clad peaks and ridges whose northern slopes are, as a rule, precipitous and difficult of ascent. The southern slopes are more regular and sparsely

[1] Camsell, C., Geol. Surv., Can., Mem. No. 2, pp. 9 and 30.
[2] Geographic Board of Canada, Decisions, Jan.-Feb. 1915. Canada Gazette, March 13, 1915.

wooded, and are usually without glacial modification. The mountain peaks, many of which are of the pyramidal or Matterhorn type, reach from 8,000 to 9,000 feet above sea-level, giving a maximum relief above the main valleys of from 6,000 to 7,000 feet. The topography in many places conforms closely to bedrock structures, the trend lines of the mountains and valleys following the formational strikes (Map 1708). There is a marked difference between the topography carved upon the soft-weathering Eldorado series, and that developed on the other, more resistant, rocks. In the northern part of the map-area, underlain by the Eldorado series, the ridges are broad, smoothly rounded, and covered with grass. The slopes are less steep than those in the southern part of the district. The close relation of erosion to anticlinal structure is illustrated by the courses of the lower parts of Bridge river and Tyaughton creek.

The effects of glaciation are particularly conspicuous in the topography of the area. Hanging valleys, glacial cirques, U-shaped valleys with steps in the valley floors, truncated spurs, and morainal drift are of common occurrence (Plate I).

HANGING VALLEYS

In the upper parts, the smaller streams within the area flow through U-shaped gently-sloping valleys, which often contain small, rock-bound lakes (Plate II A), but in their lower courses they plunge suddenly by successive falls through gorge-like incisions to join the streams below. In other words, the tributaries have hanging valleys. Such a hanging relationship appears to be due to differential ice erosion during Pleistocene time, the discordance in level being governed by the difference between the erosive power of the ice of the main valley and that of the tributary.

The higher streams also bear a hanging relationship to the main drainage courses of the region. For instance, Bridge river has this relationship to the Fraser. In its upper reaches Bridge river meanders through long stretches of marshy valley bottom containing fine gravel, sand, and silt, until within 10 miles of the Fraser. Thence, since the retreat of the valley glacier, it has incised deep box-canyons in its endeavour to cut its channel down to grade (Plate III A).

CIRQUES

The smaller streams have their sources in glacial cirques. These amphitheatre-shaped hollows, which have been sculptured by individual alpine glaciers, are most numerous at the higher altitudes. Many of the cirques are still occupied by patches of snow and glaciers, which cling to the steep walls, or are situated in hollows between the peaks.

The excavation of cirques is accomplished by the deepening of the floor through the erosive power of the ice, and also by the recession of the rock-walls, due to the disintegrating effect of the repeated freezing and thawing of the upper and steeper part of the walls along the line where the ice breaks away from the rock rim to form "bergschrund" crevasses.[1] The debris thus pried off by frost and glacial plucking is removed by the glacier and used to scour the floor of the cirque.

[1] Johnston, W. D., Journ. of Geol., vol. XII, 1904, pp. 569–578.

STEPS IN THE VALLEY FLOORS

Some of the valleys contain long glacial lakes and step-like stretches. For instance, on the north slope of Bendor mountains, Keary lake, which is about 2 miles long, lies in a smoothly curving trough-like valley 6,000 feet above sea-level, and is about 3 miles below the tongue and lateral moraine of Keary glacier. The part of the valley occupied by the lake bears a hanging relationship to the continuation of the valley below, which at this point is joined by a tributary valley. Keary creek taps the lake and flows in a series of rock-falls and rapids through a deep box-canyon flowing into Bridge river opposite Rexmount. Such steps in the valley floor are no doubt due to the increased erosion brought about by the confluence of two or more valley glaciers at such points in the drainage system.

ROCK BENCHES AT THE CONFLUENCE OF STREAMS

In Bridge River valley, between Bridge and Hurley rivers, there is a broad rocky bench, the highest part of which is 4,000 feet above sea-level. Toward the north it slopes gently down to Bridge river, 1,500 feet below. Plate I clearly illustrates its bench-like character. To the south of the bench the valleys of Hurley river and Cadwallader creek come together at almost a right angle. The coalescence of the glaciers of these valleys resulted in the spreading of the ice mass to the west and to the east, and the erosion induced in this way widened the valley by planing down the divide between Bridge and Hurley rivers. To the south of the bench Bridge river changes direction abruptly from east to north and the effect of its valley glacier was to lower the northern part of the bench with respect to the southern end, causing the slope.

On the eastern side of Hurley River and Cadwallader Creek valleys a similar bench has been formed by the junction of the glaciers of the Noel and Cadwallader Creek valleys with that of Hurley river. This bench holds a chain of small lakes and is covered with glacial drift.

DRAINAGE

The drainage of the Bridge River district, which, owing to the recency of glacial occupation is still in a youthful unorganized state, is eastward into the Fraser river. Bridge river and its chief tributaries, the Yalakom (North Fork) and Hurley (South Fork) rivers, and Cadwallader, Gun, and Tyaughton creeks drain almost the whole district, although a small area in the southeastern corner of the map-area drains into the Fraser by way of Anderson and Seton lakes and Cayoosh creek.

LANDSLIDES

On the south side of the valley of the Yalakom (North Fork) river the alluvium appears to be slowly creeping riverwards, as evidenced by the tilting and uprooting of trees, and by the landslides which have taken place within recent years. This section of the valley is particularly favourable for such slides on account of the decidedly youthful local topography, possessing an unorganized drainage system made up of a chain of lakes and creeks lying in a shallow longitudinal depression at the base of the rugged snow-clad Shulaps mountains. This drainage basin is parallel to the mountain range and Yalakom river, and is slowly draining into the latter. Owing to the dry climate, the ground-water is low in the valley and the water from the melting snow and ice above drains into the loose and porous fluvioglacial material. The boulder clay and clay-silt members, when saturated, form a plastic medium upon which the heavy overlying mass may flow riverwards. A small slip results in great masses of loose materials suddenly subsiding at the head and forcing the lower alluvium forward. The landslide surface is very rough with crevasses and uprooted trees, and is fringed with crumbling cliffs of alluvium where the head end of the mass subsided (Plate IV A).

Other landslides or "rock streams" of recent origin are common within the map-area, as for instance below Jones bluff near Rexmount; at the base of the diorite cliffs; between the Lorne and the Ida May properties; on Boulder creek; along Hawthorne creek; and in many other localities. Such "rock-streams" usually show signs of having been released suddenly in masses, rather than by gradual breaking away as in talus accumulations, and of having flowed in the manner of a liquid, which was fluid at first and then suddenly became viscid. The name "rock-glacier" has sometimes been improperly applied to such phenomena, but such a name implies slow movement as a viscid mass, such as a glacier.

PHYSIOGRAPHY

The Coast mountains and the plateaus of the Interior system to the east have been considered by many writers[1] to represent an upwarped and dissected Tertiary mature erosion surface or even a peneplain, the mountains having been uplifted higher than the plateau region, so that while the latter preserved its plateau character, the Coast mountains by reason of their greater relief, were extensively dissected, and thus became the present rugged, irregular mountain mass which has preserved its plateau features only in accordant summits.[2]

This accordance of summit level irrespective of the nature of the rocks composing the mountains is indeed a striking feature of the Coast mountains (Plate II A) and strongly suggests that the surface has been a peneplain.

Dawson,[3] however, does not believe that the region had been base-levelled. He states:

"The uniformity in height of the culminating points and ridges of the Coast range can have little if any, connexion with the original form and height of the elevated tract of the earth's crust out of which the existing ranges may have been carved by a prolonged process of denudation."

The close relationship which has been established by later writers between the original surface of the Coast mountains and the surface of the plateau region to the east, has shown that, in all probability, both regions were base-levelled at the same time. The antecedent nature of Fraser, Skeena, Stikine, and other transverse rivers[4] is, perhaps, the strongest proof of the identity of the two erosion surfaces.

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[1] Spencer, A. C., "Pacific Mountain System in British Columbia and Alaska." Bull. Geol. Soc. Am., vol. 14, 1903, pp. 117-132. Hayes, C. W., "An Expedition Through the Yukon District." Nat. Geog. Mag., vol. 4, p. 128. Cairnes, D. D., "Wheaton District, Yukon," Mem. 31, Geol. Surv., Can , 1912, p. 83.

[2] Brooks, A. H., U.S.G.S. Prof. Paper No. 45, p. 271.

[3] Geol. Surv., Can., Ann. Rept., 1895, p. 10 B.

[4] Spencer, A. C., loc. cit. p. 126.

According to Daly[1] the topography of the whole Canadian Cordilleras at the forty-ninth parallel may be accounted for by a one-cycle hypothesis. He states: "....the one-cycle hypothesis, whereby the one major episode of deformation (the Laramide) and one erosion cycle (including all Tertiary times) are postulated, seems competent to explain the present topography."

The accordance of summit levels, Daly believes, is the normal product of the forces,[2] which act upon a complex mountain range up to the mature age of its first erosion cycle, and so it might be attributed to:

"(1) Isostatic adjustment, which in the case of the Coast and Cascade mountains of British Columbia is maintained through the weakness (plasticity) of their foundations, so largely formed of granitic magma injected in a fluid state during or just after the last great period of folding in these ranges.

(2) Differential erosion during the period of alpine plications or the special erosive attack on each rising block from the moment of its first uplift. Such denudation is in some direct ratio to the height of its uplift, the higher summits being reduced while lower ones are still growing under the stress of mountain-building, resulting in a rough summit-level accordance.

(3) Later differential erosion and consequent further isostatic adjustment; the sculpture due to high-level glaciation; and the normal existence of a high-level tree-line, combine to render more perfect the accordance of levels inherited from the periods implied by (1) and (2)".

It is doubtful if such a nice adjustment of mountain blocks through isostasy, as Daly infers, is possible. Barrell,[3] in his work on "The Strength of the Earth's Crust", says that the idea of local and nearly perfect isostasy implies vertical weakness but lateral strength, since, were it not for lateral strength, the land-column would crowd against the sea-column more at the top than at the bottom, resulting in a glacier-like flow over the upper part of the sea-column, the land-column settling at the top and becoming shorter. The limit of such action would be given by the decreasing of the surface gradient, which would become so gentle as to stop the glacier-like flow. That such is not the case is shown by the presence of great foredeeps off the Pacific coast. The slope from the Andes to a depth of 7,500 metres has a submarine grade of one in eight.[4]

Other facts which are not in accord with such isostatic adjustment, are the towering heights of mount McKinley, mount Logan, and mount St. Elias, whose altitudes are about 20,000 feet above sea-level, and approximately 10,000 feet above the peaks of surrounding mountains.

It is probably true that the Coast mountains were peneplained, and the problem arises as to the geologic date when such a surface was developed. Drysdale,[5] from his study of the region southeast of the Bridge River map-area, has recognized what he believes to be the influence of a Cretaceous cycle of erosion. He states as follows:

"The Thompson and Fraser rivers are antecedent streams, whose courses transverse to the regional structures have persisted from occurrences developed during a Cretaceous erosion cycle. In the Coast range the advanced stage of dissection, which has left only accordant summit levels and a few possible plateau remnants, suggests that the former land surface was an uplifted erosion surface of an earlier age, rather than of Tertiary times."

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1 Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, p. 609.
2 Daly, R. A., Jour. of Geol., vol. 13, 1905, pp. 105–125.
3 Barrell, J., "Strength of the Earth's Crust," pt. VI, Jour. of Geol., vol. 22, 1914, p. 665.
4 Idem, p. 660.
5 Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1912, pp. 120–125.

It is difficult to conceive that remnants of a former erosion surface could have persisted since Cretaceous time. According to Barrell's "Measurements of Geologic Time Based on Radio Activity[1]" more than 30,000,000 years have passed since the beginning of the Tertiary period. It appears improbable then that records of Cretaceous erosion surfaces should now be found in the present topography.

The "few possible plateau remnants" referred to by Drysdale, in the region southeast of the map-area, are probably reproduced in the area under discussion, in the small uplands known as the Shulaps meadows of Shulaps mountains at the heads of Brett and Boulder creeks; in Cadwallader mountains west of Noel creek; and elsewhere. These small uplands below the peaks, however, appear to owe their preservation to their position relative to the drainage channels, or to their relatively greater resistance to erosion compared with the areas which have been more dissected.

According to Spencer,[2] "the development of the antecedent river systems and the production of the peneplain were contemporaneous."

At the mouth of the Fraser there is an Eocene delta (Puget group)[3] showing that the region drained by Thompson and Fraser rivers was undergoing active erosion at that time. The peneplain, therefore, was probably being developed in the Eocene.

Orogenic uplift at the close of the Eocene[4] elevated the whole region, but the Coast Mountains region was raised relatively higher than the plateau system. The rate of this differential uplift must have been exceedingly slow since the transverse antecedent rivers maintained their courses throughout.

In the Miocene, lavas were spread out over the surface modifying the existing topography by filling in the depressions.

In late Pliocene[5] or early Pleistocene time the region was again uplifted to almost its present altitude by epeirogenic movement and the present topography in large part developed. Pleistocene glaciation has left its mark distinctly upon the landscape in the broad U-shaped valleys, truncated spurs, and other effects of intensive glaciation. The youthful valleys and steep-walled canyons express the work of preglacial erosion.

FLORA AND FAUNA

The flora of the Bridge River map-area is very diversified, although the district is not heavily overgrown by vegetation, and a great part of it, on account of its high altitude and precipitous slopes, is practically bare. Timber-line, or the limit of timber growth, averages about 6,500 feet above sea-level. Below this elevation, the southern slopes support open and park-like stretches of good timber, whereas the northern slopes which are more protected from the direct rays of the sun and retain their winter's moisture for greater lengths of time, are more heavily timbered with a rather inferior and bushy forest.

[1] Barrell, J., Geol. Soc. Am., vol. 28, 1917, p. 846.
[2] Loc. cit., p. 131.
[3] Drysdale, C. W., Loc. cit., p. 128.
[4] Spencer, A. C., Loc. cit., p. 132.
Brooks, A. H., Loc. cit., p. 292.
Dawson, G. M., Bull. Geol. Soc. Am., vol. 12, p. 79.
[5] Brooks, A. H., Loc. cit., p. 291.

Through the kindness of Mr. Percy le Mare, District Forester, the following list of forest trees in the Lillooet district is given:

Douglas fir	Broadleaf maple
Western red cedar	Dwarf maple
Yellow pine	Dwarf juniper
Lodgepole pine (black pine)	Rocky Mountain juniper
Western white pine	Red cedar
White-bark white pine	Western birch
Hemlock	Mountain birch
Spruce (Engelmann)	Alder, white
Balsam fir	Alder, mountain
Poplar, aspen	White willow
White spruce	Western yew (scarce)
Western larch	Western dogwood (scarce)
Black cottonwood	Western serviceberry
Balm-of-Gilead	

Bateman[1] in his description of the flora of this district, states:

"The Douglas fir is the most valuable. It is usually confined to the south slopes of the hills below 3,000 to 2,000 feet altitude. Above this, it is replaced by the black spruce, balsam, and larch. The black spruce is the most plentiful of the trees, occurring in dense forests chiefly on the north slopes, and in the valley bottoms. It usually grows straight and clear, and stumps measure 2½ feet in diameter. The jackpine is of small size but very abundant along the gravelly river benches, and, in the district covered by lava ash, often forms impenetrable growths of trees not exceeding 6 inches in diameter. The cottonwood and poplar are usually confined to the valley bottoms and lower slopes."

A small collection of wild flowers made by C. W. Drysdale is reported upon by J. M. Macoun of the biological division, Geological Survey, Canada, as follows:

Equisetum lævigatum R. Br.	Smooth scouring rush.
Carex invisa R. Br.	
Salix nivalis Hock.	
Oxyria digyna (L.) Hill	Mountain sorrel.
Erigonum subalpinum Greene	
Silene acaulis L.	Moss campion.
Silene Macounii S. Wats.	Macouns' catchfly.
Arenaria capillaris Poir. var. *nardifolia* (Ledeb.) Rogel.	
Delphinium Menziesii DC	Larkspur.
Potentilla flabellifolia Hock	Cinquefoil.
Potentilla nivea L.	Snowy cinquefoil.
Epilobium anagallidifolium Lem.	Pimpernel, willowherb.
Phyllodece glandulifera (Hock.) Coville	White mountain heather.
Phyllodece empetriformis (Smith) D. Don.	Red mountain heather.
Polemonium humile Roem and Schult	
Phacelia sericea (Graham) A. Gray	
Myosotis sylvatica Hoffm. var. *alpestric* Koch	Forget-me-not.
Penstemon Menziesii Hock	Beard-tongue.
Veronica alpina L.	Alpine speedwell.
Mimulus Lewisii Pursh	Pink monkey-flower.
Pedicularis Langsdorfii Fisch. var. *lanata* Gray	Lousewort.
Erigeron compositur Pursh	
Selidago ciliosa Greene	Goldenrod.
Erigeron salsuginesus Gray	Daisy.
Arnica undescribed species	Arnica.
Sonecio triangularis Hock	Groundsel.

[1] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 191.

"Two of these plants, *Myosotis sylvatica* var. *alpestris* and *Pedicularis Langsdorfii* var. *lanata*, have not before been recorded west of the Rocky mountains south of the Yukon river, and their occurrence in the Lillooet region several hundred miles from where they had before been collected, is very remarkable.

"The *Arnica* is not represented in the herbarium of the Geological Survey and Dr. P. A. Rydberg is of the opinion that it represents an undescribed species.

"In addition to the above the following species were common but not collected. Lupine (probably *L. articus*), yellow monkey-flower (*Mimulus Langsdorfii*), phlox (*Phlox Douglassii*), wild gooseberry, indian paintbrush (probably *Castilleja miniata*), oregon grape (*Berberis aquifolium*), wild strawberry (*Fragaria bracteata*), wild raspberry (*Rubus strigosus*), Saskatoon or serviceberry (*Amelanchier florida*), wild onion (*Alluvium cernuum*)".

Bridge River district was formerly one of the most popular regions in Canada for big-game hunting, but of late years the abundance of game has appreciably diminished. In the less accessible parts, however, there are still to be found big-horn sheep, mountain-goat, mule-deer, and black, brown, and grizzly bear.

Shulaps mountains are the best hunting-grounds for the big-horn sheep, although a few still pasture in Bendor mountains in the vicinity of Piebiter and Roaring creeks. The latter region and the head-waters of Noel creek are the lairs of the grizzly bear. Cougars or mountain lions, wolverine, coyotes, beavers, and porcupines are also to be found; and on the open hillsides at high altitudes are to be found groundhogs and the little chief hares. Blue grouse, willow grouse, and ptarmigan are common. Nearly all the streams and lakes are well stocked with fish.

CLIMATE AND AGRICULTURE

Bridge River district has an agreeable climate, the summer months being warm and dry, and the winter months moderately cold in the valleys, but rather severe in the mountains. In the vicinity of Lillooet five degrees below zero is considered cold. Snowfall is slight and the rainfall moderate. The strong topographic relief of the district causes a marked variation in temperature and precipitation between the high altitudes and the larger and deeper valleys. The valleys have a dry summer climate similar to that of the western interior of British Columbia.

Hay, vegetables, and the hardier fruits are successfully grown at elevations not exceeding 2,000 feet in the Bridge River valley, and help to supply the local demand. Near Lillooet, fruit farming is aided by irrigation, and excellent varieties of fruit and vegetables are obtained, the most important kinds being apples, peaches, cherries, and plums.

INHABITANTS

The Lillooet and Chilcotin Indians inhabit the region, although there are not many residing within the limits of the map-area. A few of the former have small ranches along Bridge River valley, but their main habitations are at Mission on Seton lake, and at Lillooet. The Chilcotin tribe dwell in the region to the northwest of the map-area, in the neighbourhood of Chilko lake, and their interest in the map-area is that it constitutes a hunting-ground for them. They make periodic excursions into the Bridge River valley to harvest their winter's supply of deer, groundhogs, and berries, and thus conserve the resources of their own territory. These annual excursions by the aggressive highland tribe are the survival of what used to be, prior to the advent of the white man, warlike raids upon the more peace-loving and agriculturally-inclined Lillooet Indians of the lowlands. The old enmity between the two tribes still exists and there are no inter-marriages amongst them. The Lillooet Indians are quite skilful at basket-making and bead-work, but the Chilcotin Indians specialize more in tanning and making useful and ornamental articles out of deer skins and furs.

CHAPTER III

GENERAL GEOLOGY

REGIONAL GEOLOGY

General Statement

The sedimentary formations represented in the Coast mountains of British Columbia are dominantly of Pennsylvanian, Upper Triassic, Middle and Upper Jurassic ages.[1] Formations of Pennsylvanian age have been described in the Kamloops areas as "Carboniferous" by Dawson,[2] who found in his Cache Creek series the characteristic Pennsylvanian fossil *Fusilina*. Dawson refers to the possibility of Devonian strata being included in the series, but none has been identified in the region. Farther south, however, in southwestern Oregon, Diller[3] found Devonian limestones underlying the Carboniferous strata.

In the Atlin district of northern British Columbia, Cairnes[4] has described what has been called the Taku group, which he has tentatively placed in the Devonian on the basis of lithological similarity with the rocks of Dawson's Lower Cache Creek series. Here, as in the Cache Creek series, fossil evidence is scant or lacking, and the age is uncertain.

It is doubtful, therefore, if strata older than Pennsylvanian are present in the Coast mountains, and as Camsell[5] has pointed out, these rocks, although once of great areal extent, have been so intruded and covered by later rocks that they outcrop only in relatively small patches.

The outstanding event in the geological history of the Coast mountains, and the most important from the economic standpoint, was the latest Jurassic, mountain-making revolution, with the accompanying, or slightly deferred, granitic invasion and consequent mineralization. The great granitic batholiths of the Western belt form the axis of the Coast mountains, and are indicated on the geological map of Canada as being from 30 to 75 miles wide, and about 1,200 miles long. Future geological work, however, will probably greatly reduce this areal extent of the Coast Mountains batholith.

The uniformity in composition of the great batholiths is very striking. Locally they vary in composition from granite to diorite and gabbro, due to processes of differentiation in the original magma during intrusion, and in many cases differences in composition are due to separate intrusion of the many interlocking intrusive bodies.

Other intrusive rocks of the Coast mountains are gabbro, diabase, andesite, basalt, dacite, and porphyries, which occur usually in small dykes and sometimes as sills. For the most part they are genetically related to the intrusive rocks in their immediate neighbourhood.

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[1] Schuchert, Charles, "Paleogeography of North America," B.G.S.A., vol. 20, 1910. Plates 83, 87, and 89.
[2] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 37 B et seq.
[3] Diller, J. S., U.S.G.S. Bull. 546, 1914, p. 17.
[4] Cairnes, D. D., Geol. Surv., Can., Mem. 37, 1913, p. 52.
[5] Camsell, Charles, Geol. Surv., Can., Mem. 26, 1913, p. 33.

LOCAL GEOLOGY

The Bridge River map-area is situated on the eastern front of the Coast range and includes rock formations ranging in age from Pennsylvanian to Recent. The oldest formations are much metamorphosed sedimentary and contemporaneous volcanic rocks which are a continuation of those described by Dawson[1] as the Cache Creek series, and determined by him, on the basis of the fossil *Fusilina*, to be of Carboniferous (Pennsylvanian) age.

The Pennsylvanian rocks form the eroded core of an anticline which is flanked on both sides by the remnants of two series of Mesozoic formations of Upper Triassic and Lower Cretaceous ages respectively.

Between the Palæozoic and the Mesozoic formations there are remnants of serpentine volcanic rocks which covered the Palæozoic erosion surface to a great extent.

Plutonic rocks having the composition of quartz diorite and granodiorite and corresponding dykes intrude the Palæozoic and Mesozoic formations; stocks and dykes of augite-diorite cut only the rocks older than Lower Cretaceous.

A small area of volcanic rocks, chiefly of andesitic composition, outcrops within the limits of the map-area, and is referred provisionally to the early Tertiary.

Unconsolidated deposits of till, gravel, sand, silt, and clay of Glacial and post-Glacial age cover the bottoms and sides of the valleys in many places. The most recent of all deposits is a thin bed of volcanic ash which overlies even recent river gravels and forms a pulverulent mantle to the ground for extensive areas.

The mineral deposits of the area are the most important ones of Lillooet mining division. Of prime importance are the auriferous quartz veins that appear to be confined entirely to the augite-diorite, which on account of its hard, compact, and homogeneous nature is well adapted physically for the preservation of regular and persistent fissures. The fissures have served as channels for the heated alkaline carbonate solutions containing gold, which are believed to be the last manifestation of igneous activity associated with the diorite intrusion.

Other metalliferous deposits include silver-copper deposits, antimony deposits, and gold placers. Magnesite is found in certain localities, and at Jones bluff, near Rexmount, there are small seams of lignite coal. Of the non-metallic ores, magnesite is the most important. It is found associated with the serpentine rocks.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894.

GEOLOGICAL STRUCTURE OF BRIDGE RIVER MAP-AREA

The major structural feature of Bridge River district is a broad anticlinal arch or dome[1] trending northwestward across the map-area, and pitching at a low angle to the northwest. Bridge river has incised itself deeply into the Palæozoic core of this dome, exposing the contorted and faulted cherty quartzites, argillites, and metabasalt that occur near the base of the Bridge River series, whereas the northern parts of the tributaries, Tyaughton and Marshall creeks, have cut but slightly below the original erosion surface of the series, and a few remnants of the overlying Cadwallader series still remain in the vicinity of Liza lake.

Normal faulting, resulting in the down-slipping of blocks in the direction of the pitch of the anticlinal dome, has taken place in the Bridge River series, indicating tensional stresses in the earth's crust, and may be regarded as the recoil from a long period of intense compression.

Unconformably overlapping the eroded Palæozoic core, and forming the limbs of the plunging anticline, are serpentine volcanic rocks, and the remnants of two great series of Mesozoic formations; first the Upper Triassic Cadwallader series and, farther away, the Lower Cretaceous Eldorado series. The limbs of the anticline have been affected by secondary and minor folds resulting in complex distortion of the formations. The western limb, in which the principal ore deposits occur, dips west towards the Coast Mountains batholith, and is composed of serpentines and the Cadwallader series, which are now closely compressed, and deformed. They are intruded by two distinct types of igneous rock. First, by the ore-bearing augite-diorite, which was probably intruded immediately after the enclosing formations were strongly compressed, and after the uplift of the anticlinal dome; and later by the Bendor quartz diorite batholith, which made way for itself partly by magmatic stoping, in which great masses of the intruded formations were engulfed, and partly by squeezing apart the enclosing formations, which have become strongly schistose along the contact. The forces accompanying this later intrusion are believed to have been responsible in part for the movement along the fissures in the augite-diorite, and to have produced the sheeting and ribboning of the veins.

The eastern limb of the anticline is composed dominantly of the reddish weathering serpentine which underlies the Cadwallader series in small areas in Shulaps mountains. These rocks are intruded by flatly dipping, non-metamorphosed sills of Rexmount andesite porphyry.

Northwestward the anticlinal dome pitches under the Lower Cretaceous Eldorado series. To the west of the map-area this series has been closely compressed, overturned, and thrust-faulted by dynamic stresses from the west. To the northeast, however, on tracing the series transverse to the axis of the folds, the faulting and close folding give place to open folds of more simple structure.

Northwest of the map-area the somewhat folded Lower Cretaceous series are buried beneath unconformable, flat-lying, Tertiary effusives which have probably been removed by erosion from the Bridge River and other anticlinal axes.

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 80.

Table of Formations

Era	Period	Formation	Form and lithological character	Thickness
Quaternary	Recent	Volcanic ash Stream deposits	White andesitic pumice, gravel, sand, silt, and clay.	
	Pleistocene	Stream deposits Glacial deposits	Gravel, sand, silt, and clay. Boulder clay or till.	250
			Unconformity	
		Diorite porphyry dykes	Buff or red weathering porphyritic dykes, and sills with associated antimony deposits.	
Tertiary	Oligocene?	Rexmount porphyry	Light-coloured intrusive stock and sills of andesite porphyry. Volcanic breccia, tuff, and lava. The latter rests in places upon conglomerate, sandstone, and shales containing a few thin seams of lignite coal.	1,000 300
			Unconformity	
	Post Lower Cretaceous	Bendor quartz diorite	Intrusive batholith, cupola stocks and dykes of quartz diorite, granodiorite, and quartz diorite porphyry.	
	Lower Cretaceous	Eldorado series	Interbanded green sandstone and grey to black argillite with grey feldspathic sandstone and coarse to fine conglomerate. Thin beds of crystalline limestone and interflows of andesite.	15,000
			Unconformity	
	Upper Jurassic	Augite-diorite stock	Intrusive stocks of augite-diorite, containing gold-quartz veins.	
Mesozoic	Upper Triassic	Cadwallader series	Conglomerate, calcareous conglomerate and sandstone, crystalline limestone and dolomite. Andesitic and basaltic interflows (greenstone). Lenses of black fossiliferous limestone.	2,100
			Unconformity	
	Triassic (?)		Red-weathering serpentine rocks (volcanic breccia, porphyry, and dense rocks) (Shulaps volcanics).	2,000
			Unconformity	
Palæozoic	Pennsylvanian-Permian	Bridge River series	Mainly contorted, thin-bedded cherty quartzites separated by thin films of argillite schist, dark-coloured altered argillites, and crystalline limestone lenses and arenaceous schist. Flows of black and green metabasalt. In the vicinity of intrusive rocks the rocks have been metamorphosed to quartz-mica schist, squeezed conglomerate and sandstone, phyllite, talcose, sericitic, and chlorite schists.	9,500
			Total thickness	30,150

Pennsylvanian-Permian

BRIDGE RIVER SERIES

Distribution. The Bridge River series comprises nearly 75 per cent of the rocks of the map-area, being dominantly developed in the valley of Bridge river. The formations extend northward for several miles and disappear beneath Lower Cretaceous rocks and Tertiary volcanics. Eastward they may be followed 20 miles to Fraser river, where they pass into Dawson's Cache Creek series.

Lithology. "The Bridge River series[1] is composed of metamorphosed sedimentary formations with interbedded volcanic rocks. The chief sedimentary member of the series is a bluish grey chert which is much contorted in places. The chert grades into a cherty quartzite, traversed by small branching veinlets of white quartz generally normal to the bedding plane, and locally known as "crowfoot" quartzite. The cherty beds occur in bands one-half inch or more thick, and often form great thicknesses of strata. Each narrow band is separated from the next by thin layers of argillite, which give to the bedding planes a lustrous black or reddish colour. The cherty quartzites are very fine-grained like hornstone or chert, and are usually grey but range in colour from black to nearly white. They rapidly disintegrate on exposure and form large talus slopes rather than prominent outcrops."

The argillite members are composed of thin-bedded, dark argillaceous strata, highly siliceous in places, with a tendency to pass into chert. They are commonly schistose and in places show slaty cleavage. The series also includes a red-weathering arenaceous member well exposed on the northern slopes of Bendor mountains. In all probability it represents the beds near the top of the series. A series of crystalline limestone lenses, with a general east-west trend, occasionally form bold whitish outcrops throughout the whole area underlain by the Bridge River series. In colour, this limestone varies from dark grey to bluish grey and white. In places it is highly siliceous.

The volcanic rocks included in the series consist almost entirely of dense, compact, black altered basalts, which in places display pronounced pillow structure. They are often altered almost beyond recognition, and, upon exposure to weathering, rapidly disintegrate into talus slopes of crumbling greenstone. The basalt grades into light green to dark green, or almost black varieties of andesite, which can be distinguished from the basalts only by the aid of the microscope. In certain localities they are altered to chloritic schists and serpentine. The altered basalt outcrops present a dull appearance. Calcite occurs in irregular veinlets throughout the sheared mass, and in vesicles in the amygdaloidal varieties. The essential minerals of the lava, prior to metamorphism, were plagioclase, feldspar, pyroxene, hornblende, and possibly olivine, but the rock now consists of an aggregate of calcite, kaolin, chlorite, serpentine, sericite, zoisite, and iron oxides with only traces of the original minerals.

[1] From description by C. W. Drysdale. Unpublished manuscript.

Thickness. Owing to the highly metamorphic character of the sedimentary and igneous formations composing the Bridge River series, it is difficult to measure its thickness. The series has been so complexly folded and sheared that it is impossible to determine whether the observed dip of a bed is normal or overturned. No particular bed was found that could be used as a datum plane, nor was it possible to recognize either a base or a top to the series. Near the eastern edge of the area, where the chert member was found least interbedded with meta basalt flows, an approximate thickness of 1,000 feet was measured, but neither top nor bottom of the series was observed. Thirty miles east of the map-area, between Fraser and Bonaparte rivers, the formation corresponding to the Bridge River series, and with which it has been correlated, is the Cache Creek series. These rocks, first studied by Dawson,[1] present the same difficulties when one attempts to measure them. Dawson emphasizes "the extremely unsatisfactory condition of the rocks of the Cache Creek series for all purposes of measurement." However, he has estimated the minimum thickness of the series (exclusive of the massive limestone member, which is not here present) in the western part of the Kamloops sheet to be 6,500 feet.[2] The Bridge River series is estimated to be about 9,500 feet in thickness.

Structural Relations. The Bridge River series forms the Palæozoic core of an anticline that pitches northwestward at a low angle beneath the overlapping Mesozoic sediments. The strike of the formations varies a great deal from place to place, but their dominant direction is east and west or west-northwest and east-southeast with steep dips. The series is separated from those of Mesozoic age by a profound unconformity, indicative of considerable diastrophic disturbance at the close of the Palæozoic era. Complex folding is a striking feature of the series. Not only are the formations folded, but the less competent cherty members are minutely contorted, and the argillites and the contemporaneous volcanics have yielded to the pressure by mashing, shearing, and mineralogical alteration.

The Bridge River series was deposited as a series of thin sandstone beds one or more inches thick, with thin interbeds of mud. It has since been subjected to intense dynamic metamorphism, which has greatly obscured the original structures. The volcanic rocks, however, retain in some places pillow structure. The pillows are round or lens-shaped, from a few inches to 3 feet in diameter, and, on weathering, tend to exfoliate. The spaces between the compact pillows are filled with the brecciated lava, showing that the structure is an original one. Near the outer surfaces, the pillows are denser and darker in colour than in the interior, and more inclined to be vesicular. The origin of the pillow structure may be ascribed to the influence of water on subaqueous eruptions, or to the flow of lava into bodies of water or intrusion into water-bearing silts.[3] The occurrence of the amygdules near the upper surfaces of the pillows

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, pt. B.
[2] Idem, p. 46 B.
[3] Lewis, J. V., Bull. Geol. Soc. Am., vol. 25, 1914, p. 595.
Geikie, Sir A., Textbook of Geology, 4th ed., London, 1903, vol. I, p. 306; vol. II, p. 760.
Harker, A., Natural History of Igneous Rocks, 3rd ed., New York, 1909, p. 64.

points to a supersaturation of volatile constituents in the original lava, which have separated from the liquid interior in advance of crystallization.[1] Some of the volcanic rocks exhibit amygdaloidal structure due to vesicles that were present at the time of extrusion. For the most part the amygdules are lens-shaped, due either to flowage of the lavas while in a viscous state, during which the gas pores were drawn out; or to distortion of the rocks during regional metamorphism. The filling of the vesicles is calcite.

Regional metamorphism has produced a curious structure in certain parts of the cherty quartzite members. Some of these thin beds of chert have been broken into fragments which have been elongated and flattened, and appear as disconnected and overlapping lenses several inches in length surrounded by the argillite which has flowed around the harder kernels of chert.

Age and Correlation. No fossils were found in the Bridge River series so that its age could not be definitely determined. Lithologically and structurally, however, the rocks are identical with those farther to the east, described by Dawson[2] as the Cache Creek series, and found by him to contain the Pennsylvanian fossil *Fusilina.* In this connexion Dawson says: "the lower portions of the Cache Creek formation may be older than the Carboniferous period. The very general blending of the Carboniferous and Devonian systems in the west shows that no well-marked line need be anticipated at the base of the Carboniferous."

The upper formation of the Cache Creek series, namely the massive crystalline limestone member, is notably absent in the Bridge River map-area; in fact it is not developed to any important extent west of Fraser river.

The formations of the Bridge River series were included in the series described by Bateman[3] as the Cache Creek series. This writer indicated the probable occurrence of Triassic and Jurassic rocks in his Cache Creek series, and later Drysdale[4] differentiated the Mesozoic rocks from the Palæozoic, naming the latter the Bridge River series, and assigning it to the Devono-Carboniferous.

The correlation of the Bridge River series with the Cache Creek series in which the characteristic Pennsylvanian fossil *Fusilina* was found, and in which no Devonian fossils were discovered, places both series more definitely in the Pennsylvanian than in any other period. *Fusilina* is known to occur in the Permian also, and in America a single sea transgression continued throughout Pennsylvanian and into early Permian time.[5] The Bridge River series, therefore, is considered to be a westward continuation of the Cache Creek series of the Fraser River region east of the map-area, and hence is correlated with it, and also with the Pend d'Oreille[6] series at the International Boundary. Its age is considered to be Pennsylvanian-Permian.

[1] Lewis, J. V., Bull. Geol. Soc. Am., vol. 25, 1914, p. 651.
[2] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, pp. 37 B–49 B.
[3] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 192.
[4] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 78.
[5] Pirsson, L. V., and Schuchert, C., loc. cit., p. 732.
[6] Daly, R. A., loc. cit., p. 275.

BRIDGE RIVER SCHIST SERIES

A series of schistose rocks resembling the Bridge River series, but differing from them in the amount of metamorphism that they have undergone, forms a zone varying in width from 1 mile to 2 miles around the northern, western, and southwestern edges of the Bendor quartz diorite batholith.

The series is made up almost entirely of various kinds of schists, the commonest types being quartz-mica, and chloritic schists, together with squeezed argillites and thin-bedded quartzites. Lenses of crystalline limestone occur rather haphazardly throughout the series.

The original structures of the rocks have been so changed that they are difficult of interpretation. In general, however, the members of the series strike parallel to the sides of the Bendor batholiths and to the strike of the Bridge River series proper, except in the eastern and southeastern parts.

Age and Correlation. No fossils were found in the schist series, and so the definite correlation is a matter of doubt. The rocks have apparently suffered more metamorphism than those of the Cadwallader series, and less markedly than the Bridge River series proper. Lithologically and structurally they resemble certain members of Dawson's Cache Creek series in the neighbourhood of Lillooet, Cayoosh creek, and Texas creek, where the schistosity is accounted for by the proximity of the rocks to granitic intrusives.[1] In the upper Okanagan valley[2], also, the formations which are correlated with the Cache Creek series are rendered schistose in the neighbourhood of igneous intrusions. On account of the resemblances to the Cache Creek series, the schist series is included in the Bridge River series and assigned to the Pennsylvanian-Permian period.

Triassic(?)

SERPENTINE ROCKS (SHULAPS VOLCANICS)

Distribution. The serpentine rocks are dominantly developed in Shulaps mountains, extending northward along Noaxe creek beyond the map-area. On Marshall ridge in the vicinity of Liza creek, and farther west on Pearson and Taylor creeks, other smaller bodies occur. In the southwest corner of the sheet, in the Cadwallader mountains, well-defined, narrow belts of serpentine conform with the northwest structural trend of the formations of the region.

Lithology. Profound alteration is the chief characteristic of the serpentine rocks, and hence interpretation is often difficult. Two definite phases, however, may be recognized, namely, porphyritic and dense rocks. The porphyritic phase appears to have been composed of such rocks as olivine-gabbro porphyrite, or the porphyritic equivalent of peridotite. These rocks, when weathered, have a greyish-brown appearance, and in the porphyry the more resistant pyroxene phenocrysts appear in relief, presenting a "warty" surface. The freshly broken surface presents a dull bluish black appearance, which is relieved by the glistening surfaces of the pyroxene crystals.

The dense serpentine rocks are more altered than the porphyritic rocks and were probably originally olivine basalts. Their weathered surfaces are usually red-brown to brown-yellow, except where thay have been sub-

[1] Dawson, G. M , Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 43 B.
[2] Smith and Calkins, U.S.G.S. Bull. 235, 1904, p. 23.

jected to crushing forces. In the latter case the rock has been minutely sheared, the slip-planes being covered with fine films of serpentine, which gives to the rock a greasy feel. Disintegration by weathering is accomplished by the exfoliation, or scaling-off, of the fragments, and the brilliant colouring of the slickensided surfaces gives to outcrops a characteristic blue-green or yellow-green colour.

The dense serpentine rocks show flow structure and often form a volcanic breccia, the angular inclusions being principally of quartzite, but in some places, as in Taylor creek, they are of limestone.

Economic Importance. In some places the serpentines have been altered by surface waters to magnesite. Such deposits, which occur in the vicinity of Liza lake, are traversed by innumerable veinlets of chalcedony or secondary quartz, which has been liberated in the alteration of serpentine to magnesite. Further reference to the origin of the magnesite deposits is made in the chapter on economic geology.

Chromite in small segregations, and veinlets of asbestos have been found in the serpentines. The chromite contains microscopic diamonds.

The serpentine rocks, which are here grouped as a lithological unit of common geological age, include both the Shulaps volcanics and Big Sheep volcanics of Drysdale.[1]

Structure and Origin. Scattered over the broad surface of the Bridge River series on Marshall ridge and Pearson creek, are small, isolated patches of serpentine rocks. These display flow structure and hold angular inclusions of the underlying rocks. This evidence of volcanic origin for these rocks is strengthened by the occurrence of long, narrow belts of serpentine bordering and underlying the belt of Cadwallader series in Cadwallader mountains.

Evidence of the source of the volcanic flows may be found in the porphyritic serpentines of Shulaps mountains. These rocks, besides being porphyritic, have the somewhat crystalline appearance of some plutonic rocks. This points to a condition of slow cooling requiring higher initial degrees of heating. It is believed that in this locality exists the volcanic pipe which emitted the outlying flow rocks. Dykes may also have contributed to the supply of flow rocks, as in the southwestern corner of the map-area.

Age and Correlation. From the above it is concluded that the serpentine rocks were extruded over the erosion surface of the Bridge River series of Pennsylvanian-Permian age, before the Cadwallader series of Upper Triassic age was laid down. The age, therefore, is post-Pennsylvanian-Permian and pre-Upper Triassic, and will be assumed tentatively to be Triassic. They may be correlated with the serpentines of the Coquihalla district to the south, where C. E. Cairnes[2] found a narrow belt of serpentine traversing the district in a northwest-southeast direction, and lying between a chert and greenstone series which seems quite definitely equivalent to Camsell's Hozameen series[3] (Carboniferous), and another series of sediments probably of later age.

Another interpretation of the structure may be the recognition of the serpentines as sills along the unconformable contact of the Bridge River series and later formations. This would make the serpentines later than the Cadwallader series. The writer, however, inclines toward the first interpretation.

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 78.
[2] Personal communications.
[3] Geol. Surv., Can., Sum .Rept., 1911, p. 118.

Upper Triassic

CADWALLADER SERIES[1]

Distribution. The Cadwallader series is restricted in its development in the region. A narrow belt occurs along the western part of the map-area extending almost across the sheet on the western limits of the Bridge River anticline, and several isolated patches occur on Shulaps mountains, on the northeastern limb of the anticline.

Lithology and Thickness. The rocks composing the series include great thicknesses of basaltic and andesitic greenstone, conglomerate, sandstone, and shales with subordinate thin-bedded limestone and dolomite. The greenstones occur in the lower part of the series, and are fresh and light-coloured in appearance, contrasting with the volcanic rocks of the Bridge River series. The pebbles of the conglomerate vary in size from ¼ to 4 inches in diameter, and are made up principally of quartzites, with some limestone and serpentine pebbles. The conglomerates give place above to thick-bedded massive sandstone of a greenish-grey colour, which in turn is overlain by arenaceous and argillaceous shales that show ripple-marks and mud-cracks. The total thickness of the series at present exposed is about 2,100 feet.

Structure. The physical conditions under which the sediments of the Cadwallader series were deposited must have been exceedingly variable. From the general character of the sediments it is inferred that they were laid down in large part as delta deposits at the mouths of rivers, flowing from a land surface of marked relief into a shallow continental sea. The topographic relief, which was greater than that which existed during Palæozoic time, was probably due to crustal deformation at the close of the Palæozoic era.

Igneous activity contemporaneous with sedimentation accounts for the numerous interflows of andesite and basalt. Pillow structure is a pronounced feature of the basalts in certain localities. The pillows vary in size from a few inches to 3 feet in diameter. The degree of vesicularity of the pillows is variable, some showing little if any signs of it, whereas others are markedly vesicular, notably at their centres. The vesicles are filled with calcite, and the pillows are often cut by small calcite veins. The spaces between the pillows are in some cases filled with a fine breccia of basalt. In general, the pillows show signs of flattening, the broader surfaces conforming approximately with the stratification of the adjacent sedimentary rocks, thus giving a clue to the structure of the series. The pillow structure is thought to be due to the influence of water upon subaqueous eruptions, or to the flow of lava over water-bearing silts[2] which have made up the enclosing slates of the Cadwallader series.

The principal belt of Cadwallader series occupies a downfold of the Bridge River series on the western limits of the anticline. This downfold was probably accomplished during the revolution at the close of the Jurassic, and the result has been to cause the series to dip steeply. By virtue of the uplift of the anticline a great part of the series has been removed by erosion.

[1] The Cadwallader series as defined by Drysdale included part of the Bridge River series, and the serpentine rocks (Shulaps volcanics).

[2] Lewis, J. V., "Origin of Pillow Lavas." Bull. G.S.A., vol. 25, No. 4, 1914, p. 595.

Age and Correlation. The lower part of the series, consisting of great thicknesses of greenstone and agglomerate, correspond in a general way with the Sutton formation of the Vancouver group, on Vancouver island, and with the Valdez formation[1] on the Pacific coast, which consists of massive flows of pyroxene andesites and basalts that display pillow structure in places, volcanic agglomerates, and tuffs. These rocks are conformably overlain by argillites, limestones, quartzites, with intercalated sheets of diabase, and andesite, belonging to the Parson Bay group. *Pseudomonotis subcircularis* was found in the Parson Bay rocks, and determined their age as Upper Triassic.

In the upper members of the Cadwallader series, and confined to lenses of black limestone, the following fossils were collected by the writer and identified by Hervey W. Shimer.

Isastrea whiteavesi C. and S.
I. vancouverensis C. and S.
Calamophyllia suttonensis C. and S.
C. dawsoni C. and S.
Montlivaltia cf. *gosaviensis* Frech.
Terebratula suttonensis C and S.
Pleuromya pearsonensis n. sp.
Megalodon canadensis n. sp.
Myophoria sp.
Turcicula mccanni n. sp.

According to Dr. Shimer, this fauna is similar to that of the Sutton of the Vancouver group, Vancouver island,[2] which was formerly believed to be of Jurassic age. The later discovery of what is apparently the same fauna in Shasta county, northern California, in northeastern Oregon, and in Nevada,[3] where it occurs in known succession, very definitely places the horizon as lower Noric of the Upper Triassic. More recently G. C. Martin,[4] after his study of a similar coral fauna on Iliamna lake, west of Cook inlet, Alaska, has provisionally correlated the Sutton formation of Vancouver island with the lower Noric coral reefs.

Regarding the fossils found in the Cadwallader series, Dr. Shimer states:

"A consideration of the faunas found at the type locality of the Sutton, and in the equivalent beds on Pearson creek, leads to a similar conclusion as to age. In the latter region occur the majority of the type locality species, besides some new forms. Of these latter *Montlivaltia* cf. *gosaviensis* belongs to the classic Noric coral reefs; the Zlambach beds of Salzkammergut district of the northern Alps; while the large pelecypod *Megalodon*, abundant here, is characteristic of the Upper Trias of the Alps, and is especially abundant in the Noric (Dachstein and Hauptdolomite) of the northern Alps. Some of the other corals, also, have near relatives in the Alpine Zlambach beds."

"The Pearson Creek fauna is of the same age as that of the Sutton formation of Vancouver island; nearly all species are identical. These are in turn closely related to the coral reef faunas of Iliamna lake, southern Alaska, of Baker county, northeast Oregon, of Shasta county, northern California, and of Esmeralda county, southwestern Nevada."

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[1] Bancroft, J. A., Geol. Surv., Can., Mem. 23, 1913, pp. 68–77.
[2] Clapp, C. H., and Shimer, H. W., Proc. Boston Soc. Nat. Hist. 34, pp. 421–438, 1911.
[3] Smith, J. P., "The Occurrence of Coral Reefs in the Triassic of North America"; Am. Jour. Sci. (4) 33, pp. 92–96, 1912.
[4] Martin, G. C., "Triassic Rocks of Alaska," Geol. Soc. Am., Bull. 27, pp. 685–718, 1916.

Jurassic

AUGITE-DIORITE STOCK

The augite-diorite stock is the chief country rock of the gold-quartz veins in the region, so that its distribution and extent are of special economic importance to the prospectors of Bridge River district. Much of the formation is hidden by a mantle of glacial drift and volcanic ash.

Distribution. The main areas of augite-diorite may be readily seen on the geological map, and the rock occurs as irregular stock-like intrusive masses elongated in a northwesterly direction and striking with the enclosing Cadwallader series. The most important part of the intrusive, in which the Pioneer, Coronation, and Lorne mines are situated, extends from a short distance south of the Pioneer mine to a little north of the Lorne mine, where the mass pinches to a series of narrow dykes, but widens again near the mouth of Hurley river (South Fork of Bridge river), crossing Bridge river near the bridge. This belt has its maximum width in the vicinity of Blackbird creek, where it is 3,000 feet wide. On the south side of Cadwallader creek, about a mile above the Pioneer mine, an extension of the belt occurs, which has been traced southeastward to beyond Chism creek.

A detached belt of augite-diorite over 3,000 feet wide occurs on the north side of Bridge River valley at the Wayside mine. This has not been traced southward across the river. Outcrops occur in three places on the shores of Gun lake, two bodies being on the east side and one on the west. These possibly may be connected underneath the waters of the lake. Another small body occurs near Little Gun lake. The body on the west side of the lake extends northwestward to Gun creek just to the west of the map-area. A small area of this rock outcrops above the wagon road near Fivemile creek, and may be traced across Bridge river. "Float" of augite-diorite was found at the northwest end of Bendor mountains above timber-line, and in the valley of Yalakom river (North Fork of Bridge river), so that with more detailed work other areas of this intrusive may be added to those already mapped.

Petrology. The augite-diorite ranges from dark greenish-grey to almost black, and from finely granular to coarsely granular. The lighter-coloured varieties are generally finer grained than the darker varieties which owe their colour to large crystals of dark green hornblende and chlorite. The ferromagnesian minerals in the coarsely granular varieties predominate over the other constituents. The feldspars appear to fill the spaces between the ferromagnesian minerals and sometimes show glistening cleavage faces, but to a considerably less degree than the ferromagnesian minerals. Neither biotite nor quartz is visible to the naked eye.

Under the microscope the darker and more coarsely crystalline varieties are observed to be made up of hornblende, augite, plagioclase, orthoclase, and quartz, with chlorite, secondary hornblende, kaolin, zoisite, sericite, and calcite as alteration products. Apatite, titanite, and iron oxide are present as accessory minerals. The hornblende is light green and pleochroic. It is idiomorphic with respect to the plagioclase and exhibits a cleavage parallel to the prismatic faces, showing that it is a primary constituent of the rock and not paramorphic after augite. It occurs also intimately intergrown with the pyroxene, and in places as an alteration of that mineral. To a great extent it has been altered to chlorite. Augite is present in colourless short prisms with octagonal basal sections. It is very much decomposed, and has been largely altered to hornblende and chlorite, although some individuals still contain remnants of augite at their centres. The plagioclase feldspars are usually allotriomorphic with respect to the augite and hornblende, filling the spaces between them, but sometimes they occur in small lath-shaped crystals within the hornblende. They are twinned according to the albite and Carlsbad laws, and rarely show a combination of the two twinnings. Measurements of extinction angles of the plagioclases according to the statistical method showed them to be andesine ($Ab_{55}\,An_{45}$). Zonal structure of the crystals was not observed. Orthoclase is present in very small amount and occurs as interstitial fillings intergrown with quartz, which also occurs sparingly. Biotite was not observed, but may have been present originally and now altered to chlorite.

A finer-grained phase of the augite-diorite than that which has just been described occurs on the northwest edge of Gun lake. It is dark greenish grey and has a general "pepper and salt" appearance. Microscopic examination shows that pyroxene is absent, but this may be accounted for by the natural alteration of that mineral to hornblende by dynamic metamorphism. Evidence is lacking, however, to prove that pyroxene existed as a primary constituent. The hornblende is idiomorphic with respect to the plagioclases and is largely altered to chlorite, calcite, and iron oxide. The plagioclase individuals show no zonal structure, and are small and lath-shaped. They are twinned according to the albite, Carlsbad, and pericline laws, and many crystals show a combination of albite and Carlsbad twinnings. Sections of these latter cut normal to (010) were examined and the extinction angles showed them to have the constant composition andesine ($Ab_6\,An_4$). They are altered in part to zoisite, quartz, and sericite. Orthoclase intergrown with quartz is sparingly present as interstitial fillings. Apatite, titanite, zircon, and iron oxide occur as accessories; biotite appears to be absent.

Near the gold-quartz veins the augite-diorite has been greatly altered by hydrothermal solutions, and has been leached of its ferromagnesian minerals, so that next to the veins the rock is light grey in colour and in places heavily impregnated with sulphides. This alteration of the wall-rock will be discussed more fully in the chapter on economic geology.

Structure. The entire augite-diorite mass has undergone considerable deformation, as is shown by rock fracturing and cementation by veins of quartz, and also by tiny veinlets of quartz and feldspar, which traverse the rock in all directions. Two major systems of fracturing and faulting are observed, one set lengthwise of the intrusive, and the other transverse. There are also other less important and irregular minor systems of fissuring, which in places fault the other systems. Further discussion of the fissuring may be found in the chapter dealing with economic geology.

Origin. The elongated stock-like form of the augite-diorite intrusive, with pinches and swells and irregular dyke connexions, suggests that the different belts on the western limb of the Bridge River anticline represent a single narrow intrusion. The separate outcrops in that case may be expected to coalesce at depth, and represent the partly denuded top of an intrusive stock of considerable size with a roof of irregular form. At the contact with the enclosing formations, the boundaries of the intruded rocks dip outwards with depth. The intrusion possibly represents a very early injection of a basic marginal product of differentiation from the Coast Mountains batholith into the cover rocks after they had been folded and sheared.

Age Relation (of the Augite-diorite Stock). The augite-diorite stock is believed to be older than the Bendor quartz diorite of post-Lower Cretaceous age, for the following reasons:

The augite-diorite is intimately related to the Cadwallader series, and has to some extent been subjected to the same deforming stresses, whereas the Bendor quartz diorite is not metamorphosed, and its intrusion is believed to have contributed to later deformation of the augite-diorite.

Gold-quartz veins are confined to the augite-diorite, and because of the proximity of the Bendor quartz diorite, it is reasonable to suppose that similar veins would have occurred in the latter, had it been in place at the time.

The intrusive is not found cutting formations younger than the Cadwallader series, whereas the Bendor quartz diorite intrudes strata of Lower Cretaceous age. The augite-diorite is younger, therefore, than the Upper Triassic Cadwallader series and older than the Lower Cretaceous Eldorado series; probably it was intruded at the close of the Jurassic and may be genetically related to the earliest evidences of the Coast Mountains batholith.

DYKES ASSOCIATED WITH THE AUGITE-DIORITE STOCK

Albitite Porphyry Dykes

Traversing the augite-diorite are a great number of fine-grained, light-coloured porphyritic dykes. They are closely associated with the gold-quartz veins, often occupying the same fissure, either paralleling one another, as at the shaft vein of the Lorne mine, and at the Pioneer mine, or intersecting, in which case the quartz veins are observed to be younger. The latter case is illustrated at the Wedge vein of the Lorne mine. Similar dykes occur also on the Wayside, Blackbird, and Ida May properties.

Petrography. The albitite porphyry is mostly light grey, although upon exposure to weathering it becomes brownish red or buff, from the oxidation of the iron oxide which it contains. At the Wayside mine it is finely granular and the dyke has been sheeted by movement after its consolidation, so that it is banded and has the stratified appearance of a fine-grained sandstone. Usually, however, it is exceedingly fine-grained with phenocrysts of feldspars and, occasionally, quartz.

Under the microscope the albite porphyry is seen to be made up almost entirely of albite in very small interlocking grains and tabular crystals, many of which show albite twinning. Cutting the albite grains are many small acicular crystals, often in radiating or fan-shaped tufts, which are pale green and pleochroic, and which occur as an alteration of the albite. They are sericite. The feldspar phenocrysts are mostly idiomorphic and as a rule show albite twinning with extinction angles up to 15 degrees. The low index of refraction determines them to be albite. They are clouded with kaolin. Pyrite was present in most of the sections examined, but at the Wayside mine in specimens taken at the surface the pyrite has been oxidized to limonite.

Albite rocks were first described under that name by Turner[1], who found them associated with serpentine and greenstone in the Mother Lode district in the Sierra Nevada. Here they occur as dykes consisting essentially of albite in granular aggregates, with quartz sometimes entirely absent, but at other times occurring plentifully in the same dyke. Muscovite may or may not be present, and iron oxide, apatite, and garnet are sparingly distributed. In that region the dykes are directly associated with the gold deposits of Eldorado county; and at Sonora, the dykes themselves, or altered parts of them, associated with infiltrated quartz, form the lode containing the gold and sulphides. (Assays of the albitite dykes in the Bridge River district yielded traces of gold.)

Similar rocks of aplitic habit consisting essentially of albite, with small amounts of quartz, muscovite, apatite, and magnetite, have been found in the northern Urals,[2] where they are associated with gabbro, and in Australia[3] with granite where the albitites are coarse-grained.

Origin of the Albitite Porphyry. Bowen[4] has shown experimentally that if a melt of plagioclase of the composition $Ab_1 An_1$, at 1,500 degrees Centigrade, be cooled with excessive slowness, crystals of composition $Ab_{19} An_{81}$ begin to separate out at 1,450 degrees and theoretically the composition of the crystals will change continuously toward $Ab_1 An_1$ and their amount will increase down to 1,287 degrees, when the whole mass will consist of crystals having the composition $Ab_1 An_1$. The liquid remaining will continue gradually crystallizing below 1,287 degrees, and, if the cooling is at the proper rate, the final crystals may be nearly pure albite $Ab_{98.5} An_{1.5}$. Bowen has also shown that under the proper circumstances a mixture having the original composition of a gabbro, i.e., 50 per cent diopside and 50 per cent bytownite, may yield a final liquid of more than 90 per cent albite.[5]

Reasoning along these lines we may conceive that crystallization went on at an exceedingly low rate within the magma that produced the augite-diorite, until the remaining liquid consisted almost entirely of albite. Fracturing then occurred in the consolidated augite-diorite and the albitite dykes were injected into the fissures.

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[1] Turner, H. W., 17th Ann. Rept. U.S.G.S., 1895-6, pt. 1, pp. 663-665.
[2] Duparc and Pearce, Compt. Rendu. 140, 1908, p. 728.
[3] Tilley, C. E., Trans. Roy. Soc. of S. Australia, vol. XLIII, 1919, pp. 316-341.
[4] Bowen, N. L., "Melting Phenomena of Plagioclase Feldspars," Am. Journ. Sci., vol. 35, 1913, p. 597.
[5] Jour. of Geol., vol. 23, 1915, Supp. to No. 8, p. 39.

Diabase Dykes

Dykes of diabase were found along the ridge separating Gun lake and Bridge river, cutting the rocks that enclose the augite-diorite mass upon which the Wayside mine is located. It is dark greenish-grey in colour and is exceedingly fine grained and difficult to break with the hammer.

Under the microscope it is seen to be composed principally of lath-like plagioclase feldspar of the composition of andesine (Ab_{55} An_{45}) and a ferro-magnesian mineral in about equal proportions. The dark mineral, which may have been either augite or hornblende, or both, has been completely altered to chlorite, and acts as a matrix for the tabular or bladed unoriented feldspar, giving the rock a typical ophitic texture. Calcite in minute veinlets and as an alteration product, occurs plentifully. The rock may be classified as a diabase.[1]

Lower Cretaceous[2]

ELDORADO SERIES

Distribution. The Eldorado series, as the name suggests, has its greatest and typical development in the vicinity of Eldorado creek, in the extreme northwestern corner of the map-area. This creek is not shown on the map, but its location may be easily fixed by stating that it has its headwaters on the west side of the divide at the head of Taylor creek, and flows in a general westerly direction emptying into Gun creek. The series extends far to the northwest between Gun and Tyaughton creeks, where it is covered by Tertiary effusives. The formations appear again in the extreme northeastern corner of the map-area north of Yalakom river. The open folded series extends from this point northeastward to within a few miles of Fraser river.

Lithology. The rocks of the Eldorado series are chiefly interbedded green and dark grey sandstones, some of which are feldspathic, grey or black argillites in part silicified, and slates. Some of the sandstone beds measure 40 feet in thickness. Massive, compact conglomerate beds up to 50 feet in thickness occur along with the sandstones and argillites. Their pebbles vary in size from a fraction of an inch to one foot in diameter, and include representatives of almost all the older rocks, the cherty quartzites being particularly noticeable. There are also pebbles of green andesitic rocks, feldspathic sandstone, and argillite probably derived from the Cadwallader series; and pebbles of what appears to be augite-diorite are present, although microscopic evidence on this point is lacking. The pebbles are well-rounded and water-worn, but are heterogeneously arranged, indicating lack of sorting. The matrix is arkosic in character, cemented by calcite. Crystalline limestone occurs rather sparingly in the series, and forms differentially weathered light-grey outcrops. Interflows of a dense andesite occur at certain horizons.

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[1] Iddings, J. P., "Igneous Rocks," vol. 1, p. 377.
[2] The Lower Cretaceous rocks were first described by A. M. Bateman, Geol. Surv., Can., Sum. Rept., 1912, p. 192. See also, Mackenzie, J. D., Geol. Surv., Can., Sum. Rept., 1920, pt. A, pp. 74 A-76 A.

Thickness. A section of the Eldorado series was measured along the ridge north of Taylor creek and was found to contain not less than 15,000 feet of strata, together with some sills of granodiorite. Neither the top nor the bottom of the series was reached.

Structure. The alteration of the different members of the Eldorado series, with marine fossils at certain horizons and the absence of ripple-marks and mud-cracks, suggests a subaqueous origin for some of the beds, with climatic oscillation. The original structure of the sediments resembles in many respects that of the upper part of the Cadwallader series.

The members of the Eldorado series have been subjected to compressive orogenic stresses, which have thrown them into a series of folds, accompanied by some faulting along their contact with the rocks of the older series. The mountain-making forces have acted from the west, so that near the Coast Mountains batholith the series is strongly compressed and locally overturned and faulted, whereas toward the Fraser plateau, the close folds give place to open folds and more simple structure. The axes of the folds are northwest, or roughly parallel to the axis of the Bridge River anticline. The close relation of erosional valleys to anticlinal structure is well expressed in the local topography, the formations generally dipping into the hillsides. Considerable thrust faulting has taken place in the northwest corner of the map-area, and has rendered the structural relations between the Eldorado series and the Cadwallader series difficult of interpretation. The faults strike in the same direction as the folds, and appear to be of the reverse or thrust type. One of the principal faults is that along Tyaughton creek north of Tyaughton lake.

Age and Correlation. No fossils were found within the limits of the Bridge River map-area, although a collection was made in 1912, by A. M. Bateman, from limestone beds in the Eldorado series just outside the map-area. He reports as follows concerning the discovery.[1]

"In a few of the beds, in restricted places, some marine fossils were found of sufficient diagnostic value to determine the age of the rocks as Lower Cretaceous or Comanchie. The identification of the fossils was corroborated by Dr. T. W. Stanton, of the National Museum at Washington."

The fossils collected are:

Pecten sp.
Aucella crassicollis (Keyserling).
Aucella pallasi (Keyserling).
Aucella piochii (Cabb).
Aucella sp.
Belemnites sp.
Terebratula sp.
Terebratuloid.
Gasteropods sp.
Hexacorolla, either *Thamnastræa* (?) or *Thecamilia* (?).
Of these the genus Aucella is the most characteristic and diagnostic and the species *Aucella crassicollis* is the most abundant.

"The fauna of the Eldorado series is of Lower Cretaceous age and equivalent to the upper part of the Knoxville formation of California, Oregon, and Washington. It has also been collected in Canada in Queen Charlotte islands, Quatsino sound, Vancouver island, and elsewhere."

[1]Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, pp. 192–193.

Post-Lower Cretaceous

BENDOR QUARTZ DIORITE BATHOLITH

Distribution. The Bendor quartz-diorite has the form of a small batholith typically developed in the rugged Bendor mountains, intruding both the Bridge River series and the Cadwallader series. It is exposed also along the southern edge of the map-area extending southward toward Anderson and Seton lakes. In the northern part of the map-area it appears again as wedge-shaped intrusions in the Eldorado series. Smaller, stock-like intrusions of this rock occur, one in the centre of the northern edge of the map-area; one outcropping on the west side of Gun lake; and another on the broad rocky bench between Hurley and Bridge rivers.

Petrology. A comparison of specimens and sections from different parts of the batholith shows a general uniformity in composition and texture, and absence of metamorphism. A representative type of the quartz diorite may be described as follows:

The rock is phanerocrystalline, medium grained, has a granitic texture, and is of a general light-grey colour and of a fresh mottled appearance. It is composed principally of feldspar, hornblende, biotite, and quartz.

Microscopic examination shows that the following minerals are present; andesine, hornblende, and quartz, as essential constituents; titanite, magnetite, apatite, zircon, and biotite, as accessory constituents, with chlorite, epidote, and sericite as rare alteration products.

A Rosiwal measurement gave the following proportions by weight of the various constituents as shown in column I, page 37.

The feldspars show a considerable range in composition including both orthoclase and plagioclase. The plagioclase has a general tabular habit giving elongated sections which commonly show both Carlsbad and albite twinning, the latter with very thin lamellæ. Sections of plagioclase crystals showing both twinnings and cut perpendicular to (010) were determined by the Michel Levy method and found to be andesine ($Ab_{65}An_{35}$ to $Ab_{55}An_{45}$). Many andesine sections cut nearly parallel to (010) are zonal, indicating variation in composition, the inner zones being more calcic than the border zones, as is usual. Orthoclase is as a rule allotriomorphic with respect to the other constituents, and forms irregular masses filling the interspaces. It forms only 5 per cent of the rock.

Quartz was evidently the last mineral to crystallize and appears in interlocking grains associated with the alkalic feldspar, as interstitial fillings.

The hornblende is the common brownish-green variety, usually idiomorphic with respect to the feldspar, but not forming well-defined prisms. Often it is intergrown with biotite, and forms about 5 per cent of the rock.

Apatite and zircon in the form of microscopic prisms occur in all sections and titanite and magnetite are important accessory minerals. Biotite occurs in equal proportions to hornblende, and in some cases dominates over it, and sometimes the two minerals are intergrown. It is of the common brown variety, becoming green on alteration to chlorite.

In places the Bendor batholith, with increase of alkalic feldspar, approaches a granodiorite[1] in composition, and, in the northern part of the map-area, in the vicinity of Taylor creek, the intrusive altogether assumes this character. A Rosiwal measurement of a section collected from this locality gave the following proportions by weight of the various constituents as shown in column II, below.

The plagioclase feldspars range in composition from oligoclase to andesine, and zonal structure is common.

The borders of the batholith show signs of slight differentiation of the magma in that there is a noticeable concentration of ferromagnesian minerals giving to the rock a dark colour. These more basic parts weather readily and outcrops assume a rusty brown colour, due to the oxidation of the pyrite formed through contact metamorphism.

In a section collected near Truax mountain the proportion by weight of the various constituents was calculated by the Rosiwal method and is shown in column III.

	I	II	III
	Per cent	Per cent	Per cent
Andesine	52·3	40·1	51·4
Orthoclase	5·0	24·8	6·0
Quartz	19·5	14·5	5·6
Hornblende	5·5	12·5	17·4
Biotite	16·5	6·5	17·0
Accessory minerals	1·2	1·6	2·6
	100	100	100

Structure. The Bendor quartz diorite batholith is characterized by its fresh non-metamorphosed condition and absence of mineralized veins as compared with the augite-diorite stock. It is readily recognizable at great distances by its massive character and the regularity of its jointing systems. The master joint planes strike in a direction transverse to the general elongation of the main intrusive, i.e. in a northeast direction, and dip to the southeast at angles varying from 35 to 45 degrees. They are closely spaced giving to the rock a pronounced platy or sheeted structure which imparts an almost stratified appearance (Plate VI A).

A second and less pronounced jointing system with similar strike but with dips at right angles to the major system is present, and the combination of the two systems presents a conjugate system of jointing.

The Bendor quartz diorite contains many small inclusions or "schlieren" of dominant ferromagnesian composition. In size they range from a few inches to several feet in diameter, and are more or less spherical in shape, with definite boundaries. Their arrangement within the quartz diorite mass appears to be haphazard, occurring to an equal degree at the centre and the borders. The "schlieren" probably represents parts of

[1] Am. Journ. Sci., vol. IX, 1900, p. 269, Lindgren defines granodiorite as a rock containing 8 to 20 per cent alkalic feldspars, and plagioclase to at least double the amount of the alkalic feldspars.

an earlier and more basic differentiation of the original magma which have been borne along with quartz diorite magma during its intrusion, in which case they are called "constitution-schlieren"[1]; as contrasted with "resorption-schlieren", originating in the partial assimilation of included fragments of the country rocks.

Under the microscope the "schlieren" have a pronounced gneissic texture. The constituents are the same as those of the normal quartz-diorite, but there is a greater amount of ferromagnesian minerals. When phenocrysts occur they are mostly of hornblende and biotite. Titanite is present in greater amount than in the quartz diorite.

Relation to Other Formations. The contacts of the quartz diorite with the intruded formations are very irregular in detail, but strikingly regular when broadly considered. In general the dips are steep and in the direction of the intruded formations, indicating expansion at depth. There is a very intimate relationship between the intrusion of the batholith and the deformation of the enclosing rocks, which generally conform in dip and strike to the contact. For distances up to a mile from the batholith the intruded rocks have been rendered highly schistose, and at the contacts both the intrusive and the intruded rocks have been impregnated with iron sulphides which have accompanied the intrusion.

Apophyses of quartz diorite porphyry have been sent off into the enclosing rocks of the Bridge River and Cadwallader series and it is believed that the mineralizing solutions accompanying them have been responsible for the origin of the silver-copper deposits near McGillivray mountain.

Method of Intrusion. The field relations of the quartz diorite body point to its being a batholith which has reached the surface by magmatic stoping and pushing aside and squeezing the intruded rocks. In the process of magmatic stoping the cover rocks have been cut by innumerable dykes that have pried off huge blocks which have been engulfed by the magma that has arisen to occupy the spaces thus made vacant.

Age and Correlation. The Bendor quartz diorite intrudes formations of Palæozoic and Mesozoic age. The youngest formation intruded within the map-area is the Eldorado series of Lower Cretaceous age. Compared with the augite-diorite, which is believed to be late Jurassic, it is far fresher, and does not contain gold-quartz veins that are characteristic of the latter rock. It is, therefore, considered to be younger. Its age could not be determined more definitely than post-Lower Cretaceous. It is correlated with the Okanagan composite batholith described by Daly.[2]

DYKES ASSOCIATED WITH THE BENDOR QUARTZ DIORITE

Quartz Diorite Porphyry

This rock occurs as apophyses of the Bendor quartz diorite, the dykes varying in width from 2 to more than 40 feet. At the Empire mine on McGillivray mountain, the porphyry contains exceedingly large phenocrysts of idiomorphic, glistening plagioclase, together with fewer quartz phenocrysts, lying in a fine-grained groundmass. The rock is dark grey the feldspar giving it a mottled appearance.

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[1] Johannsen, A., "The Fundamental Principles of Petrology." New York, 1916, p. 44.
[2] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 492.

Petrology. Under the microscope the rock shows plagioclase feldspar, quartz, biotite, and magnetite in a fine groundmass of quartz, with feldspar, chlorite, sericite, kaolin, and iron oxide as alteration products.

The feldspar phenocrysts are for the most part fresh and clear and range in composition from andesine to labradorite. Some have a zonal structure, the borders having the composition of andesine, whereas the centres are more calcic, having the composition of labradorite. The centres of such crystals show greater signs of alteration to kaolin than the borders, although the edges of the other phenocrysts, which do not exhibit zonal structure, are slightly altered. The feldspars contain small flakes of biotite.

Pseudomorphs of hornblende are plentiful, the hornblende having been entirely altered to chlorite and iron oxide.

The quartz phenocrysts are usually rounded in outline and show undulatory extinction, showing that the rock has been subjected to deforming stresses.

Spessartite (Hornblende Lamprophyre)

This rock occurs in dykes varying in width from several inches to several feet, and is of a dense character and of greenish-black colour. A freshly broken surface has a satiny sheen due to the many slender hornblende prisms. Under the microscope it is apparent that the hornblende is the chief constituent. It occurs in minute idiomorphic prisms without apparent orientation and frequently bent where other crystals impinge upon them, in such cases showing wavy extinction. The mineral is faintly pleochroic and pale brown. Allotriomorphic plagioclase feldspars fill the interspaces and show both albite and Carlsbad twinning. There is an abundance of apatite in acicular crystals which penetrate the other constituents. Augite is present in scattered grains, and iron oxide is an important accessory mineral. Calcite and sericite occur as alteration products.

The specimen above described was from a dyke cutting the Bridge River series on Marmot mountain on the south side of Bridge river opposite Rexmount.

Tertiary (Oligocene?)

REXMOUNT PORPHYRY (AND COAL-BEARING SEDIMENTS)

Distribution. One stock, several intrusive sills, and one surface flow of andesite porphyry outcrop in the vicinity of Rex peak in Shulaps mountains. The stock and sills intrude both the serpentines and the Cadwallader series, whereas the surface flow, along with some Tertiary sediments, unconformably overlies the Bridge River series at Jones bluff at Rexmount.

Lithology. The Rexmount porphyry is a light grey, fresh-looking rock, which forms bold outcrops and is made up of dull white plagioclase feldspar (chiefly andesine) and altered hornblende phenocrysts, in a fine-grained groundmass of the same materials. Quartz, orthoclase, and magnetite occur as accessory constituents, and chlorite, calcite, and kaolin as alteration products. The rock maintains a uniformity in texture and composition throughout the different masses.

Structure and Origin. The borders of the elliptic stock are characterized by prominent vertical cliffs skirted by talus slopes. The master joint planes in the sills are vertical, giving to the rock the appearance of columnar jointing, except that the planes are not closely spaced (Plate IV B). Columnar jointing is a prominent feature of the surface flow, the top of which has been removed by erosion.

The stock probably represents a volcanic conduit through which the molten andesite was at first explosively expelled, followed by the extrusion of lava into local basins of subaerial sedimentation. Concurrent with eruption, sills and dykes of the same material were intruded into the formations at intermediate depths and gave rise to the sills exposed on Rexmount ridge (Plate VI B).

Age and Correlation. The age of the Rexmount porphyry is uncertain. At Jones bluff (Plate VI B) the andesite porphyry overlies a small series of andesitic tuffs, breccias, and agglomerates which lie upon 150 feet of soft-weathering shales, sandstones, and conglomerates containing a few thin seams of lignite. The outcrops of this series are too small to map. This series unconformably overlies the Bridge River series and has a low dip to the north and has not been involved in the folding that deformed the Lower Cretaceous sediments. It is doubtfully referred to the Oligocene and correlated with Dawson's Coldwater group[1] of the Fraser plateau to the east and with the Coldwater series[2] of the Tulameen district to the south.

DIORITE PORPHYRY DYKES

Occurrence and Distribution. Diorite porphyry occurs as dykes in the northern half of the map-area. They are found most abundantly in the area between Liza and Tyaughton lakes and on both sides of Bridge river south of Pearson ponds, where they vary in width from 10 to 50 feet. Their association with the antimony deposits makes them of particular economic interest.

Petropraphy. Weathered surfaces of the diorite porphyry are mostly reddish-brown to buff in colour. Where the outcrops have been subjected to the oxidizing heat of forest fires, the rock has a general dark red colour due to the change in colour of the large feldspar phenocrysts from white to dark red. The rock is tough and breaks with difficulty under the hammer, the faces being sub-conchoidal. Freshly broken surfaces are greenish grey to brownish grey and megascopically the rock is seen to be made up of relatively large feldspar and hornblende phenocrysts lying in a dense, sometimes almost vitreous, groundmass. Quartz is rarely detected.

Under the microscope the rock is seen to be made up essentially of plagioclase feldspar varying in composition from oligoclase to andesine, with subordinate hornblende and sometimes biotite, and such accessory minerals as magnetite and apatite. Quartz in rounded grains is sparingly present, but altogether absent in some of the sections examined. The groundmass is a microcrystalline aggregate of plagioclase with subordinate amounts of hornblende.

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[1] Loc. cit. pp. 68–160 B.
[2] Camsell, Chas., Geol. Surv., Can., Mem. 26, 1913, p. 98.

In the neighbourhood of the antimony deposits the diorite porphyry has been greatly altered and is light grey. It is highly calcified, and the feldspars have altered to sericite and in some cases to halloysite, or hydrated kaolin, in which cases it has a pearly or waxy appearance.

A section of a specimen collected at the Stibnite group of claims, near the confluence of Gun creek with Bridge river, shows this alteration to a very marked degree. All the feldspar phenocrysts have been altered, some to sericite, others to halloysite, and some to both of these secondary minerals, the centres being composed of sericite and the borders of clear, transparent, apparently isotropic halloysite.

Clarke[1] states that sericitization is "most conspicuous in regions where dynamic metamorphism has been most intense, high temperature, the chemical activity of water, and mechanical stress all working together to bring it about." Both orthoclase and plagioclase feldspars may thus be altered to sericite, the former the more readily since the necessary potassium is already present. The alteration of plagioclase to sericite, however, requires the replacement of the sodium by potassium obtained from extraneous sources. In the present case the presence of potassium in the hydrothermal solutions which in part effected the alteration of the rock, must be postulated. The alteration of sericite into halloysite indicates the probability that the effects of downward-moving waters were combined with those of dynamic stresses to produce the metamorphism of the rock. The presence of calcite suggests that carbonated solutions also were active.

Age and Relation to Other Intrusive Rocks. The genetic relationship of the diorite porphyry dykes to other igneous rocks in the district is uncertain. They are certainly younger than the Bendor quartz diorite batholith, whose dykes are cut by them, as at the Stibnite group of claims where a dyke of the quartz diorite is cut by a dyke of diorite porphyry. Its genetic connexion with the augite-diorite is not believed possible, since the latter is believed to be older than the Bendor quartz diorite. Age relation with respect to the Rexmount andesite porphyry of supposed Oligocene age could not be determined, but it is possible that they may be related. They are tentatively placed along with the latter rocks in the Oligocene period. There is the possibility, however, of their being apophyses of the Bendor quartz diorite, slightly later in age than the quartz diorite dykes.

Quaternary

PLEISTOCENE

The deposits of Pleistocene age include unconsolidated glacial and stream deposits. The two are intimately related in places, one grading into the other. The stream deposits are important on account of their content of placer gold.

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[1] "Data of Geochemistry," U.S.G.S. Bull. 491, p. 567.

Glacial Deposits

These consist of unsorted gravels, sands, boulder clay, and subangular boulders that lie scattered in patches over the entire area. In certain valleys, such as those of Cadwallader and McGillivray creeks and Bridge river, the deposits are very conspicuous, and represent the work of valley glaciers. The lateral moraines high up on the valley sides of Cadwallader and McGillivray creeks, however, were probably left by Recent valley glaciers.

The covering of glacial till or boulder clay over the augite-diorite along the valley of Cadwallader creek renders prospecting very difficult. The till is so compact that ordinary sluicing has little effect upon it. It is locally called "cement", and is of a pale greenish colour.

At high elevations—but not exceeding 6,500 feet above sea-level—glacial erratics and striations, probably referable to the Cordilleran ice-cap, are to be found.

Stream Deposits

Nearly all the valleys in the map-area contain Pleistocene stream deposits, but the most abundant and important are found in Bridge River, Hurley River, and Marshall Creek valleys. They form broad benches, in some cases several hundred feet thick, composed of crossbedded sands, well-rounded, waterworn pebbles, and granitic boulders up to 6 feet in diameter. Occasionally, as in Hurley river, below the junction of Cadwallader creek, boulders from the Cadwallader series and augite-diorite are present. The stream deposits represent the work of overloaded, swiftly-flowing streams immediately following the recession of the valley glaciers, the deposits having accumulated in the glacially deepened part of the valleys.

Marshall creek and other tributaries of Bridge river have cut to bedrock through thick deposits of gravels that were formed when Bridge River valley was filled with ice which dammed the tributary streams.

During Pleistocene times the Hurley River glacier dammed Bridge river so that the water was diverted, and the stream deposits along Little Gun and Gun lakes, and Pearson ponds were laid down.

RECENT

Stream Deposits

The older glacial and stream deposits of the Pleistocene have in many places been reworked and laid down as Recent deposits. In all probability many of the gold nuggets discovered in Recent alluvium in the creek bottoms were washed down from the older Pleistocene deposits occurring at higher elevations in the valleys. At the mouths of all the principal creeks are alluvial fans, the surface of which is 10 or 12 feet above the normal elevation of the streams into which the creeks flow. For the most part they are composed of pebbles and small boulders up to one foot in diameter, with a little sand and gravel filling the spaces between them. No large sandy or gravelly terraces of Recent age were noted along the main streams.

Volcanic Ash or Pumice

The youngest formation in the district is a thin bed of unconsolidated volcanic ash or pumice which lies on the surface over large areas, and is even found overlying Recent river gravels. It is most plentiful in the valley bottoms of upper Bridge river and its tributaries, on the hill slopes, and on many of the mountain summits, although at high elevations wind erosion has probably greatly reduced its thickness. The bed varies in thickness from a few inches to 3 feet, and is of remarkable uniformity and free from interbeds of foreign material. It is apparently thickened in the vicinity of Hurley river, and on the valley floor east of Gun lake, and gradually thins and becomes finer to the east. This change to the east, together with the fact that the western slopes of the valleys are more thickly covered than the eastern, suggests a volcanic source to the west. Bateman[1] suggests that the vent may be found between the headwaters of Bridge and Lillooet rivers along the belt of hot springs. The light fragmental material, representing particles of lava which solidified before or after ejection, was probably carried by prevailing westerly winds and deposited on the western slopes and the valley flats just as snow might be.

The ash is yellowish grey to creamy white, and is gritty to the touch. It is andesitic, composed of dull white plagioclase feldspar phenocrysts lying in a frothy cellular groundmass. In size the particles range from fine dust to fragments 2 inches in diameter. Its light pulverulent character renders travel upon it difficult, and it supports but scant vegetation.

GEOLOGICAL HISTORY

The following summary of the preceding descriptions of formations may serve to give the reader a clearer mental picture of the different events, their sequence and relative importance.

Palæozoic Era

(1) Deposition of Bridge River chert, sandstones, argillites, and limestone in a wide, shallow, and subsiding epicontinental sea-bottom of Pennsylvanian-Permian time. Uniform conditions of sedimentation prevailed with contemporaneous flows of basaltic lava upon the sea-bottom, and possible injections of lava into water-holding silts, accounting for the pillow structure of the lava.

(2) Epirogenic upwarp and local deformation of marine deposits toward the end of Pennsylvanian time or perhaps at the close of Palæozoic, followed by erosion interval.

Mesozoic Era

(3) Extrusion of olivine rocks through pipes and dykes, the lavas flowing over the Palæozoic erosion surface (Shulaps volcanics).

[1] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 193.

(4) Transgression of the Upper Triassic sea upon a land surface of considerable relief with deposition of Cadwallader series (conglomerate, sandstone, and argillites, with some fossiliferous limestone). Such sedimentation upon the subsiding sea-bottom was interrupted by accumulations of coarse clastics and outpouring of numerous basaltic flows.

(5) Nevadian disturbance at the close of the Jurassic formation of Bridge River anticlinal dome and folding of the Cadwallader and older series. Intrusion of the augite-diorite stock, followed by period of mineralization (gold-quartz deposits).

(6) Deposition of Lower Cretaceous Eldorado series, with contemporaneous volcanic activity (andesitic flows). Mechanical disintegration of the sediments was great, and conditions of sedimentation rapidly changing (arkosic and intraformational conglomerate beds). Semi-arid climate prevailed on the eastern side of the newly formed Coast mountains composed chiefly of Palæozoic cherty formations. On the Pacific coast luxuriant vegetation (coal measures). Intrusion of quartz diorite and granodiorite (Bendor quartz diorite).

(7) Upper Cretaceous cycle of erosion during long period of crustal stability in which the land surface was reduced to form sediments on the Pacific coast (Nanaimo series). (Unconformity between Mesozoic and Tertiary groups.)

Tertiary Era

(8) Laramide revolution which affected the whole Cordilleran region. Folding and uplift of the Cretaceous erosion surface. Active erosion and peneplanation during the Eocene, and establishment of through-flowing rivers to the Pacific.

(9) Orogenic uplift at the close of the Eocene, the maximum uplift occurring along the axis of the present Coast mountains.

(10) Dissection of Eocene peneplain, climatic conditions probably warm. Local sedimentation occurred (conglomerate, sandstones, and shales containing thin seams of lignite of Oligocene (?) age). Contemporaneous local volcanic activity (Rexmount porphyry) and intrusion of igneous dykes associated with antimony deposits.

(11) Continued erosion during Miocene time with outpouring of lava which filled depressions on the existing land surface. Removal of much of the volcanic flows.

(12) Further uplift in late Pliocene time, and erosion, producing in great part the present topography.

Quaternary Era

(13) Pleistocene glaciation with alternating advances and retreats of valley glaciers. Production of glacial topography with deposition of glacial and fluvioglacial deposits.

(14) Post-Glacial stream-cutting, and formation of deep box-canyons and gorges at intervals in the glacially modified valleys.

(15) Recent river deposits, landslides, and accumulations of volcanic ash.

CHAPTER IV

ECONOMIC GEOLOGY

INTRODUCTION

The most important ore deposits in the Bridge River map-area, and in fact the entire Lillooet mining division of British Columbia, are the gold-quartz deposits. These are well-defined veins, and all that have so far proved of economic value have been found in the augite-diorite. Mining operations have, therefore, been confined to a narrow belt in the southwestern and western parts of the map-area, and particularly along the northeastern side of Cadwallader creek, where the augite-diorite stock has its greatest development. The augite-diorite is believed to have been a "forerunner" as it were, or an early and relatively basic differentiate of the Coast Mountains batholith intruded into Palæozoic and Mesozoic formations along the eastern margin of the great batholithic masses.

The importance of igneous intrusion in relation to ore deposits is well known, and the relation of certain types of deposits to particular geological epochs has been pointed out by Lindgren,[1] who has shown that gold-quartz veins of almost identical character occur from lower California to Alaska associated with large scale batholithic intrusions of quartz-monzonite or granodiorite of Mesozoic age. The mineral waters accompanying these intrusions were characterized by an abundance of alkaline carbonates. In a later paper[2] the same author states that the great masses of these intrusives are usually free from mineral deposits as is shown in the High Sierra, in the Clearwater region, and in British Columbia, though the margins of the batholiths yield abundant deposits, those of gold and copper being the most important. Where limestone is present in the region invaded, lead and zinc occur, as in Idaho and Nevada. Silver in small quantities is almost always present. In early Tertiary time (according to Lindgren) a porphyritic rock ranging from a granite to a diorite was intruded in the form of numerous sheets, laccoliths, and dykes. About the margins of these bodies, contact metamorphic deposits and veins were formed, the characteristic metals of which are gold, silver, and much lead and zinc, the last two metals occurring especially where the intrusions cut the limestone. Copper, iron, antimony, and arsenic

[1] Lindgren, W., Trans. A.I.M.E., vol. 33, p. 797, 1902.
[2] Lindgren, W., Econ. Geol., vol. IV, p. 419, 1909.

are also in evidence. The following table gives Lindgren's summing up of the subject:

Principal rocks	Age	Principal metals
1. Granite, diorites, gabbros	Precambrian period	Gold and copper
2. Basalt, diabase, gabbros	Early Mesozoic	Copper
3. Granodiorite, quartz-monzonite	Late Mesozoic	Gold
4. Granodiorite, quartz-monzonite, and corresponding porphyries	Early Tertiary	Gold, silver, copper, lead,[1] zinc[1]
5. Andesite, rhyolite	Late Tertiary	Gold, silver
6. Basalt	Post-Pliocene	Quicksilver

The ore deposits of the Bridge River map-area fit in with this general scheme of classification according to "Metallogenic epochs,"[2] as they are called by Lindgren. The gold-quartz veins are associated with the latest Jurassic Coast Mountains batholithic intrusion, whereas the antimony deposits occur in association with igneous dykes which are believed to be of Tertiary age, although definite age determination could not be made.

MINING DEVELOPMENT

The mountainous character of the district enables most of the ore deposits to be developed by adits at different levels. The ore is trammed by hand to the portals of the tunnels, and gravity tramways convey it to the mill for treatment. The little timbering required, mainly short stulls to support the walls in the stopes, is obtained readily nearby.

Surface prospect work consists chiefly of open-cuts, pits, and trenches. Ground-sluicing methods are used to great advantage as water is abundant and the loose volcanic ash on the surface affords favourable ground for ditches. The glacial till below the pumice, however, is resistant, and much loosening by hand is necessary to aid the water in cutting down the rock surface.

Owing to poor transportation facilities, lack of capital, and the need of immediate returns, the early miners were forced to use home-made wooden arrastres, run by waterpower, and by this primitive method most of the quartz-gold in the Cadwallader belt was recovered. The two arrastres on the Lorne property are said to have had a capacity of 2 tons of ore a day, and the one on the Pioneer claim treated 600 to 700 pounds of ore a day.

Stamp mills later replaced the arrastres at the Lorne, Coronation, and Wayside mines, and Brian mills at the Pioneer and Ida May. No process for recovering the gold from the sulphides has yet been installed in the district, although the sulphides contain gold intimately mixed with them.

The mining properties in the district are still in the prospect stage, except in the Cadwallader Creek gold belt, where there are a few well-established mines, namely, the Coronation, Lorne, Pioneer, and Wayside, in which considerable work has been done. But even in these mines no vein has been explored to a depth exceeding 300 feet. No development work of any importance has been done on any other types of deposits than the gold-quartz veins, which will be discussed in detail in this chapter. The other deposits will be discussed briefly.

[1] When intrusives cut limestone.
[2] Idem, p. 409.

The different types of mineral deposits of the Bridge River map-area may be classified according to their genesis as follows:[1]

I.	Detrital deposits produced by mechanical processes	Gold placers.
II.	Non-metalliferous deposits produced by chemical processes of concentration	Magnesite.
III.	Non-metalliferous deposits formed by concentration of substances contained in the surrounding rocks by means of circulating waters	Asbestos
IV.	Metalliferous deposits formed near the surface by ascending thermal waters and in genetic connexion with igneous rocks	Antimony deposits.
V.	Metalliferous deposits formed at intermediate depths by ascending thermal waters and in genetic connexion with igneous rocks	Gold-quartz deposits.
VI.	Metalliferous deposits formed by concentration in molten magmas	Nickel-iron alloy. Chromite.

DESCRIPTION OF TYPES OF MINERALS DEPOSITS

In describing the different types of mineral deposits occurring within the Bridge River map-area the following scheme will be followed:

Metalliferous Deposits.
- Gold-quartz deposits.
- Placer gold deposits.
- Silver-copper deposits.
- Antimony deposits.
- Chromite deposits
- Nickel-iron alloy deposits.

Non-metalliferous Deposits.
- Magnesite deposits.
- Asbestos deposits.

METALLIFEROUS DEPOSITS

Gold-quartz Deposits

Distribution. The gold-quartz deposits of the Cadwallader Creek belt occur as vein fillings in well-defined fissures in the augite-diorite stock. Map 1882 shows at a glance the distribution of the intrusive body, and the elongated stock-like shape it assumes. The largest body of the intrusive, in which are all the important gold-quartz veins so far discovered, lies on the northeastern side of Cadwallader creek. The Lorne, Coronation, and Pioneer mines are located on this body. Figure 2 shows the distribution of the known veins in it.

The extension of this body to the southeast on the other side of Cadwallader creek has not been thoroughly prospected. One vein has been found on it, and from what may be observed in a few outcrops it appears to be of a massive character lacking the ribbon-structure characteristic of the richer veins.

The narrow dyke-like extension to the north of the main mass contains several veins which strike across the intrusive, but which have not been proved to contain much gold.

[1] After Lindgren, "Mineral Deposits," New York, 1913, p. 188.

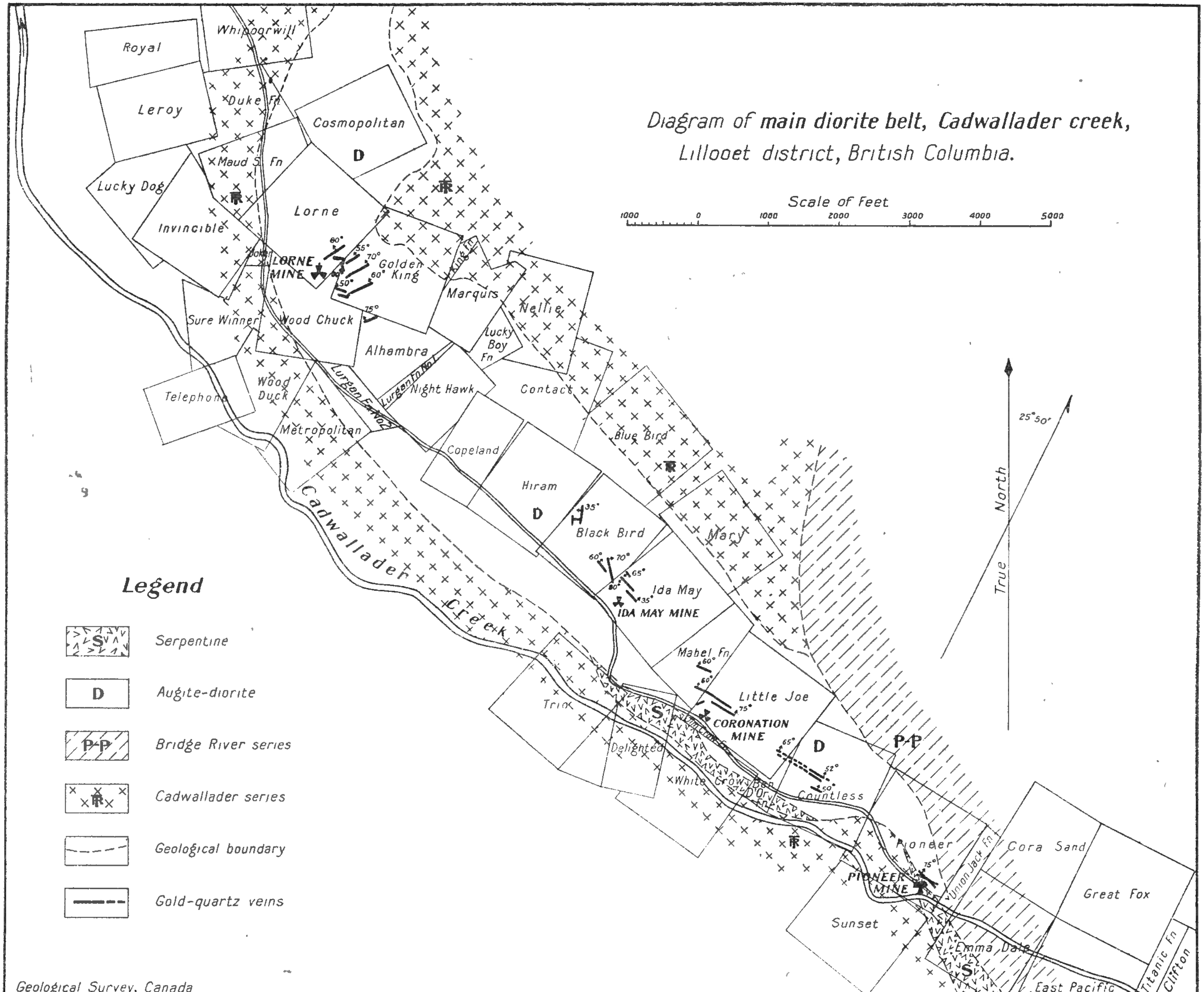


Diagram of main diorite belt, Cadwallader creek, Lillooet district, British Columbia.
Scale of Feet
1000 0 1000 2000 3000 4000 5000
True North
25°50'
Legend
Serpentine
Augite-diorite
Bridge River series
Cadwallader series
Geological boundary
Gold-quartz veins
Royal
Whippoorwill
Leroy
Duke Fn
Cosmopolitan
Maud S. Fn
Lucky Dog
Lorne
Invincible
LORNE MINE
Golden King
Marquis
Nellie
Sure Winner
Wood Chuck
Alhambra
Lucky Boy Fn
Telephone
Wood Duck
Metropolitan
Lurgan Fn No 1
Lurgan Fn No 2
Night Hawk
Contact
Copeland
Blue Bird
Hiram
Black Bird
Mary
Ida May
IDA MAY MINE
Cadwallader Creek
Mabel Fn
Little Joe
CORONATION MINE
Trix
Delighted
White Crow
Countless
Pioneer
PIONEER MINE
Cora
Sand
Great Fox
Sunset
Union Jack Fn
Emma Dale
East Pacific
Titanic Fn
Clifton
Geological Survey, Canada

Figure 2.

On the northwest side of Bridge river, 2 miles below the bridge, the Wayside mine is located on a broad mass of augite-diorite. Three gold-bearing veins occur here, one of which has been followed for over 1,000 feet.

The augite-diorite bodies on the west side of Gun lake and Little Gun lake contain several quartz veins which up to the present time appear to be of low grade. The other small areas of augite-diorite are not known to contain veins of economic value, although further prospecting upon them might be profitable.

On McGillivray mountain at the head of Roaring creek there is a well-defined quartz vein which does not appear to be associated with the augite-diorite intrusion. Although it contains gold in small amounts, it is quite different from the gold-quartz veins of the augite-diorite, and will be discussed under the head of silver-copper deposits.

Loci of Deposits. As has just been emphasized, gold-quartz veins are to be expected in any of the intrusive bodies of the augite-diorite. Only exceptionally do they occur outside the intrusive, since the lithological character of the rock is not favourable for fissures. Experience has shown that when veins pass from the augite-diorite into the surrounding rocks they usually die out within a short distance of the contact; the forces that produced the fissure in the brittle and homogeneous augite-diorite having been absorbed in the less competent rocks by plastic flow.

In prospecting for gold-quartz veins in the augite-diorite, it should be borne in mind that where the rock has been altered and is light in colour, it is an indication that vein solutions have been active, and that a vein may be encountered in the immediate vicinity. These hydrothermal solutions leached from the dark-coloured ferromagnesian constituents the ferrous iron which recombined with sulphur derived from the solutions to form iron sulphides; so that the wall-rock for distances from a few inches to 10 feet has assumed a pale yellow to whitish colour and a rather greasy feel, and contains well-formed crystals of iron sulphides. On the surface, where the rock has been subjected to the oxidizing influence of surface waters, the pyrite has been decomposed, and the altered rock assumes a rusty brown or buff colour. The hydrothermal alteration of the wall-rock will be discussed at greater length elsewhere in this chapter.

Veins that show ribbon-structure, indicative of movement within the vein, subsequent to deposition, are generally of higher grade than those of a more massive character. The line of intersection of two veins has sometimes been the locus of rich ore-shoots, as in the Woodchuck workings of the Lorne mine, and at the Pioneer mine. The wall-rock when invaded by quartz stringers sometimes contains appreciable amounts of gold, suggesting that the gold is contained essentially in the quartz.

In the upper, oxidized parts of the veins, where there has been opportunity for superficial enrichment through oxidation of the auriferous sulphides and consequent concentration of the gold, the gold content is higher than in the deeper parts. Assays of the veins taken at the surface, therefore, should not be considered as strictly representing the average tenor of the ores.

The occurrence of such minerals as arsenopyrite, galena, chalcopyrite, and tellurides is a favourable indication of the presence of gold in the veins.

FISSURES

Fissure Systems

There are two main systems of fissures (Figure 3), one having a general northeast-southwest direction, the other having a southeast-northwest direction. With relation to the outline of the augite-diorite stock, which is elongated in a southeast-northwest direction, the former system—herein called the "Transverse system"—strikes across the body, and the other, which may be called the "Parallel system," is roughly parallel to it.

The "Parallel system" so far as known is the better defined and economically the more important in the narrower parts of the intrusive mass, as at the Pioneer and Coronation mines; but at the Lorne mine, where the diorite is broadest, the "Transverse system" is the better defined. Future development, however, may throw a different light upon the subject.

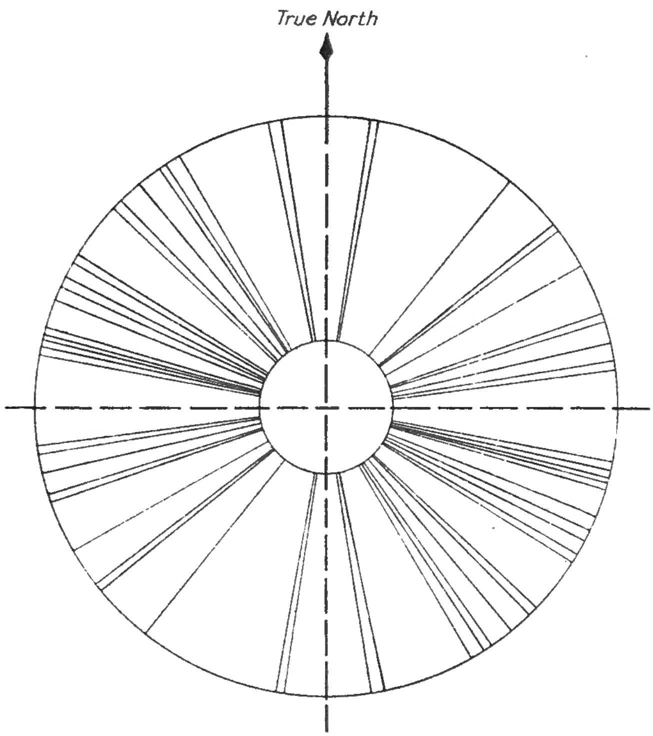


Figure 3. Diagram showing the strikes of the principal fissure veins in the augite-diorite.

The veins have as a rule steep dips ranging from 60 to 80 degrees. On the Ida May the principal vein at its outcrop dips at an angle of 35 degrees, but within 60 feet dips more steeply. Some fissures in the Lorne mine dip vertically. In general the dip of the "Parallel system" is to the northwest, or in the direction of the Bendor batholith.

Persistence of the Fissures

A fissure in a large homogeneous mass should theoretically have its vertical and horizontal dimensions equal. In section, therefore, the points at which the fissure dies out would lie roughly in a circle. If erosion removed the upper half of the vein which filled such a fissure, the depth to which the vein should extend should be roughly half the distance of the vein along its strike, or equal to the radius of the circle representing the whole fissure.

This theory cannot be applied to the fissures in the augite-diorite, because of its small size, and fractures which now cut across the whole intrusive at narrow places may have extended into the surrounding, rather incompetent rocks, and may have been immediately closed up, or the movement may have been absorbed by plastic flow. In this case the downward extension of the fissures might be many times greater than the lateral extension.

A heavy mantle of glacial drift made surface exploration difficult, and little information could be got from surface workings. The mine workings also are of small extent, so the extent of the veins could not be determined. The actual distances the veins have been developed do not exceed 600 feet and most of them have been followed for less than 400 feet, usually to a pinching of the vein. The fissures, however, remain strongly defined, and it is probable that the veins widen within a short distance and extend well beyond the present workings; or they may have been displaced by faulting. The main veins in the Little Joe (Coronation mine) workings appear to persist eastward through the Countless tunnel and to the centre of the Countless claim. If this is true, two parallel fissures extend for more than 2,000 feet along their strike. It is impossible to state to what distances the fissures in general extend, but it would appear that most of those that have slickensided walls (the evidence of relative movement of the walls) extend continuously in strike and at depth to distances of possibly 1,000 feet, unless they have been faulted, or cross the contact between the diorite and the surrounding rocks.

Influence of Rock Formations

The occurrence of all the important gold quartz veins which have been discovered up to the present time within the augite-diorite intrusive has led to the belief that important veins are confined to this mass. Consequently very little prospecting has been done outside the boundaries of the augite-diorite, and little information is at hand for determining the question. Where it has been possible to study the character of the intruded rocks at their contact with the augite-diorite, as at the entrance to the workings of the Pioneer mine and No. 4 tunnel of the Coronation mine, they are found to be exceedingly schistose and soft. In the latter mine a vein that crosses the contact into the serpentine schist frays out and disappears within a few feet of the contact. The country rock at these points is serpentine schist, and of such a character as to preclude the idea of fissures, which may have been formed, remaining open under compressive stresses.

In this connexion Irving[1] cites the case of the Bachelor vein, near Ouray, Colo., where "a vein fully 5 feet wide passes from quartzite into finely carbonaceous shales, and after passage into the shales disappears entirely. The movement along the fissure was slight and the shales have entirely absorbed it, adjusting themselves by distortion and plastic flow."

[1] Irving, J. D., Econ. Geol., vol. 1, p. 48.

Lindgren[1] has also called attention to such phenomena in the Grass Valley district. He says: "The fissures are more apt to be straight and clear cut in hard, even-grained rocks, such as diabase and granodiorite, being splintery and irregular and easily breaking up into brecciated zones in argillite. Fissures in serpentine rarely continue unbroken for a long distance; in fact to enter serpentine seems fatal to the continuation of most veins."

Along the eastern border of the augite-diorite mass the rocks are dominantly argillites, which are also incompetent, and no important veins have been discovered in them. It appears, therefore, that well-defined fissures are not to be expected in the rocks surrounding the augite-diorite because of their relatively incompetent character.

The augite-diorite, on the other hand, by virtue of its homogeneous and brittle character, has lent itself easily to deformation by fissuring. The fissuring has expressed itself in two systems normal to each other, as has been described before.

Sheeted Structure

Sheeted structure is an important characteristic of the fissures in the district. In some places it controls the structure of the lodes. On the

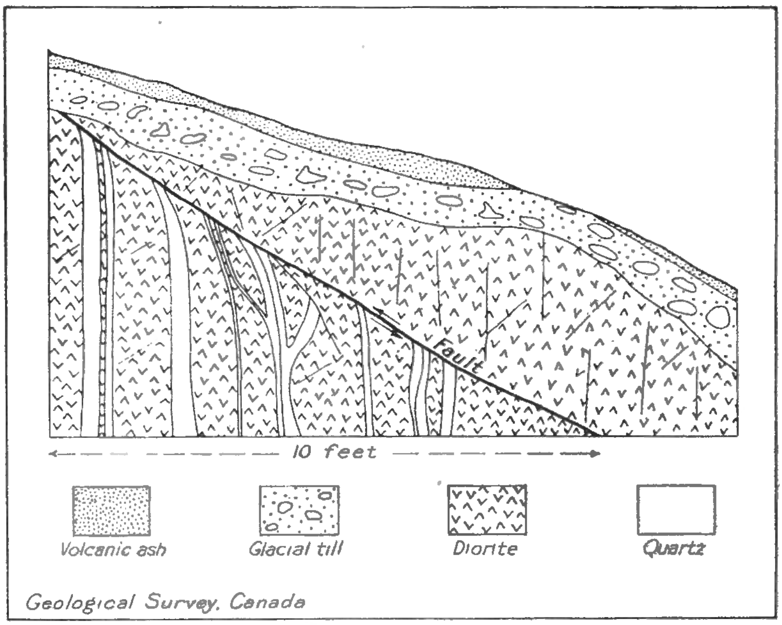


Figure 4. Detail of vertical section of "stringer lode" exposed in open-cut on Ypres claim, Gun lake.

Ypres claim on the west side of Gun lake, the lode is a sheeted zone 10 feet in width (Figure 4) consisting of a number of parallel narrow fissures in the diorite. The fissures are mere cracks showing no evidence of brecciation or slickensiding. In this respect the structure resembles that of the veins at Cripple creek[2] and the Lone Star ledge at Goldfield, Nevada.[3]

[1] Lindgren, W., 17th Ann. Rept. U.S.G.S., pt. 11, p. 167.
[2] Lindgren, W., and Ransome, F. L., U.S.G.S., Prof. Paper 54, p. 160.
[3] Ransome, F. L., U.S.G.S. Prof. Paper 66, 1909, p. 156.

Many of the important fissures of the district show sheeted structure in that the walls of the veins contain parallel jointing planes which are themselves parallel to the main fissure. Such planes have been called locally "false walls" because they are not actually the walls of the vein, but are at some distance, usually 2 or 3 feet, from the veins. The intervening rock is usually schistose and friable and contains much chlorite (Figure 5).

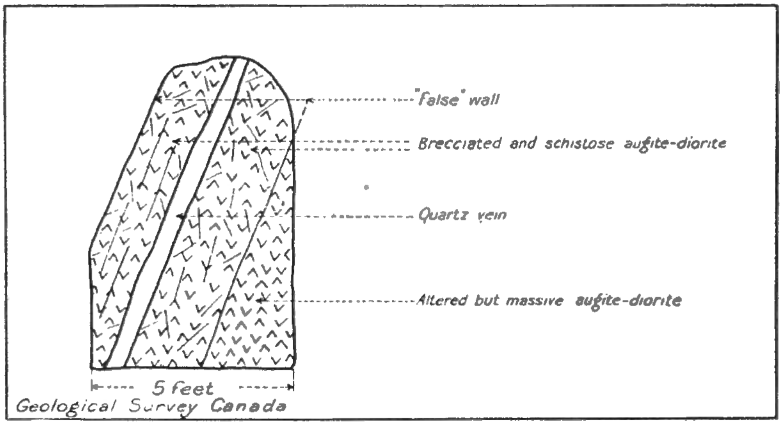


Figure 5. East face of No. 1 vein, 300-foot level, Pioneer mine, showing sheeted structure and schistosity accompanying fissuring.

The forces that have produced the schistosity are believed to have been to some extent the same as those which produced the fissures and joints,[1] and may be ascribed to tangential movement in the same direction as the fissure, but not reaching the limit of cohesion of the rocks.[2]

Origin of the Fissures

We have seen that the fissures occurring within the augite-diorite conform in general to two systems nearly at right angles to each other, having relatively steep dips. It is difficult to determine exactly what forces operated to produce this fracturing. Experiments on the part of Daubrée[3] tend to show that two such intersecting series of fissures might be expected to result from powerful torsional forces accompanying crustal movements. Becker[4] and Van Hise[5] have also shown that compressive forces operative in an approximately homogeneous substance result in the formation of two sets of fissures nearly at right angles to one another, and occurring at about 45 degrees to the direction of the applied force.

[1] Lindgren, W., "Gold Quartz Veins of Nevada City and Grass Valley, Cal." U.S.G.S. 17th Ann. Rept., 1895–96, pt. 11, p. 69.
[2] Becker, G. F., "Finite Homogeneous Strain, Etc.," Bull. Geol. Soc. Am., vol. IV, 1893, p. 13.
[3] Daubrée, A., Geologie Experimentale, p. 316.
[4] Becker, G. F., Geol. Soc. Am. Bull. vol. IV, pp. 13–90, 1893.
[5] Van Hise, C. R., 16th Ann. Rept., pt. 1, U.S.G.S., pp. 633–662.

Dynamic stresses induced by regional uplift may also have been instrumental in producing the fissures. It is known that certain parts of the Western Cordilleras were subjected to uplifting forces about late Jurassic time.[1] Spencer[2] has referred to such uplifting forces as being possibly instrumental in producing similar fissure systems in the Juneau gold belt, by setting up tangential compressive stresses.

The proximity of large bodies of younger intrusive rocks suggests that their invasion may have set up compressive fracturing stresses in the adjacent rocks. However, as will be pointed out in the following sections, the production of the fissures and the deposition of the vein is believed to have been accomplished prior to the invasion of the batholithic intrusives. But they may have supplied the forces which resulted in the later movement along the fissures that produced the characteristic ribbon-structure in the veins.

The compressive forces acting from the west, which were responsible for the folding and crumpling of the Cadwallader series on the western limb of the Bridge River anticline, could have produced fissuring similar to that noted in the augite-diorite. This is shown in the fracturing of quartzite pebbles in the conglomerate member of the series which lies only a few thousand feet west of the augite-diorite near the Lorne mine. Plate VIII A shows one of these pebbles, about 2 inches long, which contains two systems of faulting nearly at right angles to one another. The forces which produced the faulting in the pebbles must have been applied equally upon each of the flat sides of the pebble, i.e., straight compressive forces were brought to bear to produce step-faulting; and the environment of the pebble was such as to permit of its elongation.

The field relations of the augite-diorite mass indicate that it was probably not involved in the complex folding of the Cadwallader series, but was intruded after the greatest amount of folding had taken place. It may, however, have been involved in a slightly later continuation of such folding of these rocks.

On account of the imperfection of our knowledge of the forces operating within the earth's crust to produce deformation of the rocks, and because of the limited scope of the investigation of this subject in the district under discussion, it is impossible to state definitely what caused the fissuring. There is a strong probability, however, that the fissuring may be related to forces acting in a general east-west direction, which resulted also in the formation of the Bridge River anticline.

FISSURE VEINS

Introduction

The gold-quartz veins of the district occur as fillings of well-defined fault fissures in the augite-diorite. It is probable from their nature that they extend continuously much farther than they have been explored, unless they are cut off by later faulting, or cross the contact into the surrounding rocks. The veins are characterized by frequent pinches and

[1] Cairnes, D. D., Geol. Surv., Can., Mem. 31, 1912, p. 94.
[2] Spencer, A. C., U.S.G.S. Bull. 287, p. 28.

swells along their entire length. Those of the greatest economic importance display a banding or ribbon-structure due to subsequent movement along the plane of the veins, and the sheeting of the quartz veins along what may have been lines of original sulphide deposition. The hydrothermal solutions have had a profound effect upon the wall-rock close to the fissure, having altered it to a light-coloured, greasy-feeling rock containing pyrite and arsenopyrite in crystals.

Mineralogy of the Veins

Gangue Minerals

Quartz (SiO_2). The characteristic filling of the vein fissures is quartz. It is usually milky white, except where it has been stained by iron solutions near the surface. In some veins it is massive and is composed of interlocking small grains. Where the quartz shows banding or ribbon-structure the grains often show crystal faces due to recrystallization. Drusy cavities are not common, but on the Veritas claim on Little Gun lake, where the vein is of unusual width, perfectly terminated and transparent crystals of quartz occur projecting towards its medial line and towards the centres of vugs.

Calcite ($CaCO_3$). This mineral occurs in subordinate amounts in some of the gold-quartz veins, also in small stringers which traverse the altered wall-rocks of the veins. On the Jewess-National claims there is a vein 4 inches wide consisting mainly of calcite. At the Ida May mine well-formed rhombohedral crystals occur in parts of the vein where the quartz is coarsely crystallized, the calcite having formed in open spaces. Here it is of a dark smoky colour, due to inclusions of minute acicular needles of stibnite.

Sericite ($H_2KAl_3\ (SiO_4)_3$) occurs sparingly in silky scales along the darker mineralized partings of the ribboned quartz. It is an important constituent of the altered wall-rock, where it forms finely felted aggregates. In the vein on the Hazard claims and at the Empire mine on McGillivray mountain it is plentiful.

Siderite ($FeCO_3$). Iron carbonate in small amount has been observed in the veins of the Ida May mine, where it occurs as a partial replacement of calcite crystals.

Dolomite ($(CaMg) \cdot CO_3$) has been observed in small amount in the veins, occurring usually in isolated clusters of crystals.

Metallic Minerals

Gold (Au). Native gold occurs as particles scattered through the quartz of the veins, and sometimes in richly concentrated ore-shoots or pockets, where it is easily seen with the naked eye. Sometimes it occurs as thin plates or coatings on slickensided partings in sheeted or ribboned veins.

It also occurs finely distributed throughout the sulphides in minute films and particles. Free-milling gold is found associated with pyrite, arsenopyrite, chalcopyrite, tellurium minerals, and stibnite, and all these minerals are found to be usually indicative of the presence of high values of gold in the veins.

Tellurium Minerals (*Sylvanite* ?) (AuAg) Te_2. A mineral containing tellurium was found in the main vein of the Ida May property. An analysis made by H. V. Ellsworth of the mineralogical division of the Department of Mines, showed that it was apparently sylvanite, although it seemed to carry more silver than would be expected from that mineral. It is silver-white in colour and highly sectile and is intimately associated with native gold and stibnite. Figure 6 illustrates the association of the native gold with the telluride. The telluride is also reported from the shaft vein of the Lorne mine.

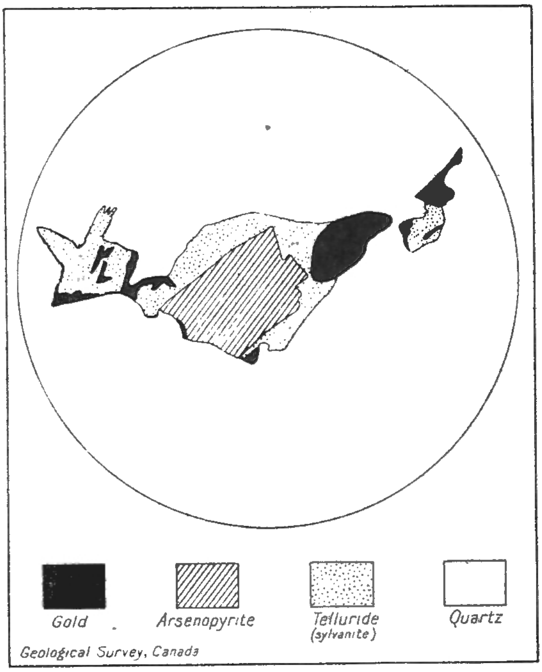


Figure 6. Camera lucida drawing showing intimate intergrowth of gold with a telluride in quartz vein at the Ida May mine. (Magnification 12 diameters.)

Arsenopyrite (FeAsS). Arsenopyrite occurs disseminated through the quartz veins and in the altered wall-rocks of the veins to a marked degree. It occurs usually in rather well-formed rhombic crystals, which often show multiple twinning. Where the quartz veins are sheeted, finely pulverized arsenopyrite occurs along the planes of movement. At the Ida May mine it occurs intimately intergrown with pyrite. Upon decomposition of masses composed of both these minerals, the pyrite is first decomposed and iron sulphate is formed, leaving the intergrown arsenopyrite in relief. Figure 6 shows the relation of arsenopyrite to gold and a telluride in the Ida May vein. Similar association of gold with arsenopyrite has been noted in the Allegheny district, Cal.,[1] and in the Nickel Plate mine at Hedley, B.C.[2]

[1] Ferguson, H. G., U.S.G.S. Bull. 580–1, 1914, p. 169.
[2] Camsell, C., Geol. Surv., Can., Mem. 2, 1910, p. 137.

Pyrite (FeS_2). Pyrite is the most abundant metallic mineral in the veins, and in the altered wall-rock. In the veins it is usually in massive form, with occasional imperfect crystals. In the wall-rock the crystals are often perfectly formed. Pyrite is often intergrown with other metallic minerals, particularly with arsenopyrite and gold, which occur in fine films and particles throughout the massive pyrite.

Chalcopyrite ($CuFeS_2$). This mineral is of rare occurrence in the gold-quartz veins of the Cadwallader gold-belt. Its occurrence has been noted at the Lorne mine and the Cosmopolitan claim. It occurs in irregularly disseminated grains, without apparent crystallization, and in the Wedge vein it is closely associated with the gold. Its presence is usually indicated by the blue and green stains of the copper carbonates azurite and malachite.

Galena (PbS). Lead sulphide occurs sparingly in small cubes in some of the veins. It was observed at the Lorne and Pioneer mines, and has been reported at the Wayside mine, and in the Countless tunnel.

Sphalerite or *Zinc Blende* (ZnS). Sulphide of zinc occurs sparingly disseminated through some of the quartz veins in about the same amount as galena. It is considered to be a good indication of a high gold content.

Stibnite (Sb_2S_3). Antimony sulphide as associated with gold quartz veins is known to occur only at the Ida May and Coronation mines, where it occurs in massive grains and tufts of fine hair-like crystals in the interspaces between the roughly formed prisms of the coarsely crystallized quartz. The small crystals of calcite are often clouded with inclusions of such hair-like particles. It is closely associated with the gold and the tellurium mineral.

Tetrahedrite ($Cu_8Sb_2S_7$). Grey copper ore was found in the Wedge vein of the Lorne mine and on the Forty Thieves claim. It is sparingly disseminated through the quartz gangue in well-formed tetrahedral crystals. In the oxidized parts of the vein it has been altered to azurite and malachite, the carbonates of copper.

Paragenesis of the Vein Minerals

The order in which the vein minerals were deposited, or their paragenesis, appears to be uniform throughout the different veins, although few of the veins are known to carry all the minerals described in the previous section. The vein solutions were probably in a state of chemical equilibrium with respect to the dissolved constituents. Hydrothermal alteration of the wall-rock took from the solutions of carbon dioxide, sulphur, and potash, but added to them appreciable quantities of silica, iron oxides, and calcium, probably causing—together with changes in physical condition—the precipitation of most of the minerals simultaneously. Quartz is intimately associated with calcite in such a manner that they must have crystallized together, although some calcite crystals occurring in small vugs in the quartz are certainly younger. Associated with the calcite is stibnite in slender hair-like crystals. Their association plainly points to simultaneous crystallization. The gold is disseminated throughout the massive quartz and occurs also with the sulphides and the tellurium mineral. Palmer and Bastin[1] have shown that arsenopyrite is an extremely effective precipitant of gold, and the intimate association of gold with the arsenopyrite points to the latter mineral as being the chief reagent in the reaction. Pyrite and arsenopyrite; arsenopyrite and the telluride; and gold, the telluride, and arsenopyrite, intimately intergrown with one another, show that they were contemporaneous (Figures 6 and 7).

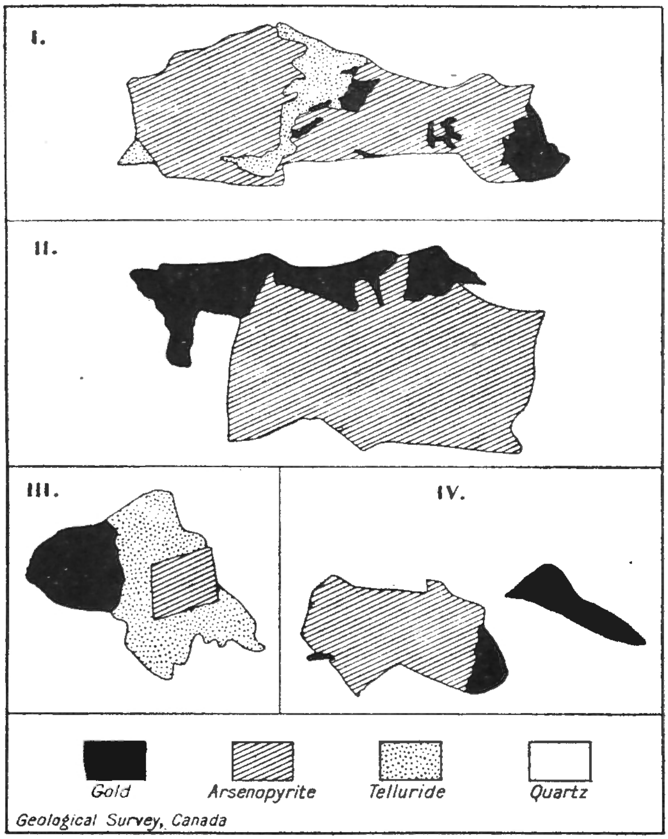


Figure 7. Camera lucida drawings showing intergrowth of metallic minerals in gold-quartz veins. (Magnification 12 diameters.)

Gold Content of the Wall-Rock

There is a striking difference in composition between the veins and the altered wall-rock. The silica, gold, tellurium mineral, and sulphides (except arsenopyrite and pyrite)were precipitated in the veins, probably because the walls were not permeable by these materials. This condition appears to hold true for most gold-quartz veins in all parts of the world.

[1] Econ. Geol., vol. 7, 1913, pp. 140-170.

Assays for gold made by the writer from samples of the wall-rock of some of the veins gave negative results, except in the case of a sample taken near the shaft on the 200-foot level of the Pioneer mine which assayed 0·30 ounce of gold. At this point, however, the wall-rock is greatly shattered and cut by numerous quartz stringers which are believed to have held the gold. A sample of wall-rock of the Wedge vein 1 to 2 feet from the vein, collected by A. M. Bateman, assayed 0·03 ounce gold per ton. Samples taken from the albitite dykes, which sometimes parallel the vein in the same fissure, showed a gold content of 0·03 ounce per ton.

Oxidation of the Veins

The lower limit to which the veins appear to be affected by surface waters containing oxygen is little over 100 feet. Near the surface for a depth of 8 to 10 feet the veins have been oxidized to a rusty iron-stained gossan composed of iron oxides and quartz loosely cemented. The sulphides have been altered to limonite which has stained the rock. Where chalcopyrite or tetrahedrite occurs in the veins the quartz nearby is stained blue or green by the formation of azurite or malachite. Such decomposed outcrops usually yield fine gold by panning.

At one time oxidation probably extended to much greater depths, probably to several hundred feet, but intensive and rapid erosion by glaciation has removed the upper parts of the veins, which have contributed all their gold to the placer deposits of Cadwallader creek and Hurley river.

Ore-Shoots and Their Origin

The small amount of development in the mines and the absence of data on ore-shoots that have been discovered, render impossible any definite statement concerning their origin. The upper parts of the veins have been stoped through to the surface and have been generally found to contain higher values in gold than parts of the same veins a hundred feet below the surface, owing to residual enrichment through oxidation.

Rich ore-shoots also occur in the lowest depths (300 feet). In the King vein of the Lorne mine and in the Coronation and Pioneer mines ore-shoots were found at the junction of intersecting veins. It appears, therefore, that ore-shoots are apt to occur at the junction of intersecting veins, the precipitation of the gold probably being brought about by the intermingling of mineralizing solutions of slightly varying composition with consequent disturbance of chemical equilibrium.

The wider parts of the veins have been favourable for the deposition of sulphides and there the veins are most strongly ribboned. Such a concentration, particularly when the sulphide is arsenopyrite, has in many cases determined the loci of ore-shoots, since the gold is very closely associated with this mineral. Such ore-shoots are most commonly met with in the outer rather than in the central parts of the veins.

Pinches and Swells

The dynamic stresses which acted upon the augite-diorite found relief in the fracturing of the mass and the production of the fissures that now contain the veins. Such fissures are never perfectly straight, but are curved or warped. Usually there has been some relative movement between the two faces or walls of the fissure, as is indicated by the film of gouge, or ground-up wall-rock, and slickensided surfaces. Such movement has caused pinches where convexities occur opposite one another, and swells where the walls are kept apart by the juxtaposition of concavities.[1] Since such variation occurs along the dip of the fissure as well as along its strike, relative movement of the walls has resulted in the formation of lens-shaped openings along the fissures which render them natural conduits for the circulation of underground waters.

The pinching of a vein to a mere stringer, therefore, does not mean that the vein has been followed to, or near, its end, especially if it is within such a homogeneous rock mass as the augite-diorite. According to information supplied by Mr. Arthur Noel, present owner of the Lorne mine, the principal veins had pinched to mere stringers at the ends of the workings when he assumed control of the property. Upon development, however, the veins were found to widen, or in other words, a swell was encountered within a few feet of the pinch. Prospectors should, therefore, not be discouraged by pinching of the veins, for such is probably but a local feature of the fissure.

FAULTING OF THE ORE-BODIES

Movement Along Fissures Subsequent to Vein-filling

There has been movement along the planes of the veins since they were formed, but the dimensions of this movement were small. There is little evidence of any great amount of wall-rock having been dragged into the vein, and there is no marked brecciation of the gangue materials. Most of the important veins in the augite-diorite, however, show pronounced sheeting or ribbon-structure (Plate VIII B) parallel to the walls, each band being separated by a film of finely pulverized sulphides, and sometimes there is a film of gouge made of carbonates, sericite, and chlorite along these planes. In places where the different bands have slickensided surfaces, exceedingly thin films of gold, also striated, coat the surfaces.

The banding may have been caused originally by local concentrations of sulphides, producing a somewhat banded structure. Such mineralized portions may then have formed lines of weakness along which subsequent movement within the veins took place, the sulphides being pulverized, and later recrystallized in part, producing the ribbon-structure now observed. Mineralizing solutions may have accompanied this movement, but it is thought that the occurrence of native gold in grains and coatings along the planes of movement is due to the release of the gold

[1] Irving, J. D., "Economic Geology," vol. III, p. 148.

through crushing of the intergrown arsenopyrite. Only those veins which show ribbon-structure formed in this way have been found to contain "bonanzas", although massive quartz veins, in which such banding is absent, contain fine specks of gold disseminated throughout them. Movement of a similar character has been noted in the gold-quartz veins of Grass Valley, California,[1] and elsewhere.

Movement Resulting in Lateral Displacement of the Veins

Faulting in the augite-diorite which has displaced the veins has been observed in several instances, and the observations up to the present time would indicate that the importance of such subsequent movement is slight, and that the greatest effect may be expected where the intrusive body is widest.

At the Lorne mine, the Wedge vein in No. 2 tunnel ends abruptly at a fault striking at a large angle to the strike of the vein. Deep grooves on the walls of the fault plane, and "drag" of the veins, indicate that the displacement of the vein has been to the west, and later development has strengthened this idea, although absolute proof is lacking. The displacement along the plane of the fault is probably under 100 feet, whereas the lateral displacement of the vein is not more than 70 feet. This is by far the greatest observed movement affecting the veins.

At the Pioneer mine (Figure 8) the workings on No. 2 vein on the 100-foot level show that the vein has been step-faulted to the north three times in less than 200 feet. The movement as far as can be ascertained has been horizontal and the displacement in two instances can be measured and is only 2 or 3 feet. The workings do not permit of measurement of the third displacement, but they prove that it is to the north, and it is inferred from the other two instances that it is only a few feet.

PERMANENCE OF ORE AT DEPTH

There are no data available for determining whether rich ore-shoots persist at depth in the gold-quartz veins of the district. The lowest depth attained by the present workings is little over 300 feet below the outcrop of the vein. It is reasonably certain, however, that the fissures extend to great depth as long as they are contained in the augite-diorite, and that the quartz and other minerals with which they are filled were deposited under almost uniform conditions within the limits of possible mining operations. Gold-quartz veins of other regions, which are almost identical with those in the region under discussion in structural and mineralogical characters, have been followed to great depths. At Grass Valley the North Star vein has been proved to contain rich ore-shoots at a depth of over 6,000 feet along the dip of the vein, or at a distance of over 2,000 feet vertically below the surface. At Juneau some of the veins have been followed along their dip to a vertical depth of more than 2,000 feet, and in the Kennedy mine, on the Mother Lode belt, good ore has been obtained at a depth of 4,000 feet.

There appears to be no reason to suppose that the veins, at depths attainable by mining operations, do not contain ore-shoots similar in character to those found in the upper parts of the veins except, however, that there will be no rich concentrations of gold corresponding to those in the oxidized surface parts of the veins.

[1] Lindgren, W., U.S.G.S. 17th Ann. Rept., pt. II, p. 129.

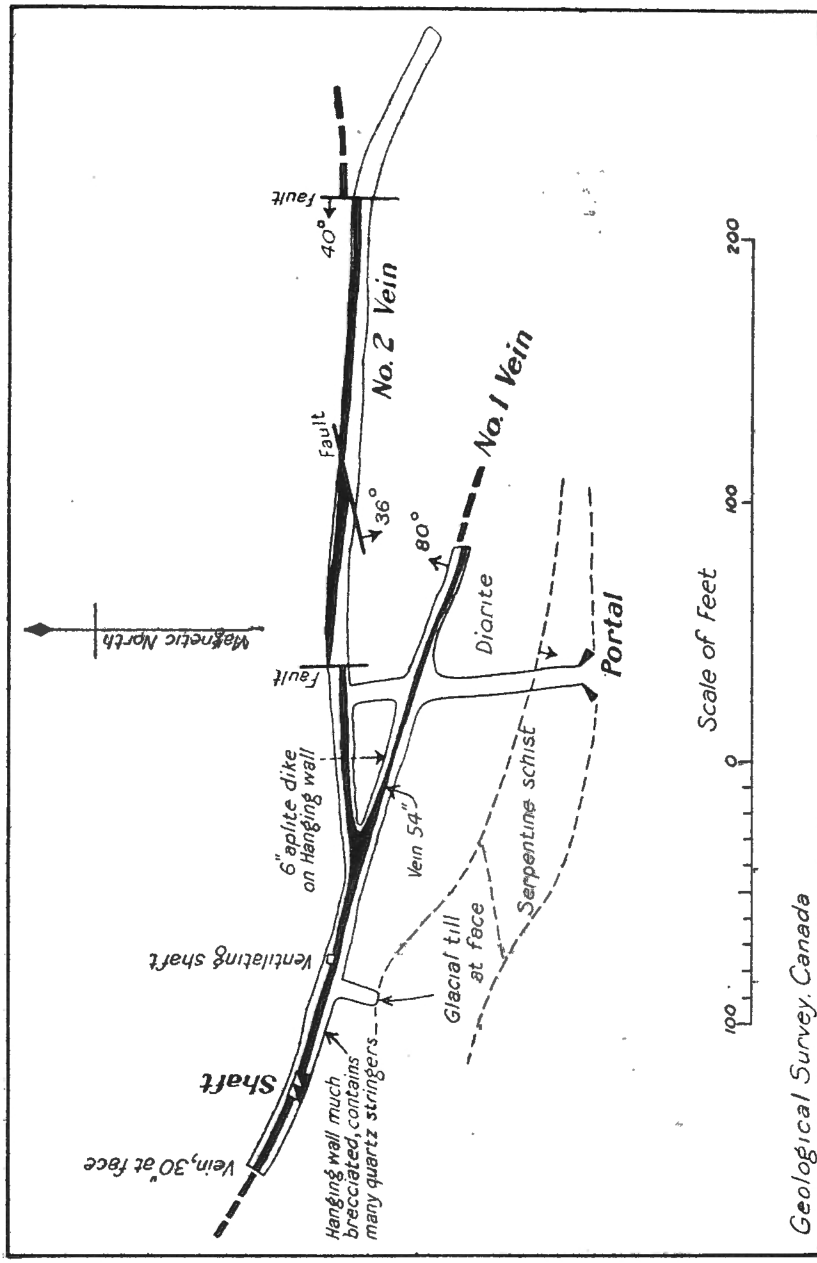


Figure 8. Plan of 100-foot level of Pioneer mine showing step faulting of No. 2.

VALUE OF THE ORES

No systematic assaying has been done by mine operators in the past so that there are few data available for determining the average value of the gold-quartz veins. When rich assays have been reported there is nothing to show that these have not been of rich specimens rather than of samples. From the observed occurrence of ore-shoots at intersections of veins, it is believed that in many cases the localization of the ore-shoots is controlled by such phenomena, and since intersections are by no means of regular occurrence it is difficult to estimate the average value of a vein.

In the east end of No. 3 tunnel of the Pioneer mine an ore-shoot 20 inches wide yielded spectacular specimens. It is stated that this ore, with all the rich specimens removed, yielded $60 to the ton on the amalgamation plates. Another ore-shoot in the same vein yielded $65 per ton.

The main vein on the Countless claim, which is believed to be an extension of the Little Joe vein, is reported to have averaged at the surface $20 in gold per ton.

It is stated that the average extraction of gold by amalgamation from the ore of the King vein of the Lorne mine is $17. The value of the ore from the Wedge vein is estimated to be from $10 to $14, and oxidized parts ran as high as $80 per ton.

Assays made by the writer and confirmed by A. Sadler of the Mines Branch of the Department of Mines gave the following results: Average of eight samples from the Woodchuck vein of the Lorne mine is $3.40 gold per ton. Average of four samples from the King vein, $6.50 per ton. An ore-shoot in the Turnplate ledge in the same workings assayed $250 gold per ton.

The close association of gold with the sulphides, particularly with arsenopyrite, makes the actual gold content of the ore greater than it would appear from the treatment of the ore by amalgamation only. Concentrates from the Pioneer and Lorne mines have assayed from $100 to $300 per ton. Up to the present time no process of treating the concentrates has been introduced into the district, and indeed it has been only during the past few years that concentrates have been saved, and most of them have passed directly from the arrastre beds and amalgamation plates of the mills into the tailings dump. The tailings contain from $3 to $6 in gold per ton.

ALTERATION OF THE WALL-ROCK

The ore-bearing solutions have had a profound effect upon the augite-diorite next to the veins. For a distance varying from a few inches up to 8 feet the wall-rock has been progressively altered by the action of hydrothermal solutions to a pale yellow colour. In some places it is actually white, and has a greasy feel. There has been a marked addition of sulphides in the wall-rock.

Comparison of sections of the fresh and altered rocks reveals in part the nature of the alteration. The fresh unaltered augite-diorite is made up essentially of plagioclase feldspars, hornblende, and augite with a little interstitial quartz and orthoclase, with such secondary minerals as chlorite, uralite, sericite, quartz, and calcite.

In the course of the alteration the augite, hornblende, and feldspars are first vigorously attacked, the alteration proceeding along cracks and cleavage planes to produce a finely felted aggregate of sericite, quartz, and ferrodolomite. The ferromagnesian silicates are first altered to chlorite before being changed finally into sericite. The quartz also shows incipient alteration and strain shadows. Well-formed cubes of pyrite and rhombic crystals of arsenopyrite are abundant in the altered wall-rock, and their growth is probably due to the leaching of the ferrous iron from the ferromagnesian constituents and its combination with sulphur and arsenic from the hydrothermal solutions which have permeated the wall-rock. Titanite and apatite are also present.

In places where the alteration has not been extreme albite is developed to a marked degree, sometimes making up 16 per cent of the altered rock as indicated by the calculated mode of the altered augite-diorite which is as follows:

Albite	Sericite	Ferrodolomite	Quartz	Chlorite	Magnetite
16·24	31·98	23·88	21·54	3·88	1·23 %

Albitization of the wall-rock has been noted elsewhere in deposits of a character similar to those of the Bridge River area, as in the Juneau gold belt[1] and the Eagle River region[2] in southern Alaska.

In order to determine more exactly the nature of the alteration that has taken place in the wall-rock, chemical analyses of both the unaltered rock and the altered rock are required. Such analyses made by M. F. Connor of the Mines Branch of samples taken by A. M. Bateman are here given. The samples were collected from the augite-diorite near the King vein at the Lorne mine in 1912.

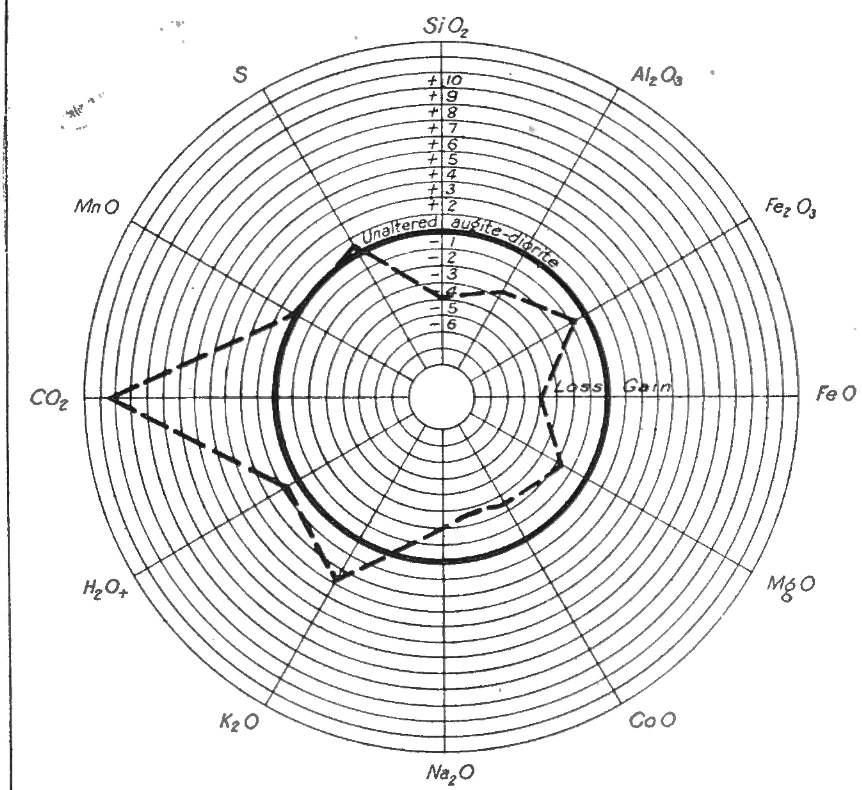
Comparison of Fresh and Altered Augite-diorite

	Ia	Ib	IIa	IIb	IIIb	IVb
SiO_2	50·69	47·60	146·56	132·80	−13·76	− 4·75
Al_2O_3	18·61	16·50	53·86	46·03	− 7·83	− 2·70
Fe_2O_3	1·51	0·76	4·37	2·12	− 2·25	− 0·78
FeO	7·45	4·11	21·56	11·47	−10·09	− 3·49
MgO	6·05	4·24	17·51	11·83	− 5·68	− 1·96
CaO	8·30	6·44	24·02	17·97	− 6·05	− 2·09
Na_2O	3·80	1·90	11·00	5·30	− 5·70	− 1·95
K_2O	0·80	3·74	2·32	10·43	+ 8·11	+ 2·80
H_2O	2·89	3·82	8·36	10·66	+ 2·30	+ 0·79
H_2O-	0·16	0·18	....	....	....	....
CO_2	....	10·75	....	29·99	+29·99	+10·36
TiO_2	0·34	0·50	0·98	1·40	+ 0·42	+ 0·14
P_2O_5	0·07	0·04	0·21	0·11	− 0·09	− 0·03
S	0·02	0·17	0·06	0·47	+ 0·41	+ 0·14
MnO	0·11	0·04	0·32	0·11	− 0·21	− 0·07
Total	100·70	100·79	291·58	281·19	−10·39	− 3·59
Sp. gr.	2·894	2·790				
Example of method	....	....	Ia × 2·894	Ib × 2·790	IIa−II−b	IIb / 2·894

Ia—Analyses of fresh, unaltered augite-diorite.
Ib—Analyses of altered augite-diorite adjoining the vein.

[1] Spencer, A. C., U.S.G.S. Bull. 287, 1906, p. 111.
[2] Knopf, A., U.S.G.S. Bull. 502, 1912, pp. 36–40.

In order to use such pairs of analyses for the determination of the amounts contributed and abstracted by mineralizing solutions[1] one must know the specific gravities of the fresh and altered rocks, and the change in volume accompanying the process. As a rule, however, there is practically no change in volume, and in the present case the porosity of the respective rocks was determined to be 0·30 and 0·54 per cent. Such a difference



Geological Survey, Canada.

Figure 9. Circular diagram illustrating gains and losses of chemical constituents in the alteration of fresh augite-diorite, in terms of per cent of the original rock. Heavy black line represents the fresh rock; heavy broken line represents the altered rock. Radial intervals correspond to 1 per cent. Areas have no significance. (After A. M. Bateman.)

is so small as to be negligible for purposes of the present calculations. The rock analyses should first be recalculated to total exactly 100 per cent. and then each analysis is multiplied through by its specific gravity, the result (columns IIa and IIb) giving grammes of each constituent in 100 cc. of each rock. Comparison of these columns will show the quantitative

[1] The method used here is that adopted by F. L. Ransome in his description of the effects of hydrothermal solutions upon the wall-rocks of the veins in the Breckenridge district, Col., U.S.G.S. Prof. Paper 75, 1911, pp.94-102.

changes that have taken place. If the one representing the fresh rock be subtracted from that representing the altered rock, the positive values represent material added by the mineralizing solutions, and the negative values represent material abstracted, in terms of grammes per 100 cc. of rock (column IIIb). If we divide this column through by the specific gravity of the fresh rock we have as the result the expression of the same quantities in terms of grammes per 100 grammes of fresh rock (column IVb). When these values are plotted upon a circular diagram the work of the mineralizing solutions is shown graphically (Figure 9).

NATURE OF THE SOLUTIONS

From this diagram (Figure 9) it may be seen that the chemical changes which have been involved in the alteration of the augite-diorite have resulted in the addition of carbon dioxide, potash, and small amounts of combined water and sulphur, whereas the remaining constituents suffered a loss. It is to be noted that considerable amounts of iron oxide have been extracted and these have probably gone to enrich the vein solutions and may have brought about the precipitation of the gold in the veins. The amount of iron oxides that have been retained in the wall-rock has combined with the sulphur to form the pyrite. Arsenic must also have been introduced to have permitted the formation of arsenopyrite. The mineralizing solutions must, therefore, have been warm alkaline waters containing much carbon dioxide, along with salts of sulphur and arsenic.

ORIGIN OF THE VEIN SOLUTIONS

Magmatic Origin Probable

The solutions from which the vein materials were precipitated are believed to be genetically related to the augite-diorite intrusion, the veins constituting the result of the last phase of magmatic differentiation within the magma from which was derived the augite-diorite. After the augite-diorite had solidified, the same magma, far below, continued cooling, probably very slowly, until it produced a differentiate consisting nearly altogether of pure albite (page 32). This albite differentiate (the albitite dykes) left behind in the remaining liquor all the silica that was not required to satisfy the soda and the alumina of the albite, and all the potash, the potash not entering into combination with the soda, alumina, and silica to form other feldspars.

The resulting solution was probably made exceedingly fluid by the addition of large quantities of magmatic water, and thus was able to permeate the wall-rocks of the fissures to effect the profound alteration which is generally observed. Similar metasomatic changes in rocks which contain gold-quartz veins have been observed at Juneau, Alaska,[1] and in California[2], where alteration has been accomplished through the agency of ascending thermal solutions.

Concerning the latter Lindgren says:[3] "Waters which have exercised such a powerful metasomatic influence on the rocks in the vicinity of the veins and contained such large quantities of carbon dioxide as are required by the facts of metasomatism are not known to occur in nature except as ascending, usually thermal, springs."

[1] Spencer A. C., loc. cit. p. 29.
[2] Lindgren, W., U.S.G.S., 17th Ann. Rept., pt. 2, p. 173.
[3] Idem.

The presence of abundant water to produce such aqueous solutions may be accounted for by the presence of a magmatic reservoir underlying the whole region. Such a reservoir, remaining molten long after its satellitic intrusions had solidified, would appear to be an adequate source of the water and the metallic minerals which are found in the veins. Day and Shepherd[1] have shown that water is an important constituent of volcanic gases and that its magmatic source is exceedingly probable. Petrographers now generally agree that the order of crystallization of the constituents of granular igneous rocks can be best explained by admitting the existence of more water in the magma before its consolidation than is shown in the analysis of the resulting rock[2], so that magmatic water resulting from the crystallization of the magma, and from igneous emanations, constituted a great part of the ascending heated solutions that formed the veins of the Bridge River district.

The necessary quartz to form the gangue material of the veins may be accounted for by the theory of fractional crystallization of the magma. As crystallization proceeds, the mother liquor, or the remaining magma, becomes more and more siliceous, since the minerals crystallize out in the order of their relative basicity, quartz being the last to crystallize if present in excess of the amount required to satisfy the silica-bearing constituents which have already crystallized.

The close association of gold-quartz veins with the intrusive rocks has been noted in so many regions that such a genetic relation may be considered to be a general one. A few of these occurrences are the Pelly River district, B.C.,[3] the Slocan district, B.C.,[4] in the Sierra Nevada of California[5], at Victoria, Australia[6], and in southeastern Alaska[7].

Conclusion

Though it has not been possible to examine the veins of the Bridge River map-area at depth, on account of the shallowness of their workings, they are observed to be practically identical in mineralogy, structure, and relation to surrounding rocks, as the veins in Grass Valley, California, and in southeastern Alaska, and it may be assumed that they are of practically the same origin. The aqueous vein solutions are considered to have originated in the magma from which the augite-diorite was formed. The intrusive, penetrating as it did the folded and sheared Palæozoic and Mesozoic formations, solidified under a thick cover of rock. This rock mantle was apparently of such a character that fissures, which were produced in the intrusive, did not persist in the surrounding rocks, and hence channels for the descent of surface waters into the intrusive mass were, probably, wanting.

The extraction of silica from the wall-rock of the veins by metasomatic processes may have contributed to the amount of quartz in the vein solutions, and indeed this addition of quartz, along with other factors, such as changes in physical conditions, probably disturbed the chemical equilibrium in which the various constituents were held in solution, resulting in the deposition of vein material.

1 Day and Shepherd, E. S., "Water and Volcanic Activity," Bull. G.S.A., vol. 24, 1913, p. 606.
2 Spencer, A. C., "Magmatic Origin of Vein-forming Rocks." T.A.I.M.E., vol. 36, 1905, p. 366.
3 Dawson, G. M., Geol. Nat. Hist. Surv., Can., Ann. Rept., vol. III, pt. 1, p. 35 B.
4 Carlyle, W. A. Quoted by J. F. Kemp, "Ore deposits of U.S. and Canada," 4th ed., p. 35 B.
5 Lindgren, W., "Mineral Deposits", 1913, p. 530.
6 Lindgren, W., "Characteristics of Gold-Quartz Veins in Victoria," Eng. and Min. Journ., March 9, 1905.
7 Spencer, A. C., "The Juneau Gold-Belt, Alaska," U.S.G.S. Bull. 287, p. 30.

AGE OF THE VEINS

A sufficient length of time must have intervened between the intrusion of the augite-diorite and the formation of the veins, to have permitted of the solidification of the intrusive to such an extent that it would yield to deforming stresses by fracturing. The greater the thickness of overlying sediments the greater would be the length of time required for the intrusive to solidify. There is no means of estimating the thickness of this overburden, but it would be difficult to account for thicknesses so great that the intrusive would remain molten for any long period. It is considered that the augite-diorite cooled soon after intrusion, and that the deforming stresses producing the fissuring acted about that same time. The augite-diorite has been intruded by light-coloured albitite porphyry dykes which are considered to be a later differentiate of the augite-diorite magma, and the veins themselves, which cut across these dykes, are believed to have been the last manifestation of igneous activity of the intrusive, and, therefore, of the same general age as the augite-diorite, but slightly younger than the dykes.

That the intrusive of the albitite dykes contributed to the greater ease with which the later deforming stresses fractured the augite-diorite is attested to by the fact that in many places the veins conform to the dykes, occurring along the same lines of weakness and in the same fissure. In the Pioneer, Coronation, and Lorne mines have been found instances where the quartz veins have one wall of albitite porphyry and the other wall of augite-diorite, and this close association is to be expected in other parts of the intrusive mass.

The augite-diorite is much more metamorphosed than the Bendor quartz diorite which is only 2½ miles away, and the quartz diorite does not contain gold-quartz veins. The augite-diorite is not known to have intruded formations younger than the Cadwallader series, which is of Upper Triassic age, whereas the Bendor quartz diorite intrudes sediments of known Lower Cretaceous age. The augite-diorite, therefore, on account of its lithological characters, its greater metamorphism, and its relation to intruded formations, is considered to be older than the Bendor batholithic quartz diorite, and its age is placed as late Jurassic.

FUTURE OF THE DISTRICT

The importance of the Bridge River map-area is largely dependent upon mineral production, and the only ore-deposits so far successfully exploited are the gold-quartz deposits in the Cadwallader Creek belt. In the past, in spite of poor transportation facilities, and the consequent lack of proper methods for treatment of the ore, some of the deposits have been profitably worked on a small scale. The intimate relationship between the arsenopyrite and the gold has led to the recovery of only a part of the gold content, and the introduction of modern metallurgical processes would enhance the value of the ore.

The fact that the veins occur in parallel systems, usually no great distance apart, should be an incentive toward active development by crosscutting rather than by drifting along the veins. In this way mine operators could estimate more readily the amount of ore available. Development of the deposits, of course, requires capital, the lack of which has in the past greatly restricted operations. With amalgamation of interests, however, it is believed that active development might be pursued, and sufficient ore blocked out to warrant the installation of up-to-date processes for treatment of ore on a large scale.

The above statement, however, is advanced with considerable reservation on account of the advanced cost of production during the past few years, and the fixed price of gold. In 1917 the average operating cost of producing a dollar's worth of gold at the largest lode mines in the United States was 70 cents. The actual cost varied from 5 to 90 cents in different states.[1] The cost of production in the Bridge River map-area in 1919 is estimated to have been 50 cents for one dollar's worth of gold.

Some of the largest gold mines in the western United States have been shut down recently because the cost production exceeds the value of the ore, and it is difficult to obtain labour at reasonable cost. The situation is acute and measures [2] are being brought before Congress advising that an excise tax be placed on all the gold used in the arts[3] and that the amount thus received should revert to the gold producers as a bonus.

Placer Gold Deposits

Regarding the occurrence of placer gold in British Columbia, Dawson has said:[4]

"It may, I think, be said without exaggeration, that there is scarcely a stream of any importance in the province of British Columbia in which the 'colour' of gold cannot be found."

Ever since the first discovery of gold in 1858 that mineral has been the chief factor in the prosperity of the province.

The placer mining industry, however, has never attained great proportions within the Bridge River map-area. The lower parts of Bridge river for 10 miles above its mouth have, however, yielded considerable gold. Deposits of small extent occur within the map-area, and to these the following remarks are confined.

DISTRIBUTION OF THE PLACER DEPOSITS

Cadwallader Creek Deposits

Placer mining is being carried on at present only near the junction of Cadwallader creek with Hurley river. The operations are not large, and the returns are small. Cadwallader creek has been well prospected and gold has been found from its mouth to the Pioneer mine, or to the southern end of the augite-diorite mass. This fact suggests that the gold has been derived mainly from the erosion of the gold-quartz veins of the augite-diorite stock.

[1] "Rep. of Comm. appointed from the Bureau of Mines and the U.S.G.S. to study the gold situation." Bureau of Mines Bull. 144, 1919, pp. 44-45.
[2] In 1919 the amount of gold used in the arts in the United States exceeded the total production.
[3] The McFadden bill, if passed, would provide for the payment of a bonus to the gold producers of $10 per ounce of gold.
[4] Dawson, G. M., Geol. Surv., Can., Rept. of Progress, 1876-77, p. 105.

Hurley River Deposits

Gold has been found in the gravels of Hurley river from its mouth to the point where it is joined by Cadwallader creek. The claims which have yielded the greatest amounts of gold are situated just below this junction. The source of the gold is probably the gold-quartz veins of the augite-diorite on the east side of Cadwallader creek.

Lower Gun Creek Deposits

The gravels of Gun creek for 4 miles from its confluence with Bridge river have yielded gold in small amounts. For the greater part of this gold-producing stretch the stream cuts across an ancient channel of Bridge river which was occupied during Glacial time when the combined glaciers of the Hurley and Cadwallader valleys dammed the river at the point where the bridge now stands. The gold content undoubtedly was derived from the gravels which were laid down in this ancient channel during the period of occupancy by Bridge river, and some of it may have come originally from quartz veins in the bodies of augite-diorite on both sides of Gun Lake valley. The amount of gold recovered was too small to warrant extensive operations.

Marshall Creek Deposits

At a point about 2 miles above the mouth of Marshall creek, operations were attempted on a large scale in 1908, but the bursting of the dam at the lower end of Marshall lake destroyed the workings. Previous to this, small amounts of gold had been found on the bedrock. There are possibilities of work being resumed in this locality.

SOURCES OF THE GOLD

It is thought that the gold found in the gravels of the streams of the Bridge River map-area had four main sources, which may be enumerated as follows:

The quartzites of the Bridge River series.

The conglomerates of the Lower Cretaceous Eldorado series.

The Tertiary conglomerates.

The gold-quartz veins of the late-Jurassic augite-diorite.

The last, and most important source will be considered in detail later; the other sources are deserving of only scant attention, and will be dealt with summarily as follows:

A sample of cherty quartzite from the Bridge River series on the southern slope of Marshall ridge yielded upon assaying, a trace of gold. The rocks at this point were much decomposed and rusty yellow owing to a rather high content of iron pyrite, which probably carried the gold. Such pyritization of the Bridge River series is of unusual occurrence but may be observed sometimes in the vicinity of lamprophyre dykes cutting the series. The contribution of gold from these quartzites is considered to be slight.

The conglomerates of the Lower Cretaceous sediments in the northern part of the map-area yield traces of gold. They include pebbles of andesite which may have been derived from the Cadwallader series, so the gold might have been derived from erosion of gold-quartz veins in bodies of igneous rocks occurring outside the map-area, since it is not believed that the bodies of diorite within the map-area were exposed to erosion as early as Cretaceous time. This source of supply is not considered great.

In the conglomerate at the base of the Tertiary sediments exposed in Jones bluff near Rexmount, traces of gold have been found. Pebbles of vein quartz occur in the conglomerate and may have originally contained the gold. The augite-diorite may have been undergoing erosion at the time these sediments were laid down and the quartz may have come from the veins contained in that rock. The distribution of such Tertiary sediments is very restricted within the map-area, but originally it was probably great, and gold placers may have been formed. Such stream deposits, however, on account of the ease with which they are removed by erosion, would not, probably, persist from this distant age, nor contribute appreciably to the placer deposits.

The gold-quartz veins of the augite-diorite have undoubtedly been the chief source of the placer gold. The erosion immediately preceding the late Pliocene uplift probably removed the rocks covering the augite-diorite intrusive and the tops of the gold-quartz veins. It is believed that the present topography was, in large part, developed at this time, and that the placer deposits were formed, most of the gold being derived from the upper, superficially enriched, parts of the veins. The regional uplift rejuvenated the drainage, and the existing placer deposits were probably worked over, the gold being reconcentrated in lower parts of the valleys, as in the lower parts of Bridge river.

The erosion during Pleistocene time must have added considerable material to the placers, since it completed the removal of the upper enriched parts of the veins. The action of the glaciers has also been a factor in the distribution of the gold-bearing gravels. The placer deposits in Recent alluvium represent the reconcentration of gold derived from the Pleistocene deposits, since it is believed that erosion of the quartz veins has been slight since Glacial time.

CHARACTER OF THE GOLD

The gold is usually coarse and tabular with jagged edges, indicating recent release from the quartz. In this respect it differs from the gold recovered from the Fraser River gravels, which is smooth, indicating its distant removal from the source of supply. In many cases particles of quartz adhere to the gold.

It is as a rule pale lemon yellow and is alloyed with considerable quantities of silver. The average calculated value per ounce is $16.40. Nuggets worth up to $120 have been discovered.

ASSOCIATED METALLIC MINERALS

Platinum. Although small amounts of platinum have been found with the gold, the quantity was never deemed sufficient to warrant its separation. It is probable that the sources of the platinum are the serpentine rocks of the district.

Mercury. Gold amalgam has been reported as occurring in this district, but definite information on the subject is lacking.

WHERE THE GOLD HAS BEEN CONCENTRATED

Placer gold has been found only in the gravels close to bedrock, i.e., the lower 4 or 5 feet of the gravels, and on the bedrock itself. Placer mining operations are difficult on account of the high velocity of the streams and the great size of the boulders, sometimes 12 feet in diameter near bedrock. The gravels are often cemented with calcium carbonate to form a friable conglomerate, and the gold is disposed throughout the matrix.

Favourable locations for the deposition of the gold have been found to be in the stream bed just below a canyon, or in any such constriction of the stream. In such cases the gold has settled to the bottom on account of the sudden decrease in the velocity of the stream.

The point of confluence of two streams is considered a favourable place to prospect for placer deposits. In the case of the junction of Noel and Cadwallader creeks a moderately rich deposit was formed at the acute angle of junction. There is a strong eddy in Cadwallader creek just above the junction. Gold in suspension in the waters of Cadwallader creek would be likely to be deposited in such eddies or places of slack water. A similar deposit has been formed at the junction of Cadwallader creek and Hurley river.

Bedrock structure plays an important rôle in determining the location of the gold. On Hurley river, where the bedrock is in places composed of serpentine, the rock floor has been worn smooth, and is even polished, by the water and gravels passing over it. Consequently, there are few crevices in the floor to form lodgment for the gold. On such a bedrock the gold is mainly in the coarse gravels which lie on top of the bedrock.

On Marshall creek, on the other hand, the gold is found mainly on bedrock which is composed dominantly of thin-bedded quartzites, with thin interbeds of argillite belonging to the Bridge River series. Differential erosion of these strata, resulting in the depressing, or wearing away, of the argillite members, produces natural riffles in which the gold lodges. Where the strike of the beds is diagonal to the direction of the stream, the greater quantities of gold should be found at that side of the stream where the strike of the beds forms an acute angle with the direction of the stream.

Silver-Copper Deposits

The silver-copper deposits, situated as they are near the top of one of the highest mountains in the southern central part of the map-area, are far removed from good transportation facilities. A good trail, however, of low gradient, connects the Empire mine with the Pacific Great Eastern railway at the point where McGillivray creek empties into Anderson lake, 20 miles to the south. The vein outcrops are 8,000 feet above sea-level and about 7,100 feet above Anderson lake. Timber-line is about 1,500 feet below the workings: fuel and supplies have to be transported by pack train. The climate is such that the deposits cannot be worked more than five months in the year.

In view of the difficulties of transportation, climatic conditions, and the low tenor of the ore in sight, the copper-silver deposits have not been actively developed, although some work was being done on them at the time of the writer's visit.

The deposits occur in a well-defined quartz vein striking with the enclosing Bridge River series. For a great part of its length it follows the contact between the cherty quartzites of the series, and a small serpentine belt, its direction being roughly parallel to the southern contact of the Bendor batholith which lies half a mile to the north. This vein is closely associated with a quartz diorite porphyry apophysis of the Bendor batholith.

STRUCTURE

The vein, the most persistent one found in the district, forms a conspicuous landmark on the side of McGillivray mountain, whence it may be traced for over a mile northwestward to the Hazard group of claims. It displays banded structure due to the filling of the fissure by crustification. The metallic minerals have been deposited in thin, banded aggregates parallel to the walls. "Comb structure" and drusy cavities render the vein permeable to surface waters, which have penetrated it, thereby causing the oxidization of the tetrahedrite. The resulting carbonates of copper, azurite, and malachite, have stained the quartz to a marked degree.

The lines of crustification along which tetrahedrite has been deposited have been lines of inherent weakness, and consequently movement, subsequent to vein deposition, has sheeted the vein parallel to the walls. A second system of jointing has fractured the quartz at right angles to the walls so that blocks roughly cubical in shape are produced. In width the vein averages 7 feet, but local swellings, due to the formation of pinches and swells by relative movement of the walls, measure 32 feet in places.

MINERALOGY

The gangue material is entirely quartz, and contains tetrahedrite (grey copper ore), azurite, malachite, and galena in small amounts. No rich concentrations have been encountered.

Two periods of mineralization are apparent from the order in which the metallic constituents have been deposited. The tetrahedrite occurs sparingly distributed throughout the entire vein, and was evidently deposited at the same time as the quartz. The galena, on the other hand, occurs only along the plane caused by the sheeting of the vein. Microscopic examination reveals the fact that the quartz in which the galena occurs has been extremely shattered and crushed.

GRADE OF THE ORE

The ore minerals have not been found in rich concentrations, but are irregularly distributed throughout the vein, large parts of which are barren. Where the ore content is greatest, tetrahedrite forms about 3 per cent of the veins. In such places it is reported that assays give $16.80 in gold, 5·75 ounces of silver, and 1·0 per cent copper. Samples collected at the Empire No. 1 claim assayed as follows:

	Gold	Silver	Copper
		oz.	
(1)	$0·40	35·2	—
(2)	trace	35·4	0·5%
(3)	trace	0·6	trace
(4)	trace	5·4	trace

(1) and (2). Brewer, W. M., Rept. Minister of Mines, B.C., 1912, p. 252 K.
(3) and (4). Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 208.

GENESIS OF THE ORE

From the mineralization of the vein and its field relations, it is probable that it was formed at intermediate depths and is genetically related to the intrusion of the Bendor quartz diorite, the vein materials being the expression of the last phase of igneous activity. It is similar in many respects to some of the quartz-tetrahedrite-galena veins at Organ, New Mexico.[1] The silver is contained in the galena, which, as far as is known, occurs in but small amount.

Antimony Deposits

DISTRIBUTION AND EXTENT

Deposits of antimony ore occur within the map-area to a limited extent, although at present they are of little economic importance. They appear to be confined to a narrow belt on the western limb of the Bridge River anticline, and have been found only within the Bridge River series. Little work has been done on them beyond prospectors' assessment work, so that only scant information is available. Such prospects have been uncovered on the east side of Tyaughton lake, and on both sides of Bridge river near Gun creek.

OCCURRENCE OF THE ORE

The antimony deposits are closely related to the intrusion of diorite-porphyry dykes. The ore occurs in a quartz gangue in shear zones bordering the dykes and is distributed for the most part in irregular lens-shaped masses through the quartz, as at the Reliance group of claims situated on the southern side of Bridge river opposite the mouth of Gun creek.

At the Stibnite group of claims, on the northern side of the river, stibnite occurs within the sheared porphyry dyke itself in small lenses or "pockets". Quartz always accompanies it. Usually stibnite is the only metallic mineral present, but at the Bluff claims small amounts of zinc blende and galena have been noted. The stibnite occurs in massive form and is coarsely columnar in structure. The surfaces of the individual columns are striated and furrowed longitudinally. Freshly broken surfaces have a highly splendent and metallic lustre, and weathered surfaces are tarnished. Lenses of ore vary from 1 inch to 1 foot in thickness, and are mostly under 4 feet in length.

[1] Lindgren, W., U.S.G.S. Prof. Paper No. 68, p. 209.

ORIGIN

The close association of the antimony deposits with the diorite-porphyry dykes in their field relations is strongly suggestive of a genetic connexion between them. The porphyry is made up of phenocrysts of plagioclase feldspars (oligoclase to andesine), hornblende, and biotite lying in a microcrystalline groundmass of the same minerals. In contact with the antimony deposits the rock has been altered to calcite, sericite, and halloysite. The presence of sericite suggests the combined action of high temperature, the chemical activity of water, and mechanical stresses[1], so that the solutions which have brought about this alteration were probably ascending thermal solutions, contemporaneous with, or slightly later than, the intrusion of the dykes. Dykes of similar composition have been found cutting the Bendor quartz diorite of the post-Lower Cretaceous age, and may be related to that intrusion and slightly younger than the quartz diorite dykes which are cut by diorite-porphyry dykes, as at the Stibnite group of claims. The exact age could not be determined, so they are considered tentatively to be related to a Tertiary cycle of igneous activity, and to have been formed near the surface.[2]

VALUE

The irregularity of the stibnite lenses and their small extent, combined with the difficulties of transportation, render the deposits unsuitable for working as an ore of antimony at the present time. Gold occurs associated with the stibnite in some localities, and at the Reliance group a sample[3] of the ore assayed $10.40 in gold, and future development may show that the deposits are of greater value.

Small amounts of antimony ore proper are being mined at present in the United States[4] and Canada, the price being low and subject to rapid fluctuations. In Canada the price of antimony[5] during the war ranged from 12 to 14 cents a pound, the numerous uses for the manufacture of munitions having accounted for the high price. Upon the signing of the armistice the price dropped to 8 cents per pound. The uses of antimony include the manufacture of type metal, shrapnel bullets, poison gases, and the hardening of copper.

Chromite Deposits

A small deposit of chromium ore occurs on the northern slope of Taylor basin in the northwestern corner of the map-area. It is associated with a small outcrop of serpentine rock. Occurring as films along the fracture planes, and as fillings of cavities in the chromite is a white, compact, hydrated silicate of magnesium.

[1] Clarke, "Data of Geochemistry," U.S.G.S. Bull. 491, 1911, p. 567.
[2] Lindgren, W., "Mineral Deposits," New York, 1913, p. 423.
[3] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 84.
[4] Lindgren, W., "Mineral Deposits," 1913, p. 473.
[5] Canada, Dept. of Mines, Mines Branch, "Production During 1918," p. 8.

The chemical analysis of a specimen collected by C. W. Drysdale[1] was made by the Mines Branch, and is as follows:

	Per cent
SiO_2	4·82
Al_2O_3	19·94
CaO	0·05
Cr_2O_3	48·72
MgO	12·79
FeO	12·80
Ni	undet.
H_2O	undet.
	99·12

A specimen was examined by R. A. A. Johnston,[2] mineralogist of the Geological Survey, who noted in the chromite the presence of microscopic diamonds, which, upon release from the chromite, broke up into fragments. This occurrence of diamonds in chromite is similar to that in the Tulameen district[3], and Scottie creek near Ashcroft, B.C.[4], and southern Quebec.[5]

ORIGIN OF THE CHROMITE AND DIAMONDS

The close association of the chromite with the serpentine rocks points to a genetic relationship. It undoubtedly represents a basic concentration by magmatic differentiation within an originally olivine-holding magma, the chromite probably being the first metallic mineral to crystallize. The small diamonds which are embedded within it, must have crystallized first of all and represent dissolved carbon[6] in the molten magma.

The outcrop of this deposit was so covered over with talus that no estimate of its extent could be made. However, since the extent of the serpentine at this point is small, it is doubtful if a large deposit of chromite occurs here. Other larger areas of serpentine in the Shulaps and Cadwallader mountains, however, might be prospected profitably for this mineral.

NON-METALLIFEROUS DEPOSITS

Magnesite Deposits

Several outcrops of magnesite occur within the map-area in the vicinity of Liza lake. They are in all cases closely associated with the serpentines (Shulaps volcanics) which underlie the Cadwallader series, of Lower Jurassic age. The outcrops stain buff-colour, owing to the presence of limonite.

STRUCTURE

The deposits are characterized by the complexity of the veinlet systems. Anastomosing veinlets of magnesite and chalcedonic quartz make up a large part of the altered serpentine (Plate IX). In some places the magnesite is massive and forms relatively pure deposits up to 60 feet in diameter and probably more, since a great deal of overburden covers the deposits.

[1] Geol. Surv., Can., Sum. Rept., 1915, p. 83.
[2] Idem, p. 83.
[3] Camsell, C., Geol. Surv., Can., Mem. 26, pp. 146–153.
[4] Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, pp. 23–124.
[5] Dresser, J. A., Geol. Surv., Can., Mem. 22, 1913, p. 76.
[6] Lindgren, W., "Mineral Deposits," New York, 1913, p. 744.

The veinlets are mostly composed of both chalcedony and magnesite, either irregularly mixed together throughout the veinlets, or as typical crustification bands. Magnesite rarely occurs without chalcedony, although the latter may be present in insignificant amount. In such veinlets the magnesite is well banded, the differently coloured bands being due to the varying amounts of limonite present.

In massive varieties the magnesite is vuggy, the spaces being filled with chalcedony, the spaces resulting from the alteration of the serpentine rocks to magnesite, in which case there is a shrinkage of one-fifth the volume.

Weathered surfaces are rough, due to differential erosion, the chalcedonic parts standing in relief compared with the more easily weathered magnesite. A peculiar nodular structure is sometimes observed on such surfaces and is believed to be due to the imperfect replacement of the serpentine which the weathering has emphasized.

ORIGIN OF THE MAGNESITE

The magnesite has undoubtedly been formed by the alteration of the olivine of the serpentine rocks of the Shulaps volcanics. Van Hise[1] supposes that magnesite may result from the decomposition of olivine, as follows:

$$3Mg_3FeSi_2O_8+3CO_2+4H_2O+O = 2H_4Mg_3Si_2O_9+Fe_3O_4+3MgCO_3 +2SiO_2 + \text{heat}.$$

By this reaction, one-third of the olivine passes into magnesite.

Hess[2] considers that since little magnetite is associated with magnesite deposits, whereas hydrated iron oxides are common, sufficient water should be added in order to hydrate the iron, along with greater amounts of carbon dioxide, which is common in meteoric waters, and he writes the chemical equation as follows:

$$4Mg_2Fe_2Si_2O_8+6H_2O+8CO_2+4O = 2(2Fe_2O_3.3H_2O) + 8MgCO_3 +8SiO_2.$$

According to Lindgren[3] magnetite also results from the decomposition of serpentine, and so the formation of magnesite is continued. This change is represented by the following equation:

$$H_4Mg_3Si_2O_9+3CO_2 = 3MgCO_3+2H_2O+2SiO_2.$$

In the above reactions the silica is deposited as chalcedony or colloidal silica, which is a characteristic feature of deposits formed at or near the surface.[4]

The magnesite deposits of the Bridge River map-area correspond closely to the California deposits described by Hess[5] and may be regarded as having been formed by the alteration of the serpentine rocks (Shulaps volcanics) through the agency of carbonated surface waters.

[1] Van Hise, C. R., Mon. U.S.G.S., vol. 47, 1904, p. 309.
[2] Hess, F. L., U.S.G.S. Bull. 355, 1908, p. 18.
[3] Lindgren, W., "Mineral Deposits," 1913, p. 344.
[4] Idem, p. 25.
[5] Loc. cit.

VALUE

The magnesite deposits compare favourably in degree of purity with similar deposits of economic value. The following analyses are presented for comparison.

—	I	II	III	IV
MgO	43·42	42·20	45·20	45·17
CaO	0·46	3·25	1·04	1·32
FeO	0·56	....	....	....
Fe_2O_3	0·25	0·95	1·09	0·26
Al_2O_3	0·23	0·59	0·25	0·03
CO_2	47·28	48·55	50·43	50·74
SiO_2	7·46	4·08	1·60	2·28
H_2O	0·58	....	....	....
H_2O	0·10	....	....	....
	100·34	99·62	99·61	99·80

I. Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 49, Bridge River map-area.
II. Same as I.
III. Hess, F. L., loc. cit. p. 23, specimen from Sonora co., Cal.
IV. Hess, F. L., loc. cit., p. 46, specimen from Tulare co., Cal.

The relatively lower content of CO_2 in the Bridge River area renders the magnetite well suited to the manufacture of caustic magnesia, since the amount of heat required to drive off the carbon dioxide is lessened. The calcined residue would be pure enough to permit of its use in the manufacture of various compounds of magnesia for medicinal purposes. Other uses of magnesite include the manufacture of (1) carbon dioxide gas, for which it is more suitable than limestone, on account of the greater content of carbon dioxide, (2) furnace linings for basic metallurgical processes, (3) fireproof flooring, partitions, and paints.

The price of pure magnesium before the war was $1.45 a pound, but during the war it rose as high as $7.50 per pound. Recently it has declined to normal.

Irregularity and uncertainty of extent are characteristic of such magnesite deposits the world over, and the Bridge River deposits appear to be no exception to the rule, although no prospecting work has been done on them. The difficulty with which access is gained to the deposits precludes their being worked at the present time. Better transportation facilities may render them of economic importance.

The occurrence of magnesite with the serpentine rocks suggests that other deposits nearer main routes of travel may be found, a fact which prospectors would do well to keep in mind.

Asbestos (Chrysotile Deposits)

Although no asbestos of economic importance has been found within the Bridge River map-area, it is possible that future prospect work in the large areas underlain by serpentine may result in its discovery. It should be borne in mind, however, that chrysotile veinlets are to be expected in any serpentine area, but they are rarely found in sufficient abundance to be worked profitably. Small stringers have been noted in the Cadwallader mountains, so a brief description will be given regarding the occurrence to serve as a guide for future exploration.

In the Cadwallader mountains immediately south of the Pioneer mine, at 7,000 feet above sea-level, several small stringers of chrysotile cut the serpentine rocks. Their average width does not exceed one-quarter of an inch, but the fibres are of excellent quality, and are easily reduced to a white fluff.

The rock for distances ranging from a few inches to several feet on either side of the chrysotile veinlets has been more intensely serpentinized than the bulk of the serpentine rocks in general. The similarity in chemical composition of serpentine and crysotile suggests that the crysotile resulted from the recrystallization of the serpentine along joint planes which have served as channels for circulating solution.

The occurrence of the chrysotile in the Bridge River district is similar to that of Thetford, Que., which Dresser[1] believes to be due to the alteration of peridotite by both magmatic and meteoric waters, the former playing the greater part in the process. Lindgren,[2] however, believes that it is more likely that the alteration was effected by the action of meteoric waters entirely, and so took place near the surface. In the latter case the chrysotile would not, probably, persist to any great depth. At Thetford, Quebec, the asbestos is mined in open-cuts, the deepest of which is about 175 feet.

Nickel-Iron Alloy—Awaruite

Specimens of a nickel-iron alloy were collected from the gravels of Bridge river by E. Poitevin, of the Division of Mineralogy, in 1920.

It occurs in fine grains or pellets and has the appearance of having been rolled. Analyses have not been made, but the metal resembles awaruite, which is a nickel-iron consisting of 67·93 per cent Ni, 0·70 per cent Co, and 31·02 Fe, and corresponding to the formula Ni_2Fe. Awaruite was discovered by G. H. F. Ulrich[3] in a primary deposit in peridotite and associated serpentine in New Zealand.

In the river beds of Josephine and Jackson counties of Oregon[4] a similar metal was discovered, whose composition corresponds to the formula Fe_2Ni_5. It is called josephinite, and is associated with olivine rocks.

In Bridge River district the metal probably had its origin in the serpentine rocks of Shulaps mountains.

[1] Dresser, J. A., Geol. Surv., Can., Mem. 22, 1913, pp. 66-67.
[2] Lindgren, W., "Mineral Deposits," 1913, p. 349.
[3] Quart. Jour. XLVI, 1890.
Melville, W. H., Amer. Jour. Sc., 1892 and 1905.

CHAPTER V

DETAILED DESCRIPTIONS OF MINES AND PROSPECTS[1]

INTRODUCTION

The Bridge River map-area owes its present status as the most important district in the Lillooet mining division, to the gold-quartz veins contained in the augite-diorite stock near Cadwallader creek. The silver-copper deposits of McGillivray mountain, the antimony deposits, and gold placers are of minor importance.

The mining properties of the district are still in the prospect stage of development with the exception of a few of the properties on Cadwallader creek. The difficulties of transportation combined with the lack of capital required for exploitation of the properties has accounted for the slow development of the region. Moreover the district has never been affected by a "boom" which would have served to attract outside interest.

In the present chapter the properties will be described in alphabetical order under the following heads:

Gold-quartz veins
Silver-copper deposits
Other properties

Many of the properties have little, if any, present value, but a description of them is given because of the possibility of their becoming more valuable.

For the descriptions of some of the mining properties which the writer was unable to visit during the course of the field season of 1919, or which were not suitable for examination because of outcrops having been covered over, the writer has taken advantage of previous descriptions published by the Geological Survey and the Minister of Mines of British Columbia.

GOLD-QUARTZ VEINS

Under this heading are included the free-milling ores of the Cadwallader and McGillivray Creek gold belts. The highest grade ores occur in shoots in quartz-filled fissure veins cutting the augite diorite stock. The areal limits of this ore-bearing augite-diorite as well as the various mineral claims located on it, with the fissure vein systems so far developed, are indicated on Map 1882 plotted to the scale of 1,000 feet equal 1 inch (in pocket).

[1] All bearings are magnetic.

ALHAMBRA[1]

Location and History. "The Alhambra claim adjoins on the east the Woodchuck workings of the Lorne mine and has an area of 24·65 acres. The augite-diorite stock in this locality forms steep, cliff exposures skirted by coarse talus. The claim was located August 28, 1897, by F. O. Richardson and G. Glen, and both it and the adjacent Nighthawk, Lurgan Fraction, and Metropolitan claims were purchased in the autumn of 1900 by a New York syndicate headed by the late Milton Rathburn."

"Several thousand dollars were expended in 1901 on development work and the claim was crown granted. Two veins have been developed, one by a short adit 25 feet long and the other—the main vein—by an adit 263 feet long. A shaft on the property has been inaccessible for several years. There are several other smaller openings and prospect cuts."

Geology. "The quartz vein has a strike of north 48 degrees east and dips to the northwest at an angle varying from 72 to 85 degrees and is about vertical in places. Numerous pinches and swells occur in the vein, the width varying from 6 to 36 inches but averaging about 22 inches. The walls are of fine-grained augite-diorite now much altered and impregnated with pyrite. They are well defined and covered with gouge. The quartz is very finely ribboned and splits readily along the slickensided surfaces. Arsenopyrite and pyrite are sparingly disseminated in the quartz and the gold is in the free state. A sample taken by W. M. Brewer in 1913 across 6 inches of ore in the face of the adit assayed $4 in gold to the ton with a trace of silver.[2] The other vein 25 feet distant strikes north 72 degrees east and dips to the north at an angle of 78 degrees. The vein is 3 inches wide in the "back" and pinches at the "sill". Fault striæ on the hanging-wall pitch at an angle of 48 degrees to the east. The vein and country rock are much oxidized at the surface."

BLACKBIRD

Location and History. The Blackbird claim lies between the Ida May on the east and the Hiram on the west about halfway between the Coronation and Pioneer mines. The claim which includes an area of 37·7 acres was located August 19, 1897, by William Young and is owned by Geo. A. Kirk and Arthur J. O'Reilly. Blackbird creek flows through the western part of the claim, and has been used for sluicing the overburden to exploit the bedrock in numerous open-cuts.

Development and Geology. In 1913 the Blackbird Syndicate, of Victoria, furnished capital for the driving of two tunnels, one about 80 feet higher than the other, to intersect the quartz vein exposed in the surface trenches. The upper tunnel was full of water at the time of visit and hence inacessible.

The lower and main tunnel is driven 110 feet in a north 6 degrees east direction. From the mouth of the tunnel for a distance of 10 feet from the portal the rock is normal, dark-coloured diorite. Thence for 80 feet the tunnel cuts through a dyke of light-coloured albitite porphyry highly impregnated with sulphides in places, striking north 50 degrees east and dipping

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[1] Description from unpublished manuscript of C. W. Drysdale.
[2] Report of the Minister of Mines, B.C., 1913, p. 260.

74 degrees to the north. The albitite dyke is strongly jointed, breaking up easily into thin plates near the contact with the diorite, but into cubes farther away. It weathers easily along the joint planes to a buff colour. Beyond the albitite porphyry dyke the diorite continues thoughout the workings, but it is highly altered.

At 110 feet from the portal a vertically dipping quartz vein 12 to 15 inches wide striking north 61 degrees east was found, along which the tunnel wás driven for a distance of 55 feet at which point another vein 3 feet wide was encountered striking at right angles to the other vein and dipping steeply to the south. A drift follows the latter vein in a northwesterly direction for a distance of 40 feet. Owing to the timbering the relationship of the two veins could not be determined.

The diorite walls of the veins have been strongly altered to a light-coloured sericitic rock. The quartz is of the white, massive variety and lacks the characteristic ribbon structure of the more important veins of the region. The gold content is said to be low. Two other undeveloped veins are exposed in open-cuts on the eastern part of the claim near the Ida May workings. One vein is 11 inches wide and the other 30 inches wide at the outcrops.

CORONATION MINE[1]

Location. "The Coronation Mining Company of Victoria, B.C., owns and operates a group of six claims on the north side of Cadwallader creek, about 10 miles east of Bridge river and at an elevation of about 3,800 feet above sea-level. The property was located in 1897 and 1898 and was known as the Bend'Or mine until 1911 when it was taken over by the present company."

Development. "Five veins have been developed on the property. The Little Joe vein which outcrops on a steep hillside has been intermittently mined since discovery; the others have been receiving attention in recent years. There are four tunnels on the Little Joe vein. The upper or No. 1 tunnel follows the strike of the vein for 250 feet and attains a depth of 30 feet at the face. The ore from this level has been stoped to the surface. No. 2 tunnel has a total length of 750 feet. No. 3 tunnel is a crosscut for 230 feet where it intercepts the vein at an acute angle. The vein is drifted on for 370 feet to the east. The work was discontinued on account of a pinch in the vein. Westward the vein was drifted on for 240 feet until surface wash was reached. At a point about 140 feet back from the western face, the vein was found to split and was followed to the southwest for 135 feet where the surface wash was again encountered. No. 4 tunnel is a crosscut penetrating the hill in a northerly direction for 540 feet. This tunnel was driven without regard to the geological formations. As a result much money and time were wasted in trying to locate the vein which, like the other veins in the belt, is confined to the diorite intrusive and does not persist into the schistose rocks of the Cadwallader series. After considerable tunnelling a crosscut to the east was run from a point 350 feet from the portal, in diorite, and intersected the vein at a distance of 300 feet. From this point east and west drifts were run as well as a raise to No. 3 tunnel level. A shaft was also sunk 62 feet on the vein."

[1] Description of this mine is taken from A. M. Bateman's report, Geol. Surv., Can., Sum. Rept., 1912, pp. 196-198, and unpublished manuscript by C. W. Drysdale.

Geology. "The veins lie near the southern border of the augite-diorite stock, which at this locality is in contact with the serpentine and calcareous schist members of the Cadwallader series. The contact is well exposed in No. 4 tunnel of the mine at a point about 260 feet from the portal. The first 130 feet of the tunnel is in a pure serpentine, the remainder being an altered zone composed chiefly of calcareous schist, serpentine, and altered diorite. The schistose members of the Cadwallader series do not lend themselves readily to fissuring, so that the vein frays out and disappears in a short distance from the contact."

"The Little Joe vein has been exposed by underground workings for an horizontal distance of 850 feet and a vertical depth of over 300 feet. It has an average strike of north 80 degrees west, and dips steeply (70 to 74 degrees) northward into the hillside. The walls are clearly and sharply defined and the vein is persistent. The width of the vein varies from a few inches to 5 feet, perhaps averaging 18 inches. The foot-wall of the vein is mainly diorite, with the shear planes striking east and west to form acute angles with the fissure vein, although in No. 2 tunnel some massive coarse-grained diorite is present on the foot-wall and fine-grained diorite on the hanging-wall. The hanging-wall is as a rule more coarse in grain and massive than the foot-wall. The foot-wall is generally 'frozen,' whereas the hanging-wall is free and marked by clay selvage. The vein is terminated to the west by the border of the augite-diorite mass and a quartz cross vein 4 feet wide known as the 'Bull lead.' The strike of the 'Bull lead' is nearly parallel to the main crosscut tunnel and dips westward at an angle of 40 degrees. The fault striæ on the walls vary from vertical at the western end to 69 and 65 degrees a couple of hundred feet farther east to 42 degrees eastward on the 4th level near the pinch at the face of the east drift. The shear planes in the diorite are not so prominent in the vicinity of the pinch. The vein is slightly warped, appearing in place as a gently reversed curve between terminations or pinches."

"The quartz in No. 1 tunnel is more massive and exhibits less ribbon-structure than elsewhere in the vein. The workable ore is confined to a shoot 18 inches wide, the remainder of the quartz being of low gold content. This shoot has been stoped to the surface. Many pinches and swells occur in the vein in No. 2 tunnel the width varying from 4 to 30 inches. The vein pinches to 3 inches, 450 feet in from the portal, but widens again 130 feet farther in, to form another workable and high-grade ore-shoot. The vein in No. 3 tunnel varies considerably in width, only a part of it being of sufficient size to work. At the eastern end of the vein is an ore-shoot about 20 inches wide, which has yielded the spectacular specimens of the Coronation mine. It is stated by the previous owners that the ore from this shoot, with all the rich specimens removed, yielded $60 per ton on the plates. Part of this ore has been stoped up to No. 2 tunnel level. Another ore-shoot has been traced for 280 feet and varies from 12 to 28 inches in width. A 20-ton lot is reported to have yielded $65 to the ton on the plates. From the end of this ore-shoot to the face of the tunnel, about 200 feet, the vein is locally pinched. Part of the ore has been stoped up to No. 3 tunnel, but not below. The vein on the 4th and lowest level is strong and well defined, varying in width from 7 to 17 inches. The winze is said to follow the vein to a depth of 62 feet, but this working was inaccessible at the time of visit. In No. 2 tunnel a small parallel vein was opened up for a few feet on the hanging-wall side of the main vein. It dips northward at an angle of 60 degrees and has a diorite schist hanging-wall and massive diorite foot-wall. Probably the same vein is intersected by No. 4 crosscut tunnel 370 feet in from the portal. At this point the fault striæ on the hanging-wall pitch eastward at an angle of 70 degrees."

"About 500 feet due north of the Little Joe vein and on the Mabel Fraction a parallel quartz vein has been recently disclosed by Will Haylmore in a series of trenches. The vein strikes nearly east and west and dips steeply to the north."

"There are three parallel veins on the eastward adjoining the Countless claim, all trending in a general east and west direction and dipping from 50 to 65 degrees to the north. The main vein on the Countless claim is exposed for a distance of 750 feet along the surface by a series of open-cuts. The width of the vein varies from 5 to 60 inches, averaging about 22 inches, and resembles in general character the Little Joe vein, of which it may be an extension. It is stated that the average of all the samples taken from the surface cuts gave a value of $20 to the ton in gold. About 150 feet to the south of and below the main vein a parallel vein was exposed during the summer of 1915 in an open-cut and contained promising surface ore. Both albitite-porphyry dykes and normal diorite are present, but owing to the surface wash it was impossible to determine their structural relations to one another. A crosscut tunnel about 500 feet long was run during 1913 and 1914, unfortunately without consideration of the lateral extent of the ore-shoots as exposed in the surface workings. The tunnel crosscuts the two parallel veins, which at this level, about 200 feet lower than the outcrops, are only 100 feet apart. The north vein dips at 65 degrees and the south vein at 52 degrees to the north. As the veins contained no ore-shoots at this section, very little drifting was done on them."

COSMOPOLITAN

Location. The Cosmopolitan Crown-granted claim lies northwest of and adjoining the Lorne mine. It includes an area of 40·34 acres, and was located August 28, 1897, by F. O. Richardson. The present owner is Paul Santini.

Development and Geology. A shaft is sunk 25 feet on a quartz vein dipping vertically and striking north 40 degrees west. The vein has a width of 26 inches and lies between sharply defined walls of slightly altered diorite. The quartz contains scattered pyrite and chalcopyrite and is partly oxidized. The values are very low in the vein at this point. In a tunnel 250 feet northwest of the shaft, and near the end line of the claim, a vein is cut which is probably the extension of the same vein. The oxidized ore at this locality is more mineralized, the quartz exhibiting more ribbon-structure than the ore at the shaft. The ore from the tunnel is said to assay $16 per ton in gold. Several open-cuts and trenches have been made on the property in search for other veins. The contact between the Cadwallader series and the diorite lies a short distance beyond the northeastern edge of the claim.

COSMOPOLITAN FRACTION[1]

The Cosmopolitan Fraction claim lies to the northwest of and is adjacent to the Cosmopolitan. It is owned by the Mark K. Eagleson estate. During the summer of 1915 some trenching was done on this property in search for the extension of the Cosmopolitan vein, but owing to the thickness of the overburden the results were not very satisfactory. The country rock is augite diorite.

FORTY THIEVES[1]

Location and Development. "This group of claims which includes the Berta, Ural, Forty Thieves, and Elephant crown-granted claims, is situated on the steep eastern canyon slope of Hurley river. The group adjoins to the north the Why Not group, and is about 5 miles below the Lorne mine. The Ural, Forty Thieves, and Elephant claims were the first ones to be staked in the district. All these were located July 2, 1896, the Ural by John R. Williams, the Forty Thieves by John Marshall, and the Elephant by Paul Santini. The property is owned by the estates of J. Marshall and R. B. Skinner. The Berta was located July 3, 1897, by the present owner, C.A. Phair. No development work has been done on the property since 1898, when it was worked under bond to a Vancouver syndicate and crown-granted."

Geology. "A rusty-coloured quartz vein is exposed for 200 feet along the top of a 200-foot vertical cliff in the canyon of Hurley river. It varies in width a great deal, averaging about 3 feet. It strikes from north 30 to 40 degrees west and dips 55 degrees to the northeast. The gangue is massive quartz containing very small amounts of pyrite, grey copper, and azurite. The quartz at the main outcrop lacks the ribbon-structure so typical of the high-grade ores, although ribboned quartz was noted in a vein a short distance east, which was striking north 22 degrees west, and dipping to the northeast at an angle of 46 degrees.

"Two parallel quartz stringers were noted to the southwest of the main vein, one of which has a width of 18 inches and trends north 50 degrees west with northeasterly dip of 26 degrees. There is an old cross-cut tunnel over 100 feet long which was started under the rock talus from a point near high-water mark in the river. The difference in elevation between the outcrop of the vein and the tunnel level is about 200 feet. The tunnel was abandoned before it reached the vein. Some rich specimens are reported to have been taken out of the vein. The country rock is augite-diorite intrusive into the greenstone (andesite) member of the Cadwallader series. Both diorite and greenstone are intimately related, the one appearing in places to grade into the other. The diorite is the pinched and tongue extensions of that outcropping at the Lorne mine. The greenstone and diorite are bounded on the west by a wide band of serpentine and beyond that, argillaceous schists all belonging to the Cadwallader series."

[1] From descriptions by A. M. Bateman and C. W. Drysdale.

IDA MAY GROUP

Location and Development. The Ida May Crown-granted claim lies between the Blackbird claim on the northeast and the Coronation mine on the southeast. It has an area of 45·71 acres and was located August 31, 1897, by Nat. Coughlan, who, while looking for his horses, which had broken loose, stumbled over some gold-bearing quartz on the outcrop of a vein. The group includes the Ida May, Trio, Nellie Fraction, and Mary Fraction claims.

During 1898 about 500 feet of tunnelling was done, a great deal of which is now inaccesssible. The present workings consist of two tunnels. No. 1 tunnel is 4,250 feet above sea-level and consists of an irregularly shaped working on a well-defined quartz vein which dips at a low angle.

No. 2 tunnel is at an elevation of 4,100 feet, about 250 feet west of No. 1. Its direction is north 22 degrees east and, 73 feet from the portal, it intersects a quartz vein. Drifts have been run on this vein 20 feet to the west and 80 feet to the east.

In 1912 Mr. F. A. Brewer acquired an interest in the property and under his direction a 3½-foot gasoline-driven Huntingdon mill was erected. The capacity of the mill is 10 tons in 24 hours.

Geology. Three veins have been developed to a small extent. In No. 1 tunnel a flat dipping vein is exposed. At the mouth of the 80-foot tunnel the dip is 15 degrees to the north, but at the end the veins begin to dip more steeply (35 degrees). The strike of the vein is 90 degrees. In width it varies from 18 inches at the portal to 4 inches at a point 40 feet in. Beyond this it widens rapidly and at the end of the tunnel is 42 inches.

The vein displays ribbon-structure and, locally, is of high tenor. The gold is free and closely intergrown into sylvanite (gold-silver telluride) and arsenopyrite. Calcite occurs sparingly in dark-coloured rhombohedral crystals, the coloration being due to minute hair-like crystals of stibnite as inclusions in the calcite, and as tufts in small vuggy cavities. Galena also occurs sparingly in some parts of the vein.

In the lower (No. 2) tunnel another vein is disclosed which varies in strike from north 68 degrees west (magnetic) at the west end to north 75 degrees west at the east end. It is almost vertical, with a tendency to dip southwestward. The width varies from 4 to 40 inches and the quartz is slightly ribboned and locally contains abundant iron sulphides. The diorite walls are well defined, the foot-wall being the more schistose, and on it is exposed a relatively flat-lying thin dyke of albitite porphyry which is older than the vein. Fault striæ on the hanging-wall pitch 70 degrees to the east.

Another vein is exposed in a surface trench about 200 feet west of the lower tunnel at an elevation of 4,150 feet. Owing to the limited exposure, little information could be gained about it, but a brief examination indicated that it was about 4 feet wide at this point and composed of rather massive milk-coloured quartz containing small amounts of metallic minerals. Its strike is parallel to that of the vein in No. 2 tunnel and the dip is apparently southeastward about 65 degrees.

LORNE MINE

Location and History. The Lorne Amalgamated Mining Company controls the Lorne, Golden King, Woodchuck, Wood Duck, Telephone, and Marquis Crown-granted claims, situated about 1½ miles northwest of the Coronation mine. The Lorne, Golden King, and Marquis claims were all located on July 4, 1898, the Lorne by William Young, the Golden King by Nat. Coughlan, and the Marquis by John A. Williams. The Woodchuck was located July 30, 1897, by Ervin J. Taylor, who on October 2, 1899, located the Telephone claim. The Wood Duck was located October 6, 1897, by L. G. Burns. The group was sold to a Victoria syndicate, who worked the property in a desultory manner, treating the ores in home-made arrastres, of which there were three on the property (Plate VII B).

In 1900 a 5-stamp mill was erected, the power being supplied by a creek which flowed above the property. No methods for treating the sulphides have been installed, and the recovery of gold is stated to be only about 60 per cent.

In 1916 A. F. Noel acquired the controlling interest, and has developed the property in a systematic manner. The total production is said to be about $100,000.

Development. King Vein. The most important veins developed are the King, the Wedge, and the Woodchuck, all of which outcrop on a steep hillside and have been opened up by tunnels. The King vein is opened up by four tunnels, of which No. 1 is the highest. No. 1 tunnel has caved in, but is said to be about 250 feet long. The ore from this level is stoped through to the surface. No. 2 tunnel is 50 feet lower than No. 1 at an elevation of 4,153 feet above sea-level, and has a total length of 315 feet. The greater part of the vein exposed by this tunnel has been stoped up to No. 1 tunnel. No. 3 tunnel is 45 feet lower than No. 2 and is 266 feet long. No. 4 tunnel is 108 feet below No. 3 and crosscuts the "Turnplate ledge" 255 feet in from the portal. This vein has been drifted on 20 feet to the north and 70 feet to the south. The tunnel continues for 75 feet and crosscuts a quartz stringer, then bends to southward 30 feet to pick up the King vein, along which it continues, resuming its original direction for about 60 feet. At this point a raise affords connexion with No. 3 tunnel.

Wedge Vein. The Wedge vein lies about 200 feet north of the King and has been opened up by three tunnels. No. 2—the main tunnel—is driven at an elevation of 4,152 feet in a northwesterly direction. At 140 feet from its portal it intersects the Wedge vein, along which it continues for 140 feet, at which point the vein is cut off by a well-defined fault plane dipping 45 degrees to the north. The tunnel then turns northward and, 75 feet farther, a vein which appears to be the faulted part of the King vein, is intersected.

The vein in the central part of No. 2 tunnel is stoped to another tunnel 75 feet higher, which is now inaccessible. The same vein is opened up again by the Wedge Arrastra East tunnel, which is 60 feet long and 90 feet above No. 2 tunnel. The diorite wall-rock is strongly altered for a distance varying from a few inches to 5 feet.

Other workings which are arbitrarily included with those of the Wedge vein are: the Penstock Ledge open-cut, which is 50 feet west of the Penstock of the power pipe-line; the old shaft 150 feet north of the Penstock Ledge, which is said to be 70 feet deep; the Noel tunnel, and the Wedge Arrastra West tunnel, both of which lie to the north of the Wedge vein.

Woodchuck Vein. This vein is opened up by three tunnels about 450 feet south of the King workings. No. 4 tunnel is at an elevation of 4,003 feet, and is driven east-northeast for 200 feet, at which point the vein is reached, striking roughly at right angles to the tunnel. The vein splits at this point and drifts have been run 100 feet west, where the vein is lost in the hanging-wall, and 60 feet east.

No. 3 tunnel is 93 feet above No. 4 and is 85 feet long. For the last 30 feet the vein is exposed. No. 2 tunnel is 105 feet above No. 4 and is driven on the outcrop of the vein which it follows for 135 feet. There are several open-cuts and ground-sluices included in the Woodchuck workings.

Geology. All the Lorne workings lie within the augite-diorite stock which is traversed by albitite porphyry dykes which, in many instances, appear to have been lines of inherent weakness along which the fissures now filled with quartz have been formed. The formations of the Cadwallader series cut across the southwestern corner of the Woodchuck claim and across the extreme northeastern corner of the Lorne claim and northern quarter of the Golden King claim. Ten veins and a few small stringers have been exposed on the Lorne group of claims. Of these the King, Wedge, Shaft, and Woodchuck veins are the most important. The veins vary in strike and dip from place to place as may best be seen on Figure 10 which also shows their relative positions.

The King vein, in the upper workings where the richest ore was recovered, varies from 4 to 6 feet in width and in one place in No. 2 tunnel level is over 8 feet wide, 6 feet of which is solid quartz. The quartz is strongly ribboned and sparingly mineralized with arsenopyrite, pyrite, chalcopyrite, and tetrahedrite. The country rock adjoining the vein is altered, leached of its ferromagnesian minerals, and slightly mineralized with pyrite and arsenopyrite. Most of the ore between this tunnel level and the surface has been stoped. An ore-shoot 30 feet long by 30 feet deep has been stoped at a point where the vein is 6 feet wide near the southwest end. In No. 3 tunnel the vein is a little wider than in No. 2 and less oxidized. No ore has been stoped from this level. The King vein was found in No. 4 tunnel 350 feet in from the portal. Three other veins are crosscut by No. 4 tunnel. At a distance of 225 feet from the portal a quartz stringer dipping 72 degrees east is cut, and 30 feet farther is a 2-foot vein of well-banded and mineralized quartz striking south 37 degrees east and dipping 64 degrees to the east. At a distance of 75 feet beyond this vein is another stringer 4 inches wide striking north 15 degrees west and dipping 70 degrees to the east.

The Wedge vein varies in width from 5 to 27 inches, averaging about 22 inches, and has been followed underground for 145 feet to a point where it is faulted. Further work in the same tunnel has revealed a vein with corresponding strike and dip which is probably the continuation of the Wedge vein from the fault plane. If this is the case the displacement of the vein is about 60 feet to the east. The vein strikes almost north and south and dips 55 to 60 degrees to the west. The vein is well defined between gorge-covered walls and exhibits the typical ribboned structure. Arsenopyrite and pyrite are sparingly disseminated throughout the quartz, with smaller amounts of tetrahedrite and the carbonates of copper, malachite, and azurite, the latter occurring in the upper oxidized parts of the vein. The dioritic wall-rock has been leached in places of its dark constituents and impregnated with sulphides.

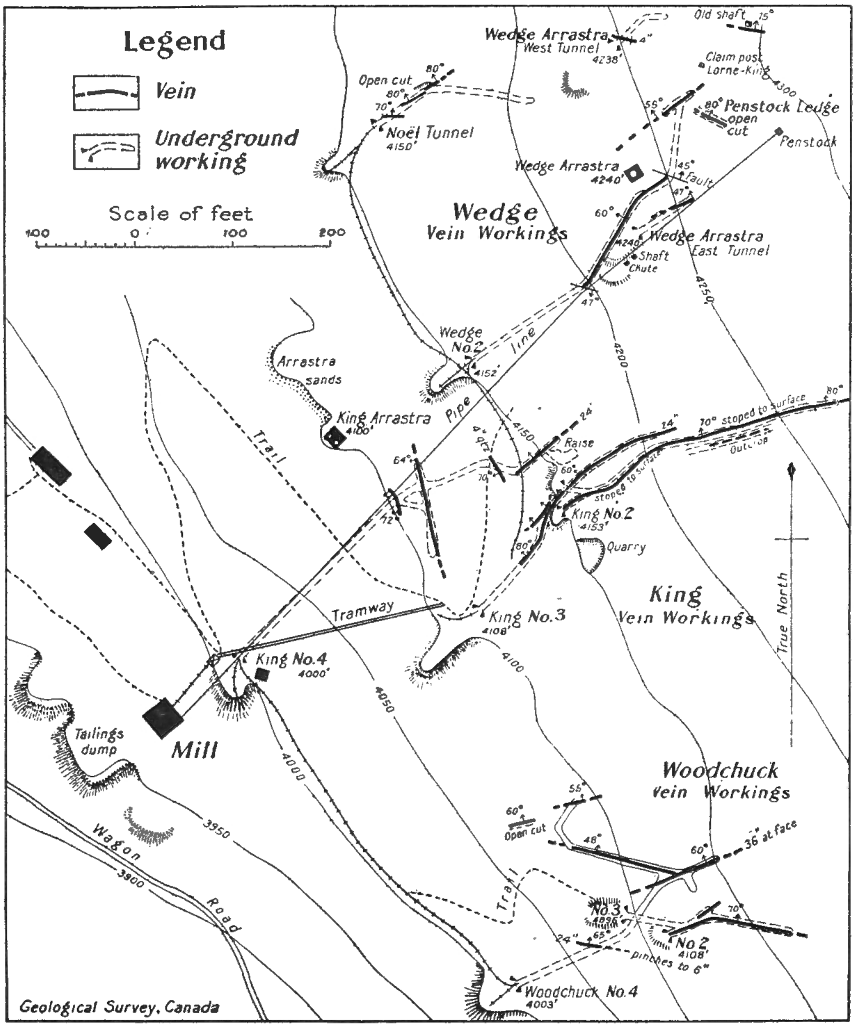


Figure 10. Diagram of Lorne mine showing surface and underground workings, July 1919.

The other veins which are arbitrarily included in the Wedge groups are the Penstock Ledge, the Shaft, the Wedge Arrastra West, and the Noel.

The Penstock Ledge is a 2-foot ribboned quartz vein exposed in an open-cut 50 feet west of the Penstock of the power pipe-line 4,275 feet above sea-level. The strike is north 85 degrees east and the dip 80 degrees to the north.

At the old shaft 150 feet north of the Penstock Ledge is another nearly parallel vein dipping 75 degrees to the north. The vein is about 3 feet wide and strongly ribboned and oxidized. It is stated that the richest ore treated in the arrastres came from this vein, and that a tellurium mineral was abundant. Chalcopyrite and copper carbonates with which the gold is closely associated also occur.

Forming the hanging-wall of the Shaft vein is an albitite porphyry dyke with prominent jointing parallel to the sides. The dyke has evidently been a line of weakness in the diorite along which the fissure now filled with quartz formed. This phenomenon is common in the district.

The Wedge Arrastra West vein where exposed in the tunnel is merely a 4-inch quartz stringer sparingly mineralized, striking north 75 degrees east and dipping vertically.

The Noel vein is exposed in an open-cut above the Noel tunnel and also in the tunnel itself. In the open-cut about 5 feet of broken and rusty quartz mixed with gouge and fragments of diorite fills the fissure. It appears that the vein is thrust-faulted and at this point has doubled back upon itself. The southern part, which is exposed in the tunnel, is probably the one which persists at depth. Its strike is north 45 degrees east and the dip 80 degrees to the north.

The Woodchuck veins have a general east and west strike, the dips varying from 48 to 70 degrees northward. In width they vary from a few inches to 5½ feet. The quartz is well banded and contains pyrite, arsenopyrite, and a small amount of native gold.

Tenor of the Ore. It is stated that the total production of the Lorne mine is about $100,000. The King vein has been the most productive, having maintained, it is reported, an average value of $17 per ton by amalgamation. An ore-shoot in the Turnplate ledge in the King No. 4 tunnel assayed $250 per ton. The average extraction from other veins is said to be $14 or about 60 per cent of the gold in the ore. Most of this ore, however, has come from the upper oxidized parts of the veins. From the upper part of the Wedge vein a 4½ ton ore-shoot yielded $80 per ton. Concentrates collected by Bateman from the arrastre beds assayed from $90 to $380 per ton, and the tailings from the arrastre and the mill assayed from $3 to $6 per ton. Assays of altered diorite wall-rock yielded 0·04 ounce gold per ton.

JEWESS-NATIONAL

The Jewess-National group of claims held by location are situated on the wagon road adjoining to the east the Why Not group. They were located in 1914 and 1915 by F. S. Kinder.

Several short tunnels and numerous trenches testify to the diligent prospect work done on the property. The most northerly working (which is east of the road) is on the National claim. It consists of a prospect pit and open-cut which exposes a vein striking in a general east and west direction. A crosscut tunnel driven from the roadside is 75 feet long bearing north 65 degrees east and is in the greenstone member of the Cadwallader series. At a distance of 40 feet from the portal the south border of a diorite tongue was drifted on for 55 feet and found to contain three quartz stringers striking east and west with northerly dips of 45 degrees. The greenstone is intruded by interfingering tongues of diorite that is difficult to distinguish in places from the greenstone.

On the Jewess claim a quartz vein with general southeast and northwest strike and northeasterly dip has been exposed in a series of trenches and in a short tunnel at the southeast end where the best values were obtained. The workings are just below the wagon road. The ore is much oxidized and lies between walls of schistose argillite and greenstone of the Cadwallader series.

LUCKY BOY FRACTION (ARGYLE)

The Lucky Boy Fraction formerly called the Argyle Fraction and held by location by the Mark Eagleson estate lies northeast of the Nighthawk claim between the Marquis on the northwest and the Tango group on the southeast.

The contact between the augite-diorite and the argillaceous and arenaceous schist members of the Cadwallader series to the northeast passes through the middle of the claim. Ground-sluices and a trench to bedrock expose stringers of quartz in a sericite schist cut by an albitite dyke. The quartz stringers trend east and west and are much oxidized.

MARCONI AND GOLDEN DREAM

The Marconi group consists of the Marconi, Wireless No. 1, and the Lodge claims. The first two were located in 1909 and the last in 1918 by Messrs. O. Fergusson and C. Walker. The claims are situated at the mouth of Fergusson (Sucker) creek.

Considerable work was done to find veins and the possible extension of the Wayside body of diorite across the river. The great thickness of overburden in this vicinity rendered difficult the work of prospecting, which was carried on in co-operation with the owners of the Golden Dream placer claim, represented by C. P. Dam. The water from Fergusson creek, one mile distant, was used for cutting trenches, one of which was 250 feet long, 25 to 40 feet deep, and averaged 45 feet wide. A few narrow quartz veins were exposed cutting an arenaceous member of the Cadwallader series with some argillaceous material. One such vein strikes north 25 degrees west and dips 70 degrees to the northeast. The conglomerate member of the same series is present farther east, but no diorite was exposed in the trenches. The bedrock is overlain by a cemented gravel and till or "hard pan" varying from 3 feet to 6 feet in thickness, which is in turn overlain by 8 feet and more of silt and gravel and 8 inches of volcanic ash at the surface. Gold occurs on bedrock, but owing to the heavy overburden which is 20 feet thick in places and which includes large boulders, it was not found profitable to mine.

The property was worked during the summers of 1915 and 1916 by C. P. Dam, who built a wagon road to the property, installed a 20-horsepower sawmill of 3,000 feet per day capacity, and did considerable ground-sluicing.

MAUD S. FRACTION

The Maud S. fractional Crown-granted claim lies to the northwest of and adjoins the Lorne claim, lying between the Lorne and the Duke claims. The claim covers an area of 30·5 acres and was located September 20, 1897, by Thos. P. Reed who with Samuel Gibbs and Dr. H. A. Christie owns the property.

The contact between the diorite and the conglomerate member of the Cadwallader series passes through the centre of the claim. The part of the claim underlain by diorite has been prospected by numerous trenches and prospect pits. Two quartz veins striking east and west were found, the main one nearer the road and at the north of the claim. The main vein has been opened up by four prospect pits and a 12-foot shaft, which is full of water, that prove its continuance for at least 200 feet horizontally. It is about 4 feet wide. The other quartz vein was exposed farther to the southeast in a series of trenches and pits which are now caved in. Thorough systematic prospecting is difficult on the property owing to the heavy overburden, and scarcity of water.

McGILLIVRAY CREEK MINE[1]

Location. The McGillivray Creek mine includes two Crown-granted claims on the north side of McGillivray creek about 5 miles from Anderson lake and 3,725 feet above sea-level. A wagon road connects the mine with the Pacific Great Eastern railway at Anderson lake. The property was first located in 1898 by F. Brett and has changed hands a number of times. It was bonded in 1904 to J. Burley Smith and was worked intermittently. The last work was done under lease in 1910. The owners are the Anderson Lake Mining Company.

Development. The veins outcrop on a steep hillside and have been developed by three tunnels and a number of open-cuts. The upper or No. 1 tunnel is now caved in but is said to be 450 feet long. The No. 2 tunnel is 670 feet long and contains one stope 450 feet long, 45 feet high, and 7 to 30 feet wide. The lowest or No. 3 tunnel is 150 feet above No. 2 and is 175 feet long.

The mine is equipped with a 10-stamp mill and a 750-foot gravity tramway leading from No. 2 tunnel. The mill is a log building and contains a grizzly, jaw-crusher, and two 5-stamp batteries fitted with automatic feeders, amalgamating plates, and mercury traps. Power is provided by a 48-inch Pelton driven under a 300-foot head of water.

Geology. There appears to be no intrusive bodies of diorite with which the ore is associated and the country rocks of the veins are mashed and contorted members of the Bridge River series intruded by tongues, and stocks of the Bendor granodiorite.

The main vein which is developed by the two upper tunnels strikes nearly north and south and dips steeply to the west. It has been traced by underground and surface workings for 600 feet and has been stoped for 45 feet above the tunnel. In the top of the stope the vein is strongly defined with gouge walls and is 14 feet wide. At the bottom of the stope the vein is 20 feet wide of which 17 feet is quartz and the remainder is com-

[1] Description from reports by A. M. Bateman and C. W. Drysdale.

posed of fragments of country rock. The vein in the uppermost cut is narrow and scattered, although the gold values are said to be high. The normal quartz of the property is a hard, milky-white massive variety and contains only a small amount of pyrite. Bands of red oxidized schist traverse the quartz near the portal of the lower No. 3 tunnel which is exposed in a ground sluice for a width of 12 feet. The walls are in many places irregular, poorly defined, and intersected by branching veinlets of quartz joining the main vein.

The vein developed in No. 3 tunnel strikes and dips parallel to the main vein and has a width of from 3 to 4 feet. It has been followed for 175 feet and stoped to a height of about 40 feet and exhibits the same irregularities as the upper vein.

The values are scattered in irregular pockets and the richest specimens have been taken from the oxidized parts. It is stated that $35,000 has been extracted from the upper parts with an average yield of $25 per ton on the plates. The value of the ore exposed in the stopes is admitted to be less than $2 per ton.

PIONEER MINE

Location and History. The Pioneer mine is situated about four-fifths of a mile east of the Coronation mine and about 4 miles above the junction of Cadwallader creek and Hurley river. Seven claims and three fractional claims comprise the Pioneer group, as follows: Pioneer, (which was located on September 6, 1897, by William Allen,) Great Fox, Emmadale, Corasand, East Pacific, Clifton, Sunset, Union Jack Fraction, Olympic Fraction, and Titanic Fraction.

The mine was opened up by F. H. Kinder, who, for eleven summers, single-handed, mined and treated all the ore in a small arrastre, and made a comfortable living by it. Kinder sold the property to A. F. Noel, who in turn sold it to Messrs. Peter and Andrew Ferguson and Adolphus Williams for $30,000.

Development. Abundant waterpower is supplied by Cadwallader creek, and the present plant includes a dam from which the water is carried in a 4 by 5-foot flume 1,700 feet to a 195 horsepower turbine. The mining machinery includes a five-drill compressor, a 5-foot Chilian mill, with a capacity of 24 tons per 24 hours. The tailings are treated on two concentrating tables, but no process has been installed for treating the concentrates.

Two intersecting veins have been developed by three tunnels, two of which, Nos. 1 and 2, have been abandoned, and are now inaccessible. In the upper or No. 1 tunnel No. 1 vein was encountered at a distance of 40 feet, and was drifted on to the west for 42 feet. In No. 2 tunnel the same vein was cut at a distance of 29 feet, and was followed to the east for 15 feet and to the west for 40 feet.

The main tunnel (No. 3) crosscuts No. 1 vein at a distance of 78 feet and No. 2 vein 18 feet farther north. At this level (100-foot) No. 1 vein has been followed eastward for 60 feet, and westward for 200 feet. For almost the entire length of the workings this vein has been stoped nearly to the surface. No. 2 vein has been followed at this level 275 feet east of the main tunnel, and 60 feet west, where the drift joins that of No 1 vein at the intersection.

The shaft is on No. 1 vein at a point 160 feet west of the main tunnel and 90 feet west of the vein intersection. A small crosscut has been driven 20 feet from No. 1 vein at a point 30 feet east of the shaft. The 100-foot level is 65·5 feet below the collar of the shaft.

The 200-foot level is 166·5 feet below the collar of the shaft. Here the shaft is in diorite, and the intersection of the veins lies about 15 feet to the south. To the east of the shaft the intersection is encountered at a distance of 25 feet, and both veins are exposed in the drift for 30 feet, or as far as the ventilating shaft. From here No. 1 vein has been drifted along for 150 feet, where it is still exposed in the face. At a point 150 feet east of the main shaft a crosscut has been driven 35 feet northward, where No. 2 vein was encountered, and which has been followed eastward for 50 feet, where the vein appears to split.

To the west of the shaft, at the 200-foot level the intersection of the veins, which, on account of the narrow angle of intersection, holds for about 100 feet, is met with at a distance of 30 feet, and is followed for 55 feet. Here the veins diverge, No. 1 vein (now lying to the north of No. 2 vein) being followed for 180 feet, and No. 2 vein is followed for 40 feet.

The 300-foot level is 253·5 feet below the collar of the shaft. The bottom of the shaft is an enlargement of the drift, just south of the eastern intersection of the veins. No. 2 vein has been followed westward for 150 feet, and at a point 70 feet east of the shaft a crosscut 30 feet northward encounters No. 1 vein, which is followed westward for 90 feet. East of the shaft the drift continues for 70 feet.

Geology. The Pioneer mine is situated at the eastern extremity of the main diorite mass, which at this point is about 300 feet wide (Figure 2). The diorite cannot be traced across Cadwallader creek on the surface, but another dyke-like body lies a mile to the southeast.

The rocks surrounding the diorite are those of the Cadwallader series, quartzites and argillites to the north and serpentine schist to the south. From the incompetent nature of these rocks it is unlikely the veins persist in them beyond the contact of the diorite intrusive.

Two veins have been developed; they come together near the shaft at such an acute angle that it is not clear whether they are intersecting or merely curving, roughly parallel fissures. Movement in the plane of the veins subsequent to vein filling, resulting in the sheeting or ribboning of the quartz, has obscured the original character of the veins along the hundred feet or so where they come together. From the plotting of the workings at the various levels it is suggestive, however, that No. 2 vein (or the original fissure, at least) has been faulted by No. 1 vein. It was noted that at the 100-foot level an albitite porphyry dyke lies on the hanging-wall of No. 1 vein, and on the 300-foot level at the western face of the northernmost vein an albitite dyke forms a wall of the vein, but here it lies on the foot-wall. It is easily conceivable that the vein has cut across the albitite dyke somewhere between these two points.[1] In view of these criteria it has been assumed that the veins are intersecting, but the relative ages of the two are still in doubt.

[1] It is shown elsewhere that in this camp the albitite dykes are older than the quartz veins.

The veins show pronounced ribbon-structure, due to sheeting of the quartz parallel to the walls, and the quartz is easily cleavable along these sheeting planes, which are coated with finely-divided arsenopyrite and pyrite, and sometimes slickensided films of gold. The veins vary in width from 1 to 4 feet, averaging about 2 feet; where they come together the quartz is sometimes 6 feet wide.

Faulting resulting in the lateral displacement of the vein is apparent in the eastern part of No. 2 vein, where within a distance of less than 200 feet the vein is displaced three times. The combined horizontal dimensions of these movements, as far as can be observed, is only a few feet (Figure 8).

The average tenor of the ore is estimated by the management to be $13.50 per ton. Ore-shoots in No. 1 vein yielded (after the rich specimens had been removed) $60 and $65 to the ton on the amalgamation plates. The wall-rock, though highly impregnated in places with pyrite and arsenopyrite, has not been enriched with gold, except where it is locally cut by numerous quartz stringers. A sample taken from the shaft at the 300-foot level assayed $5.60, but at this point the diorite includes many small quartz stringers. On the 100-foot level, however, the highly brecciated and quartz stringer-cut wall-rock assayed only $2 a ton. Assays taken from the albitite dyke which parallels and lies on the wall of No. 1 vein averaged $1.10. Below the mill there is a tailings dump of about 100,000 tons, estimated to contain $4 in gold per ton. One assay of these sands gave $22.80 per ton. The gold of the ore occurs in the free state, and also in close association with arsenopyrite, in which it is included in a fine mechanical mixture. The total production of the mine is about $1,350,000.

SILVER BASIN GROUP

Location. The Silver Basin group, including the Last Dollar, Last Nickel, New Era, London, No. 1 London, and White Plains claims, is situated in the canyon of Cadwallader creek about a mile above its confluence with Hurley river. The Last Dollar and White Plains are on the north side of the creek, and were located in May and June of 1913. The London and No. 1 London were located April, 1912, and the adjoining New Era claim in the spring of 1913. The locators were Carl Wihksne and John Boyd, the former being at present the main owner. Both placer and quartz prospecting are in progress on the property. The Blue Ribbon claim was located August 10, 1913, at the junction of Cadwallader creek with Hurley river, on a vein reported to be from 18 inches to 3 feet wide of ribboned quartz containing gold and sulphides running from $2 to $32 per ton.

Geology and Development. The rocks outcropping on the property are the arenaceous schists and argillites and squeezed conglomerate members of the Bridge River series.

On the Last Dollar claim an arenaceous schist is traversed by a network of quartz stringers striking north 10 degrees east. This zone is opened up by means of a tunnel driven 35 feet in the canyon side. A series of parallel and reticulating quartz pockets 1 to 6 inches in width are exposed, which dip steeply to the east, although one slip plane containing gouge material, on which a raise has been driven for a few feet, dips to the west at 35 degrees. The quartz contains sparsely scattered arsenopyrite and pyrite. The arenaceous schist strikes north 10 degrees west and dips vertically or steeply to the west.

The New Era claim is situated back of and above the bench upon which the cabin and camp are erected. A tunnel, commenced as a cross-cut, bearing north 42 degrees west, runs for 45 feet to a point where the vein bends to the east and strikes north 10 degrees west for 22 feet to the face. The walls are pyritized and well defined, having gouge material along them. The quartz vein varies in width from a few inches to 2 feet and has a hanging-wall of albitite porphyry 4 feet in width. The vein strikes in a general north-northwest and south-southeast direction, dipping to the east at an angle of 75 degrees. The country rock is a pyritic, argillite schist intruded by an albitite porphyry dyke, which strikes with the formation but dips to the east in the opposite direction to the schists. The porphyry is traversed in places by stringers of quartz. The ore from the vein is said to average $5.50 in gold, the highest assay being $20 per ton. A sample taken by W. M. Brewer across 22 inches of ore in the face assayed 40 cents in gold to the ton and a trace of silver.[1]

VERITAS

Location and Development. The Veritas claim, owned and worked by Mat Forster, is situated on the west side of Little Gun lake. The workings consist of a tunnel 225 feet long and several open-cuts.

Geology. In this locality a tongue of diorite is intrusive into the quartzites and argillites of the Bridge River series and serpentine. A well-defined vein, which outcrops boldly above the lake, cuts the diorite and the serpentine. It is characterized by numerous pinches and swells, narrowing rapidly from the outcrop, where it is 3 feet wide, to a mere stringer in the first 75 feet of the tunnel. At a point 200 feet from the portal it widens suddenly until at the face it is 3 feet wide.

The vein strikes east and west and dips 85 degrees to the north. The hanging-wall is composed of altered and leached diorite impregnated with sulphides, and the foot-wall is strongly schistose and, in places, is a breccia of altered diorite and serpentine.

The quartz is not ribboned but rather massive and milky-white. It contains small amounts of pyrite, arsenopyrite, galena, and native gold. No ore-shoots have been discovered. On the foot-wall irregular masses of massive pyrite occur up to a foot in thickness. Vugs containing large crystals of quartz occur in the wider parts of the vein.

WAYSIDE MINE

Location. The Wayside mine is situated on the north side of Bridge river 3 miles above Gun creek. The Wayside helium and radium claims were staked in 1900 by J. C. Patterson, who in 1906 sold them to O. Fergusson and C. Walker. In 1908 they were again sold, to D. C. Paxton

[1] Report of the Minister of Mines, 1913, p 261.

and associates, of Cincinnati, Ohio, who are the present owners. Other claims which have been added to the group are the Argon, Queen City, Covington, Newport, Camp Denison, Commodore, Howard, Cincinnati, and Ohio. A single-stamp mill driven by gasoline is installed upon the Wayside claim, upon which the principal workings are grouped.

Development and Geology. The workings, which consist of eight tunnels, and numerous open-cuts, are mainly situated on the northern extremity of the main diorite stock, but two unimportant tunnels are in the argillites of the intruded Cadwallader series (Figure 11). At least three veins are exposed in the workings. The northernmost vein has been followed for 1,000 feet north 45 degrees west, and continues in the hanging-wall when the tunnel bends westward. The dip is 68 degrees east. No. 1, No. 2, No. 3, and No. 7 tunnels are believed to be on the middle vein, which dips from 36 to 50 degrees east, and whose strike is roughly parallel to that of the northernmost vein. A third parallel vein was followed in No. 6 tunnel for 90 feet. This vein dips to the east at 44 degrees. The relative positions of the workings are shown in Figure 11.

The quartz of the veins is ribboned and contains small amounts of arsenopyrite, pyrite, chalcopyrite, and native gold. The diorite walls are strongly altered and schistose in places. Sheeted structure is common and the planes of fracture parallel to the veins are often filled into quartz stringers. It is reported that the ore from No. 2 tunnel gave $38 per ton from a 1,000-pound mill sample. No high-grade ore was observed in No. 4 tunnel.

YPRES CLAIM

The Ypres claim is situated on the northwest side of Gun lake at the point where the creek empties into the lake. It was located in October, 1917, by O. Fergusson and C. Walker. A narrow body of diorite which continues northwestward to Gun creek intrudes the cherty quartzites of the Bridge River series in this locality. In the diorite occurs a shatter-zone or "sheeted" zone striking south 68 degrees east and dipping 75 degrees southwest. The narrow fractures have been filled into quartz, forming a "stringer lode" (Figure 4). This is shown in a ground-sluice near the lake. The diorite between the quartz stringers is weathered a rusty brown from the oxidation of the sulphides with which the diorite adjacent to the veinlets have been impregnated. Colours of gold are obtained by panning from the quartz.

Another vein several feet wide is exposed in the cutting about 500 feet west of the stringer lode. It conforms in strike to the latter.

SILVER-COPPER DEPOSITS

EMPIRE GROUP[1]

"The Empire group of three claims, owned by the McGillivray Mountain Mines, Ltd., is located at the head of Roaring creek near upper McGillivray creek and the workings are in a steep basin above a small glacier at an elevation of 8,000 feet above sea-level, or about 1,500 feet above timber-line."

[1] From description by A. M. Bateman, loc. cit.

"These claims were staked some twelve years ago, but were subsequently dropped because of low gold values. Since then they have been intermittently held by a number of prospectors, none of whom ever completed the assessment work. They were restaked in 1911 by the present owners who plan considerable development work."

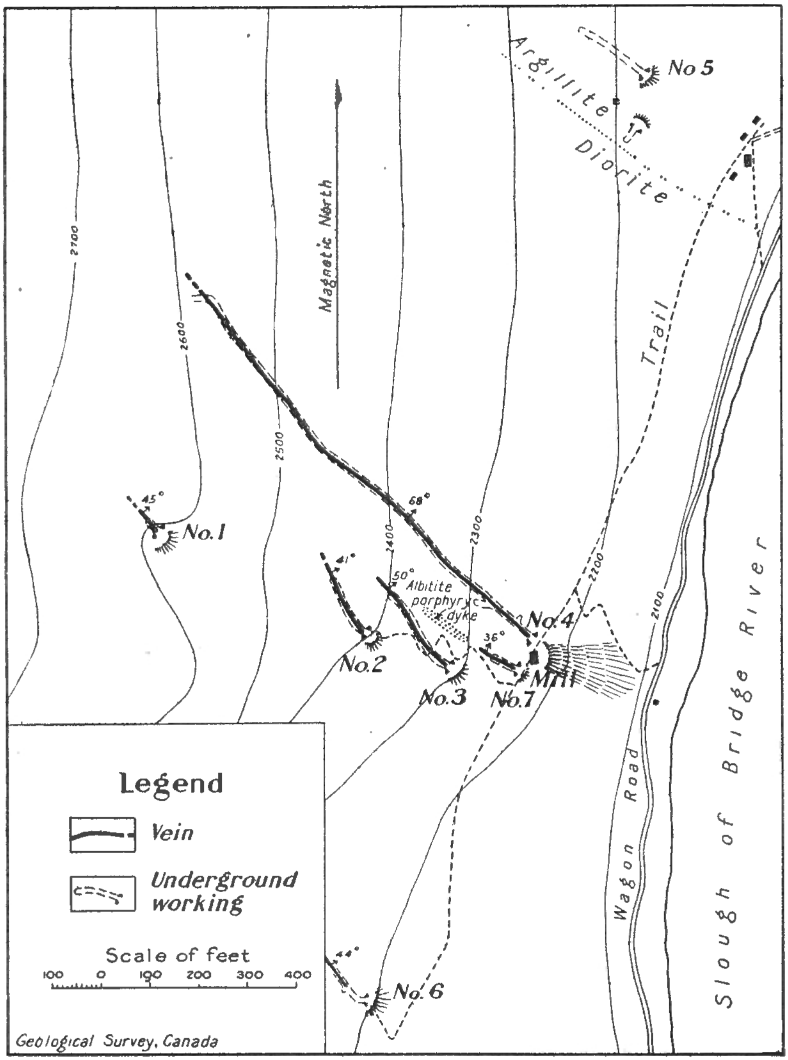


Figure 11. Diagram of Wayside mine showing surface and underground workings, August 1918.

Geology. "The rocks consist of sheared quartzites, altered argillites, mica schists, chloritic schists, serpentine, and a few thin beds of limestone. They are a part of the Bridge River series but are extremely metamorphosed in this locality. They are intruded by sills and dykes of bird's-eye porphyry or granodiorite porphyry which contains large phenocrysts of feldspar in a groundmass of quartz, feldspar, hornblende, and biotite".

"The ore deposit is a large quartz vein which cuts the Bridge River series rocks nearly parallel to their strike and is associated with one of the granodiorite porphyry dykes. The vein strikes south 80 degrees east and dips 70 degrees south. It has been traced by a series of open-cuts and one short tunnel for about 1,000 feet and in this distance varies in width from 3 to 14 feet. In the tunnel the walls are well defined and consist of an impure serpentine. In the lower cuts they are less clearly defined and consist of argillite."

"The quartz is a hard, white, massive variety containing small amounts of pyrite, chalcopyrite, zinc blende, stibnite, azurite, malachite, and a little tetrahedrite. Silver telluride and silver bromide are reported to occur in the quartz, but no trace of any could be seen."

Assays of samples yielded results as follows:

	I	II	III
Gold	trace	trace	trace
Silver	0·60 oz.	35·2 oz.	35·4 oz.
Copper	trace	....	0·5%

I. Sample from upper cut, A. M. Bateman, loc. cit.
II. Sample from Empire No. 1 claim, W. M. Brewer, loc. cit.
III. Sample from upper tunnel, W. M. Brewer, loc. cit.

SPOKANE GROUP

The Spokane group of seven claims owned by Dr. H. Christie is located in Holbrook gulch on the south side of Christie creek on the northern slope of Shulaps mountains. The workings are 7,300 feet above sea-level and consist of three tunnels. In the upper tunnel a quartz vein varying from 7 to 4½ feet in width is exposed. The quartz is massive in character and is slightly mineralized with chalcopyrite, pyrite, and pyrrhotite.

It is reported that assays of the ore gave the following results:

—	I	II	III	IV
Gold	1·20 oz.	0·54 oz.	0·02 oz.	0·48 oz.
Silver	0·60 oz.	2·80 oz.	2·74 oz.	0·52 oz.
Copper	1·60%	2·60%	3·40%	1·42%
Total	$29·96	$21·41	$10·35	$14·15

I and IV. Ore from upper tunnel.
II. Ore from lower open-cut.
III. Ore from open-cut below cabin.

The rocks are the cherty quartzites and argillites of the Bridge River series cut by a narrow dyke-like belt of serpentine and dykes of Rexmount andesite porphyry with which the mineralization appears to be associated.

OTHER PROPERTIES

WHITE AND BELL GROUP

Near the headwaters of Eldorado creek in the northwestern corner of the map-area is located a group of claims staked by George Bell and Grant White, in 1909.

The workings consist of two nearly parallel tunnels, each about 40 feet long, driven along shear zones in shales and sandstones of the Eldorado series which have been locally altered by mineralizing solutions to a white, soft, disintegrated rock, cut by numerous veinlets of chalcedony. Small lentils of stibnite occur near the outer edges of the decomposed rock, and well-formed crystals and masses of pyrrhotite and arsenopyrite occur.

Assays of samples collected by W. M. Brewer[1] gave the following results:

	I	II
Gold	\$3·60	\$7·20
Silver	trace	0·20 oz.

SUMMIT GROUP[2]

"This is a group of three claims located at an elevation of 4,800 feet above sea-level near the summit of the ridge between Alexander and Tyaughton creeks.

"A basic dyke, 8 feet wide, strikes in a northerly direction across a series of quartzites, argillites, and chloritic volcanic rocks (Bridge River series). Cutting across this dyke are a number of short parallel stringers of quartz containing arsenopyrite and pyrite. The gold content of these stringers is said to be \$30 per ton, but they are small and their extent is limited to the width of the dyke. A sufficient number of stringers are not exposed to justify the working of the dyke as a whole.

"Farther up the hill a tunnel was driven to intercept an irregular quartz vein containing pyrite, arsenopyrite, galena, and zinc blende, but did not cut it. The vein has been traced on the surface for some distance and was found to vary in width from 2 to 26 inches. In places there is 16 inches of solid sulphides. The deposit, however, is small and extremely irregular."

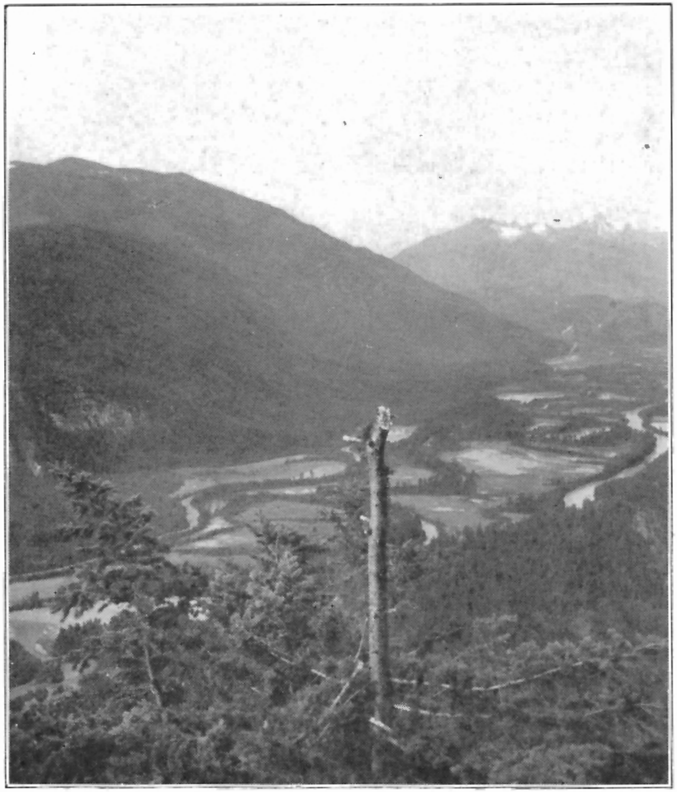
[1] Ann. Rept., Minister of Mines, B.C., 1914, pp. 269–270.
[2] From description by A. M. Bateman, loc. cit.

PLATE II

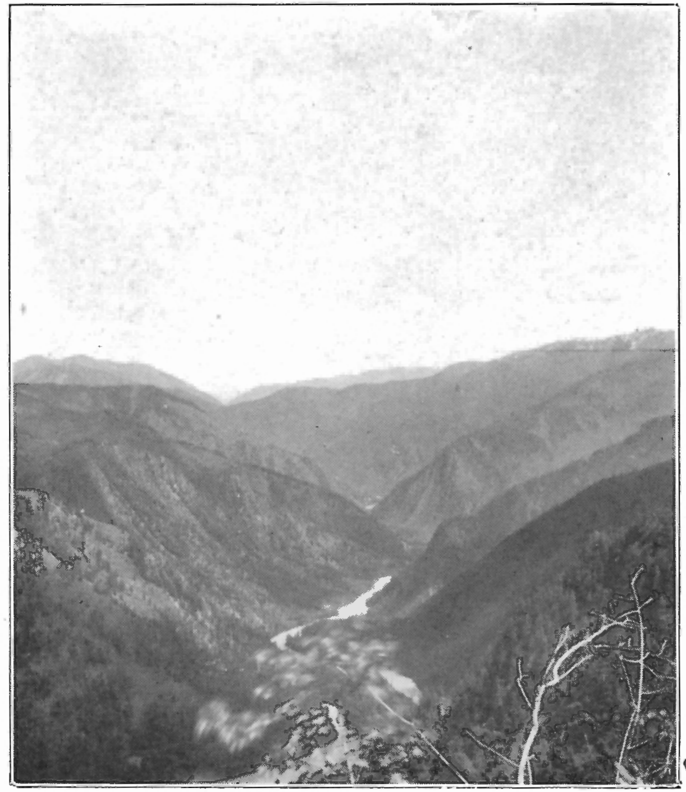
A. Rugged topography of Coast mountains. Maximum elevations are 10,000 feet above sea-level. Many of the glacial basins at high altitudes contain small rock-bound lakes. (Pages 8, 11, 13.)

B. Glacier at the head of Keary creek. (Page 12.)

PLATE III

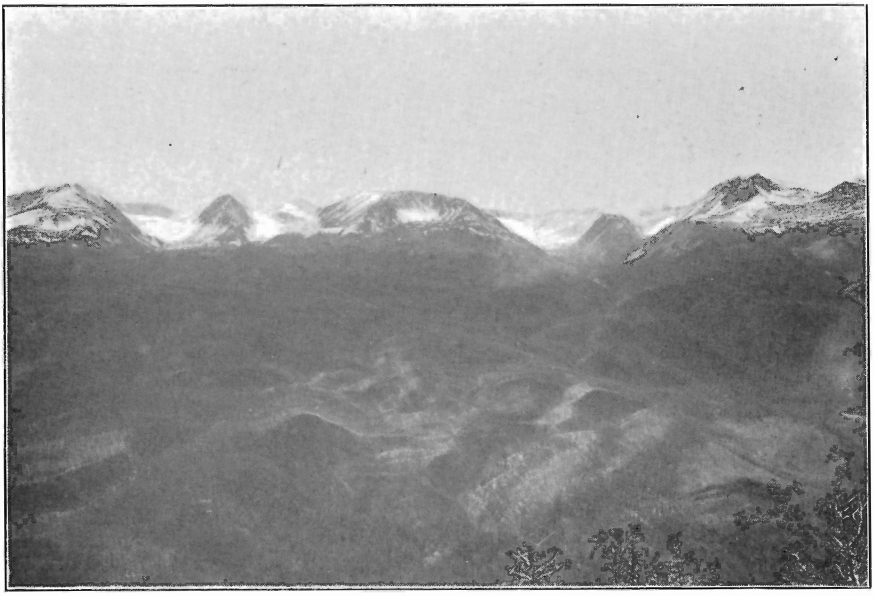


A. Looking up Bridge river from Marshall ridge. The larger streams in their upper reaches meander until they approach the major rivers where they have incised deep box canyons. (Page 11.)

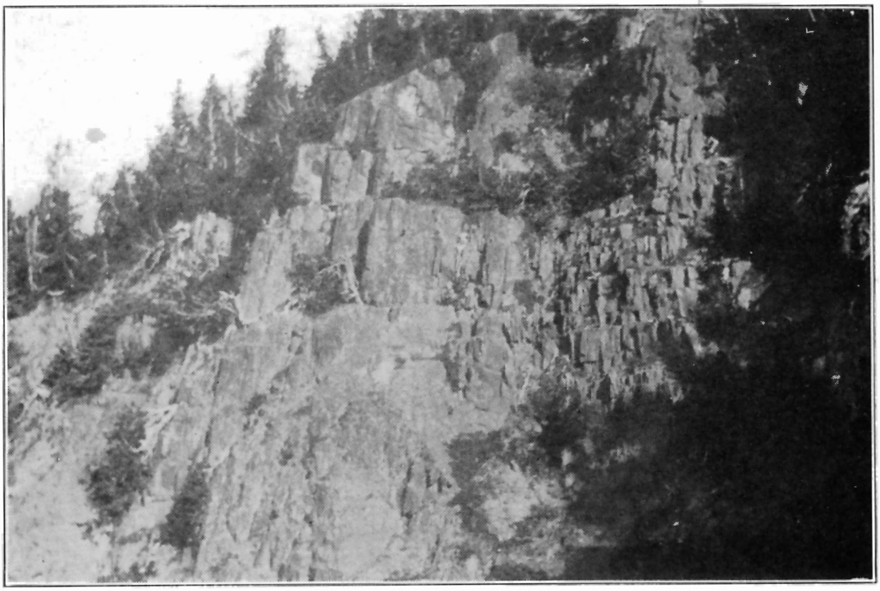


B. Bridge river near Horseshoe bend. (Page 3.)

PLATE IV



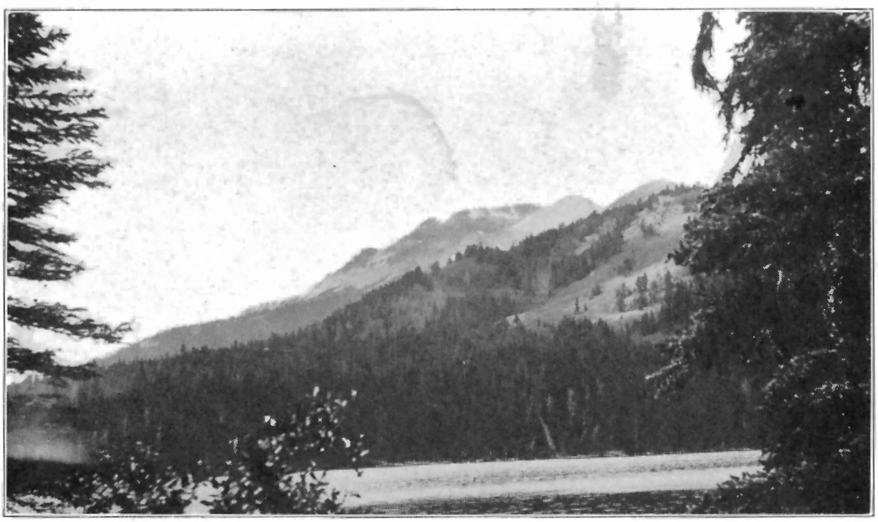
A. View southwest from Yalakom River valley towards Shulaps mountains, showing local landslides, caused by slow riverward creep of the alluvium. (Page 13.)



B. Examples of jointing in igneous rocks: Rexmount porphyry. (Page 40.)

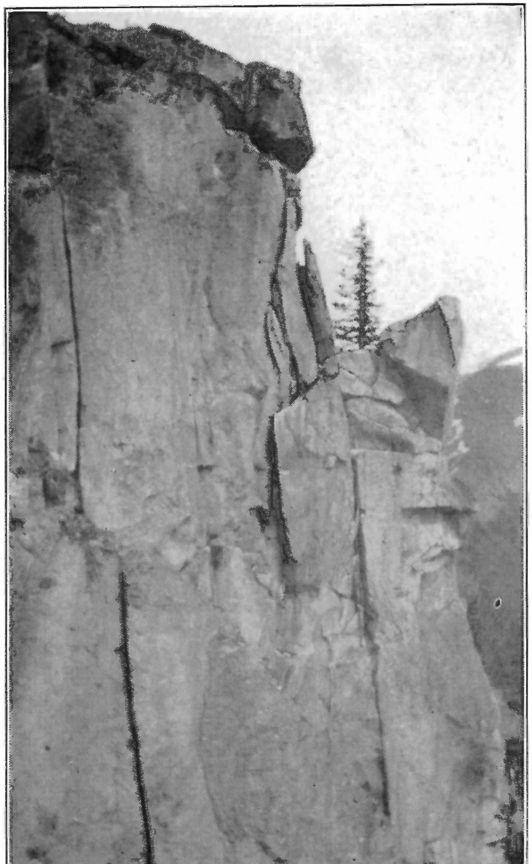
PLATE V

A. Typical topography developed upon the soft-weathering Lower Cretaceous Eldorado series. (Page 11.)

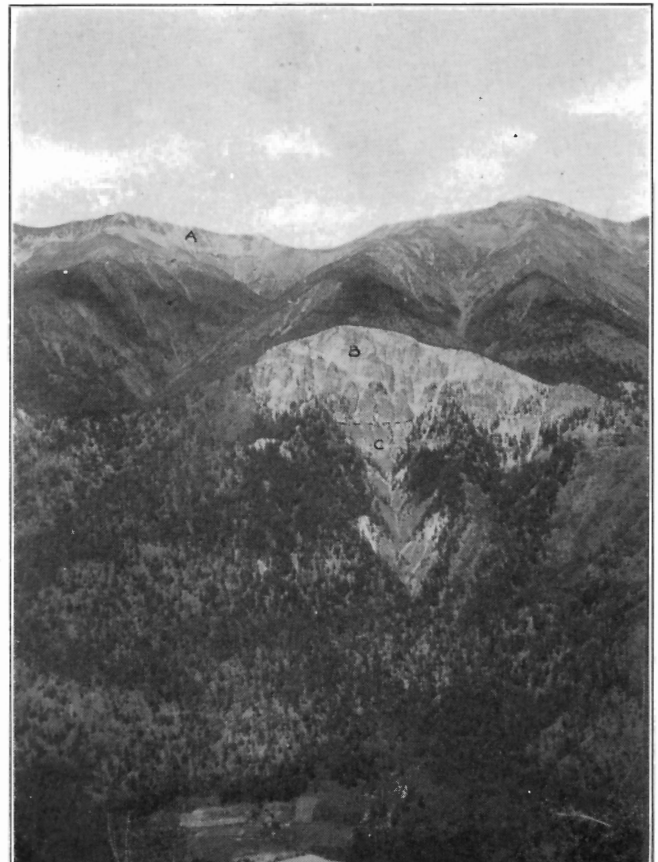


B. Typical topography developed upon the soft-weathering Lower Cretaceous Eldorado series. (Page 11.)

PLATE VI



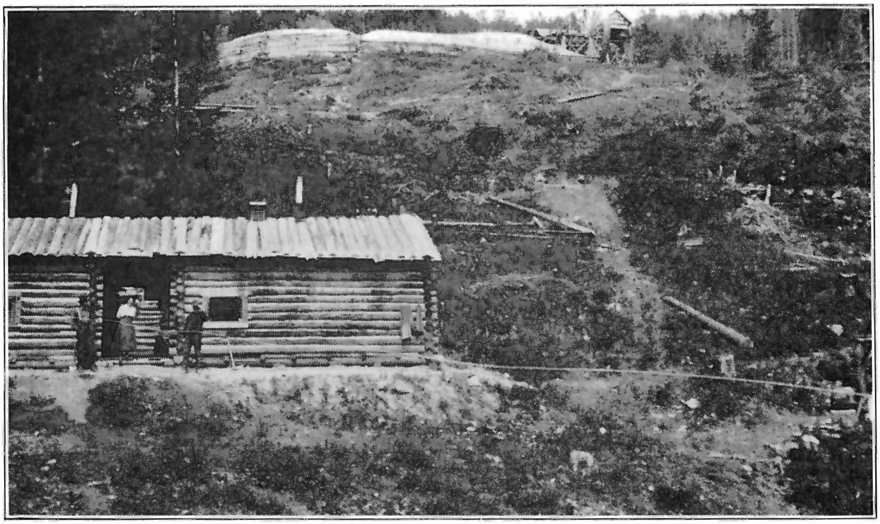
A. Examples of jointing in igneous rocks; Bendor quartz diorite. (Page 37.)



B. "Jones bluff" with Rexmount at its base.
A—Rexmount porphyry sill;
B—Rexmount porphyry agglomerate;
C—Oligocene (?) sediments containing a few thin seams of lignite. (Page 40.)

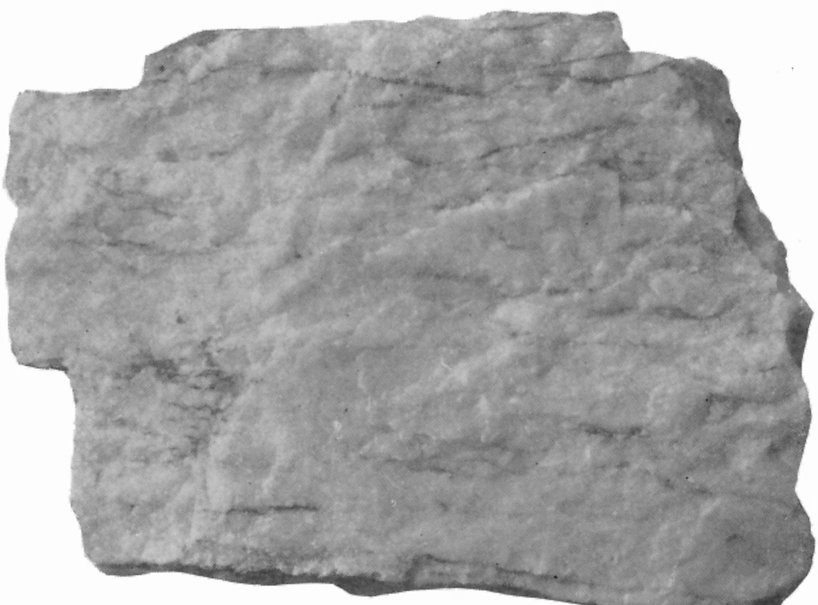
PLATE VII

A. Pioneer mine, Cadwallader creek. (Page 92.)



B. Lorne mine showing ruins of arrastre. (Page 86.)

A. Quartzite pebble (natural size), from the Cadwallader series, showing two systems of faulting comparable to the fissure systems of the augite-diorite. (Page 53.)



B. Ribbon-structure of the gold-quartz veins (natural size). (Page 59.)

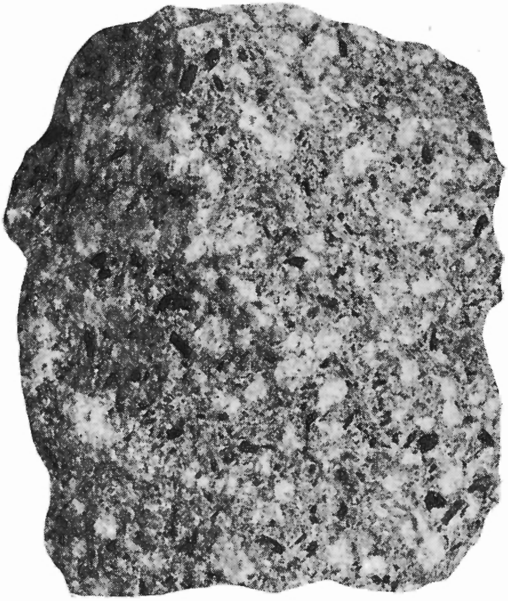
PLATE IX

Chalcedony veinlets in magnesite near Liza lake. (Page 75.)

PLATE X

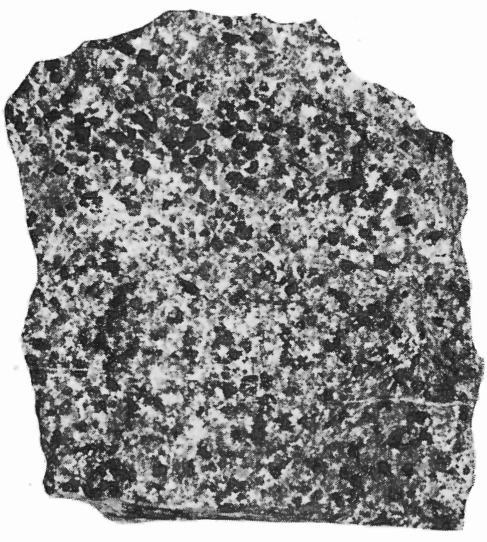
A. Black limestone of the Cadwallader series containing *Megalomus canadensis* (one-half natural size). (Page 29.)

B. Sandstone of the Eldorado series containing *Aucella crassicollis*. (Page 35.)



A.

A. Granite porphyry (Bird's-eye porphyry). (Page 97.)



B.

B. Augite-diorite. (Page 30.)

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