CANADA

DEPARTMENT OF MINES

HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report, 1921, Part A

CONTENTS

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1922

No. 1955

SUMMARY REPORT, 1921, PART A

SILVER-LEAD DEPOSITS OF DAVIDSON MOUNTAINS, MAYO DISTRICT, YUKON

By W. E. Cockfield

CONTENTS

Illustrations

INTRODUCTION

The investigation of the Mayo silver-lead ores was, during the field season of 1921, confined to the mapping of three small areas in Davidson mountains, on which some prospecting had been done. These areas—Stand-to hill, Rambler hill, and mount Cameron—comprising a total of slightly more than 60 square miles, were mapped on a scale of $\frac{1}{12,000}$ and the maps (Nos. 1937, 1940, 1943) accompany this report.

The writer was ably assisted by N. T. Ellis, C. A. Merritt, and T. D. Guernsey, all of whom performed their duties in a satisfactory and efficient manner. Mr. Ellis was in charge of the topographical mapping, and Mr. Merritt and Mr. Guernsey assisted in both the topographical and geological work. The miners and prospectors of the district assisted in every way possible and for the many courtesies and favours received the writer wishes to express his hearty thanks.

GENERAL CHARACTER OF THE DISTRICT

Location and Accessibility. Mayo district takes its name from the town of Mayo, on Stewart river, 180 miles above its confluence with Yukon river.

Davidson mountains occupy the area enclosed by Ladue, McQuesten, and Beaver valleys, and form a range 30 miles long and 12 miles wide, having a general east-west trend. In general the southerly slopes of the range are gentle, being governed to some extent by the dip of the strata; the northerly slopes are steep, frequently precipitous. This also applies to those stream valleys flowing in an easterly or westerly direction within the range. Numerous sharp peaks occur, the highest of which is mount Cameron (6,893 feet).

The position of the areas with respect to Mayo is shown on Figure 1.

During the summer a regular passenger and freight service is maintained on Stewart river by the steamers of the White Pass and Yukon route. From Mayo, roads lead to all the principal creeks. The most direct route to the properties under discussion is by way of Galena creek. A winter road leads from Galena creek to mount Cameron, and a trail leads from this winter road across Ladue lakes to Stand-to hill, and another, up Cache creek to Rambler hill. A better road for summer traffic leads to the base of Keno hill, where there is a trail down Christal creek to the Mount Cameron road.

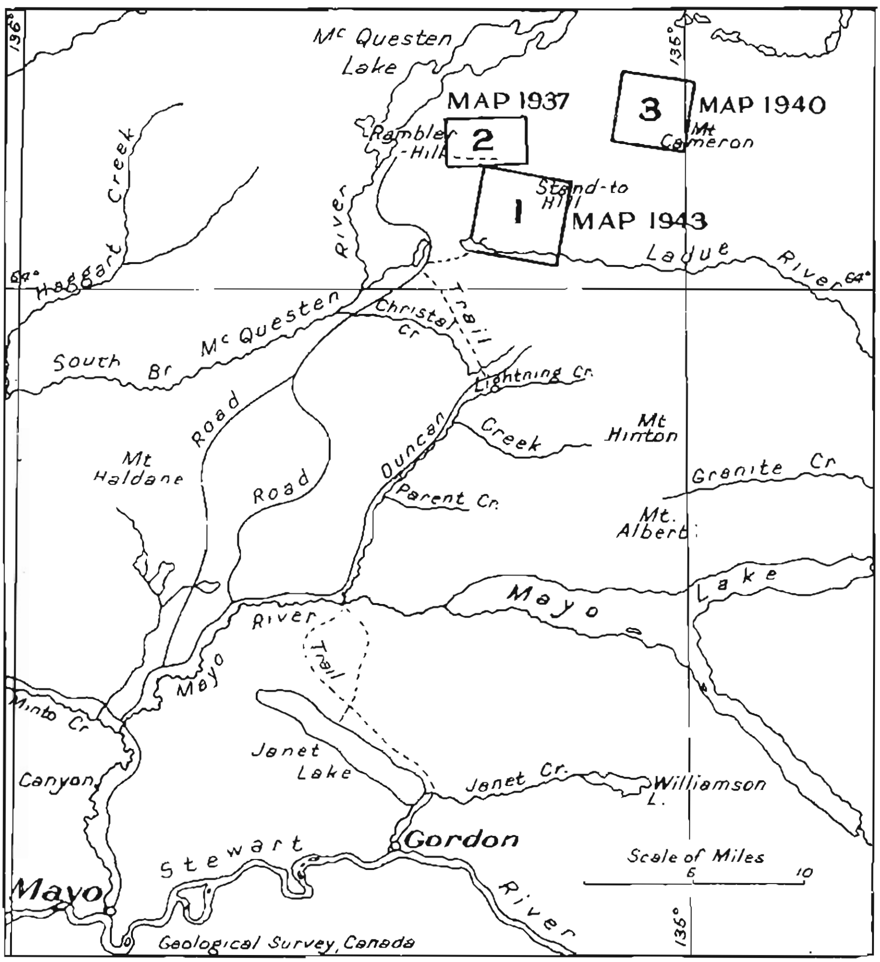

Figure 1. Index map showing location of mineralized areas, Mayo district, Yukon.
1. Stand-to Hill area.
2. Rambler Hill area.
3. Mount Cameron area.

The rates charged for freight vary greatly. From Dawson to Mayo the freight rate is from $50 to $60 a ton, depending on the stage of water in Stewart river. Ore at the present time is hauled 42 miles from Keno hill to Mayo for $30 a ton. The freight rate from Mayo to Keno hill is 15 cents a pound in summer and about half that amount in winter. In considering the three areas covered by this report it must be remembered that at present summer haulage is out of the question, there being no road, and that owing to greater distance and poorer roads winter haulage would be more expensive than to Keno hill.

Topography. Mayo district lies within the physiographic province known as Yukon plateau, which is in this district characterized by its subdivision into isolated mountain groups, separated by broad, flat-bottomed valleys. The interstream areas are mostly flat-topped (Plate I A) and stand at an average elevation of 5,500 feet. These upland areas are parts of a former plain-like surface which has been uplifted and dissected. Occasional hills rise from the plateau to heights of 500 to 1,000 feet.

The district has been intensely glaciated, all but the upland having been covered by ice, which scoured the valley walls, giving to the valleys typical U-shaped cross-sections. The valleys are floored with glacial accumulations, through which the streams have formed terraces.

GENERAL GEOLOGY

Mayo area as a whole is floored by crystalline schists and gneisses. These are the oldest rocks of the district, and, by analogy with similar districts where the age of the rocks has been determined, they are tentatively referred to the Precambrian. These schists and gneisses consist of banded blue and white gneissoid quartzites, grading into quartz-mica schists, and mica schists, graphite schists, and crystalline limestone. These schists are intruded at many points throughout the district by later igneous rocks, diorite and diabase, granite, quartz porphyry, and granite porphyry.

These conditions also obtain in Davidson mountains—one of the three groups referred to above—where the greater part of the areas mapped consists of banded blue and white quartzites, quartz-mica schist, mica schist, graphite schist, and crystalline limestone. Cutting these are dykes and sills of greenstone, which vary widely in colour, texture, and composition, ranging from diorite to diabase, but which appear to belong to one general age of intrusion. These have been intruded along the bedding planes of the schists and have been subsequently sheared and altered. Many of them have become so altered, and now consist to such an extent of secondary minerals, that it is difficult to determine what their original compositions have been. In the field they are nearly always well-defined owing to their dark green colour, different texture, and the fairly sharp dividing line between them and the schists. Owing to their superior resistance they frequently control the topography and form the crests of the ridges.

The granitic intrusives are more prominent in Mayo district than in those parts of Davidson mountains that have been mapped; but one small body of granite was found in Stand-to Hill area, occurring well down on the slope toward Ladue valley. This occurrence is distinguished by the presence of muscovite, whereas in all other granitic occurrences observed in the district biotite is the predominating ferromagnesian mineral.

Overlying all the consolidated rock formations is a mantle of superficial deposits of varying thickness. It is thickest in the valleys, where boulder clay and stream deposits cover bedrock, but it is also prevalent on the hillsides and even on the upland surface where soil, frost-heaved blocks of bedrock, rock rubble, and talus make outcrops scarce. Outcrops are most numerous along the crests of ridges, particularly at the edges of the steep northerly slopes referred to above. They also occur in small jagged peaks at irregular intervals along the upland surface. On the hillsides rock outcrops are rare and are usually of the more resistant rocks, such as greenstone. In the valley bottoms there are occasional outcrops, particularly in the small canyons on the creeks. An attempt has been made to show on the map, by means of stippled areas, the distribution of the superficial deposits. It was found impracticable to show single outcrops and these, where fairly numerous, have, therefore, been grouped into areas.

ECONOMIC GEOLOGY

The silver-lead ores of Davidson mountains are the only known deposits of economic value. They have many characteristics in common and are presumably similar in origin. They are veins formed by the filling of fault fissures. The ore mineral is galena in a gangue of siderite and quartz, with which is associated manganite, and in some cases pyrite, chalcopyrite, and zinc blende.

DESCRIPTION OF DEPOSITS

Stand-to Property. The Stand-to property (Map 1943) is situated on the east side of Homestead creek about 2 miles from its mouth. The workings are about 500 feet above the creek level. There is no road to the property, a winter trail from the workings across Ladue lakes to the Mount Cameron road—5 miles distant—being sufficient for its present needs.

The Stand-to property comprises seven claims, Elsie, Dorothy Brown, Janet Agnes, Two Donalds, Victoria, Mary Bell, and Glengarry, owned by J. Zahn, W. Forbes, D. Forks, D. MacDonald, J. Falconer, and J. A. MacDonald. These claims are grouped for the purpose of representation on the map. They were staked August 15 and 16, 1920. At the time of the writer's visit (July, 1921) the workings consisted of a number of surface trenches, and a 50-foot adit on the vein, about midway between the creek and the summit of Stand-to hill.

The vein is formed in a fault fissure which at the elevation of the workings brings a band of schist into juxtaposition with a greenstone sill, the fault having a vertical displacement of about 50 feet. The vein has been traced on the surface by open-cuts for 200 feet, but probably extends farther in both directions, for in this vicinity bedrock is covered by soil and talus, and the extent of the vein can be ascertained only by trenching. The average strike of the fissure is south 50 degrees east (magnetic); the dip is about vertical. The trend, however, is irregular, for the vein is broken by slip faults. The vein, which varies in width from 16 inches to 2 feet, is mineralized with galena, calcite, siderite, cerussite, limonite, manganite, chalcopyrite, and quartz. The galena occurs as bands from 1 to 6 inches wide in the other gangue minerals, and the chalcopyrite as small specks in the galena. The presence of the cerussite and limonite shows that some oxidation has taken place and possibly also some leaching. The workings are at no place more than 50 feet below the surface. Two samples were taken, No. 1 across 14 inches of the working face and No. 2 from the roof of the tunnel 25 feet from the entrance. These were assayed and the results are given below:

	No. 1	No. 2
Gold	Trace	Nil.
Silver	17·60 ozs. per ton	3·30 ozs. per ton
Lead	19·36%	4·40%

Many other claims have been staked around the original locations, but on the majority of these only representation work has been done. On one group, however, stripping and open-cutting have shown traces of mineralization. This group lies on the summit to the west of the head of Homestead creek, and consists of three claims, the Surprise, the Enterprise, and the Hillside, owned by C. Coutts and J. McKinnon. On the Hillside claim there are two veins, both of which show float containing iron, manganese, and lead minerals. On the Surprise claim a wide band of float with the same minerals apparently shows the location of another vein. Stripping work was in progress at the time of the writer's visit, but bedrock had not been reached, and consequently it was impossible to estimate the value of these veins.

The *Rambler Hill property* (Map 1937) is situated on Rambler hill, about 6 miles east of the foot of McQuesten lake. The workings lie above timber-line, at an elevation

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Issued 1922

LEGEND

QUATERNARY — RECENT AND PLEISTOCENE — Superficial deposits

- Soil, slide-rock and muck, not of sufficient thickness to interfere with prospecting.
- Q1 — Chiefly sand, gravel, muck and ground-ice, sufficiently thick to prevent prospecting of the underlying bedrock.

MESOZOIC — CRETACEOUS (?)

- 2 — Granite

PALÆOZOIC — DEVONIAN (?)

- 1 — Diorite and diabase

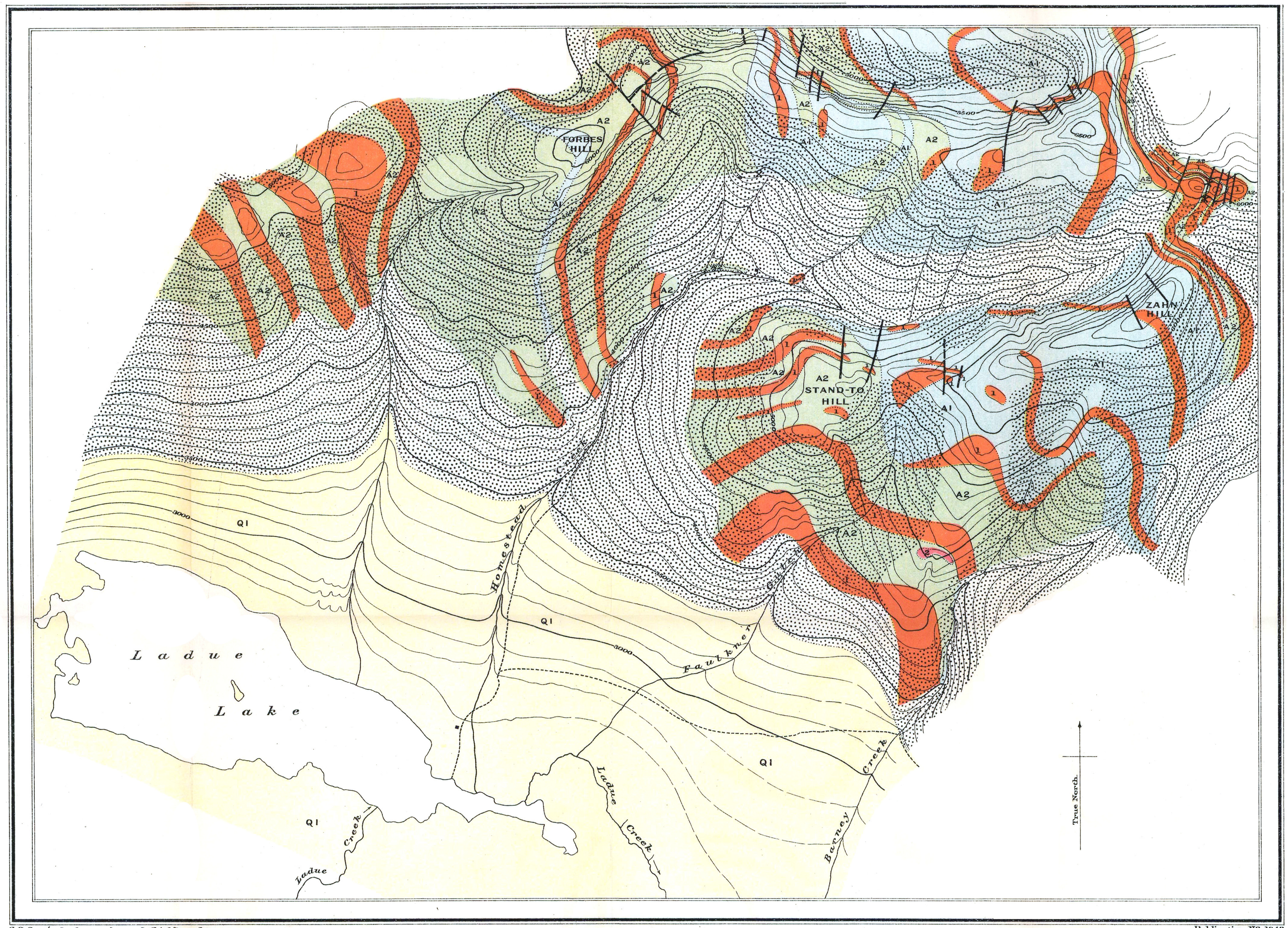
PRECAMBRIAN — NASINA SERIES

- A2 — Quartz-mica schist, mica schist, and graphite schist.
- A1 — Quartzite with thin beds of black schist.

Symbols

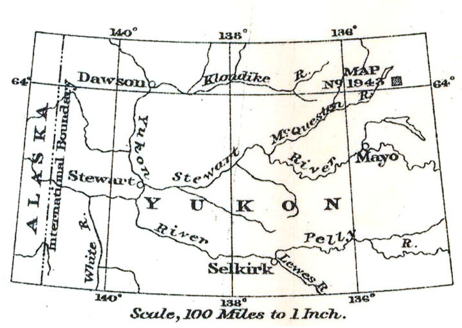
- Geological boundary (defined)
- Geological boundary (assumed)
- Fault (defined)
- Fault (approximate)
- Trail
- × Prospect
- Contours, interval 100 Feet

Approximate magnetic declination, 37° 25' East.



C. O. Senécal, Geographer and Chief Draughtsman.
A. Joanes, Draughtsman.

Publication Nº 1943



STAND-TO HILL AREA, MAYO DISTRICT, YUKON TERRITORY.

Scale of Feet: 1000 0 1000 2000 3000 4000 5000 6000

Geology and topographical reconnaissance by W. E. Cockfield, 1921.

To accompany Report by W. E. Cockfield, in Summary Report, Part A, 1921.

of about 5,000 feet. Eight claims are held, owned by Messrs. A. Martin, A. Lamb, A. R. Thompson, H. Colley, J. Alverson, G. Forey, J. Lake, and J. Robertson, each of whom owns an undivided eighth interest. The property is connected by a 4-mile trail to the winter road from Galena creek to mount Cameron. The workings consist of a shaft about 80 feet deep on the summit of the hill and a crosscut of 12 feet. The vein was traced down the hill for about 300 feet in elevation by means of open-cuts, and an adit has been started here.

At the time of the writer's visit (July, 1921) the shaft was full of water and the upper workings could not be examined. The data obtained from a previous examination[1] are given here for purposes of reference. The vein-filling consists of limonite, galena, pyrite, quartz, cerussite, anglesite (?), malachite, and chalcopyrite. Limonite makes up by far the greater mass of the deposit. Included in it are small nodules of galena, coated with oxidation products. Near the surface and extending downward for 37 feet are large masses of galena. Farther down, these disappear, leaving only the small nodules.

Galena appears in three open-cuts along the vein between the shaft and the adit. In the adit the vein is 3 to 4 feet wide. The strike and dip are both variable. The vein-filling consists of iron oxide and carbonate, manganite, and galena with lead carbonate and a little chalcopyrite. The galena occurs in small bands in the vein, and the chalcopyrite as small specks in the galena.

Two samples of the massive galena were taken. Although these do not represent the average content of the vein, they do give valuable information with regard to the ratio of ounces of silver to one per cent of lead. This ratio determines whether the ores can be concentrated sufficiently to pay for shipment. The samples gave the following results:

	No. 1	No. 2
Gold	Nil	Nil
Silver	36·80 ozs. per ton	36·00 ozs. per ton
Lead	54·91%	52·60%

On claims surrounding Rambler Hill property very little, other than representation work, has been done. In some places veins have been uncovered but work has not progressed far enough to enable much data to be given. One of the most promising of these properties is the Lucknow claim owned by A. R. Thompson. This lies on the long, flat stretch of upland to the east of Rambler hill. Here a fault fissure occurs: it can be traced on the surface by means of float for more than 2,000 feet and is partly exposed in a trench that has not yet reached bedrock but which discloses part of a broken outcrop of massive galena that is, probably, almost in place. Judging from the galena the vein has a width of 6 or 7 feet and of this width the massive galena occupies, probably, about 5 feet; but until more work is done nothing definite can be ascertained about the vein.

The Homestake group on Cache creek owned by A. Martin, W. J. Elliott, Fred Arnold, and B. Verschoyle, shows several veins. There are at least two fault fissures which have float showing iron manganese and lead minerals, but until the overburden is cleared away the character and content of the veins cannot be known.

At other points on the hill, particularly on both hillsides overlooking Rambler creek, galena float has been found, but the veins from which it comes have not been located. Some of this float is reported to be richer in silver than any of the galena tested during the past summer.

The *Mount Cameron property* (Map 1940) is situated on Cameron mountain about 45 miles in a direct line northeast of Mayo, and lies near timber-line on the central fork of Alverson gulch. The winter road from Galena creek to the property has not been completed, but there is a trail from the end of it to the workings. The distance from Mayo by way of this road is about 65 miles. The property consists of three claims, Cameron No. 1, No. 2, and No. 3 owned by J. Scougale, J. Alverson, and J. Philip.

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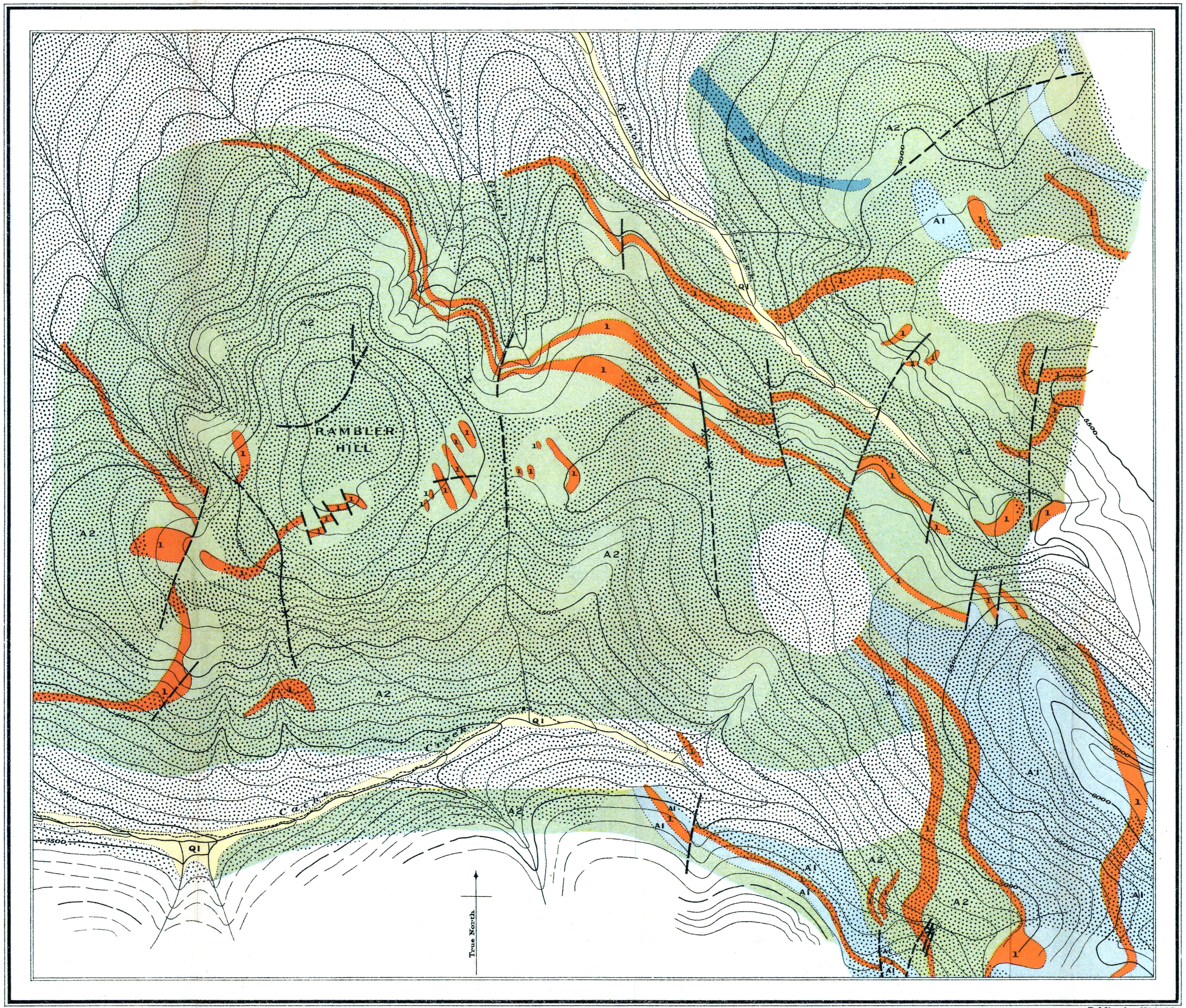
[1] Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1918, p. 6 B.

Canada
Department of Mines

Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister.

GEOLOGICAL SURVEY
W. H. Collins, Director.

Issued 1922



C. O. Senécal, Geographer and Chief Draughtsman.
A. Joanes, Draughtsman.

Publication Nº 1937

LEGEND

PRECAMBRIAN — PALÆOZOIC — QUATERNARY

RECENT AND PLEISTOCENE — Superficial deposits
- Soil, slide-rock and muck not of sufficient thickness to interfere with prospecting.
- Q1 — Chiefly sand, gravel, muck and ground-ice, sufficiently thick to prevent prospecting of the underlying bedrock.

DEVONIAN (?)
- 1 — Diorite and diabase

NASINA SERIES
- A3 — Crystalline limestone
- A2 — Quartz-mica schist, mica schist, and graphite schist.
- A1 — Quartzite with thin beds of black schist

Symbols

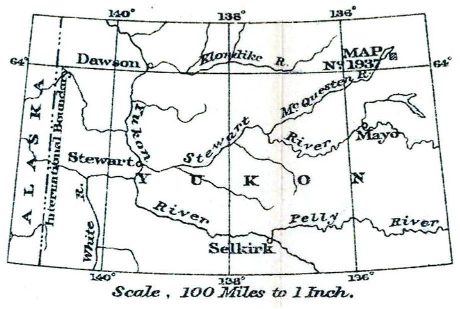
- Geological boundary (defined)
- Geological boundary (assumed)
- Fault (defined)
- Fault (approximate)
- × Prospect
- Trail
- Contours, interval 100 Feet

Approximate magnetic declination, 37°28′ East.

RAMBLER HILL AREA, MAYO DISTRICT, YUKON TERRITORY.

Scale of Feet
1000 0 1000 2000 3000 4000 5000 6000

Geology and topographical reconnaissance by W. E. Cockfield, 1921.



Scale, 100 Miles to 1 Inch.

To accompany Report by W. E. Cockfield, in Summary Report, Part A, 1921.

The workings consist mainly of an adit and a crosscut, but at the time of the writer's visit (August, 1921) the entrance to these was blocked by caving of the roof. There are, also, several trenches. The outcrop (Plate I B) is a decomposed mass of iron and copper minerals, chiefly limonite, manganite, malachite, and azurite, and judging from the material which had been excavated from the adit, the chief minerals present are pyrite, arsenopyrite, galena, sphalerite, chalcopyrite, limonite, siderite, manganite, and calcite. The galena, apparently, occurs in streaks and small masses in the other gangue minerals and, judging from the material on the dump, these streaks would reach a width of 6 to 8 inches. The mineralized outcrop is 50 feet wide and can be traced on the surface for 440 feet, and occasional patches of float show that the vein continues. When, however, the fault passes out of the limestone the fissure is, apparently, filled with a fault breccia composed of broken schist, apparently barren. Passing downward in the series the character of the fault is unknown, as its track is covered by forest growth.

A sample of the galena on the dump was picked so as to represent as nearly as possible the best of the material in sight. Although such a sample in no way represents the average content of the ore, it gives useful information as to the ratio of ounces of silver to one per cent lead. This assayed:

Gold	Nil
Silver	76·00 ozs. per ton
Lead	56·83%

It is manifestly impossible to make a fair estimate of the value of this property, as deductions made from the weathered outcrop are sure to be misleading. The vein is a large one—the widest noted in the Davidson Mountain group—and it extends probably for 2,000 feet, but the character and extent of any ore-bodies it contains cannot be judged from the few tons of material on the dump.

Conclusions

The ores of Stand-to hill, Rambler hill, and mount Cameron—and in fact of all the other prospects noted in Davidson mountains—are strikingly similar in mode of occurrence and mineralization. They also resemble the Keno Hill ores in many ways. Keno hill is 5 miles away directly across Ladue valley from Stand-to hill. There are, however, marked differences between the Davidson Mountain ores and those of Keno hill, the former being much lower in their silver content and mineralization. The Keno Hill ores almost invariably show a silver content of 3 or 4 ounces to 1 per cent lead, whereas the highest obtained during the past summer from the Davidson Mountain ores was 1·33 ounces to 1 per cent lead. This is due to the fact that the Keno Hill ores contain freibergite, a rich copper-silver salt, whereas in the others chalcopyrite, probably carrying little or no silver, is present. The cause of this difference in mineralization is not yet apparent.

In considering these properties from an economic standpoint it must be borne in mind that the deciding factor at the present time is the cost of transportation. Under present conditions it is doubtful if ore or concentrates could be successfully shipped unless the content realized at least $100 per ton. Ore cannot be hauled 65 miles by sled and then shipped several hundred miles to a smelter unless that ore is extremely rich—a condition which the deposits in the Davidson mountains do not fulfil.

Canada
Department of Mines

Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister.

GEOLOGICAL SURVEY

W. H. Collins, Director.

Issued 1922

LEGEND

QUATERNARY — RECENT AND PLEISTOCENE — Superficial deposits

- *Soil, slide-rock and muck, not of sufficient thickness to interfere with prospecting.*
- Q1 — *Chiefly sand, gravel, muck and ground-ice, sufficiently thick to prevent prospecting of the underlying bedrock.*

PALÆOZOIC — DEVONIAN(?)

- 1 — *Diorite and diabase*

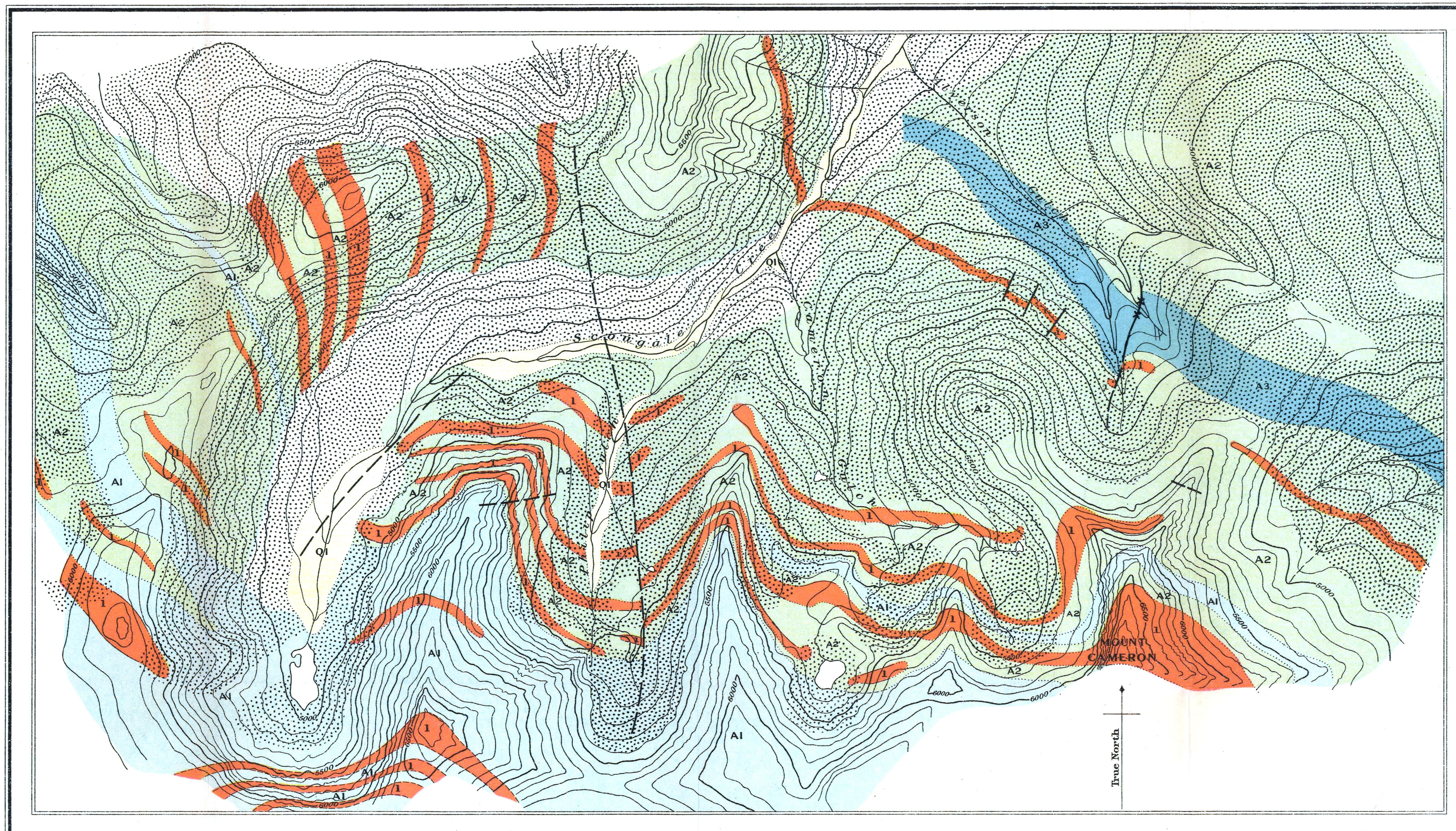
PRECAMBRIAN — NASINA SERIES

- A3 — *Crystalline limestone*
- A2 — *Quartz-mica-schist, mica-schist and graphite schist.*
- A1 — *Quartzite with thin beds of black schist.*

Symbols

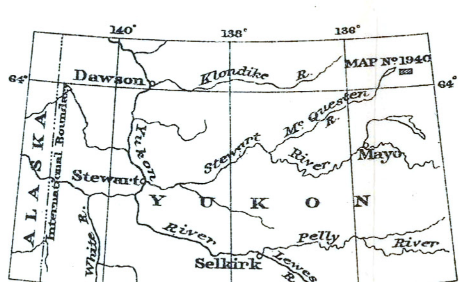
- Geological boundary *(defined)*
- Geological boundary *(approximate)*
- Geological boundary *(assumed)*
- Fault *(defined)*
- Fault *(approximate)*
- Prospect
- Contours, interval 100 feet

Approximate magnetic declination, 37° 25' East.



C.O. Senécal, *Geographer and Chief Draughtsman.*
A. Braidwood, *Draughtsman.*

Publication No. 1940



Scale, 100 Miles to 1 Inch.

MOUNT CAMERON AREA, MAYO DISTRICT, YUKON TERRITORY.

Scale of Feet

1000 0 1000 2000 3000 4000 5000 6000

Geology and topographical reconnaissance by W. E. Cockfield, 1921.

To accompany Report by W. E. Cockfield, in Summary Report, Part A, 1921.

UPPER KITZAULT VALLEY, BRITISH COLUMBIA

By George Hanson

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1921 a detailed investigation was made of the geology and mineral deposits of the Upper Kitzault Valley map-area. This area which lies at the headwaters of Kitzault river, 16 miles north of Alice Arm, B.C., is mineralized with quartz veins carrying values in silver. Two mines, the Dolly Varden and North Star, have shipped ore, the production from the Dolly Varden amounting to 1,304,411 ounces of silver. The area lies a few miles east of the eastern contact of the Coast Range batholith and is part of the great mineral belt that fringes this edge of the batholith. It was the writer's purpose to examine these mineral deposits, ascertain if possible their mode of origin and relation to the geological formations of the district, and to map these formations for the encouragement and direction of further prospecting in this and adjoining districts.

The district had not been examined previously by the Geological Survey, although in 1893 J. E. McEvoy mapped the shore geology of Alice Arm[1] and in 1911, R. G. McConnell[2] did some further geological mapping along Alice arm and reported upon the mineral deposits at the head of the arm. Kitzault district has also been described in the Annual Reports of the Minister of Mines, British Columbia, for 1913, and from 1915 to 1921.

The topographic map prepared in 1920 by W. H. Miller was used as a base for mapping the geology. R. W. Goranson and F. Buckle gave efficient assistance in the field. The writer wishes further to express his indebtedness to C. B. North and the officials of the Taylor Mining Company for their many courtesies and for the complete information placed at his disposal, also to D. W. Cameron, P. Anderson, the officials of the Consolidated Homestake Mining and Development Company, and to other holders of mineral claims for courtesies and helpful information.

GENERAL CHARACTER OF THE DISTRICT

Upper Kitzault Valley map-area embraces about 50 square miles and lies about 16 miles north of Alice arm. It is within the drainage basin of Kitzault river, which flows into Alice arm at the town of Alice Arm, a calling point for boats of the Union Steamship Company. The Grand Trunk Pacific Steamship Company maintains a

[1] Geol. Surv., Can., Ann. Rept., 1893, p. 13 A.
[2] Geol. Surv., Can., Mem. 32, 1913, pp. 81-94.

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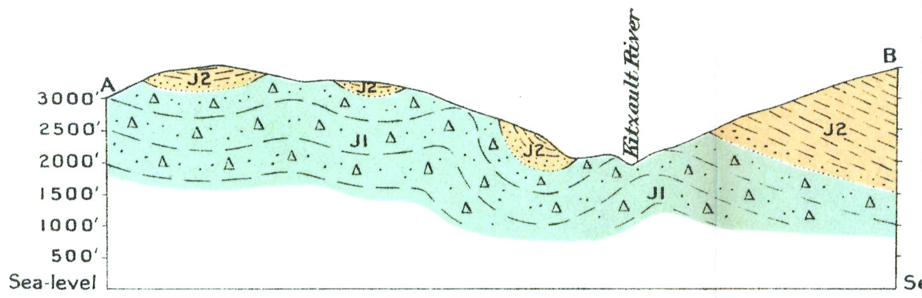
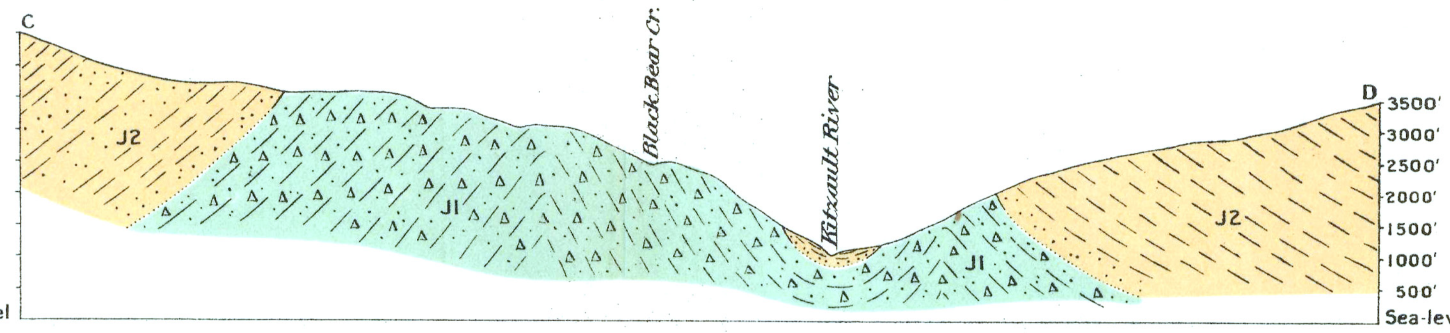
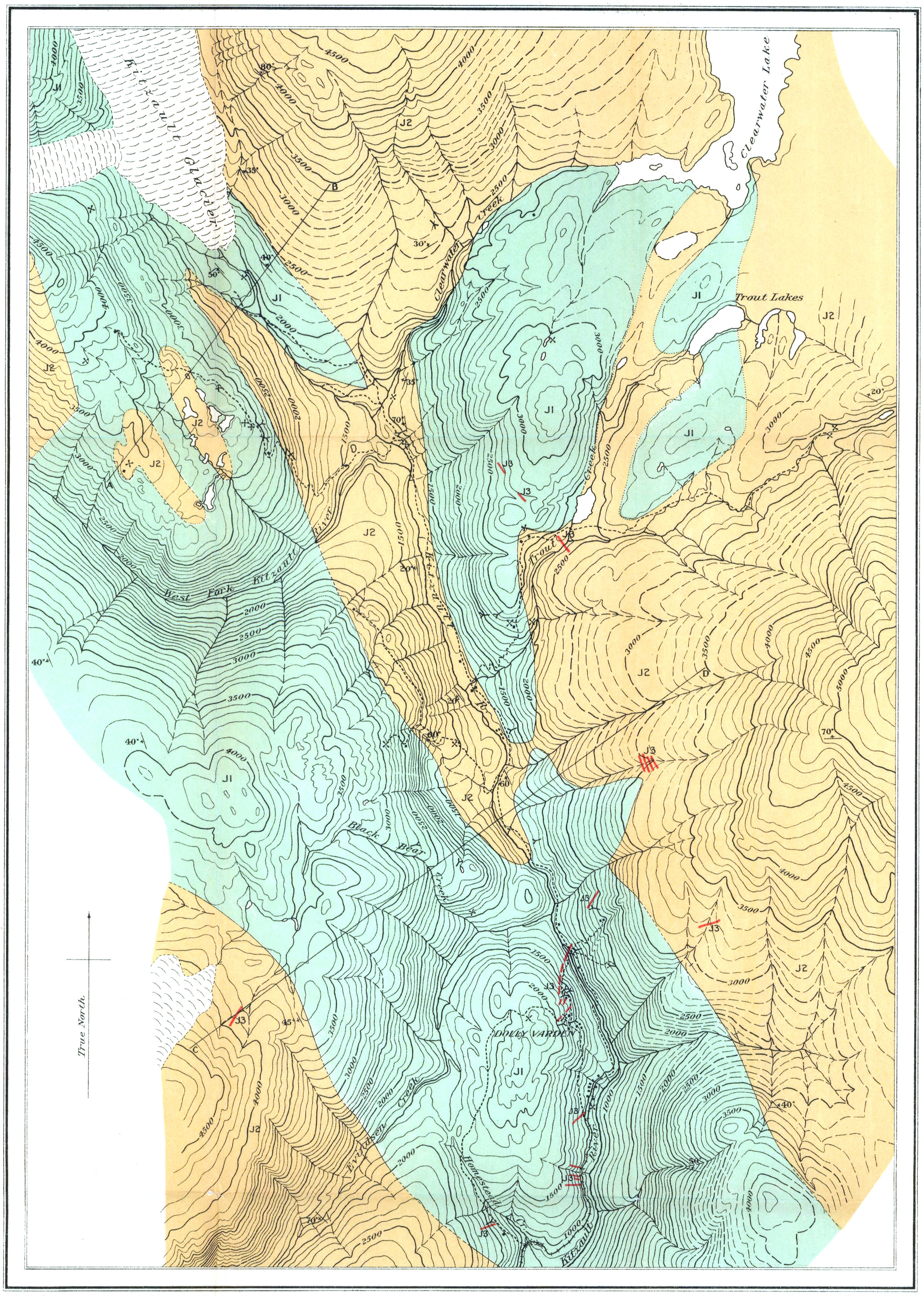


Structural section along line AB



Structural section along line CD



LEGEND

JURASSIC (?)

- J3 — *Lamprophyre and diabase dykes*
- J2 — Kitzault River formation (*argillites, quartzites, conglomerates, tuffs.*)
- J1 — Dolly Varden formation (*fragmental and massive volcanic rocks*)

Symbols

- Geological boundary (*defined.*)
- Geological boundary (*approximate*)
- Geological boundary (*assumed*)
- Dip and strike (50°)
- Vertical strata

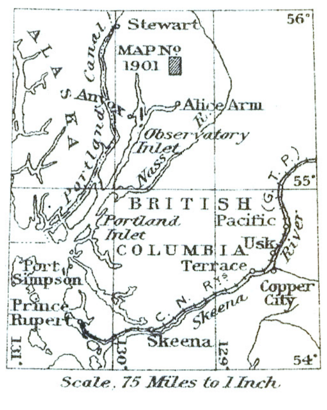
LEGEND

- Buildings
- Trails
- Railways
- Bridges
- Tunnels
- Prospects
- Rivers and lakes
- Watercourses (*with intermittent flow*)
- Glaciers
- Contours (*showing land forms and elevations above sea-level*) *Interval 100 feet*
- Contours (*not well determined*)

Approximate magnetic declination, 30° 28' East.

C. O. Senécal, *Geographer and Chief Draughtsman.*
A. McGregor, *Draughtsman.*

Publication No 1901



UPPER KITZAULT VALLEY

(*ALICE ARM*)

CASSIAR DISTRICT

BRITISH COLUMBIA

Scale $\frac{1}{36,000}$

Miles: 1 ¾ ½ ¼ 0 1

Kilometres: 1 0 1 2

3000 FEET TO 1 INCH

TOPOGRAPHY
W. H. Boyd, *Chief Topographer.*
Surveys and topography by W. H. Miller, 1920.

GEOLOGY
Geology by G. Hanson, 1921.

To accompany Report by G. Hanson, in Summary Report, Part A, 1921.

regular service to Anyox, and there is a tri-weekly boat service between Anyox and Alice Arm. A narrow-gauge railway runs from the wharf at Alice Arm up Kitzault valley to Camp 8, a distance of 16 miles.

The district surrounding the map-area is characterized by the steep-sided valleys and rugged peaks typical of Coast Range topography. The relief in the district itself, however, is not great, the highest mountain being 5,450 feet above sea-level. All the mountain tops are rounded. The lowest point in the area is 850 feet above sea-level.

The steep sides of Alice arm are somewhat straight and show no projecting spurs. Alice arm has the appearance of a typical glacially eroded valley. The valley of Kitzault river, however, does not appear to have any features of glacial erosion except in its upper part. The same is true of its two largest tributaries, which head in glaciers. Boulder clay is found on the banks of Kitzault river as far as a mile south of the glacier, and above this point the valley is U-shaped. Evindsen and West Fork creeks also are U-shaped for a short distance below the present glaciers. It would seem that all the canyons in the district were cut by running water.

Continental glaciation has been effective up to elevations of over 5,400 feet above sea-level, as shown by glacial striæ and foreign boulders. Although there is this indisputable evidence for widespread glaciation, the valleys show features of glacial erosion only in their upper parts. Following continental glaciation, the Kitzault glacier was probably almost stagnant and, therefore, would not be an effective agent of erosion. It is possible that the first ice-sheet disappeared entirely and that there was a second and much more limited epoch of glaciation which filled only the higher valleys. The present glaciers are, apparently, remnants of the second period.

The chief streams are Kitzault river, and its tributaries Evindsen, West Fork, Clearwater, and Trout creeks. Clearwater and Trout creeks head in small lakes on the low divide, 2,700 feet above sea-level, between Kitzault and Nass rivers. The other streams mentioned head in glaciers. Practically all the streams in the area, except Kitzault river, flow in steep canyons in the lower parts of their courses. All the tributaries with the exception of Trout creek enter the Kitzault at a steep grade. Trout creek has the characteristic of a hanging valley in that it tumbles into Kitzault Valley bottom, in a series of falls and cascades 500 feet high.

Kitzault river heads in Kitzault glacier, flows in a steep but shallow canyon for 1½ miles, then continues in a broad valley as a shallow stream for about 3 miles. One-quarter of a mile north of the mouth of Evindsen creek it again enters a canyon, through which it flows for 3 miles. Below this it is a broad, shallow stream to Alice Arm, with the exception of a short canyon 7 miles from its mouth. The river follows very closely the strike of the surrounding rocks.

It is apparent that most of the minor details of topography in the map-area, such as canyons and low eminences, have resulted from the unequal resistance to erosion. From the combined topographic and geological map it will be seen that eminences, such as Combination mountain, Dolly Varden hill, and the low peaks to the southeast, are composed of rocks of the Dolly Varden formation. The rocks of this formation are harder and more resistant to erosion than the sediments of the Kitzault River formation. The same relation between eminences and character of rock is seen in the area between Trout lake and Kitzault river. The low pass to Nass river is underlain by soft rocks.

Where Kitzault river cuts through rocks of the Dolly Varden formation it flows in a canyon; where argillite forms the banks the river is shallow and broad. The softer rocks are cut away easily to form a broad valley, and to keep a uniform grade the stream cuts canyons in the more resistant rocks.

The climate is temperate. The summers are never very hot, and the temperature in winter does not fall much below zero. Precipitation is heavy throughout the year. July is usually a clear sunny month and September is occasionally fine. As a general rule June and August are showery. A winter's snow usually attains a depth of 15 feet in the valleys. Spring and summer are late. By the first of June snow still covers the rocks down to a line about 2,000 feet above sea-level.

GENERAL GEOLOGY

GENERAL STATEMENT

The eastern contact of the Coast Range batholith lies a few miles west of the map-area, which is located in the great mineral belt that fringes the batholith. This eastern mineral belt has been investigated by the Geological Survey in many places[1]. That part of the belt lying between Unuk river on the northwest, and Skeena river on the southeast, a distance of 150 miles, has been examined at Unuk river, Bear river, Salmon river, Alice arm, Nass river, and Skeena river.

Alice arm lies midway between Unuk and Skeena rivers. In order to give the relation of the area to the whole region the geology along the belt will be briefly summarized.

The eastern contact of the Coast Range batholith trends northwesterly and the rocks bordering the intrusives on the east strike roughly parallel to the contact. On Unuk river the rocks are chiefly sedimentary. Along Bear river two sedimentary formations are found, one underlying and one overlying a thick series of volcanic fragmental rocks (Bear River formation). In Salmon River district a sedimentary series overlies the Bear River volcanics. Here there are also sills of quartz porphyry of late Jurassic age. In Kitzault River district a sedimentary series overlies volcanic rocks similar to the Bear River formation. The rocks along Nass river are chiefly sedimentary. This sedimentary series is apparently of the same age as the sediments overlying the volcanic rocks to the north. In Skeena River area, volcanic rocks occur similar in many ways to those farther north. Here again sedimentary rocks overlie the volcanic series.

It is believed that the volcanic rocks along this belt are, in the main, of Jurassic age. The overlying sedimentary rocks are probably of Jurassic age along the greater part of the belt. The sediments on Skeena river and also north to the Groundhog district are, however, of Lower Cretaceous age. It seems probable that the belt under discussion rose out of the sea at the end of the Jurassic period and that sedimentation continued along its eastern flank.

The geological formations in Upper Kitzault valley have been classified tentatively as follows:

Table of Formations

Period		Formation	Lithology
Quaternary......	Pleistocene and Recent..............	....	River gravels and glacial drift

[1]Wright, F. E., "The Unuk River Mining Region," Geol. Surv., Can., Sum. Rept., 1905, pp. 46-53.

Schofield, S. J., and Hanson, George, "Salmon River District", Geol. Surv., Can., Sum. Rept., 1920, pp. 6 A-12 A.

O'Neill, J. J., "Salmon River District," Geol. Surv., Can., Sum. Rept., 1919, pp. 7 B-12 B.

McConnell, R. G. "Portland Canal District", Geol. Surv., Can., Mem. 32, 1913.

McEvoy, J., Geol. Surv., Can., Ann. Rept., 1893, pp. 13 A-16 A.

McConnell, R. G., "Prince Rupert and Skeena River", Geol. Surv., Can., Guide Book No. 10, pp. 5-35, 1913.

MacKenzie, J. D., "Telkwa Valley and Vicinity," Geol. Surv., Can., Sum. Rept., 1915, pp. 62-69.

Also papers by W. W. Leach in the Summary Reports of 1906-1910, and G. S. Malloch in the Summary Report of 1911.

Table of Formations—Continued

Unconformity

	Post-Jurassic(?).........	....	Lamprophyre and diabase dykes
	Intrusive contact		
		....	Lamprophyre and diabase dykes
		Intrusive contact	
Mesozoic.........	Jurassic.............	Kitzault River formation...........	Argillites (fossiliferous), thickness 2,500 + feet
		Dolly Varden formation...........	Agglomerates and tuffs, thickness 3,000 + feet
		(Base unexposed)	

The formations have been given local names. When the areas intervening between Kitzault River district and other known areas are mapped, the names here proposed can probably be discarded in favour of other well-established names.

DESCRIPTIONS OF FORMATIONS

Dolly Varden Formation. The name is taken from the Dolly Varden mine which has been the outstanding mining property in the district. This formation underlies about one-half of the area of the district. The main body of the formation crosses the area in a northwest-southeast band 1½ miles wide. Another area outcrops south of Clearwater creek.

The formation consists chiefly of purple and green fragmental rocks probably over 3,000 feet in thickness. Tuffs and breccias predominate, but there are some andesite flows. The rocks of the formation are known locally as andesites.

The green members of the series contain fragments of porphyrite, tuff, feldspar, and quartz. The rocks are very much weathered. Calcite is the most abundant alteration product; sericite and chlorite are fairly plentiful, but epidote is rare. The purple rocks are of much the same mineral composition as the green members, but they appear to contain more magnetite. Vermilion red tuffs of the series contain a good deal of hematite in the matrix between the fragments of the tuff. A thin section of an augite andesite flow showed a content of andesine and augite with magnetite as an accessory mineral. Epidote and chlorite are the chief alteration products. Sericite and calcite are not common. A flow structure is evident in the arrangement of the feldspar laths.

The rocks are in general massive and their structural relations are not as a rule evident. In only a few places was it possible to determine the attitude of the beds. The rocks are very similar in composition and lack of structure to the Bear River formation of Portland Canal district, and also to the Kitsalas formation and parts of the Hazelton group along Skeena river.

A belt of rocks known locally as the copper belt enters the area mapped west of the Kitzault glacier and extends southeasterly to Evindsen creek. The belt is one-fourth to one-half a mile wide. It is bordered on the east by argillite of the Kitzault River formation and on the west by the Dolly Varden formation. Another similar belt of rocks enters the mapped area at the junction of Kitzault river and Homestead creek and extends northwesterly for a short distance north of Evindsen creek. This belt is bounded on the east by the Dolly Varden formation and on the west by argillites. The rocks of these belts contain a great deal of disseminated pyrite, and, consequently, the weathered outcrops are conspicuous and are easily distinguishable from a distance by their reddish-brown colour.

The rocks are severely sheared and weathered, and, consequently, are not easy to determine. Grey tuffs and breccias, apparently, predominate. Diorite appears to be present in the northern belt. Tuffaceous sediments and quartzite are also present. In many places the rocks contain a great deal of calcium carbonate and, particularly in the southern belt, frequently effervesce readily with cold dilute hydrochloric acid.

Lithologically the two belts are very much alike and probably belong to one horizon. The western border of the northern belt is gradational. The writer was unable to determine whether the copper belts were part of the Dolly Varden formation or a separate formation and thought best to include them with the Dolly Varden formation. McConnell in his traverse from Bear river to Meziaden lake, found that the Bear River formation where overlain by the Nass formation on the east, contained a rusty band one-half mile wide along the contact.[1] The area mentioned is about 15 miles north of the Kitzault area and the same belt may extend through the intervening unexplored area. Future work in adjacent areas may settle this problem.

Kitzault River Formation. A series of sedimentary rocks consisting chiefly of black argillites overlies the Dolly Varden formation to the north, northeast, and east, and occurs, also, in a band along Kitzault river. The thickness is estimated at over 2,500 feet. This series may yet prove to be the Nass formation, found 15 miles to the north, but for the present it is given the local name, Kitzault River formation. At the northwestern and southwestern corners of the mapped area, argillites, sandstones, and conglomerates are found. These rocks are coarser than the argillites to the east, but they appear to overlie the Dolly Varden formation. They have been mapped as part of the Kitzault River formation. To the south of the map-area these western sediments which have an easterly dip extend to Alice Arm and along the railway. The contacts of this southern part have not been studied.

Wherever the dips of the rocks of the Dolly Varden formation could be observed near the contact with the argillites the strike and dip of both formations are concordant. If the copper belt, however, is at a certain horizon in the Dolly Varden formation and not a result of hydrothermal alteration, it is very likely that locally at least, the Kitzault River formation lies unconformably on the volcanic series. In several places at the base of the Kitzault River formation tuffs and sediments are interbedded. This favours the view that the sedimentary period succeeded the volcanic period gradually, and that though there may be local unconformities, the argillites are in the main conformable on the series of extrusive rocks.

Stratigraphically above the interbedded tuffs and sediments and at the base of the argillite series is a fairly continuous band of greywacke and quartzite about 100 feet thick. The greywacke consists of poorly assorted, irregular grains of feldspar, quartz, biotite, and rock fragments. Calcite is the common alteration mineral. Above this band the rocks are almost entirely argillite. A few narrow bands of chert and slate pebble conglomerates, and narrow bands of sandstone are present. No limestone beds were found in the series, but some of the sediments are very calcareous. The argillites contain angular quartz and feldspar grains embedded in a black, fine-grained matrix. Much of the argillite is heavy bedded, but in some places, thin bands of black argillite alternate with thin beds of argillaceous sandstone.

Fossils from the sandstone members of the transition zone of interbedded tuffs and sediments at the base of the Kitzault River formation were identified by F. H. McLearn as *Gryphæa* sp., *Oxytoma* sp., *Belemnites* sp., and *Rhynchonella* sp. Mr. McLearn writes: "It is regrettable that in the present stage of study of the Mesozoic

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[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, 1913, pp. 75-76.

of British Columbia a more exact report cannot be given. It can be said, however, that the above fauna is certainly either Jurassic or Cretaceous and very probably Jurassic."

Lamprophyre Dykes. Intrusive into the rocks previously mentioned are numerous lamprophyre dykes. The rock is black and resembles diabase, but very few typical diabase dykes are present. Thin sections from some of the dykes contain albite-oligoclase feldspar laths, a little orthoclase, rare quartz, and numerous long, well-formed crystals of light brown hornblende. Others contain oligoclase-andesine feldspar laths and augite. Apatite, present as long slender needles, is a common accessory mineral in all these dykes. Chlorite and calcite are the usual alteration products. Some of the dykes are cut by mineral veins; others cut mineral veins, but are cut by faults. Others are later than both the veins and faults.

Some of the dykes, therefore, are apparently of Jurassic age and some are post-Jurassic.

Pleistocene and Recent. Glacial drift is not plentiful. Boulder clay on the banks of Kitzault river is 50 feet thick for a mile below the glacier, and is also found on the hillside east of Camp 8.

Stratified sands and clays occur south of the map-area about 9 miles north of Alice Arm and about 400 feet above sea-level. Similar deposits have been found at this level in several inlets along the coast. Marine fossil shells were found in similar clays along Bear river[1].

STRUCTURE

In Kitzault River district, as elsewhere along the borders of the Coast batholith, the rocks strike roughly parallel to the contact of the intrusive mass. In this area the strike is approximately north 25 degrees west. Structures showing the attitude of the beds of the Dolly Varden formation are scarce. On Combination mountain, between Evindsen creek and the West Fork of Kitzault river, the breccias dip to the west, and here the argillites and the volcanics appear to be conformable. Similar relations exist at the eastern contact of the small area of tuff extending southeast from Kitzault glacier.

The area of argillite outcropping along Kitzault river between Evindsen creek and Kitzault glacier is a canoe-shaped syncline. This area joins with the north-east dipping sediments north of Clearwater creek and also with the large area of sedimentary rocks east of Kitzault valley. The sediments along the western part of the sheet dip to the west. These areas were probably originally continuous.

It is believed that an anticline crosses Combination mountain. A syncline exists along Kitzault valley, and part of the sediments are still preserved here. This is succeeded by another anticline between Trout lake and Kitzault river. Folding, transverse to the main structural lines, caused the formation of a transverse anticline at the mouth of Evindsen creek. This is succeeded by a transverse syncline about a mile farther north.

Judging from the number of faults encountered in mine workings, the district has been subjected to a great deal of faulting. The greatest horizontal offset noted was 160 feet. The throw may have been much greater than this. Most of the faults have a north-south trend and most of these are reverse faults. Several faults with an east-west trend were observed. The only place where faulting could be studied was underground; consequently, the data obtained were not complete enough for the working out of the nature of the regional movements which produced the faults.

ECONOMIC GEOLOGY

DISCOVERY

Before the advent of the railway, the upper parts of Kitzault valley were difficult of access. The canyons and steep slopes could not be travelled. For this reason, although many mineral claims were located around Alice arm in 1901, it was not

[1] McConnell, R.G., op. cit., p. 22.

until 1911 that any mineral claim was located on the upper waters of Kitzault river (Figure 2). The first claim recorded was the Dolly Varden, staked by Evindsen, Pearson, and partners. The other claims staked were located in the copper belt. Not until after 1913 was attention directed to the properties located in the breccias and tuffs.

The properties in the district were described in the Report of the Minister of Mines, B.C. in 1913. Since 1915 descriptions of the district have been given each year.

Production

1919	42 tons	Yielding 50,562 ozs. silver	Dolly Varden
	6,668 "	" 376,562 "	"
	27 "	" 968 "	North Star
1920	93 "	" 82,298 "	Dolly Varden
	27,944 "	" 749,340 "	"
1921	1,862 "	" 45,647 "	"
	Also a small shipment from the North Star.		

GENERAL STATEMENT

The primary veins and replacements in the district were formed during the closing stages of igneous activity of the Coast batholith. The metals and much of the accompanying vein matter were derived probably from ascending, or hypogene, solutions. The primary vein matter now exposed at the surface was formed, apparently, several thousand feet below the surface. Since then erosion has stripped off rock several thousand feet in thickness. The rock was weathered and disintegrated more rapidly than it was removed. The metals from the outcropping veins were, consequently, dissolved and the solutions seeped downward along the easiest passageways. Solution, chemical reaction, and replacement went on, resulting in secondary minerals being deposited by these surface, or supergene, solutions. The process continued until Pleistocene time, and in several places deposits of secondary silver ore were formed. Pleistocene erosion stripped off all the oxidized part of the veins and probably part of the enriched portion, leaving the veins practically as they are today. It is possible that nuggets of silver removed by Pleistocene erosion still remain in Kitzault river.

The mineral deposits have been classified as follows:[1]

Quartz veins and replacements in the volcanic fragmental rocks.
Quartz veins and replacements in the copper belt.
Quartz veins in the sedimentary rocks.

Upper Kitzault valley is only a small part of the area examined by Mr. Turnbull, but the classification is suitable.

Not all the claims in the district were examined. A brief description follows of those properties visited, and other descriptions can be found in the British Columbia reports for 1913, and 1915-1921.

QUARTZ VEINS AND REPLACEMENTS IN VOLCANIC FRAGMENTAL ROCKS

All these properties—which are noted for their content in silver—are located in the Dolly Varden formation, exclusive of the copper belt, and all of these lie either in the green or grey members of the formation, or at the contact between these rocks and purple breccias. The veins contain a moderate proportion of metallic minerals and where the values are high in silver the mineralization is usually native silver, ruby silver, argentite, etc. High values from a galena or grey copper ore are not so common.

In some of these properties barite and jasper are common gangue minerals. The richer silver veins have, however, a quartzose gangue. It is probable that the barite

[1] Turnbull, J. M., "Alice Arm District", Ann. Rept. Minister of Mines, B.C., pp. K 53-K 83, 1916.

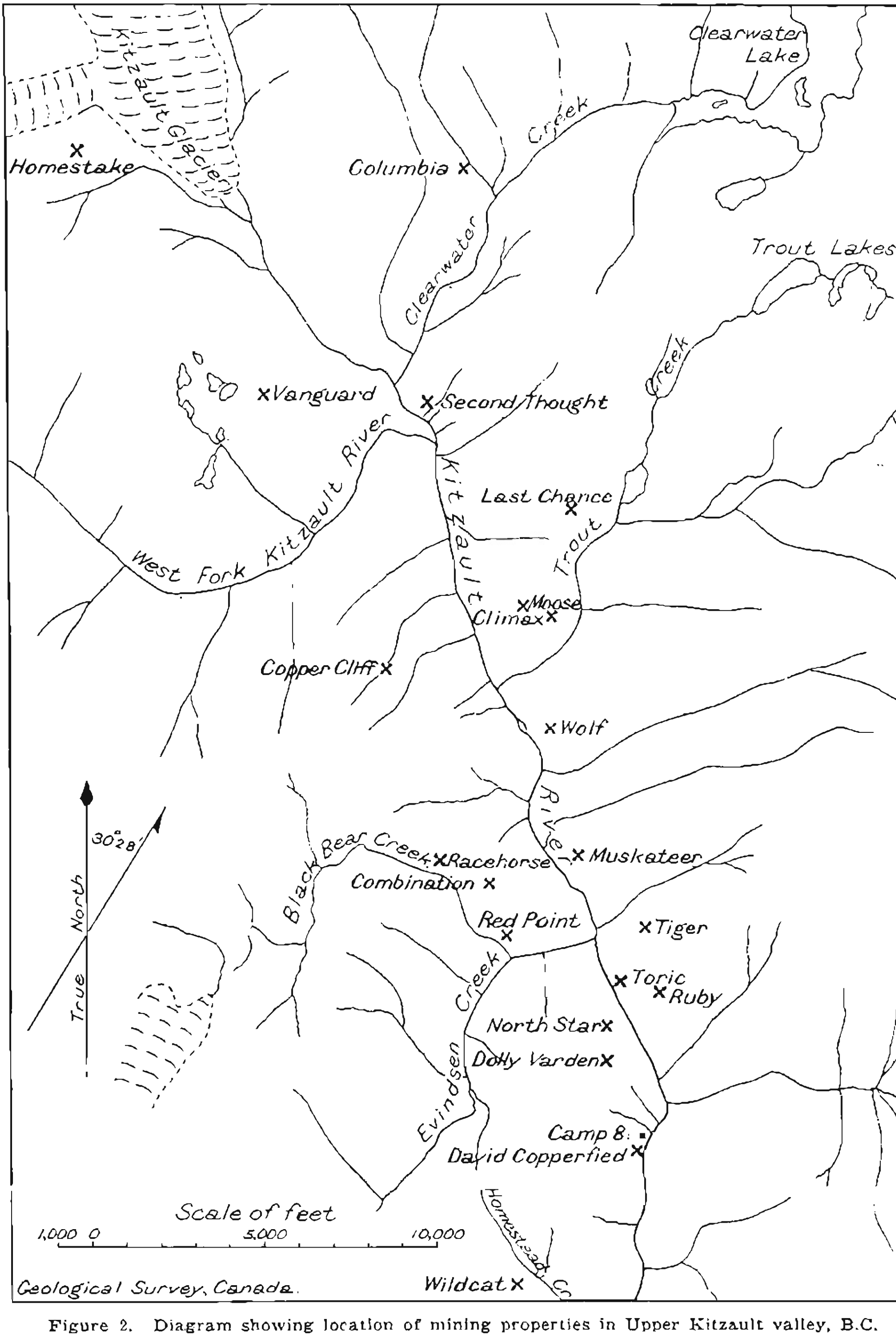

Figure 2. Diagram showing location of mining properties in Upper Kitzault valley, B.C.

was formed during the period of primary mineralization, and that it did not contain metallic minerals. Secondary ore is formed chiefly by the replacement of primary ore; consequently, even after secondary enrichment, the barite would not contain much ore. Further, quartzose vein matter, being brittle, might fracture more readily than barite, and surface solutions would then penetrate the quartzose gangue more easily.

North Star-Toric-Ruby Mineral Zone

This zone appears to be continuous northward from the Dolly Varden through the North Star to the Toric, where it bends sharply (at Kitzault river) and extends southeastward through the Toric and Ruby groups, beyond which it has not been traced. This zone lies in grey breccia and has a hanging-wall of purple breccia. It is of indefinite width, up to perhaps 150 feet in some places. It is not mineralized throughout its entire width, but is simply a zone in which quartz barite veins lie roughly parallel to the contact with the overlying purple breccia. The rocks along the zone appear to be folded into a northerly plunging anticline. The Toric is located at the apex, the Ruby on the eastern limb, and the North Star on the western limb of the anticline. The veins are in general bedded veins; that is, they are parallel to the strike and dip of the enclosing rocks.

This zone may pinch out in Dolly Varden ground or it may be the eastern extension of the Dolly Varden zone faulted into its present position, or interrupted by a northerly-plunging syncline. No evidence was found to show that the zone was faulted here and it probably continues for some distance past the Ruby group to the southeast. The vein in the Tiger group may belong to this zone, as a syncline passing between the Ruby and the Tiger group could bring this about. Further field work is necessary, however, to settle these problems.

The *North Star group* is controlled by the Alice Arm Silver Mining Co., Ltd. Development consists of open-cuts and 250 feet of tunnel. The North Star vein has a north-south strike and dips steeply to the west. The country rock is grey breccia, although purple breccias are present 50 feet west of the vein. Lamprophyre dykes parallel the vein and in some places form its foot or hanging-wall. Faulting has taken place, but development has not been extensive enough to ascertain whether the parts of the vein observed are one vein faulted, or two veins. The vein is 4 to 12 feet wide and has been traced for over 500 feet.

Silver is the metal extracted. Where mining has been carried on the vein is essentially a quartz-pyrite vein carrying the silver minerals ruby silver, native silver, and argentite. Lower down the hill toward the Toric, the vein changes in character and becomes essentially a barite vein containing a little galena and small amounts of silver.

The *Toric group* is owned by Strombeck Bros. Development consists of a number of open-cuts and 90 feet of tunnel. Two or more veins are exposed striking southeast and dipping to the northeast. The main vein is 4 to 12 feet wide and has been traced for over 500 feet. At Kitzault river the vein consists almost entirely of barite. Around the tunnels and more promising stripping is a jasper-barite quartz vein. The jasper-barite vein matter is beautifully banded, forming irregular crustification patterns. Parts of the vein contain numerous irregular fragments of rock cemented by jasper and barite. In several places thin bands of barite and jasper alternate with thin seams of galena. Metallic minerals are not prominent in the barite-jasper gangue, but some of this vein matter carries about 20 ounces of silver per ton. During the summer of 1921 a new ore-shoot was uncovered within the main vein. This shoot contains native silver, ruby silver, galena, etc., in a gangue of quartz. The values are high.

The *Ruby group* is owned by T. W. Shackelton. Development consists of a few open-cuts and 110 feet of tunnel. The foot-wall is a greenish, and the hanging-wall a purple breccia. The vein matter consists almost entirely of quartz. Pyrite is present but other minerals are rare. The vein is 4 to 8 feet wide and is parallel to the strike and also apparently to the dip of the enclosing rocks. Open-cuts extend for an horizontal distance of 350 feet and appear to be on the same vein.

Dolly Varden Mineral Zone

This is a zone of grey breccia underlying a series of purple fragmental rocks. Quartz veins in the zone are, in general, parallel to the strike of the rocks. The Dolly Varden vein is one of these veins. Its western extension has not been traced beyond the Dolly Varden claims, but the zone in which it is located appears to continue west to Evindsen creek through either the Silver Tip or Royal groups or through both. The eastern part of the vein is cut off by a fault, which offsets the vein east of this in a southern direction.

The *Dolly Varden group* is owned by the Taylor Mining Co. Development consists of open-cuts, 7,000 feet of tunnels, raises, etc., and a good deal of diamond drilling. The main vein strikes roughly east and west and dips 60 degrees to the north (Figure 3). It lies in part along the contact between a purple and green breccia and in part in the latter rock. The primary vein matter was deposited from ascending solutions. The process of vein formation was accompanied by a considerable development of pyrite, and some quartz and sericite, in the foot-wall. The purple breccia hanging-wall has not been altered by solutions accompanying ore deposition.

Numerous reverse faults with a north-south strike and a steep westerly dip offset the vein. Later normal faults with approximately the same strike and dip also cut the vein; consequently the vein outcrops as a series of disjointed blocks 30 to 200 feet in length. The greatest horizontal offset along faults in the mine workings is 160 feet. Horizontal faults are also present. Lamprophyre dykes cut the vein, some of which antedate and some postdate the faults. Mining is rather a complicated proceeding.

The vein has been traced for 1,500 feet, but the eastern 300 feet has not been developed underground. Mining has been carried on in the four fault blocks adjoining this, an horizontal distance of 300 feet. The western extension of 900 feet has not been developed underground except at the western end where some diamond drilling was done. This vein varies from 8 to over 20 feet in width.

About 100 feet north of the western extension another quartz vein is exposed, but has not been investigated. Another large body of quartz and brecciated rock cemented with quartz extends into the Dolly Varden ground from the North Star claims. This body has been tested in two places by diamond drilling.

The main vein is essentially a silver-bearing quartz-pyrite vein. Pyrite is fairly abundant. Zinc blende, galena, chalcopyrite, and tetrahedrite, are rare. The ore extracted contained a good deal of native silver, ruby silver, and argentite. Quartz is the predominant gangue mineral, but calcite, barite, and jasper are present in small amounts. Barite is plentiful in some parts of the vein, but was not common in the ore extracted.

In the upper workings, native silver, ruby silver, and argentite were plentiful and occurred in plates and seams as much as a quarter of an inch in thickness, and in numerous irregular masses. In the deeper workings, the native silver occurred in thin flakes and wires, and the other silver minerals as well were found chiefly in minute fractures. It is believed that the ore mined was essentially secondary, i.e. it was the result of enrichment of primary vein matter by descending surface solutions. The thick plates of silver, etc., near the surface, represent intensive enrichment. The thin flakes and wires of silver are near the bottom of the enriched zone where secondary action was dying out.

Ore has been worked to a depth of 240 feet; 36,609 tons yielding 1,304,411 ounces of silver have been shipped since 1919. One shipment of 42 tons in 1919 yielded

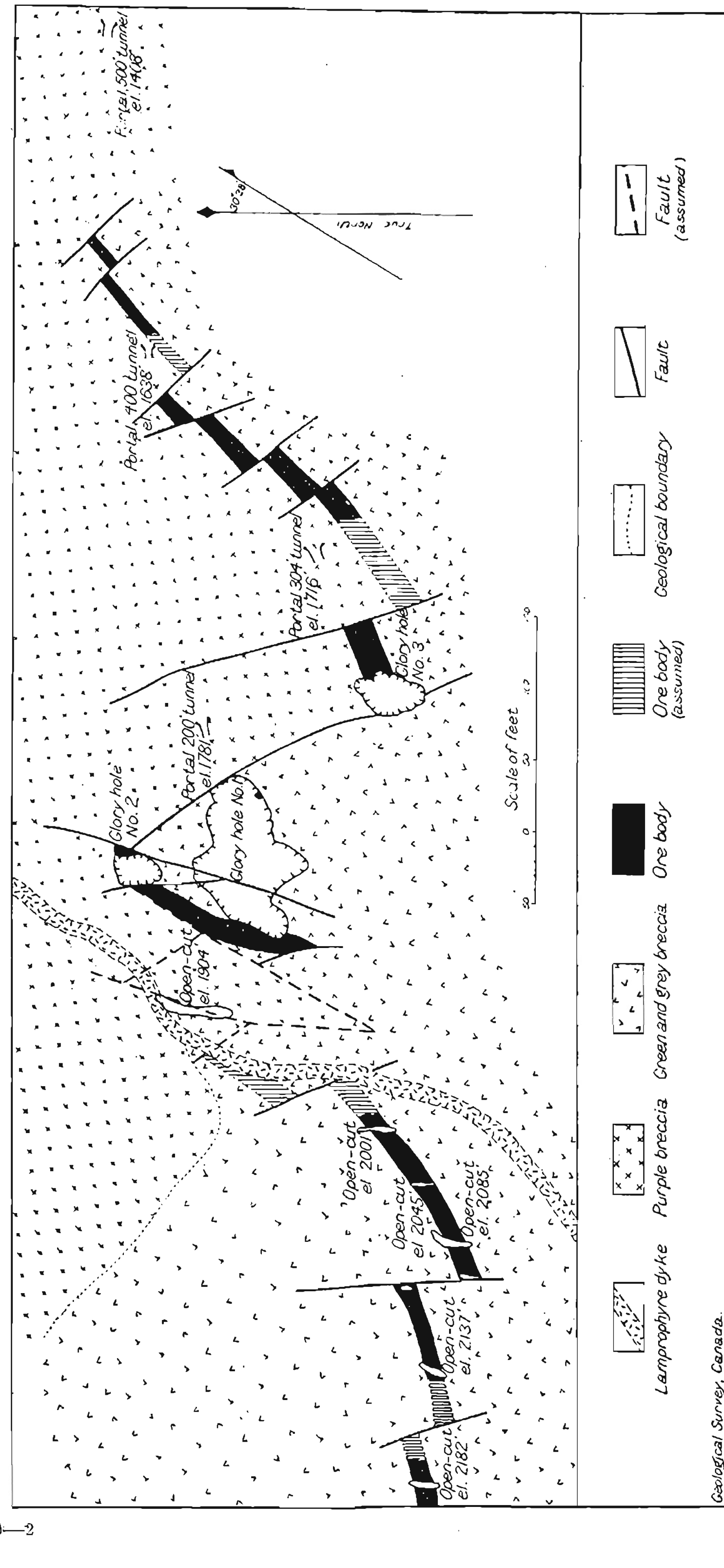

Figure 3. Plan showing geology and surface workings of the Dolly Varden property, Upper Kitzault valley, B.C.

1,202 ounces of silver per ton. The lowest grade ore shipped yielded 24 ounces silver per ton.[1]

Other Properties

The *Tiger group* is owned by Ed. Pickett. Development consists of a number of open-cuts, 185 feet of tunnel, and about 1,500 feet of diamond drilling. The country rock is a hard, grey, fine-grained tuff. The vein is 4 feet to 18 feet wide striking north 30 degrees east and dipping steeply to the northwest. It has been traced on the surface for several hundred feet. The vein has been faulted into four or more blocks by faults having an east-west trend. Mineralization consists of pyrite, and a little galena and zinc blende, in a gangue of quartz. Ruby silver and native silver occur locally in small quantities. Assays of samples across 18 feet of vein matter have run as high as 38 ounces of silver per ton, but in most places where samples have been taken across the vein the values have been lower. Apparently much of the vein is low grade, although in places high grade material has been obtained.

The *Wolf group* is owned by the Taylor Mining Company. Development consists of a large number of open-cuts, a tunnel 85 feet long, and several thousand feet of diamond drilling. The country rock is a grey breccia. The property was only hastily examined; it contains, probably, only two veins, but faulting has so dislocated them that they appear to be three. They vary in width from 10 to 50 feet and are the largest known in the district, being 1,500 feet long, as proved by open-cuts. The metallic minerals are chiefly pyrite, and some galena, ruby silver, and native silver. Development has not shown very high values in silver, but it has indicated a large body of possible ore of moderate to low grade. One vein strikes north 70 degrees east and apparently dips to the northwest; the other strikes north 20 degrees east and has a westerly dip.

The *Musketeer group* is owned by A. D. Meenach. Development consists of a few open-cuts and 185 feet of tunnel.

The country rock is a hard, fine-grained tuff and appears to contain some sedimentary material. The tunnel is in part a drift along the southwestern side of a vein striking south 50 degrees east. A crosscut penetrates about 50 feet of mineralized rock. Although a good deal of work has been done the size and attitude of the vein or veins are not clear. The mineralization is much like that of the Toric vein, in that it contains a good deal of jasper and barite as well as quartz. The metallic minerals are pyrite, chalcopyrite, galena, and zinc blende. Fair values in silver have been shown in assays.

The *Moose group* is owned by D. W. Cameron, M. Donald, and associates. Development consists of a number of open-cuts and over 300 feet of tunnel. The country rock is a medium to fine-grained grey tuff. The vein varies in width from 4 to 18 feet. It strikes due east, dips steeply to the north (Figure 4) and has been traced for 450 feet. Development has shown that the vein has been broken by two sets of faults, one with a north-south strike, and one with an east-west strike. The lower tunnel has developed the ore-body 200 feet below the outcrop. The metallic minerals are essentially pyrite, tetrahedrite, and galena in quartz. It is probable that silver minerals are present. Picked samples from the surface have assayed over 200 ounces silver to the ton. The vein has not been sampled very extensively underground, but at one crosscut 150 feet below the surface, 5½ feet along the hanging-wall assayed over 17 ounces silver per ton.

The *David Copperfield group* is owned by W. McLean. Development consists of a number of open-cuts and a short tunnel. The country rock at the eastern side of the property is a green tuffaceous sediment. On the western side of the rocks are

[1]For further details of the Dolly Varden mine the reader is referred to the Reports of the Minister of Mines of British Columbia, 1915-1921, and especially for evidence for secondary enrichment to a paper by the writer on the Dolly Varden mine, which was presented at the Annual Meeting of the British Columbia Division of the Canadian Institute of Mining and Metallurgy in Vancouver in February, 1922, and which will appear in an early number of the Bulletin of the C.I.M.M.

tuffs and breccias. The vein varies from a few feet to 12 feet in width and is composed of quartz, barite, calcite, galena, zinc blende, and pyrite. Low values in silver have been obtained. Metallic minerals are not plentiful. From the eastern boundary of the group the vein extends northwesterly for perhaps a thousand feet. On the east it passes into the Surprise claims which adjoin the David Copperfield. Here the vein is split up into a number of quartz-barite veins separated by tuffaceous sedimentary rocks.

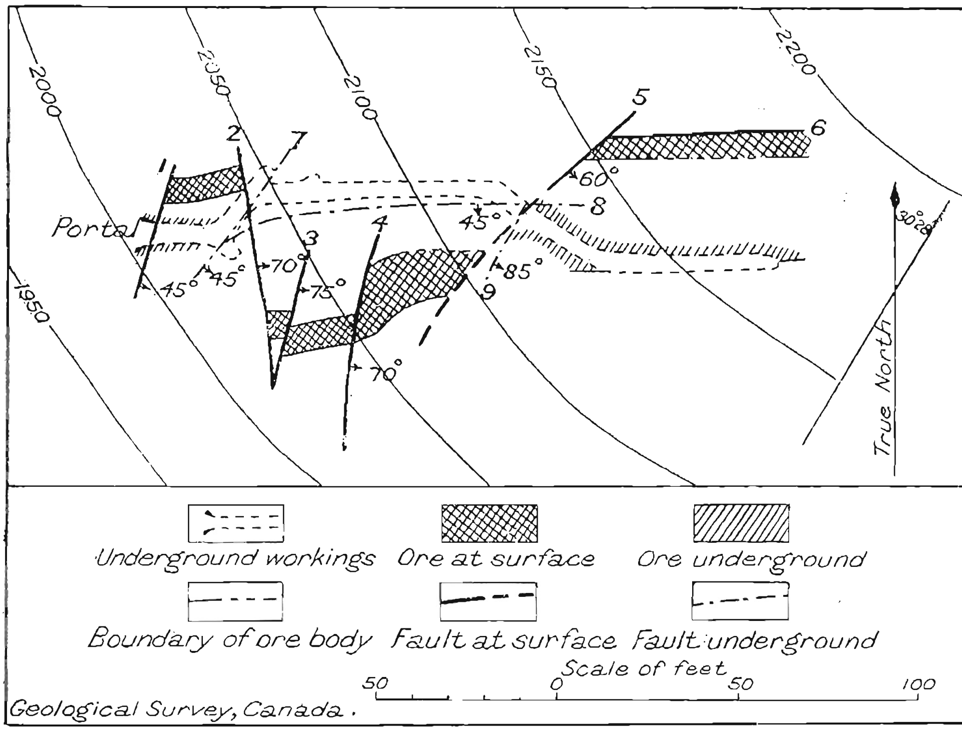

Figure 4. Plan showing ore deposit and lower tunnel, Moose property, Upper Kitzault valley, B.C.

The *Last Chance group* is owned by A. McPhail and P. Morley. Development consists of open-cuts, a tunnel, and diamond drilling. The vein is in the volcanic rocks near the contact with the sedimentary rocks. The owners believe that the lead has a strike of about north 80 degrees west, and state that it has been traced for 600 feet. In several places the lead is evidently a crushed and brecciated zone cemented by vein matter and in some places is 15 feet or more wide. The metallic minerals are chiefly pyrite, galena, and tetrahedrite. The gangue minerals are quartz, barite, jasper, and calcite. High assay values have been obtained from picked specimens.

Good mineral specimens were seen from the Climax, Mr. Hauber's claims, and other claims in the district, but, since the writer's examination of these properties was very brief, they will not be described here.

QUARTZ VEINS AND REPLACEMENTS IN THE COPPER BELT

Properties of this type are quartz veins and carry low values in silver, but in some places good values in copper. Most of the veins or lodes in the copper belt have apparently been formed along brecciated zones and shear zones. Low values in gold are reported, and in some of the properties the mineralized zones are simply bands of country rock carrying disseminated pyrite and chalcopyrite. Irregular gashes and small lenses of chalcopyrite are found in a few places.

The *Homestake group,* owned by A. Davidson and partners, is now being developed under option by the Consolidated Homestake Mining and Development Co., Ltd. Development consists of a number of open-cuts and tunnels. The country rock is apparently a fine-grained breccia of the copper belt. The property contains several quartz veins, of which the two largest have apparently been traced over several claims. The width of the veins in some places exceeds 50 feet. This width is not entirely vein matter but consists of a few closely spaced veins. In some places the vein matter is over a width of 20 feet. The strike of the veins is roughly northwest. The veins or lodes appear to represent mineralization along brecciated zones and shear zones. Operations on a large scale might be carried on here if the values are high enough. The mineralization consists chiefly of pyrite, chalcopyrite, galena, and zinc blende, in a gangue of quartz.

The *Vanguard group* is owned by Morris Peterson and Strombeck Brothers. Development consists of open-cuts and 170 feet of tunnel. The country rock is a grey breccia of the copper belt. Mineralization here appears to be in lenses or lenticular veins. In one place about 6 feet and in another place 3 feet of almost pure chalcopyrite is exposed. The strike of the ore-shoots was not clear to the writer from his brief examination. The tunnels, driven under the best exposures, show disappointing results. There may be a number of small, high-grade lenses, however. and faults are likely to be present. Careful work in outlining the ore-bodies on the surface might well repay the owners. The most important mineral is chalcopyrite. Pyrite is fairly common and a little galena is present. The ore also contains values in silver and gold.

The *Copper Cliff group* is owned by A. Davidson and partners. Development consists of open-cuts. 50 feet of tunnel, and some diamond drilling. The country rock is grey in places resembling a diorite and in others a tuffaceous sandstone. The workings are near the contact with the slates on the east. The grey country rock contains a good deal of disseminated pyrite and some chalcopyrite. At the time of the writer's visit snow filled most of the cuts, but it was evident that the ore here was of a disseminated type. The mineralized zone is several hundred feet wide.

The *Racehorse and Combination groups* are owned by Chas. Swanson and partner. Development in the former consists of open-cuts and 72 feet of tunnel, and in the latter, of open-cuts and 135 feet of tunnel. The workings of these two groups lie along the same mineral zone and appear to be on the same vein. The country rock is a grey breccia and coarse tuffaceous sandstone of the copper belt. The cuts are located on a quartz vein striking about north 65 degrees west. The vein averages about 10 feet wide, but in some places is wider. The tunnel on the Combination group crosscuts over 20 feet of vein matter. In places the vein is solid quartz, but in a few places it appears to be an imperfect replacement along a brecciated zone. Small masses of chalcopyrite are found locally, but the whole seems to be very low grade. The metallic minerals are pyrite and chalcopyrite. The vein has been traced for 3,000 feet in a northwesterly direction from the Combination tunnel.

The *Redpoint and Wildcat groups* are owned by Evindsen and partners, and by A. Davidson and partners. On the Redpoint a broad zone contains disseminated pyrite, chalcopyrite, pyrrhotite, and also some quartz veins. The mineralization on the Wildcat is pyrite, chalcopyrite, galena, and zinc blende, chiefly as disseminations and irregular gash veins.

QUARTZ VEINS IN THE SEDIMENTARY ROCKS

In Upper Kitzault valley these veins contain low values in gold and silver, but the veins of this type have not been developed to any great extent. They are in general either stringer leads or lenticular veins lying parallel to the strike and dip of the enclosing sediments. Persistent veins crosscutting the strike of the sediments are less common. A common feature of the veins is the presence of numerous fragments of argillite enclosed in the quartz.

The *Second Thought group* is owned by Geo. Casey and J. Graham. Development consists of open-cuts and 35 feet of tunnel. The mineralization is in quartz veins lying parallel to the dip and strike of the country rock, which is a black argillite. Two veins, 4 to 6 feet wide, are known. In most places these veins are split up into a number of closely spaced veinlets. The vein matter is white vitreous quartz containing numerous inclusions of argillite. Metallic minerals are scarce, but it is claimed that some samples have yielded high values in silver and gold. Values are evidently very sporadic. It is interesting to note that the Esperanza mine at Alice Arm which has been worked on a small scale for a number of years, obtains its ore from a quartz vein in an argillite country rock.

The *Columbia group* is owned by P. Anderson. Development consists of a number of open-cuts and about 100 feet of tunnel. The country rock is argillite striking east-west and dipping north. Two veins are exposed on the property. The larger one is 10 to 15 feet wide of fairly solid white quartz, and is very uniform and persistent. The veins strike north-south cutting the argillites at right angles to their strike. Metallic minerals are scarce. Assay values up to $6 in gold have been obtained.

Several properties in the argillites were not visited.

PROSPECTING

The following remarks apply to upper Kitzault valley.

The volcanic fragmental rocks of the Dolly Varden formation are worth prospecting for silver-bearing veins. The purple and red members of this formation do not appear to contain any silver veins, the grey or green members containing all the known silver veins in the district.

Secondary enrichment has not proceeded at a uniform rate throughout any area, nor even in any particular vein. Consequently, if a vein is stripped in a few isolated places and found to be too low grade for mining in these places, it does not follow that the intervening parts of the vein are also of low grade, and vice versa. In prospecting the silver-bearing veins in the district, thorough surface examination is of the greatest value.

Surface prospecting would probably be of value along the Dolly Varden mineral zone, the North Star, Toric, Ruby mineral zone, and the extension of the Ruby zone.

If the values are contained in a native silver, ruby silver ore, it is probable the silver content will decrease in depth. Where the silver is contained in a grey copper, galena ore, the values will probably be more persistent in depth.

Where surface ores contain thick plates and leaves of silver and similar seams of ruby silver, and where fracturing has been extensive, high values can be expected to continue to greater depth than where surface ores contain very thin flakes of native silver, etc.

It is worthy of note that the high-grade silver values are obtained from a siliceous ore. In barite veins, the higher grade vein matter is found in quartzose shoots.

COAST AND ISLANDS OF BRITISH COLUMBIA BETWEEN BURKE AND DOUGLAS CHANNELS

By V. Dolmage

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Illustrations

INTRODUCTION

The field season of 1921 was spent in making a shore-line geological map of the coast and islands of British Columbia lying between Burke channel and Kitimat, and examining the mineral deposits of this district. This work is a continuation of that begun by O. E. LeRoy[1] in 1906, continued by J. Austen Bancroft[2] in 1907, and by R. P. D. Graham[3] in 1908 who completed the shore-line mapping as far as Bella Coola, at the head of Burke channel. Three months of 1921 were spent in the field, two weeks of which were devoted to the study of Surf Inlet gold mine, which is one of the large producers of the province. Admiralty charts on a scale of approximately 4 miles to the inch served as a base for geological mapping, and the work was confined chiefly to the shore-line.

Almost no previous geological work has been done in the region. The only published information on the country is in brief descriptions in the recent numbers of the Annual Reports of the Minister of Mines of British Columbia of the mineral deposits of the country, and a short description of the whole coast region by R. G. McConnell.[4]

M. E. Hurst and D. H. Rae assisted in the work, the former taking charge of the shore-line mapping while the writer was at Surf inlet. Much assistance was also received from the miners and prospectors of the district, and the writer is particularly grateful to Mr. F. H. Penn, superintendent, and Mr. P. W. Racey, mining engineer, at Surf Inlet mine, for their friendly co-operation and assistance. The writer is also indebted to Mr. J. Koski for information as to the hot springs of the district.

[1] Geol. Surv., Can., Pub. No. 996, 1908.
[2] Geol. Surv., Can., Mem. 23, 1913.
[3] Geol. Surv., Can., Sum. Rept., 1908, pp. 38.
[4] Twelfth Inter. Geol. Cong., Guide Book No. 10, 1913

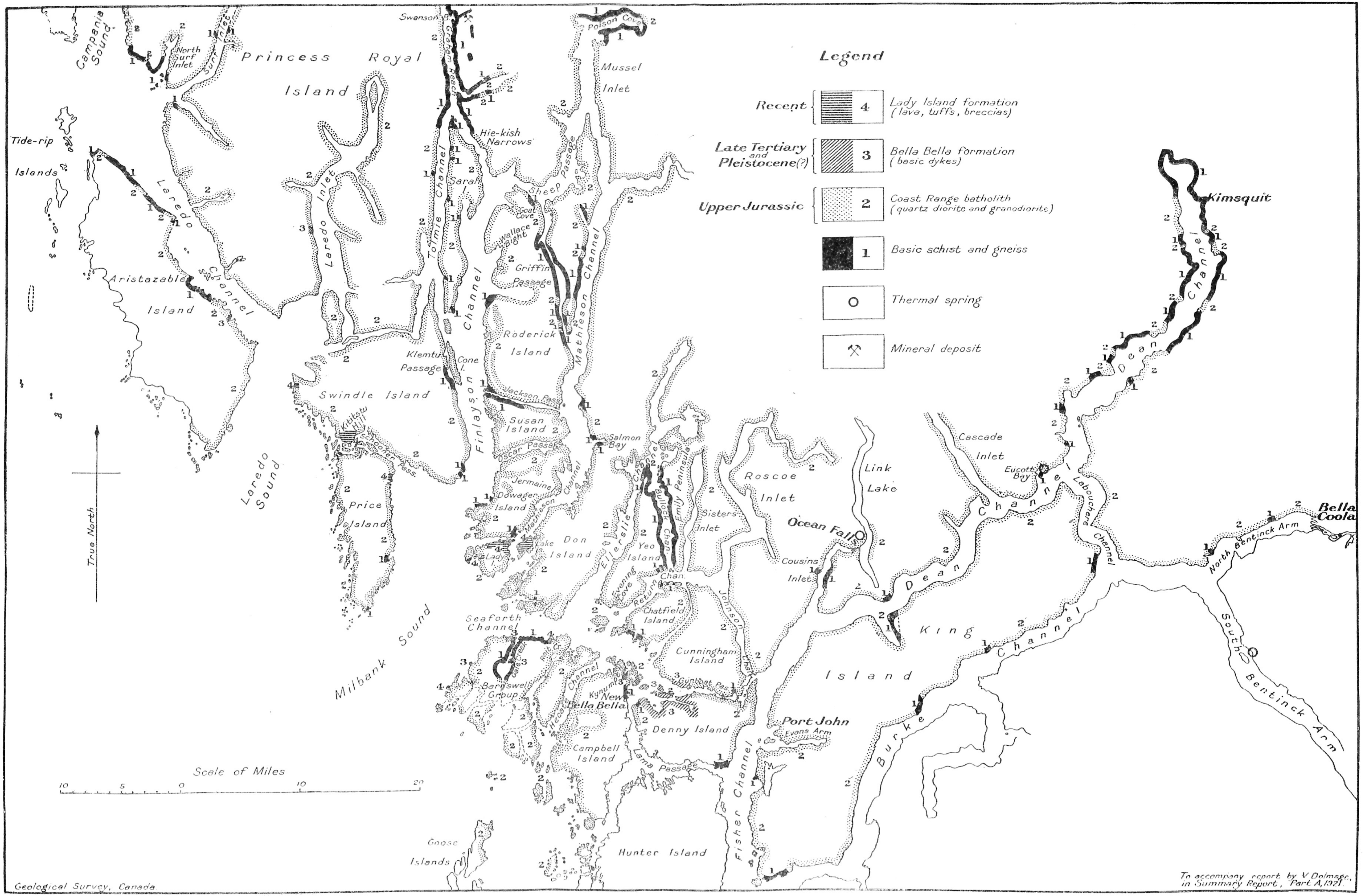

Figure 5. Coast and islands of British Columbia between Burke channel and Campania sound.

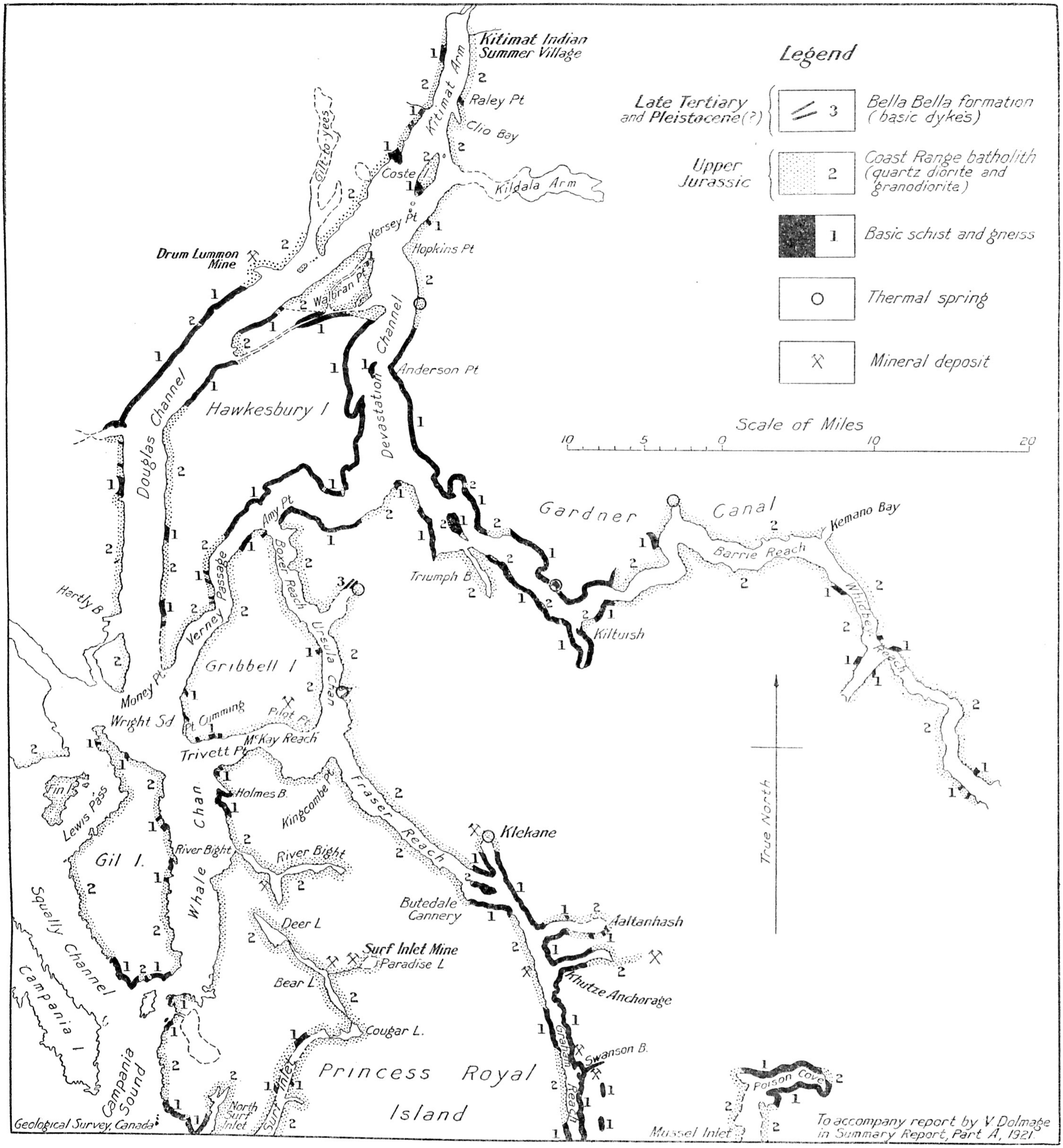

Figure 6. Coast and islands of British Columbia between Campania sound and Kitimat arm.

GENERAL CHARACTER OF THE DISTRICT

Climate and Population. The section of the coast dealt with in this report (Figures 5 and 6) lies for the most part between the northern end of Vancouver island and the southern end of Queen Charlotte islands and is, therefore, unprotected from the full sweep of the Pacific ocean. Because of this and also because of the high Coast Range mountains the district has an excessive rainfall, averaging in places as much as 200 inches annually. The temperature is, however, very even and, for such high latitudes, rather moderate. There is little frost except at the heads of the longer inlets which are occasionally frozen over. Where the rocky slopes of the mountains are not too steep and where they are protected from strong ocean gales, vegetation is luxuriant and large timber is plentiful up to elevations of 2,000 or 3,000 feet.

The population is sparse, the great majority being employed in the large pulp and paper mills at Ocean Falls and Swanson Bay and their attendant logging camps. The six canneries of the district support a small number of fishermen; the Surf Inlet mine has a camp of over 200 inhabitants; the Drum Lummon mine has a much smaller camp and there are a few prospectors and trappers in the remoter parts. The only arable land is found in the broad valleys at the ends of the larger inlets, and in two of these, namely Bella Coola and Kitimat, there are small agricultural settlements. The six or seven Indian villages in the district contain a population of about 1,000.

Shoreline. The shoreline of this part of the coast is extremely irregular. It consists of an intricate network of channels, bays, and inlets, which form numerous islands and extend far inland; conditions which admirably facilitate a geological study of the district from its shoreline. The channels may be classified into: (1) large fiords 1 to 3 miles in width, which reach inland for 40 to 100 miles; and (2) the smaller but more numerous channels lying closer to the ocean.

The fiords are the most striking feature of the British Columbia coast, and for size and grandeur are unequalled, except, perhaps, by the fiords of Norway. They range in width from 1 to 3 miles. The shores are usually fairly parallel, with few enlargements or constrictions and scarcely any small indentations. They form lofty rock walls so steep as often to appear perpendicular, and generally rising shear from the water's edge to culminate in snow-capped peaks 4,000 to 7,000 feet high. This steepness is as marked below the surface of the water as above. Depths as great as 300 fathoms have been recorded, and even greater depths may exist in the larger fiords, which have not been sounded. Anchorages are consequently few and difficult to find. Some of these large inlets are unusually long. For example, Burke channel extends for 53 miles well into the heart of the Coast range. Dean channel penetrates the range to a distance of over 70 miles. Most notable of all is Gardiner canal, the head of which is about 160 miles from the outer coast. Some of these channels are remarkably straight; others, such as Roscoe inlet and Gardiner canal, are composed of a number of long, straight reaches at rather abrupt angles to one another.

Near the outer coast much smaller channels occur in such numbers that they form a maze of intricate passages surrounding numerous islands. These are narrow, crooked, and shallow with numerous obstructions, and many of them are still unsurveyed. Because of these characteristics and also on account of the strong tides in many of them they are somewhat difficult to navigate. The shores are irregular, low, and rocky, covered with stunted trees and grass.

There are conspicuous marks of glaciation everywhere along the rocky shores in the form of polished surfaces, striations, and grooves. The grooves are the most striking. They are best seen on the vertical cliffs where they are often a foot or more deep and are visible over 1,000 feet above the surface of the water. Whether these great fiords owe their origin chiefly to glacial action is a much disputed problem.

There is, however, no doubt that during the Glacial period they were filled with ice to a depth of several thousand feet, which, with the rock debris which the ice carried along its sides and floor as it moved for centuries seaward, certainly must have had a great influence in carving them into their present form.

Physiography. Almost the entire area is occupied by the formidable Coast range of the Cordilleran system. The small remaining part of the district is a rolling lowland fringing the outer coast and composed largely of islands. The drop from the high upland of the Coast range[1] to this narrow lowland is very abrupt.

The Coast range has been fully described by Dawson[2] and Bancroft[3]. It extends along the Pacific coast from the delta of Fraser river to the head of Lynn canal, a distance of about 900 miles, and has a width of from 50 to 100 miles. From Fraser river to about latitude 51 it trends about north 60 degrees west, but from this point north it has a direction about north 30 degrees west. This change in direction causes it to diverge farther and farther from the Insular system of the Cordilleras, in which system are included the Vancouver Island mountains and the Queen Charlotte mountains. The rugged granite peaks of this system reach elevations of from 4,000 to 9,000 feet. The elevations decrease towards the shore, gradually at first, then near the mouths of the larger fiords they drop abruptly to the narrow lowland fringing the coast, whose average elevation is less than 100 feet.

The lowland occupies a strip from 10 to 25 miles wide and is composed largely of islands. Some of the low flat islands such as Aristazable, Price, and Swindle are quite large. Those which lie farthest seaward are only sparsely wooded and are said to have considerable land suitable for grazing. Those examined by the writer, however, were found to have little or no soil. In consequence of this and the excessive rainfall the flat parts of the islands are occupied by vast muskegs. Attempts made several years ago to raise cattle on Aristazable island failed.

GENERAL GEOLOGY

This section of the Pacific coast (Figures 5 and 6) consists largely of one great formation, the Coast Range batholith. More than nine-tenths of the area is occupied by the quartz-diorites and related plutonic rocks of this formation. The only rocks older than the batholith are a few relatively small inclusions of highly metamorphosed volcanic and sedimentary rocks now in the form of schist or gneiss. The only rocks of the district younger than the batholith, which is of late Jurassic age, are volcanic dykes of late Pliocene or early Pleistocene age and some tuffs and flows of post-Pleistocene age.

PRE-BATHOLITHIC ROCKS

The pre-batholithic rocks consist of about thirty-five small inclusions a mile or so in width scattered throughout the district, and three much larger inclusions which occur towards the northern part of the district and project beyond it. The largest of these lies in the vicinity of Douglas and Desolation channels, and Gardiner canal, and is probably the southern extension of a large area of schist which lies to the north of the area near Prince Rupert. It is very irregular in shape, has a maximum width—on Douglas channel—of 10 miles, and extends southeast into Gardiner canal for 25 miles. The second largest inclusion lies south of this, outcropping along Fraser and Graham reaches for 21 miles. The smallest of the three inclusions outcrops for 7½ miles along Bullock channel.

1 According to the Sixteenth Report of the Geographic Board of Canada, the term "Coast range" has been abandoned. The western range of the western belt of the Canadian Cordilleras is to be known as the Insular sytem, and the eastern range of the western belt is to be known as the Pacific system. The Insular system includes the Vancouver Island mountains, the Queen Charlotte mountains, and part of the St. Elias mountains. The Pacific system includes the Cascade, Coast, and Bulkley mountains and some unnamed ranges and groups.

2 Dawson, G. M., "Report on the Northern Part of Vancouver Island and Adjacent Coast," Geol. Surv., Can.

3 Bancroft, Austen, J., Geol. Surv., Can., Mem. 23, p. 13.

The less metamorphosed of these older rocks consist of andesite, basalt, and breccias of a basic composition, all of which contain considerable chlorite, mica, and quartz, and are somewhat schistose. A few more acid varieties occur, for example, on Bardswell islands. Here, very light-coloured pyroclastic rocks are composed of angular fragments of fine-grained feldspathic and siliceous volcanic rocks. In many places, particularly in the southern part of the district, the volcanic rocks are interbedded with beds of limestone from a few feet up to 50 feet in thickness. This association of limestone and andesite is so characteristic of the Vancouver volcanics which are widely distributed along the coast to the south, as to suggest that some, at least, of these remnants belong to that formation. A highly metamorphosed conglomerate containing pebbles of limestone up to 8 inches in size was found on the west shore of Mussel inlet near the south end of Roderick island. The other pebbles consist of metamorphosed volcanic rock, biotite schist, and an acid plutonic rock, composed of plagioclase, quartz, and hornblende, with usually a segregation of pyrite in the centre.

The rocks composing the large inclusions in the northern part of the district are much more highly metamorphosed, and consist of chlorite schist, biotite gneiss, and, in places, garnet gneiss. A schist which contains a considerable amount of finely disseminated graphite occurs in Poison cove, at the head of Mussel inlet.

The strike of the foliation in most of these inclusions conforms in general with the tectonic lines of the district which trend north 10 degrees to 40 degrees west. The most notable exception to this rule is in the large inclusion outcropping along Douglas and Desolation channels, where the strike varies from north 60 degrees to 85 degrees east. The batholithic rocks in the vicinity of the inclusions have a well-developed gneissic structure parallel to that of the inclusions.

All that can be said at present regarding the age of these pre-batholithic rocks is that some of them, which consist of interbedded limestone and andesite, bear strong lithological resemblances to, and are probably related to the Vancouver volcanics of Upper Triassic age.

COAST RANGE BATHOLITH

The Coast Range batholith is the principal geological feature of the coast region of British Columbia. It extends from Fraser river north to Alaska, and has an average width of over 100 miles. It occupies over 90 per cent of the area here described (Figures 5 and 6) and has a width of over 75 miles. Just north of this area there is, however, a marked constriction in the batholith north of which it gradually narrows for the remainder of its length.

The rocks composing this immense intrusion are surprisingly uniform in appearance and composition throughout, and in the district under present consideration the variations were found to be too slight to be mapped. The most typical rock of this section of the batholith is a medium-grained, light grey quartz diorite, consisting of white plagioclase, quartz, hornblende, a varying amount of biotite, little or no alkali feldspar, and, in places, a conspicuous amount of honey-yellow sphene. The plagioclase consists of andesine, or oligoclase-andesine, and very rarely a little andesine-labradorite. Quartz forms from 10 to 25 per cent of the rock and is always one of the later minerals to crystallize. The hornblende, which is a constant and plentiful component, is a peculiar variety and decidedly different from that found in the batholithic rocks to the south. In thin section it is strongly pleochroic from light yellowish green to deep greenish blue, and has extinction angles up to 24 degrees. The hornblende of the batholithic rocks to the south is brownish green with extinction angles up to 14 degrees. The alkali feldspar in the typical quartz diorite does not exceed 1·5 per cent. Biotite is usually present in small amounts and occasional grains of augite are found.

The most common variation of the quartz-diorite is a lighter coloured rock with more quartz, a more acid plagioclase, and decidedly more alkali feldspar, so that it approaches granodiorite in composition. Two large areas of such rock were found, one on Labouchere channel and the neighbouring parts of Dean and Burke channels, and the other at the head of Ellerslie channel. The rock of the first-mentioned area is a light grey to almost white, medium-grained granodiorite. It is composed of much quartz, oligoclase, oligoclase-andesine, muscovite, and alkali feldspar, with small amounts of biotite, hornblende, and augite. The alkali feldspar is chiefly orthoclase, some of which is intergrown with the quartz, forming micropegmatite. Considerable microcline is also present, and some anorthoclase. Microscopic quantitative determinations were made of the relative amounts of alkali feldspar and live-alkali feldspar, by immersing powdered samples of the rock in a liquid with an index of 1·530, which lies between the indices of these two groups of feldspars, and then applying the Rosiwal method. The results showed about four times as much lime-alkali feldspar as alkali feldspar, thus fixing the classification of these rocks in the granodiorite family. The Ellerslie channel granodiorite is similar to this, but has less muscovite, and slightly more orthoclase, giving it a pinkish colour. The Labouchere granodiorite is the only phase of the Coast Range batholith known by the writer to contain a high proportion of muscovite and a relatively low proportion of biotite and hornblende. This quality, together with the beautiful white colour and medium, fine, even grain of the rock makes it a very desirable building stone and superior to any other rock of the batholith.

A hornblende granodiorite, as distinguished from the above biotite-muscovite granodiorite, was found on Mathieson channel. It consists of quartz, oligoclase, andesine, hornblende, microcline, and orthoclase, with a small amount of biotite.

Pegmatitic and aplitic variations are not common in the southern part of the batholith, but in the northern part of this district, in the vicinity of Douglas channel and on Princess Royal island, they are fairly plentiful, and are associated with the gold deposit of the Surf Inlet mine and the copper-gold deposits of the Drum Lummon mine. Along the northwest shore of Douglas channel between Hartley bay and Helen point pegmatite dykes and pipe-like masses of pegmatite are numerous. They are composed of microcline, orthoclase, anorthoclase, oligoclase, albite, perthite, micropegmatite, quartz, and biotite and at the Drum Lummon mine also chalcocite, bornite, chalcopyrite, hematite, and gold. The microcline and orthoclase occur in large pink crystals up to 18 inches in length and were deposited earlier than the quartz. The anorthoclase is in small white to clear euhedral crystals less than an inch in size, and closely resembles the albite, which has a similar colour and appearance and is not always twinned. The biotite forms large thin leaves 8 or 10 inches in diameter, which occupy fractures in the feldspar and quartz. The quartz varies from a small amount up to over 50 per cent of the vein or dyke. It is one of the latest minerals to form and is almost invariably segregated in the central parts of the dykes. In the dyke at the Drum Lummon mine a small cavity in the quartz was found filled with laumontite. This mineral is somewhat irregular in its optical properties, having lower indices of refraction than is normally found and extinction angles up to 45 degrees. Some well-developed crystals were found and measured by E. Poitevin, Mineralogical Division, and several of the typical forms of laumontite recognized, thus proving the identity of the species.

None of the minerals of the rarer elements which are so characteristic of pegmatite dykes were found. The only differences between the pegmatites and the normal country rock are in their coarse texture and much higher percentage of potash and soda.

Basic variations are very uncommon, but occur in the vicinity of some of the more basic inclusions. They differ from the normal rock by having no quartz and a high proportion of hornblende which gives them a dark grey to black colour.

In a great many places the batholithic rocks are strongly gneissic. The foliation is parallel to that of the inclusions, varying from north 5 degrees to 30 degrees west. This gneissic banding is more strongly marked in the vicinity of the inclusions and is particularly well developed in and about the Surf Inlet mine.

Faulting in the batholithic rocks is commonly found. The most strongly developed fault zone in the district is at Surf Inlet mine. A similar one occurs in Rivers bight, a large inlet on the west shore of Princess Royal island, and about 12 miles to the north. Both of these are strike faults and have shear zones up to 50 feet in width.

The age of the batholith is generally considered to be late Jurassic, but in a few localities its rocks have been found cutting Cretaceous sediments.

BELLABELLA FORMATION

Along the north shore of Denny island, in the vicinity of Bellabella, the batholithic and older rocks are cut by a vast number of peculiar dykes so numerous in places that the older rocks are completely replaced. East of this locality the number of these dykes diminishes rapidly, but westward they occur in considerable numbers as far as Bardswell islands where they again become very numerous. West and north of this place occasional dykes of a similar composition are found as far as Douglas channel. These have been grouped in one formation and named after the nearby settlement, the Bellabella formation.

Throughout the district these dykes maintain vertical dip and a fairly uniform strike of north 5 to 35 degrees west. They are occasionally found cutting one another and in general the more basic varieties are the younger. They vary in width from a foot or less up to 150 feet.

Some of the later members are very similar lithologically to the post-Pleistocene volcanics found on Lady and Lake islands, which lie 16 miles northwest of Denny island and 7 miles north of Bardswell islands. Many of the dykes are composed entirely of amorphous volcanic glass and practically all the others have all the characteristics of surface flows. These facts indicate that the dykes are of recent date and perhaps related to the post-Pleistocene volcanics. Some of the larger dykes have glaciated surfaces, but these are cut by more recent dykes which show no signs of glaciation. It is the writer's opinion that they were injected during a period extending from late Pliocene to late and probably post Pleistocene.

The dykes of this formation have a peculiar and, for this region, a unique petrology. They vary from black diabases or basalts through andesites and trachytes to highly siliceous rhyolites. Many of them are abnormally high in soda and abound in such minerals as riebeckite, ægirine, ægirine-augite, anorthoclase, and albite. They vary in texture from coarse porphyries with phenocrysts up to an inch in length to completely amorphous glass. The majority are exceedingly fine-grained and possess most of the characteristics of surface flows such as trichites, globulites, cumulites, spherulites, amygdules, and flow structures. Many of them are extremely agglomeratic, containing fragments similar to the dykes themselves and also fragments and pebbles of quartz diorite.

The most common type of rock found in this formation, and the only one which is widely distributed in the district, is a dark to black, fine-grained rock which weathers to a buff colour and is composed chiefly of augite and labradorite-bytownite. Dykes of this nature have an exceptionally well-developed columnar jointing. The columns lie horizontally and weather out very perfectly, giving the dyke the appearance of a pile of cordwood. Many examples of this phenomenon occur in the district, and are just as striking and somewhat similar to the famous Devil's Wall of Oschitz, Bohemia.

Microscopically the rock composing these dykes is a medium to fine-grained mixture of clear amber coloured labradorite-bytownite, and clear, glassy, brownish or greenish, augite with considerable associated brownish glass in the intercrystal spaces and in veinlets in the augite and feldspar crystals. It is this glass which gives the rock its peculiar brownish colour. The glass occupying the intercrystal spaces is somewhat devitrified and characterized by minute radial and concentric structures. The feldspars frequently contain very fine acicular crystals too minute to identify but which are probably pyroxene.

Another rock type similar to this but decidedly porphyritic is also found abundantly. In this type the phenocrysts are mainly of clear, fresh labradorite, but there are also phenocrysts of albite which are thickly clouded with sericite and in the outer portions are graphically intergrown with the groundmass material. Augite also forms phenocrysts up to an inch in size. In the hand specimens these are dark brownish-green and of glassy lustre, but under the microscope they are seen to be replaced by serpentine glass and groundmass material. The groundmass consists of augite, andesine, and labradorite.

A rock somewhat similar to the above in composition but very different in appearance, and in some respects a very unusual rock, was found in a dyke 60 feet wide on Tree island, just north of Denny island. It consists of large, clear, glassy phenocrysts of feldspar up to an inch in length, so numerous as to constitute over 50 per cent of the volume of the rock, enclosed in a fine, dense, dark brown groundmass. A few equally large phenocrysts of augite also occur but these are much shattered and corroded. The feldspar phenocrysts consist of bytownite and anorthite, principally the latter, in which the anorthite component is often well over 90 per cent. These phenocrysts are clear and glassy except for included veinlets and blebs of volcanic glass and groundmass material. Like the above rocks this one also contains feldspar phenocrysts of a much more acid type, such as oligoclase and andesine, which are densely clouded with sericite and an opaque alteration product which is frequently graphically intergrown with the feldspar, particularly along the margins of the crystals. The groundmass consists of labradorite, andesine, augite, much brownish glass, and a still larger amount of brownish, opaque material in the form of grains and rods, which probably consist largely of iron oxide.

There are many dykes composed of a dense, dark-bluish groundmass that contains fragments of similar material, fragments of quartz and feldspar, and a great many small, peculiarly-shaped, yellowish-green masses. Many of these yellowish-green bodies are angular; others are spherical or ellipsoidal and arranged in straight parallel rows about one-quarter of an inch apart; still others form spherical shells up to 1 inch in diameter which are filled with groundmass material, but often have at their centres small clusters of quartz or feldspar fragments. Under the microscope the feldspar is seen to consist of orthoclase, albite, anorthoclase, and much microperthite. The yellowish-green areas are so extremely fine grained, that their composition could not be determined, but epidote seems to be one of the components. The angular rock fragments consist of micropegmatite, glass, riebeckite, biotite, ægirine-augite, ægirine, and spherulites composed of radial intergrowths of quartz, feldspar, and riebeckite. The groundmass is a cryptocrystalline aggregate of riebeckite, quartz, and feldspar, and has a perfectly developed flow structure curving around the larger crystals and rock fragments. The quartz encloses ægirine-augite, riebeckite, and magnetite. The rare mineral ænigmatite was found as small phenocrysts in these rocks. Small epidote veinlets were found in a few specimens.

Lighter-coloured varieties of these dyke rocks are plentiful in which the proportion of riebeckite is much less and quartz and feldspar, both as phenocrysts and groundmass, are much more abundant. They are light bluish grey and decidedly porphyritic. These rocks are evidently sodic rhyolites and closely resemble tauralite or comendite.

Some of the light-coloured dykes have ægirine and ægirine-augite as the principal coloured constituent instead of riebeckite. They are medium rather than fine-grained, have a light grey colour with a greenish rather than bluish cast, and are only slightly porphyritic. They are usually quite porous and some of them are slightly banded. They consist of abundant quartz, orthoclase, micropegmatite, ægirine, and ægirine-augite, with small amounts of albite, microcline, anorthoclase, arfvedsonite, and riebeckite. In one of these rocks small prisms of ægirine occur on the walls of spherical vesicules and project towards the centres of the cavities.

A few dykes of a very light colour are composed of quartz, orthoclase, biotite, and oligoclase.

POST-PLEISTOCENE VOLCANICS

On Lake and Lady islands, in Mathieson channel, is a considerable thickness, but small area of stratified volcanic tuff and some flows. These lie on the glaciated surface of the batholithic rocks and were evidently ejected in post-Pleistocene time. Small flows of similar rocks are found on Bardswell islands, on Price island, and on Swindle island. These other occurrences consist of flows with no tuff, and their relation to the glaciated surface was not discovered. However, they are nowhere glaciated themselves, the thin flows conform to the present topography, and they have strong lithological similarities to the Lake Island volcanics. For these reasons it is thought that they belong to the same post-Glacial period of eruption as those found on Lady and Lake islands. All the extrusions occur close to a line striking north 50 degrees west through the south end of Lake island.

Lake island is about a mile wide and 2 miles long and is situated about 3 miles above the entrance to Mathieson channel. Its shores, except at two places, are composed of quartz diorite, quite flat and strongly glaciated. Covering the whole central part of the island is a conical mountain nearly 1,000 feet high composed entirely of brownish volcanic tuff. On the east shore of the island the tuffs clearly rest on the flat glaciated surface of the quartz diorite. On the north shore, large, well-rounded boulders of quartz diorite up to 6 feet in diameter and with a pronounced tendency to exfoliate are found buried in the tuffs. On Lady island, which lies a mile to the west, similar tuffs are found. Here they have a maximum thickness of about 60 feet and in three different places they were found lying on glaciated surfaces of the quartz diorite. At the base of the formation in several places numerous large glacial boulders were found, and in one place the tuffs rested on a small bed of till.

These tuffs are well bedded and generally horizontal. In some places, however, they have gentle depositional dips seaward conformable to the surface on which they rest.

They consist of rock fragments, usually of quartz diorite, a large amount of brownish, partly devitrified, spherulitic and pumaceous volcanic glass; a large amount of clean amber-coloured augite in the form of broken crystals often having a rim of glass frozen to them; fragments of quartz, hornblende, and a great many rounded phenocrysts of beautiful yellowish, glassy labradorite—a very characteristic mineral and invariably found in all the above-mentioned occurrences of recent volcanic rock.

The flows on Price and Swindle islands are from 20 to 100 feet thick and have a beautifully developed columnar jointing. They have an exceedingly fine-grained, dense black groundmass, enclosing a large number of the yellowish, glassy labradorite and augite phenocrysts, similar to those found in the tuffs of Lady and Lake islands. The groundmass consists of minute rods of augite and laths of labradorite, with which is mixed a large amount of fine magnetite which gives the rock its black colour. A small amount of glass containing spherulites is present, some chlorite, and a small amount of highly pleochroic, bluish-green amphibole.

ECONOMIC GEOLOGY

Gold, silver, copper, and iron occur in this district (Figures 5 and 6). Large quantities of gold and some silver and copper have been produced, and are still being produced, by the Surf Inlet mine on Princess Royal island. Small quantities of copper, gold, and silver have been produced by the Drum Lummon mine, on Douglas channel, and a few tons of magnetic iron ore have been shipped from a deposit on Dean channel. Small, gold-bearing quartz veins at several other localities on Princess Royal island and on the adjacent mainland have, so far, proved to be of no commercial value. Small deposits of copper with associated gold occur also on Klekane inlet, on the south end of Gribbell island, on Kemano river, which flows into Gardiner canal, and on the river which enters at the head of Kutze inlet. The deposit in Klekane inlet is being worked in a small way. That on Gribbell island has been extensively developed, but is now abandoned. The deposit on Kemano river is in the early stages of prospecting, and the deposit in Kutze inlet has been considerably explored and is equipped with several miles of tram-line. It is reported to have promise as a copper and gold producer.

SURF INLET MINE

The Surf Inlet gold mine, owned and operated by the Belmont Surf Inlet Mines, Limited, is situated about 7 miles inland from the head of Surf inlet, on Princess Royal island. The mine is 1 mile from Bear lake, which is 1 mile above Cougar lake, and Cougar lake extends to within 200 yards of the head of Surf inlet. By the construction of a dam at the outlet of Cougar lake its level was raised to that of Bear lake and a good water route for tugs was established between the dam and the landing at Bear lake. From this landing an electric tram-line runs to the mine, and from the head of the dam to the bunkers at the beach there is an incline cable tram operated by an electric winch.

The dam also creates a sufficient hydrostatic head for a hydro-electric generating plant situated at the beach, and capable of supplying power for all purposes about the mine. A well designed mill with a capacity of 300 tons a day is used to concentrate the ore.

This deposit, though discovered many years ago, began producing on a large scale only in 1917. It is now one of the important gold producers of the province and in 1920, 108,082 tons of ore were mined, yielding 9,687 tons of concentrates which gave 44,051 ounces of gold, 20,104 ounces of silver, and 685,259 pounds of copper. The mine is now developed down to the 1,000-foot level and has approximately 50,000 feet of underground workings. An adjoining property, known as the Pugsley, recently acquired by the Belmont Surf Inlet Company, is now being developed and will soon commence producing.

The equipment and layout of this property has been fully described by Geo. A. Clothier in the report of the Minister of Mines of British Columbia for the year 1919.

The ore-bodies, which are large pyritized quartz veins in a zone of intense shearing in the rocks of the Coast Range batholith, outcrop on either side of a deep, U-shaped valley. The Surf Inlet ore-bodies are on the north and the Pugsley on the south side. The shear zone strikes a few degrees east of north and intersects the valley at nearly right angles. The veins dip from 45 degrees to 60 degrees to the west, hence the outcrops of the ore-bodies trend northeasterly up the north side of the valley and in a southeasterly direction up the south side. The valley, though only about 3 miles in length and less than half a mile wide, has, nevertheless, a depth of over 3,000 feet, and its walls are so steep that in places they appear to be almost perpendicular. The upper end of the valley, which terminates abruptly amid steep mountains, is occupied by Paradise lake. The lower end opens into the broad valley occupied by Cougar, Bear, and Deer lakes. The main haulage, of 550-foot level of the Surf Inlet mine, is at an elevation of 538 feet, or about 450 feet above the bottom of the valley; that of the Pugsley is about 30 feet above the tram-line which runs to the landing on Bear lake.

The ore of the Surf Inlet mine occurs in large pyritized quartz veins in places 37 feet in width. These lie in a zone of intense shearing which cuts the rocks of the Coast Range batholith in a direction about north 3 degrees east and for a distance passes through an inclusion of chloritic schist whose foliation and contacts also strike approximately parallel to the shear zone. The veins are in general parallel to the shearing and dip from about 40 to 60 degrees to the west. They have a maximum length of 1,000 feet and a width of 40 feet. There are, however, cross veins which lie more or less perpendicular to this direction. One of these cross veins, lying between the 550-foot and the 200-foot levels, is of considerable size and importance. The only other rocks in this vicinity are two small pegmatite dykes on the 550-foot level and a black basic dyke which cuts the ore on the 100- and 200-foot levels.

Inclusions of older rocks in the form of schist and gneiss occur at several places in the vicinity of the deposits. A fairly wide band of gneiss with a north 30 degrees west strike and 90 degrees dip occurs in the cuts along the tram-line about 600 feet west of the Pugsley lower tunnel, and what appears to be a continuation of this band occurs on the cliffs at the opposite side of the valley a considerable distance west of the main dump of the Surf Inlet mine. A large band of schist occurs on the surface above the upper levels of the Surf Inlet mine and extends down through the mine to the lower levels. A similar band also occurs on the surface above the Pugsley mine.

On the 50-foot level of the Surf Inlet mine the country rock consists entirely of schist, though quartz diorite occurs a short distance south of the portal. On the 100-foot level the schist is still the dominant country rock, though a wide band of quartz diorite occurs in No. 1 east crosscut and in recent workings in the southern part of this level. On the 200-foot level there is about an equal amount of quartz diorite and schist, the schist occurring chiefly along the contacts of the west vein and large cross vein, the diorite as the principal wall-rock of the east vein. On the 320-foot level the schist forms only a small part of the country rock, but is found adjoining the widest and richest part of the west vein and to a less extent in the vicinity of the large cross vein, which has a width of 31 feet on this level. On the 420-foot level the schist is still less in amount and is found adjoining both the east and west veins, but is most abundant at the north end of the west vein where it has its greatest width. On the 550-foot level where the ore reaches a maximum in both width and values, there is very little schist to be found, the only body of any account being on the hanging-wall towards the northern end of the west or main vein, and beyond this in west crosscut No. 6. Below this level only very small bodies of schist occur, and these lie in the northern extremities of the workings. It is evident, therefore, that the schist lies in general in the west or hanging-wall and pitches to the north, whereas the veins pitch to the south. In the Pugsley mine it is likewise found mostly in the higher workings. In general it may be said that slightly higher values are found where the veins lie in schist than where they lie in quartz diorite.

The schist is a dark greenish, medium fine, strongly schistose rock, grading in places into gneiss. It consists chiefly of chlorite, sericite, and talc with small amounts of quartz, andesine, apatite, augite, and, in the vicinity of the veins, considerable ankerite.

The batholithic rocks in the mine and its vicinity consist entirely of quartz diorite. They are fairly coarse-grained and are strongly gneissic, the foliation being generally parallel to the veins. They consist of quartz, andesine, and green hornblende with small amounts of biotite, augite, and sphene. On the 900-foot level of the Surf Inlet mine the quartz diorite contains besides the above minerals small amounts of oligoclase-andesine, orthoclase, and micropegmatite, and has a slightly higher proportion of the biotite and sphene than is ordinarily found in the quartz diorites of this district. The proportion of orthoclase is, however, too small to place this rock in the granodiorite family.

The pegmatite dykes occur on the 550-foot level, 900 feet from the portal and 200 feet from the nearest vein. These dykes which are only a foot or two in width are exactly like those found at the Drum Lummon mine and elsewhere along the coast. They are composed of orthoclase, microcline, anorthoclase, albite, oligoclase, quartz, and biotite. The two pegmatite dykes in the Surf Inlet mine have a smaller proportion of quartz than most of the other pegmatites of the district. The relation of these dykes to the veins is not known, but as some of the veins carry small amounts of albite, orthoclase, and microcline, and the pegmatites at the Drum Lummon mine carry sulphide of iron and copper as well as some gold, it would seem that the veins and pegmatites are very similar in composition, and, therefore, probably closely related in origin.

The ore occurs principally in two large quartz veins, one on the west or hanging-wall side, and the other on the foot-wall of the shear zone. In the upper levels, the veins are from 100 to 160 feet apart, but gradually converge until they meet at the 550-foot level to form one large vein which persists to the lowest levels. The veins dip to the west from 40 to 60 degrees with an average of about 45 degrees. Above the 550-foot level the dips are much more irregular than below it, a feature which may help to explain the occurrence of higher values above than below this level. Above the 550-foot level the two veins are connected by a large cross vein, in places 35 feet wide, which strikes almost at right angles to the main veins and dips nearly vertically. Besides these there are numerous small veins in the fractures and shear planes of the diorite. These strike in all directions.

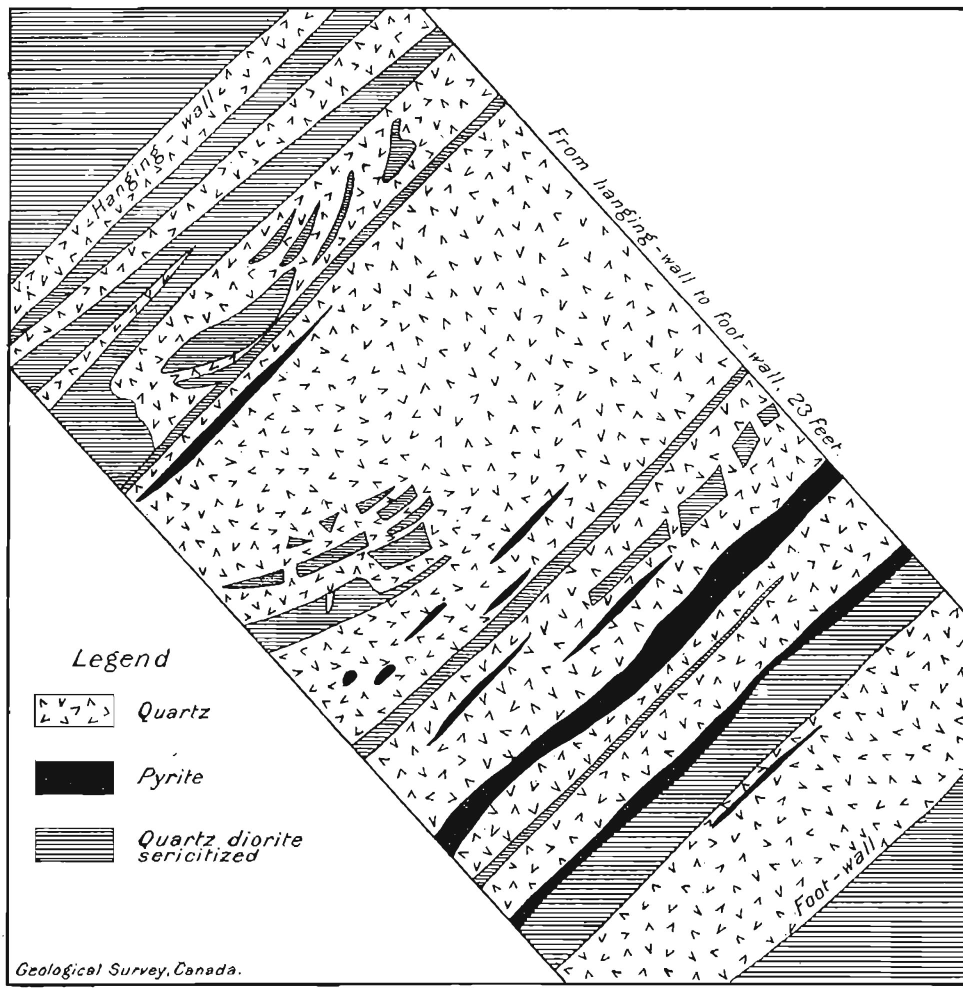

Figure 7. Section of vein exposed in stope No. 4, between 550- and 700-foot levels, Surf Inlet mine.

The margins of the veins are almost invariably made up of a number of alternating bands of quartz and sericitized country rock, lying parallel to one another and to the vein walls and ranging in width from several feet down to a few inches. Large angular blocks of sericitized country rock also are found scattered irregularly through the quartz veins and are more or less silicified, in some cases so completely that only mere shadows of the original blocks remain. The pyrite usually lies in streaks and bands parallel to and sometimes adjacent to, the bands of included country rock, as shown in Figure 7.

The lengths of the main veins vary from 100 feet up to a maximum of 1,000 feet on the 550-foot level, and the width from 2 or 3 feet up to 40 feet. The axes of the ore-body pitch to the south 45 degrees.

The veins consist chiefly of quartz and pyrite, the latter carrying the gold. After these the most conspicuous mineral is a creamy white ankerite found abundantly in places, particularly at the extremities of the veins, where they pinch out. It is usually associated with considerable chlorite and sericite. Other gangue minerals occurring in small amounts are hornblende, mariposite, calcite, dolomite, and kaolin. On the 100-foot level there is a vein which is decidedly pegmatitic in character and contains microcline, orthoclase, albite, albite-oligoclase, biotite, and small quantities of magnetite. A narrow band in the altered schist on the 550-foot level consists of calcite, andradite, and pale green translucent diopside, and probably represents a band of metamorphosed limestone in the schist. The metallic minerals, other than pyrite, are chalcopyrite, native silver, chalcocite, bornite, covellite, hematite, and molybdenite. Small quantities of malachite and azurite are now forming on the walls of the stopes and tunnels.

Quartz is exceedingly abundant throughout the deposits, and at certain places, such as on the 550-foot level, there are solid masses of almost pure quartz nearly 40 feet in width. It is slightly milky in colour, and is composed of an aggregate of very fine anhedral crystals. These contain many minute inclusions of foreign matter, some of which are liquid or gaseous, whereas others are solid and clear or opaque, but too minute to identify. The quartz was deposited throughout a long period in the earlier stages of the formation of the deposit.

Ankerite is widely distributed in the mine but is usually more abundant in the schists than in the quartz diorite. It has an unusually light colour varying from pure white to cream or pink, and only very rarely has it the grey colour so common to this mineral. In places it forms very fine-grained masses, but usually it is coarse grained with large, curved cleavage faces. It was deposited during a considerable period of time, some of it being earlier than the quartz and some of it later, the fine-grained masses usually being earlier.

Chlorite in the form of scattered films and veinlets is plentiful and is as a rule associated with the ankerite.

Sericite is exceedingly abundant throughout the mine. The quartz diorite close to the veins, and the blocks of it included in the veins, are frequently altered to aggregates of pure sericite. Alteration, however, never extends more than a few inches, or a foot at most, from the veins. In some cases the flakes of mica are sufficiently large to be called muscovite.

Hornblende was found in small quantities associated with quartz and sericite.

A bright greenish coloured mica with optical properties closely approximating those of mariposite, or chrome mica, was found in small quantities on the 900-foot level, where it is associated with calcite, quartz, ankerite, and pyrite.

Calcite in small amounts is found in all parts of the mine and under various conditions. That associated with the diopside and garnet is probably residual from a limestone band in the schists. In other places it forms small veinlets cutting the latest ore minerals.

A small amount of dolomite was found on the 550-foot level associated with chlorite and small flakes of hematite.

Kaolin occurs in the gouge of the sheared diorite, sometimes in considerable amounts.

Orthoclase, microcline, albite, albite-oligoclase, and biotite were found only in the pegmatites on the 550-foot level and in a small vein on the 100-foot level. Albite occurs also at a number of places in the quartz veins.

Diopside and grossularite were found only in the small band of altered limestone mentioned above.

Pyrite is very abundant and is the chief ore mineral, but is much less plentiful than quartz. In the richest parts of the veins the pyrite would not constitute more than 25 per cent of the total volume. It occurs in streaks parallel to the strike and usually adjacent to the sericitized wall-rock, or to large sheets of the altered wall-rock now included within the quartz veins. A small amount of it occurs in rounded masses or as very irregular cross veinlets in the central parts of the quartz. The mode of occurrence is shown in Figures 5 and 6.

The pyrite is usually massive but in numerous places it is also coarsely crystalline, forming strongly striated, truncated cubes. It is very light yellow and except for small veins of chalcopyrite and blebs of native silver it appears quite homogeneous under the highest power of the microscope. All the gold is known to be contained in the sulphides, as the siliceous tailings from the concentrating mill contain not even a trace of gold. However, though the gold content is rather high, no gold could be found under the microscope. It must, therefore, occur in the sulphides in an extremely fine state of division, if not in solid solution or chemical combination. The silver—not nearly as plentiful in the ore as the gold—can be seen in considerable quantities under the microscope. The pyrite was deposited over a considerable length of time and is older than some of the quartz and younger than other portions of it. It is, however, unquestionably much the earliest of the metallic minerals.

Chalcopyrite is found plentifully in all parts of the mine, but is not always visible to the naked eye. It occurs as veinlets cutting the pyrite crystals and gangue minerals, and was deposited during a later period than the pyrite, quartz, and other gangue minerals.

Bornite was found in only minute quantities in a specimen from the 340-foot level. It forms small, sharply defined veins in the chalcopyrite and is clearly much later in origin.

Chalcocite was found in minute quantities intergrown with the bornite and also as small veinlets in the chalcopyrite. It is later than the chalcopyrite but not all of it is later than the bornite.

Native silver was found in the pyrite and chalcopyrite in the form of rounded blebs. It forms veinlets in the pyrite and is undoubtedly much later in origin than this mineral. In no place, however, does it form veinlets in the chalcopyrite. It occurs as rounded or irregular masses in the chalcopyrite which shows that it was not deposited later than, but probably simultaneously with, that mineral.

Covellite was found in minute quantities on all the levels of the mine and invariably replaces the chalcopyrite veinlets. It is one of the latest minerals formed and is very likely due to the action of surface waters which flow freely through the shattered vein material.

Malachite and azurite are forming rapidly on the walls of the tunnels and stope.

The veins of the Surf Inlet mine were formed by solutions which originated in the uncooled parts of the batholith and percolated up through the shear zone in which the veins occur. In so doing the solution sericitized the country rocks and replaced them by quartz, pyrite, and other minerals. The earliest solutions deposited quartz, pyrite, and ankerite. Later solutions deposited chalcopyrite and native silver, and still later solutions deposited bornite and probably some chalcocite. After this the veins remained unchanged until a recent date, probably after the Glacial period; when surface waters found their way down through the shear zone and replaced small quantities of the chalcopyrite and bornite by covellite and probably chalcocite. As the gold could not be seen it is not known at what stage it was deposited, but it was most probably deposited simultaneously with the pyrite in which it occurs.

The distribution of the values in that part of the deposits already worked show that they were highest where the veins had their maximum width. The country rock seems to have had some influence in precipitating the metallic minerals and in general the values are slightly higher in the schist than in the diorite. The highest values were found where the dips and widths of the veins were most irregular, and the lowest values were found where the dips and widths were most regular. It would, therefore, appear that these were important factors in the distribution of the values.

OTHER GOLD DEPOSITS

Other gold prospects have been staked at several localities on Princess Royal island, the most promising of which is one located and owned by Mr. Wells, one of the original owners of the Surf Inlet. This claim is situated on the steep side of the precipitous mountain which stands just west of the point where Paradise creek enters Bear lake, and three-quarters of a mile from the camp at Surf Inlet mine. The outcrop occurs in a small gulch on the north side of the mountain at an elevation of about 2,180 feet or about 2,000 feet above Bear lake. The surface showing consists of several small irregular veins of quartz which converge to form a large mass up to 12 feet in width and lying in unaltered and only slightly sheared quartz diorite. Below this point a drift adit was driven for over 300 feet. This exposed a well-defined quartz vein about 4 feet in width carrying pyrite, and similar in every respect to the Surf Inlet veins.

The claim which attracted the most attention during the field season is located on the southern arm of Rivers bight, and is known as the Cordilla group. It is owned by David Cordilla, J. Koski, and others, of Swanson Bay. The deposit is a small, much broken quartz vein in a large, intense shear zone, striking north 25 degrees west and dipping vertically, in the quartz diorite of the Coast Range batholith. It has attracted much attention because of its proximity to, and similarity to, the Surf Inlet. Several assays have been made, some of which are reported to have shown good values, in one case up to $9 a ton. This property was sampled at two points by the writer in company with Mr. Cordilla, the principal owner. One of these samples taken near the tunnel contained no gold or silver, and the other, taken at a point 150 feet higher than the tunnel, showed no gold and a trace of silver.

A property known as the Malcolm claim, situated on the northeast of Princess Royal island, about 5 miles north of Swanson bay, and just opposite Kutze inlet, is reported to carry free milling gold. The vein is situated at an elevation of about 480 feet and about half a mile from the beach. It consists of a small but persistent quartz vein ranging from 4 inches to 12 inches in width lying in biotite-sericite schist. It strikes parallel to the schist, north 22 degrees west, and dips northeast 36 degrees. In the face of one of the small tunnels there is exposed a quartz-diorite dyke. The vein contains besides quartz, considerable pyrrhotite and some pyrite, but no free gold could be seen.

On the opposite side of Fraser reach and about a mile south of this property, there is another gold prospect on which considerable work has been done, and which was at one time owned by J. Plattenberger, of Swanson Bay. The deposit is situated at an elevation of about 600 feet above and about one-half mile from the east shore of Fraser reach. It consists of a pyritized band in sericite schist from 4 to 6 feet wide striking north 10 degrees west with a dip of 54 degrees northeast. This pyritized band has been traced for over 1,000 feet and has every appearance of being a good deposit. Fair values have been reported, but a sample taken by the writer contained no silver or gold.

DRUM LUMMON MINE

From the standpoint of production the Drum Lummon (Figure 8) is the second most important mine of the district, having produced in 1919 and 1920 (according to the reports of the Minister of Mines of British Columbia for those years) 355 ounces of gold, 1,281 ounces of silver, and 59,559 pounds of copper. Owing to a number of causes, however, these metals were produced at a loss and during the greater part of 1921 no mining was done on the property. The original company, the

Drum Lummon Copper Mines, Ltd., was reorganized into a new company registered as the Drum Lummon Mines, Ltd., and placed under the management of Glenville A. Collins, of Vancouver. At the time of the examination the new company was carrying on a small amount of development work in preparation for reopening the mine, but it will probably be some time before production is again resumed.

The camp and workings are situated about 4,000 feet from the shores of a small bay on the west side of Douglas channel, about 100 miles southeast of Prince Rupert. Hartley bay, at the entrance to Douglas channel, and about 26 miles from the mine,

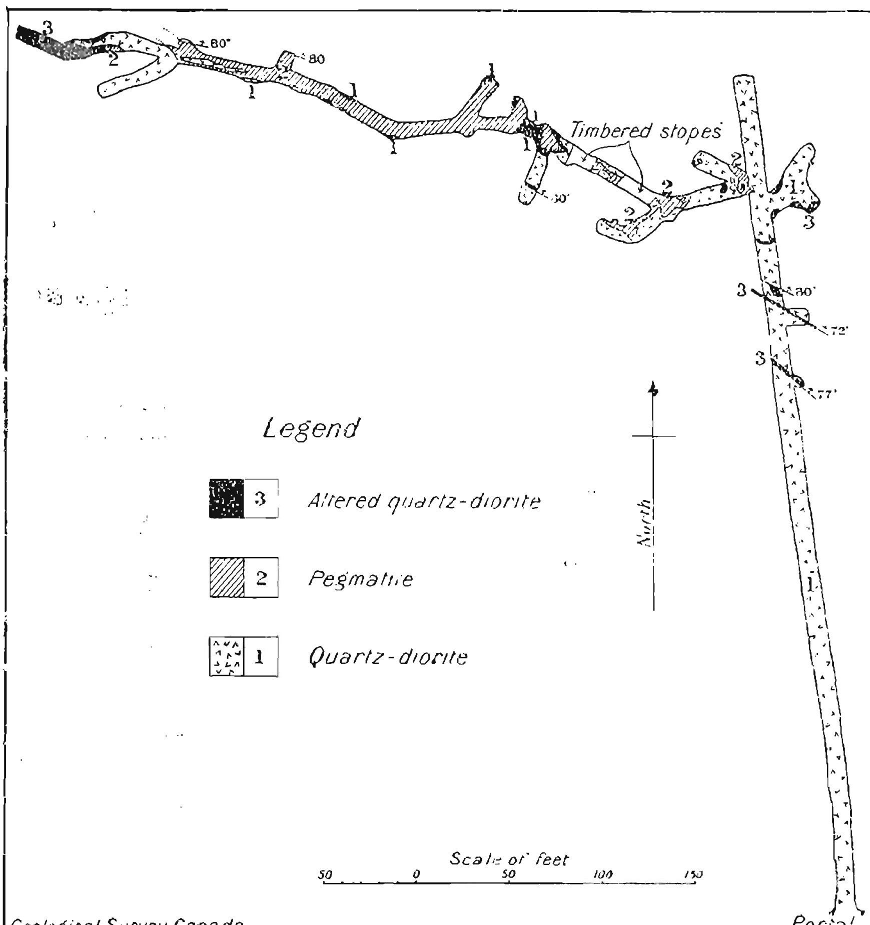

Figure 8. Geology of the Drum Lummon mine.

is the nearest port of call on the steamboat route between Prince Rupert and Vancouver. The tunnel is about 400 feet above sea-level and a good wagon road connects it with the beach, so that transportation problems are unusually simple.

The surface showings occur in the canyon of a small creek, and consist of three pegmatite dykes carrying chalcocite, bornite, and chalcopyrite. The largest of these forms an irregular mass about 20 feet in diameter with narrow dykes extending from either end. The second largest showing lies 70 feet farther up the creek. It is about 8 feet wide and extends across the canyon and west for some distance. The third showing is quite small and occurs high up on the east side of the canyon about 220 feet above the second showing and is similar in character to the others. Several bands of aplitic material also occur in the canyon, and, though they contain no metallic minerals, they are, nevertheless, very similar to the altered rock found at the contacts of the mineralized pegmatite dykes.

The underground work consists of a 440-foot crosscut tunnel which intersects a large dyke of pegmatite at a distance of 360 feet from the portal; a somewhat crooked drift which follows the pegmatite to the west for about 400 feet; two small stopes and a vertical raise which goes up through quartz for 100 feet.

The only rocks in the district are the rocks of the Coast Range batholith which occupy virtually the entire area, and, in addition the pegmatite dykes, an insignificantly small inclusion of schist, and a very fine-grained grey dyke of recent origin occurring at the smallest of the three surface showings.

The batholith at this point consists of coarse-grained quartz diorite composed of quartz, oligoclase, andesine, hornblende, biotite, and small amounts of orthoclase, microcline, and bright yellow sphene. Along the contacts of the pegmatite dykes the quartz diorite is altered to a fine-grained, light grey or pinkish rock resembling an aplite, and consisting of quartz, oligoclase, albite, orthoclase, microcline, green mica, and a few small crystals of micaceous hematite. This altered rock forms persistent bands up to 6 feet in width lying along the contacts of the pegmatite dykes. Where the dykes contain little or no feldspar and are composed chiefly of quartz the adjoining country rock is invariably altered to sericite in a manner similar to that at the Surf Inlet mine. Altered rock of the former, or aplitic type, occurs at several places in the mine at distances as great as 100 feet from the pegmatite. These bands are very straight and uniform in width and are developed along well-defined joint fissures, and appear to have been developed by pneumatolitic action similar to that which formed the pegmatite.

The small dyke which occurs at the smallest of the three surface showings is composed of small, rare quartz phenocrysts in a microcryptocrystalline groundmass containing sericite, feldspar, iron oxide, chlorite, and other minerals too fine to determine. The dyke is later than the ore and had, therefore, no influence on its formation.

The pegmatite dykes are similar to those occurring along the shore of Douglas channel north of Hartley bay, and also to those at the Surf Inlet mine. Those at the Drum Lummon, however, are much larger and more irregular in shape. The dyke exposed in the drift and stopes varies from 1 up to 50 feet in width, and there are several smaller masses separated from the main dyke but adjacent to it. Many inclusions of country rock occur in the dyke, some of which are 40 feet long. The dyke has been traced by the drift for 340 feet, but at this distance from the crosscut tunnel the drift passes through the south wall of the dyke and the last 80 feet are not in the dyke. This part of the drift, however, exposes an altered quartz diorite like that adjoining the dyke, thus strongly indicating that the pegmatite lies not far to the north. The dyke, therefore, has a proved length of 340 feet, but is most probably much longer. Its vertical extent has been proved for 100 feet above the tunnel by the raise and in all probability it extends for a great distance below this level.

The gangue minerals named in the order of their abundance are quartz, orthoclase, microcline, biotite, albite, and anorthoclase; and the metallic minerals are chalcocite, bornite, chalcopyrite, micaceous hematite, magnetite, gold, and silver.

The quartz greatly exceeds in amount all the other minerals, in places forming solid masses 40 feet wide. Its situation in the central parts of the dykes with the feldspars and metallic minerals on its margins is invariable. In appearance the quartz strongly resembles that of the Surf Inlet vein. It has a clear to milky colour and is composed of an aggregate of small anhedral crystals containing many inclusions.

The feldspars are all closely associated with one another and constitute about 30 per cent of the total volume of the dykes. They are invariably situated along or near the margins of the dykes, or around the margins of masses of country rock included in the dykes. They are also present in large amounts in the altered country rock adjoining the dykes and the altered bands of rock bordering joint fissures. Orthoclase and microcline are the most abundant and occur as large, well-formed pink crystals up to 18 inches in length. Albite and anorthoclase are plentiful, but form much smaller crystals. The feldspars contain many veinlets of quartz and were, therefore, deposited earlier.

The biotite varies from dull grey to black and forms large, thin leaves up to 10 inches in diameter which occupy fractures in the quartz and feldspar.

Laumontite was found in veinlets cutting the altered country rock in the vicinities of the dykes. It was deposited much later than the sericite and other alteration products. This mineral was also found in vugs in the quartz of the central parts of the dykes.

The metallic minerals form a small proportion of the total volume of the dyke, large parts of it being free from ore minerals. Other parts, however, contain lenses of almost pure bornite and chalcocite up to 4 feet in width. They lie, as a rule, on the margins of the dykes between the feldspars and the wall-rock, but occasionally small masses of sulphide are found in the quartz. Considerable sulphide is also found in the wall-rock.

Chalcocite and bornite in nearly equal proportions constitute over 90 per cent of the ore minerals. Chalcopyrite occurs in small quantities and native gold and silver in quantities still smaller. The gold in places is coarse, forming nuggets, but is sporadically distributed. Micaceous hematite is fairly plentiful but was deposited much earlier than the other metallic minerals. Pyrite, as in most bornite-chalcocite deposits, is conspicuously absent.

All the metallic minerals were deposited much later than the gangue minerals.

From the above description, it is evident that this deposit is of an unusual type, being one in which chalcocite, bornite, silver, and gold are associated with an acid pegmatite dyke. The pegmatite was formed from the residual liquor that resulted from the more or less complete crystallization of the magma which formed the Coast Range batholith. From these residual liquors, which were undoubtedly rich in water, the minerals—feldspar, hematite, quartz, and biotite—were deposited in the order named. The minerals were formed at temperatures considerably above the critical temperature of water (365 degrees C.) and, therefore, when the depositing solutions were in a gaseous state. The chalcocite, bornite, and other metallic minerals were deposited by relatively cool liquid solutions which found their way into the pegmatite at a very much later date and after the temperature had fallen considerably below 100 degrees C. The fact that these solutions formed only a very small amount of chalcopyrite and no pyrite indicates that they had a relatively low proportion of iron.

Surface enriching solutions may have had some influence on the ore and may have deposited some of the native silver and chalcocite, but it is not likely that this ore has been enriched to any appreciable extent.

At present the Drum Lummon mine is unproductive and at the time of the examination very little ore could be seen in the workings. What was seen, however, was very high grade and no doubt good sized shoots of similar ore have been mined. There is still a large amount of pegmatite unprospected that probably contains shoots of ore similar in size and amount to those already mined. They will, however, be scattered and disconnected which will add considerably to the cost of mining.

OTHER COPPER DEPOSITS

The only other copper deposit being worked in the district is one known as the Bolton group. It is under a working bond to A. McLeod and associate, of Vancouver, who were engaged, at the time of the writer's visit, in building a sleigh road for the high-grade ore. The property is situated at an elevation of 2,150 feet and about 2 miles north of the shore of Klekane inlet, which lies about 100 miles south of Prince Rupert. The deposit is of the contact metamorphic type, formed in limestone near the contact of an intrusion of quartz diorite of Coast Range batholith age. The limestone forms a bed about 7 feet in width interbedded with chloritic schists all of which are steeply folded, strike north 60 degrees west, and dip vertically. The contact of the quartz diorite is exceedingly irregular and surrounds the limestone on three sides. The limestone is altered into the usual minerals epidote, actinolite, hornblende, augite, quartz, and garnet, and for a width of about 18 inches is heavily mineralized with chalcocite and bornite, making fairly high-grade ore. The ore can be traced over an horizontal distance of 100 feet and a vertical distance of 60 feet, but over most of this distance the ore-shoot is quite narrow and much of it is of fairly low grade. Mr. McLeod reported that there was a lead in the schist which assayed $125 a ton in gold, but this could not be found.

On Gribbell island, near the southeast corner, there is a copper deposit of the same type, which was extensively developed in the years 1900 to 1906 during which time $30,000 was spent on equipment and development work. The project failed owing to the irregularity and low value of the ore.

The mine is at an elevation of 1,200 feet, and about 1 mile from the beach, with which it is connected by a corduroy road still in a fair state of repairs. A boiler house, compressor, and fairly large camp still remain, but these are in a dilapidated condition. The workings consist of two tunnels several hundred feet in length, several stopes, and a shaft.

The deposit occurs in a band of limestone 20 to 30 feet wide interbedded with schist and cut by quartz diorite. The limestone dips nearly vertically, and is impregnated with garnet, epidote, pyroxene, chalcopyrite, bornite, chalcocite, covellite, and small amounts of an undetermined white metallic mineral. Very little ore was seen in the lower tunnel and the stopes were not accessible. The upper workings showed considerable ore of fairly high grade, but owing to the condition of the tunnel it was impossible to get even a rough idea of the amount present. This deposit is similar to a great many of the same type found in the coast section of British Columbia, and only two or three of which have proved to be of commercial value.

Another deposit similar to this occurs also on Gribbell island and was extensively explored at the same time, but the writer could get no information regarding its location.

An interesting copper deposit occurs on the east side of Kemano river 7 miles from its mouth. This river flows into Gardiner canal about 30 miles above its entrance into Douglas channel. The property was discovered and staked in 1901 by an Englishman named Pocklington, who was later found dead in his cabin with bullet wounds in his head, which were presumably inflicted by himself. In 1914 J. L. Stewart, a well known prospector of Prince Rupert, restaked the claims, which had lapsed, and named them the Tekla group, by which name they are still known. Stewart sold the claims to the present owners, Messrs. M. M. Stephens, H. B. Babbington, and H. Flewin, the last of Port Simpson, and the two first of Prince Rupert. In September, while the writer was examining the shores of Gardiner canal, he fortunately met Mr. Flewin with a number of associates, including Mr. Stewart, who were camped at the mouth of Kemano river waiting for suitable weather to ascend the river and complete the assessment work for the season. The extremely wet weather prevented the writer from visiting the claims, but the following information was obtained from the owners; and from the examination of a number of specimens which were kindly supplied by Mr. Flewin and his partners.

According to Mr. Flewin's description, the deposit is a mineralized zone 100 to 200 feet wide and a smaller ledge 7½ feet wide lying 300 feet to the east and carrying bornite and chalcopyrite.

The specimens from the main ledge consist of quartz and aplite and some altered quartz diorite, in all of which are disseminated small particles of chalcopyrite, molybdenite, and a very small amount of bornite. Specimens from what was thought to be the hanging-wall of this zone represent a very highly altered quartz-bearing rock now consisting of quartz, muscovite, sericite, chlorite, and epidote, and strongly coloured by iron oxides. A sample from the 7½-foot quartz ledge consisted of quartz with considerable amounts of bornite and chalcopyrite, forming medium high-grade copper ore.

What is said to be the most promising copper-gold deposit of the district occurs at a high elevation and on both sides of a deep canyon on the river that flows into Kutze inlet, a short branch on the east side of Graham reach, about 5 miles north of Swanson Bay. The property is owned by Messrs. William Shannon, George Martin, and J. B. Mathers of Vancouver. The sum of $150,000 has been spent in developing the property and in constructing a tram-line, which runs from the beach up the river for 3 miles the greater part of the distance to the deposit. It was reported during the season that eastern capitalists were negotiating with the above-mentioned owners for the purchase of the property, but up to the present the sale has not been reported.

The showings are, in spite of the tram-line, at present rather difficult of access and, through lack of a map of the property or a guide, the writer was unable to see them. The geology of the district shows that the deposits lie east of the eastern contact of the large inclusion of schist which outcrops along Fraser and Graham reaches for 21 miles.

MAGNETITE DEPOSIT

A small deposit of very pure magnetite occurs on the northwest shore of Dean channel about halfway between its head and its junction with Labouchere channel. Shipments amounting to 1,200 tons were made from the deposit to a company in Seattle who used it experimentally in an attempt to convert magnetite directly into steel by an electrical process. As these experiments were made some months ago, and as no shipments of magnetite have been made since, it may be assumed that the process was not a success. The deposit occurs only a few hundred feet from the shore and at an elevation of about 200 feet. The magnetite occurs in a dark green chloritic schist which lies between two large dykes or masses of quartz diorite, one of which is about 200 feet wide and the other about 500 feet wide, and situated about 300 feet part. About one-half mile to the northeast a mass of quartz diorite several miles in length outcrops along the shore. The magnetite occurs as large masses of almost pure mineral, which have been uncovered for an horizontal distance of about 200 feet and a vertical distance of 100 feet. The width is quite irregular, varying from a few feet up to 40 feet and averaging about 20 feet. Its unusual purity and very convenient location make it one of the more promising of the numerous small magnetite deposits which occur along the coast mostly to the south of Queen Charlotte sound.

GALENA DEPOSIT

A small but interesting deposit of galena occurs about half a mile from Swanson Bay on the southwest bank of the creek from which the pulp mill derives its water. The deposit is a small, irregular, mineralized zone in micaceous schist. The minerals lie in a faulted zone parallel to the schistosity and striking north 30 degrees west and dipping 65 to 75 degrees northeast.

The mineralized zone consists of quartz stringers and silicified schist containing considerable pyrite and a little galena. Under the microscope the ore was seen to consist of pyrite, pyrrhotite, zinc blende, galena, and chalcopyrite. The iron sulphides were deposited first, then the zinc blende and chalcopyrite, and lastly the galena. No silver minerals were detected. The chief interest in this deposit lies in the fact that it is the only occurrence of galena in the district, and one of the few deposits of galena occurring west of the Pacific system.

THERMAL SPRINGS

Hot springs occur at eight widely separated localities in this district, at most of which there are several springs. Six of these localities were visited by the writer and the springs sampled. Owing to the lack of suitable containers the samples were taken in ordinary commercial acid bottles holding about two litres. The samples were analysed by R. T. Elworthy of the Mines Branch, Ottawa, but, because of the smallness of the samples not all the determinations asked for could be made. The results of the analyses are given in the tables (pages 42-49).

The flow of water from each of the springs is not great, but in most cases is sufficient for bathing establishments even on a fairly large scale. At most of the more accessible springs the loggers or fishermen have built small bathing houses, with wooden tubs, which are much used by the men of the district. A large spring in South Bentinck arm has been equipped with enamel bath tubs by the Pacific Mills Paper Company of Ocean Falls, for the use of the employees of the company engaged in logging in that vicinity.

The analyses show that four of the seven springs sampled contain less than 400 parts a million of dissolved salts, which is rather low for hot springs. The three remaining springs contain 1,229, 3,623, and 8,640 parts a million of dissolved salts, the last being comparatively high.

All of the springs but two have sulphate waters and all of these are sodium sulphate except the Dean Channel spring (sample 1) which is a calcium sulphate-calcium bicarbonate spring. The two which are not sulphate springs are the Klekane spring (sample 2) and the Surf Inlet Mine spring (sample 6), both of which are sodium chloride springs and greatly exceed all the others in total salinity. The bicarbonate radicle is prominent in only three springs, the Dean Channel spring and the two Gardiner Canal springs (samples 5 and 7), both of which are sodium sulphate springs. Silica is moderately high in all except the two chloride springs, in which it is very low. Excepting the Dean Channel spring calcium forms less than 10 per cent of the dissolved material. Magnesium is absent from all the sulphate springs except the two in Gardiner canal, and forms about 2 per cent of the salts of the chloride springs. There is no indication of the presence of hydrogen sulphide in any of the springs. There are then three clearly defined types of water in these springs, sodium sulphate, sodium chloride, and calcium sulphate.

All of the springs issue from fissures in the quartz diorite of the Coast Range batholith, except one in Gardiner canal which occurs in a large inclusion of schist. Masses of schist also occur within half a mile of the Dean Channel spring and the Surf Inlet Mine springs, but not within several miles of the other springs.

Springs of the sodium sulphate and calcium sulphate types, although common in sedimentary rocks, are rarely found, as these are, in igneous rocks. Sodium chloride springs are also commonly found in sedimentary rocks, but are equally common in igneous rocks associated with recent volcanic activity. Although recent igneous activity has taken place in this district it is doubtful in most cases if the springs have any genetic connexion with such activity. Most of the springs occur at great distances from any of the recent dykes or tuffs, and no hot springs occur within 24 miles of—and most of them are from 45 to 80 miles distant from—the centre of this vulcanism. Recent dykes were found near the Bishop Cove spring, but this spring differs in no respect from the other sodium sulphate springs. The absence of boron is a further indication that they are not related to the recent vulcanism. Similar springs of both the sodium sulphate and sodium chloride types occur in southeastern Alaska about 400 miles northwest of this district. These occur in similar rocks and their origin has been attributed by Alfred H. Brooks and Gerald A. Warring[1] to the fact that they occur in a region which has been repeatedly subjected to deformation and fissuring, some of which took place during Tertiary time.

The springs here described occur in the same general region of deformation and some of them, such as the Surf Inlet Mine spring and the Dean Channel spring, occur in the vicinity of pronounced faulting. It is probable that these springs owe their heat to the great depths from which they ascend through these fissures.

[1] "Mineral Springs of Alaska," Water Supply Paper 418, U.S. Geol. Surv., 1917.

This fact, however, makes it all the more difficult to account for the source of the calcium and sodium sulphate and sodium chloride. The rocks through which they pass are rich in both sodium and calcium, but the sulphate and chlorine cannot be accounted for. The fact that those having no chlorine occur right at the seashore scarcely above high tide, whereas those high in chlorine are the farthest inland, that at Surf Inlet being 7 miles from the sea, would strongly indicate that the waters are not contaminated to any extent by sea water.

The therapeutic value of these springs cannot be fully estimated until more complete analyses be made to determine the presence of lithia, barium, strontium, iodine, bromine, etc., and until the radio-activity of the springs has been determined. Though they lack such characteristic ingredients as sulphuretted hydrogen, carbon dioxide gas, and magnesium sulphate, still their compositions are similar to some of the well-known medicinal springs and they may yet prove to have considerable therapeutic value. The inhabitants of the district claim to have received beneficial results from bathing in these springs. Very similar springs in southeastern Alaska have been popular health resorts for many years.

Sulphate waters which precipitate chiefly calcium sulphate on evaporation, such as the Dean Channel spring, are among the most common potable waters on the market.

Sample I

Source. Water from hot spring in Eucott bay, west side of Dean channel, opposite Labouchere channel. Spring 200 feet from shore and about 15 feet above high tide.

Issues from a crevice in the quartz diorite at the foot of a steep cliff.

Temperature too hot for bathing.

Colour—Colourless.

Turbidity—Clear.

Taste—Flat.

Reaction to methyl orange—Alkaline.

Specific gravity at 15° C.—1·0005.

Properties of reaction in per cent—	Per cent
Primary salinity	28·2
Secondary salinity	49·6
Primary alkalinity	....
Secondary alkalinity	22·2

Analysis

Constituents	Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid (CO_3)	....	....	....
Bicarbonic acid (HCO_3)	33	17·2	11·1
Sulphuric acid (SO_4)	80	41·8	34·4
Chlorine (Cl)	8	4·5	4·5
Sodium (Na)	16	8·3	14·1
Potassium (K)	....	....	....
Calcium (Ca)	35	18·2	35·9
Magnesium (Mg)	trace	....	....
Iron oxide and alumina	3	1·5	....
Silica (SiO_2)	16·9	8·7	....
Total	191·9	....	....
Total solids in solution, residue dried at 110°C	145	....	....

Hypothetical Combination

Constituents		Parts per million	Solids in sol. Per cent
Sodium chloride	($NaCl$)	13	6·8
Potassium chloride	(KCl)	....	....
Magnesium chloride	($MgCl_2$)	....	....
Sodium sulphate	(Na_2SO_4)	33·5	17·5
Magnesium sulphate	($MgSO_4$)	....	....
Calcium sulphate	($CaSO_4$)	81·7	42·6
Sodium carbonate	(Na_2CO_3)	....	....
Sodium bicarbonate	($NaHCO_3$)	....	....
Magnesium bicarbonate	($Mg(HCO_3)_2$)	....	....
Calcium bicarbonate	($Ca(HCO_3)_2$)	43·8	22·8
Ferric oxide and alumina	(Fe_2O_3 and Al_2O_3)	3·0	1·5
Silica	(SiO_2)	16·9	8·7
Total		191·9	100·0

Sample II

Source. Water from hot spring at head of Klekane inlet off Fraser reach, 5 miles north of Butedale cannery. The spring is about 200 yards from the shore and 20 feet above high tide.

Issues from crevice in quartz diorite.
Temperature above 112° Fahrenheit.
Colour—Colourless.
Turbidity—Clear.
Taste—Slightly salty.
Reaction to methyl orange—Alkaline.
Specific gravity at 15° C.—1·0075.
Properties of reaction in per cent—

	Per cent
Primary salinity	76·8
Secondary salinity	22·4
Primary alkalinity	....
Secondary alkalinity	0·8

Analysis

Constituents		Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid	(CO_3)	....	....	....
Bicarbonic acid	(HCO_3)	58	0·7	0·33
Sulphuric acid	(SO_4)	717	8·3	5·12
Chlorine	(Cl)	4600	53·3	44·50
Sodium	(Na)	2523	29·2	37·7
Potassium	(K)	82	0·9	0·7
Calcium	(Ca)	385	4·5	6·6
Magnesium	(Mg)	179	2·1	5·0
Iron oxide and alumina		58	0·6	....
Silica	(SiO_2)	38	0·4	....
Total		8640	100·0	100·0
Total solids in solution, residue dried at 110° C.		9384		

Hypothetical Combination

Constituents	Parts per million	Solids in sol. Per cent
Sodium chloride........................(NaCl)............	6410	74·3
Potassium chloride........................(KCl)..........	156	1·8
Magnesium chloride........................($MgCl_2$)............	701	8·1
Sodium sulphate........................(Na_2SO_4)..........	......	......
Magnesium sulphate........................($MgSO_4$)..........	......	......
Calcium sulphate........................($CaSO_4$)..........	1014	11·7
Sodium carbonate........................(Na_2CO_3)..........	......	......
Sodium bicarbonate........................($NaHCO_3$).....	......	......
Magnesium bicarbonate........................($Mg(HCO_3)_2$).......	......	......
Calcium bicarbonate........................($Ca(HCO_3)_2$)......	76	0·8
Ferric oxide and alumina........................(Fe_2O_3 and Al_2O_3)	38	0·4
Silica........................(SiO_2)..........	58	0·6
Calcium chloride........................($CaCl_2$)........	188	2·2
Total........................	8641·0	100·0

Sample III

Source. Water from hot spring on shore of Ursula channel 2¾ miles north of Fisherman cove and 15 miles northwest of Butedale cannery. Spring is right at shoreline and 1 foot above high tide.

Issues from crevice 1 inch wide and about 6 feet long in quartz diorite.
Temperature much higher than 112° Fahrenheit.
Colour—Colourless.
Turbidity—Clear.
Taste—No taste.
Reaction to methyl orange—Alkaline.
Specific gravity at 15° C.—1·008.

Properties of reaction in per cent—	Per cent
Primary salinity..................	75·7
Secondary salinity..................	16·5
Primary alkalinity..................	....
Secondary alkalinity..................	7·8

Analysis

Constituents	Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid........................(CO_3)	9·9	2·5	3·55
Bicarbonic acid........................(HCO_3)	2·0	0·5	0·35
Sulphuric acid........................(SO_4)	173·6	44·1	38·85
Chlorine........................(Cl)	24·0	6·1	7·24
Sodium........................(Na)	81·0	20·5	37·83
Potassium........................(K)	......	......	......
Calcium........................(Ca)	22·2	5·6	11·93
Magnesium........................(Mg)	0·3	......	0·22
Iron oxide and alumina........................	22·7	5·7	......
Silica........................(SiO_2)	58·8	14·9	......
Total........................	394·5	100·0	100·00
Total solids in solution, residue dried at 110° C.	370		

Hypothetical Combination

Constituents		Parts per million	Solids in sol. Per cent
Sodium chloride	($NaCl$)	39·4	10·0
Potassium chloride	(KCl)	.....	.....
Magnesium chloride	($MgCl_2$)	.....	.....
Sodium sulphate	(Na_2SO_4)	204·0	51·8
Magnesium sulphate	($MgSO_4$)	1·2	0·3
Calcium sulphate	($CaSO_4$)	50·0	12·7
Sodium carbonate	(Na_2CO_3)	.....	.....
Sodium bicarbonate	($NaHCO_3$)	.....	.....
Magnesium bicarbonate	($Mg(HCO_3)_2$)	.....	.....
Calcium bicarbonate	($Ca(HCO_3)_2$)	2·6	0·6
Ferric oxide and alumina	(Fe_2O_3 and Al_2O_3)	22·7	5·7
Silica	(SiO_2)	58·8	14·9
Calcium carbonate		16·0	4·0
Total		394·7	100·0

Sample IV

Source. Water from west side of Bishops cove, Ursula channel, 24 miles northeast of Butedale cannery. The spring is 60 feet from the shore and 10 feet above high tide.

It issues from a crevice in quartz diorite.

Temperature much higher than 112° Fahrenheit.

Colour—Colourless.

Turbidity—Clear.

Taste—Tasteless.

Reaction to methyl orange—Alkaline.

Specific gravity at 15° C.—1·0012.

Properties of reaction in per cent—	Per cent
Primary salinity	31·64
Secondary salinity	12·84
Primary alkalinity	....
Secondary alkalinity	5·52

Analysis

Constituents		Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid	(CO_3)	6·6	1·7	2·25
Bicarbonic acid	(HCO_3)	3·3	0·8	0·51
Sulphuric acid	(SO_4)	178·5	44·6	37·95
Chlorine	(Cl)	32·0	8·0	9·29
Sodium	(Na)	92·0	23·0	40·82
Potassium	(K)	.....	.....	.....
Calcium	(Ca)	17·6	4·4	8·98
Magnesium	(Mg)	0·3	.....	0·20
Iron oxide and alumina		5·0	1·2	.....
Silica	(SiO_2)	64·7	16·2	.....
Total		400·0	100·0	100·0
Total solids in solution, residue dried at 110° C.		408		

Hypothetical Combination

Constituents	Parts per million	Solids in sol. Per cent
Sodium chloride (NaCl)	52·2	13·0
Potassium chloride (KCl)	....	....
Magnesium chloride ($MgCl_2$)	....	....
Sodium sulphate (Na_2SO_4)	219·5	54·9
Magnesium sulphate ($MgSO_4$)	1·2	0·3
Calcium sulphate ($CaSO_4$)	41·5	10·4
Sodium carbonate (Na_2CO_3)	....	....
Sodium bicarbonate ($NaHCO_3$)	....	....
Magnesium bicarbonate ($Mg(HCO_3)_2$)	....	....
Calcium bicarbonate ($Ca(HCO_3)_2$)	4·1	1·1
Ferric oxide and alumina (Fe_2O_3 and Al_2O_3)	5·0	1·2
Silica (SiO_2)	64·7	16·2
Calcium carbonate	11·0	2·8
Total	399·7	100·0

Sample V

Source. Water from hot spring on Gardiner canal, between Shearwater and Low points and about 12 miles from the entrance of the canal into Desolation channel.

Spring is at water's edge on a small vertical cliff about 2 feet above high tide.

It issues from a crevice about 2 inches wide and several feet long in chloritic schist.

Temperature much higher than 112° Fahrenheit.

Colour—Colourless.

Turbidity—Clear.

Taste—Tasteless.

Reaction to methyl orange—Alkaline.

Specific gravity at 15° C.—1·002.

Properties of reaction in per cent—	Per cent
Primary salinity	75·88
Secondary salinity	6·76
Primary alkalinity	....
Secondary alkalinity	17·36

Analysis

Constituents	Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid (CO_3)	....	....	....
Bicarbonic acid (HCO_3)	167	13·6	8·68
Sulphuric acid (SO_4)	546	44·4	36·07
Chlorine (Cl)	60	4·9	5·25
Sodium (Na)	258·5	21·1	35·57
Potassium (K)	29·3	2·4	2·37
Calcium (Ca)	67·4	5·5	10·66
Magnesium (Mg)	5·4	0·4	1·39
Iron oxide and alumina	5·0	0·4	....
Silica (SiO_2)	90·4	7·3	....
Total	1229	100·0	100·00
Total solids in solution, residue dried at 110° C.	1132	....	....

Hypothetical Combination

Constituents		Parts per million	Solids in sol. Per cent
Sodium chloride	($NaCl$)	55·0	4·4
Potassium chloride	(KCl)	55·4	4·5
Magnesium chloride	($MgCl_2$)	....	....
Sodium sulphate	(Na_2SO_4)	732·0	59·6
Magnesium sulphate	($MgSO_4$)	26·4	2·1
Calcium sulphate	($CaSO_4$)	42·8	3·5
Sodium carbonate	(Na_2CO_3)		
Sodium bicarbonate	($NaHCO_3$)	....	....
Magnesium bicarbonate	($Mg(HCO_3)_2$)	....	....
Calcium bicarbonate	($Ca(HCO_3)_2$)	221·9	18·0
Ferric oxide and alumina	(Fe_2O_3 and Al_2O_3)	5·0	0·4
Silica	(SiO_2)	90·4	7·4
Total		1229·0	100·0

Sample VI

Source. Water from the 900-foot level on Surf Inlet mine, Princess Royal island. This is 7 miles from the nearest salt water at Surf Inlet, and 200 feet above sea-level.

The water issues from a crevice in quartz diorite.

The temperature is slightly below atmospheric temperature in the mine.

Colour—Colourless.

Turbidity—Clear.

Taste—Slightly salty.

Reaction to methyl orange—Alkaline.

Specific gravity at 15° C.—1·0034.

Properties of reaction in per cent—

	Per cent
Primary salinity	62·4
Secondary salinity	36·6
Primary alkalinity	....
Secondary alkalinity	1·0

Analysis

Constituents		Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid	(CO_3)	....	....	....
Bicarbonic acid	(HCO_3)	33	0·9	0·5
Sulphuric acid	(SO_4)	553	15·3	9·6
Chlorine	(Cl)	1696	46·9	39·9
Sodium	(Na)	816	22·5	29·6
Potassium	(K)	75	2·1	1·6
Calcium	(Ca)	318	8·7	13·3
Magnesium	(Mg)	78·5	2·2	5·5
Iron oxide and alumina		5·0	0·1	....
Silica	(SiO_2)	49	1·3	....
Total		3623·5	100·0	100·0
Total solids in solution, residue dried at 110° C.		3971	....	....

Hypothetical Combination

Constituents	Parts per million	Solids in sol. Per cent
Sodium chloride.....($NaCl$).....	2075	57·3
Potassium chloride.....(KCl).....	143	3·9
Magnesium chloride.....($MgCl_2$).....	311	8·6
Sodium sulphate.....(Na_2SO_4).....	.....	.....
Magnesium sulphate.....($MgSO_4$).....	.....	.....
Calcium sulphate.....($CaSO_4$).....	784	21·6
Sodium carbonate.....(Na_2CO_3).....	.....	.....
Sodium bicarbonate.....($NaHCO_3$).....	.....	.....
Magnesium bicarbonate.....($Mg(HCO_3)_2$).....	.....	.....
Calcium bicarbonate.....($Ca(HCO_3)_2$).....	43·7	1·3
Ferric oxide and alumina.....(Fe_2O_3 and Al_2O_3)	5·0	0·1
Silica.....(SiO_2).....	49·0	1·3
Calcium chloride.....	213	5·9
Total.....	3623·7	100·0

Sample VII

Source. Water from a hot spring on the southeast side of Brim river which flows into Gardiner canal 20 miles from its entrance into Desolation channel.

The spring was found about 200 yards above the mouth of the river, and on the bank of the river. The sample was probably diluted with the river water.

The temperature was about 100° Fahrenheit, which is lower than that of any of the other hot springs.

Colour—Colourless.
Turbidity—Clear.
Taste—Tasteless.
Reaction to methyl orange—Alkaline.
Specific gravity at 15° C.—1·0005.
Properties of reaction in per cent—

	Per cent
Primary salinity..	50·8
Secondary salinity..	31·8
Primary alkalinity..	...
Secondary alkalinity	17·4

Analysis

Constituents	Parts per million	Total inorganic matter in solution Per cent	Reacting value Per cent
Carbonic acid.....(CO_3)	.....	.....	.....
Bicarbonic acid.....(HCO_3)	40·0	14·2	8·7
Sulphuric acid.....(SO_4)	78	27·9	21·7
Chlorine.....(Cl)	52·0	18·5	19·6
Sodium.....(Na)	43·4	15·6	25·4
Potassium.....(K)	.....	.....	.....
Calcium.....(Ca)	16·6	5·9	11·1
Magnesium.....(Mg)	12·2	4·3	13·5
Iron oxide and alumina.....	3·0	1·0	.....
Silica.....(SiO_2)	35·5	12·6	.....
Total.....	280·7	100·0	100·0
Total solids in solution, residue dried at 110° C.....	273		

Hypothetical Combination

Constituents		Parts per million	Solids in sol. Per cent
Sodium chloride	($NaCl$)	85·2	30·4
Potassium chloride	(KCl)	....	....
Magnesium chloride	($MgCl_2$)	....	....
Sodium sulphate	(Na_2SO_4)	30·5	10·9
Magnesium sulphate	($MgSO_4$)	60·7	21·6
Calcium sulphate	($CaSO_4$)	12·2	4·3
Sodium carbonate	(Na_2CO_3)	....	....
Sodium bicarbonate	($NaHCO_3$)	....	....
Magnesium bicarbonate	($Mg(HCO_3)_2$)	....	....
Calcium bicarbonate	($Ca(HCO_3)_2$)	53·6	19·1
Ferric oxide and alumina	(Fe_2O_3 and Al_2O_3)	3·0	1·0
Silica	(SiO_2)	35·5	12·6
Total		280·7	100·0

Sample VIII

Source. Salts deposited by the hot spring on Dean channel from which sample I was taken.

The sample was taken from the edge of a large boulder which projected over the top of the spring and was about 3 feet above the surface of the water. The salts were deposited by the vapours from the hot water.

	Per cent
CaO	29·50
MgO	0·44
Fe_2O_3 and Al_2O_3	0·62
Na_2O	0·26
SO_3	42·00
CO_2	Very small quantity, undetermined
H_2O	25·00
SiO_2	2·00
Boron	trace
	99·82

COPPER DEPOSITS ON LASQUETI ISLAND, BRITISH COLUMBIA

By J. D. MacKenzie

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Illustrations

INTRODUCTION

Lasqueti island is situated between Vancouver island and Texada island, in the strait of Georgia. It is separated from the south end of Texada island by Sabine channel. The island is 10 miles long and averages between 2½ and 3 miles wide, with its longer axis lying northwest and southeast. It has a much indented shoreline, which is for the most part steep and rocky, with shingle beaches at the heads of the narrow bays. The surface is characterized by irregular, rounded rocky hills, the highest of which, mount Tremeton, attains an altitude of 1,056 feet. Bare rock forms a large proportion of the surface, but some of the valleys near sea-level are filled with till or alluvium sufficient to form soil suitable for cultivation.

There are small settlements at Tucker bay on the east coast, and at False bay at the northwest end of the island, where there is also a salmon cannery. A coasting steamer calls once a week at Tucker bay, and a regular service is maintained by gasoline launch between that bay and Pender harbour on the mainland.

The field work on which this report is based occupied ten days in July, 1921. The primary object in visiting the island was to study the basal Cretaceous rocks which occur there in several places, but the greater part of the ten days was spent examining and mapping the area here reported on. The general map (Figure 9) of Lasqueti island accompanying this report is a revision of the one published by Dawson in 1886; the map of the Venus and St. Joseph groups was made during the present examination.

Previous investigations on Lasqueti island were made by Richardson[1] and by Dawson[2]. Dawson gives a full description of the Cretaceous sediments as well as of the pre-Cretaceous volcanic rocks. He also mentions the "granite" of False bay, but did not follow its extension across the island to Barnes cove.

In 1920 the mineral claims were described by W. M. Brewer.[3]

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[1] Richardson, James, Geol. Surv., Can., Rept. of Prog., 1876-77, pp. 168-169.
[2] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. II, pt. B, 1886, pp. 41-44.
[3] Brewer, W. M., Ann. Rept., Min. of Mines, B.C., 1920, p. 213.

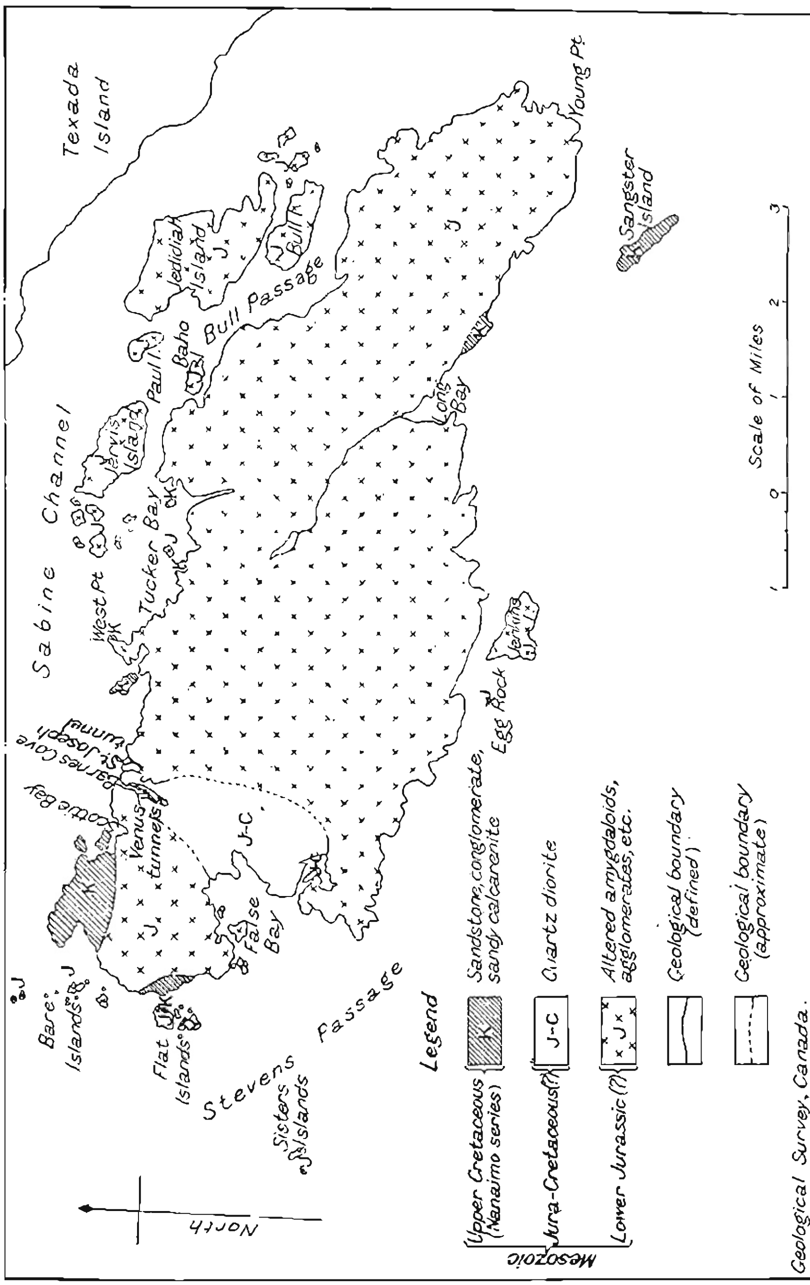

Figure 9. Geological map of Lasqueti Island, strait of Georgia, B.C.

GENERAL GEOLOGY

Table of Formations

Period	Formation	Lithology
Pleistocene and Recent.....	Alluvium and Glacial deposits....	Stratified sand, till, swamp deposits
	Unconformity	
Upper Cretaceous...........	Nanaimo series.....................	Conglomerate, sandstone, sandy calcarenite
	Unconformity	
Jura-Cretaceous (?).........	Dykes............................	Quartz diorite porphyries (?)
	Intrusive contact	
	Satellitic rocks of the Coast batholith............................	Quartz diorite
	Intrusive contact	
Lower Jurassic..............	Texada formation.................	Altered amygdaloids and agglomerates

Except for the small area underlain by quartz diorite between False bay and Barnes cove, and that occupied by Cretaceous rocks, the whole surface of Lasqueti island is occupied by altered volcanic rocks to which the name Texada formation is applied.

These rocks are amygdaloids, agglomerates, and tuffs and with them are dense compact rocks which may have been flows or sills. Dawson's general description is quoted here:

"The island is composed, for the most part, of altered volcanic rocks, which are probably a repetition of those met with on the adjacent portion of the shore of Texada island, Sabine channel, occupying an intervening synclinal. The strikes of the beds, on the sides of the channel, diverge to the northwestward, coinciding approximately in direction with the opposite shorelines. The northern portion of the island is chiefly composed of amygdaloids, while the southern is formed principally of agglomerates, which have, however, in many places, been so much altered as to require very close examination to detect their true character. Some compact trappean beds occur in association with the agglomerates, which have evidently been lava-flows; one of these, near point Young, shows a fairly well-marked columnar structure, and another, three-quarters of a mile north from the southeast point, on Bull passage, affords an excellent example of the 'ropy' structure above alluded to. This peculiar structure was not infrequently observed in other places in connexion with the altered volcanic rocks and is pretty evidently that of the surface of a lava-flow, resembling those found on Vesuvius and other recent volcanoes. The flow of the viscous or partly consolidated mass, has produced a confused aggregate of knotted, rounded, and irregularly cylindrical forms of an involved character, and without distinct interspaces. The structure is not merely superficial, but affects a considerable mass of material, which in this instance is now a bluish feldspathic rock, not evidently amygdaloidal. The lithological characters of the other rocks of the altered volcanic series on Lasqueti are so similar to those of the rocks of Texada as not to require special description."[1]

Two typical specimens of these rocks were examined in thin section, and found to consist essentially of andesine feldspar in lath-like and tabular crystals, and a pale brown hornblende. An opaque mineral, probably magnetite, is present in considerable amounts as an accessory. This mineral composition determined the rocks to be andesites. They are comparatively fresh rocks, and their slight alteration is surprising.

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. II, pt. B, p. 41.

The structure of these volcanic rocks is not evident, but it is fairly apparent that they form part of an effusive and pyroclastic bedded formation, striking northwest (parallel to the longer direction of the island) and dipping from 20 to 40 degrees to the northeast. This interpretation agrees with the views of Dawson as quoted above.

A feature of these volcanics is the vertical crushed zones contained in them. There are many such zones along the shore from Barnes cove to Scottie bay; they are from 1 inch to 2 feet wide and strike from 10 degrees west of north to 25 degrees east of north. These zones have apparently had a considerable localizing influence on the mineralization presently to be described. On the basis of Dawson's description, and their lithological composition, these altered volcanics are correlated with the Texada formation of Texada island. McConnell, who named this formation, states that it "probably belongs to the same volcanic period as the Vancouver volcanics of Vancouver island,"[1] which are of Lower Jurassic and Triassic age.[2]

SATELLITIC ROCKS OF THE COAST BATHOLITH

Under this name are included plutonic rocks which underlie the area between False bay on the south of the island and Barnes cove on the north.

The rock at False bay is light grey, medium to fine, even grained, with a pinkish cast on the weathered surface. Quartz is plainly visible in the hand specimen. In thin section the essential minerals are andesine (plagioclase feldspar) and quartz; with subordinate hornblende, biotite, and augite, and accessory apatite and magnetite. The constituents, except the quartz, are all sharply crystallized and the texture is even. The rock is fresh; the andesine is only slightly altered, and the biotite shows only incipient alteration to chlorite.

In the vicinity of Barnes cove the most common rock is grey, fresh-looking, medium even-grained quartz diorite. In thin section it is generally similar to the rock just described, but there is noticeably less quartz and rather more ferromagnesian minerals. This agrees with the difference in appearance in the hand specimen; the Barnes Cove rock being several shades darker than the False Bay variety, and with inconspicuous quartz. The hornblende forms rims surrounding the augite, which is not abundant. The quartz diorite is usually fresh looking and very little alteration can be detected in thin section, but in the shear zones the rock is greatly altered, and its identity is often doubtful in the field. This sheared, altered variety appears under the microscope as a mixture of altered feldspar, calcite, quartz, and chlorite, with the usual accessory minerals, and in addition titanite, which was not found in the slides of the fresher rocks. It is as a replacement of this altered and sheared quartz diorite that the ore-shoots occur.

Near the contact with the volcanics variations in grain are common, but the quartz diorite is not chilled. In some places on the Venus group concentrations of bladed crystals of hornblende up to 2 inches long occur in irregular schlieren in the quartz diorite. At the contact on the shore west of the St. Joseph tunnel the intrusive is exceptionally rich in hornblende, which forms 80 per cent of the rock, forming equant crystals up to $\frac{3}{16}$ inch across. This rock is tightly sealed against the volcanics, without any sign of chilling. Here, also, the contact relations indicate intrusion of the quartz diorite into rocks which were sufficiently hot not appreciably to chill the intrusive. The dykes and apophyses extending from the quartz diorite into the volcanics are frequently fine-grained, pinkish and reddish aplitic rocks. These aplites also occur in dykes or veins of varying shape and size cutting the quartz diorite itself.

DYKES

Besides the dykes and apophyses clearly related to the quartz diorite that cut the volcanics, certain others occur which have not been observed intruding the quartz

[1] McConnell, R. G., Geol. Surv., Can., Mem. 58, 1914, p. 26.
[2] Clapp, C. H., Geol. Surv., Can., Mem. 36, 1913, p. 28.
Clapp, C. H., Geol. Surv., Can., Mem. 96, 1917, p. 123.

diorite. These are dark grey, tough, hard porphyries, with yellowish and greyish white phenocrysts of plagioclase up to ⅛ inch across in a dense matrix in which smaller hornblende phenocrysts also occur. They are probably quartz diorite porphyries.

Near the St. Joseph tunnel one of these dykes contains sparingly disseminated fine-grained pyrite, and along one contact is a crushed zone 6 to 8 inches thick, containing lenticles of pyrite and chalcopyrite 12 inches long by ½ inch thick.

NANAIMO SERIES

Conglomerate, sandstone, and the fragmental type of limestone known as calcarenite, of Upper Cretaceous age, and belonging to the Nanaimo series, outcrop at several localities in such a way as to suggest that the rocks are parts of a once continuous fringe that formerly ran almost around the island. As they were formed after, and have no connexion with the copper deposits they will not be further described here. A description of them is given by Dawson.[1]

ECONOMIC GEOLOGY

COPPER DEPOSITS

Venus Group

The Venus group consists of nine mineral claims and a fraction, extending southerly from Barnes cove across the island. The principal workings are on the Mars claim, which almost surrounds Barnes cove. At the head of the cove two adits have been driven, the lower one at the shore and 5 feet above high-tide line, the upper one 16 feet directly above. The length of the upper tunnel is 80 feet; that of the lower 140 feet. Part of the intervening ground has been stoped, and a winze was extended from the lower tunnel to a depth at the time the property was examined of 70 feet. Besides these underground workings, numerous surface pits, trenches, and strippings have been made.

Only vague surface indications were evident on the Mars claim, but the slight mineralization at the St. Joseph mine and at the mouth of Barnes cove induced some prospectors to do surface stripping at the head of the cove. This work disclosed a seam of oxidized minerals no wider than a knife blade, on which a pit was sunk, disclosing a considerable body of chalcopyrite. The accompanying plan (Figure 10) of the Venus and St. Joseph groups illustrates the surface geology. A tongue of diorite, the most northerly extension of the mass outcropping at False bay, intrudes the metamorphosed volcanics with very irregular contacts. Bifurcating this tongue is a long, narrow strip of the invaded rocks which is thought to represent a roof pendant. Numerous inclusions of the volcanics are found in the diorite, some of which are large enough to be shown on the plan.

It will be observed that the deposit on the Mars claim lies in the intrusive, which at this place is a dark grey, fresh-looking, medium to fine, even-grained rock, composed of about equal amounts of plagioclase and hornblende. It shows minor variations in texture, and is cut by a few narrow aplitic veins.

At the place where the adits have been driven this is crushed and slickensided in a nearly vertical zone striking north 25 degrees east. The width of the zone varies from 4 inches to several feet, and the intensity of crushing is also variable. In some places the rock is so slickensided, crushed, and chloritized that its recognition is a matter of some difficulty. Two hundred feet from the shore at the Venus adit a fault striking east and west offsets the tongue of volcanics for a distance of 45 feet measured horizontally along the fault plane. Further than this the relative movement of the two sides of the fault is not known. In this crushed zone in the diorite

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. II, pt. B, 1886, pp. 41-44.

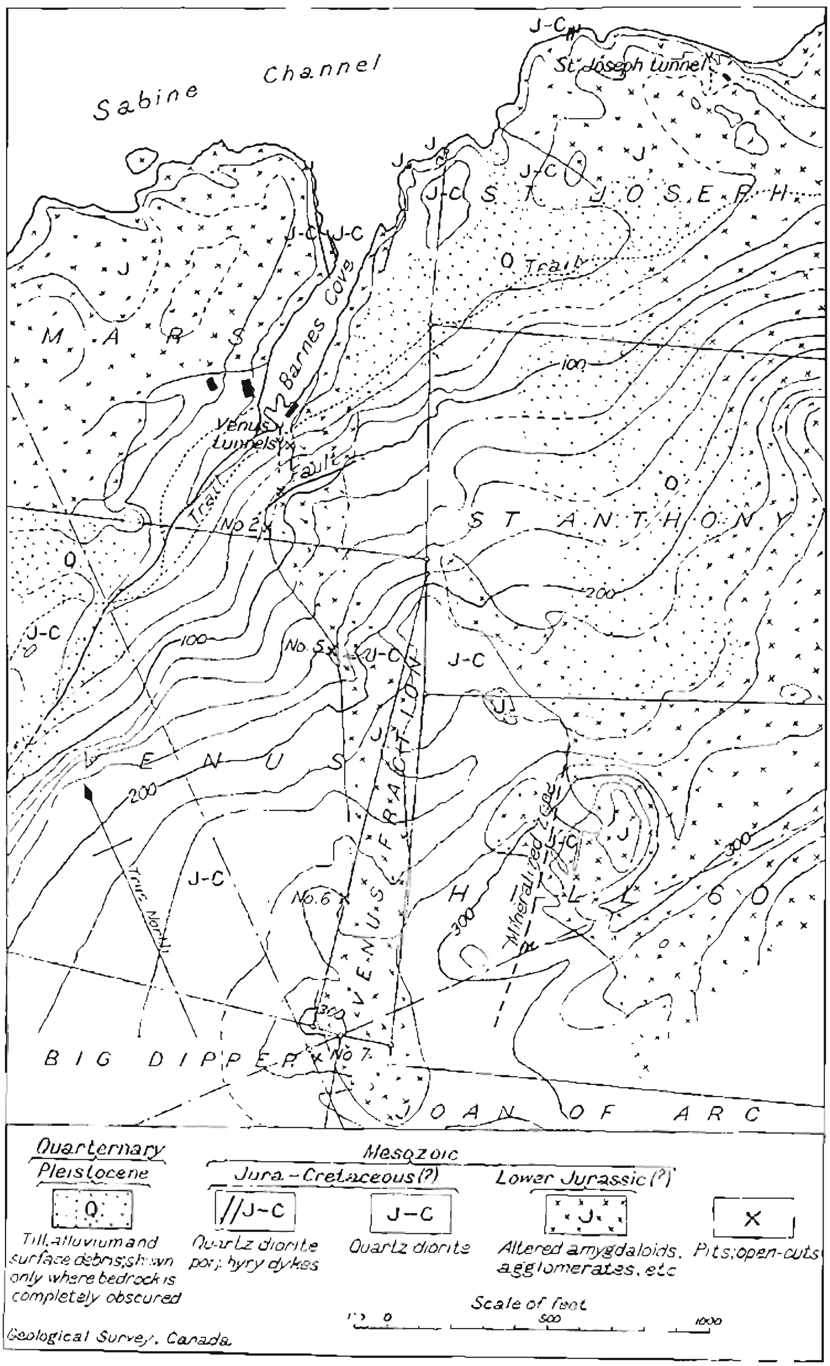

Figure 10. Plan of Venus and St. Joseph groups of mining claims, Lasqueti island, B.C.

occurs the principal mineralization. This is a shoot of nearly solid chalcopyrite with some pyrite, the greatest thickness of which is 4 feet; in some places now stoped this was solid chalcopyrite, but generally the shoot contained strips of crushed diorite. The stope length of the shoot in the lower tunnel is about 80 feet; as the lower part has not yet been extracted its pitch length or direction is not known.

In the less crushed portion of the zone the chalcopyrite occurs in thin lenses which appear to have been caused partly by filling and partly by replacement. In the more crushed zones the chalcopyrite forms a larger proportion of the total mass, surrounding various sized fragments of slickensided and chloritized quartz diorite and in these zones the principal mode of introduction of the ore is apparently replacement of the crushed rock. A polished surface of typical ore, for the preparation and examination of which the writer is indebted to Mr. George Hanson, corroborates the ideas concerning the formation of the ore by replacement which had been inferred from the field relations and hand specimens. By means of this polished specimen, small, disjointed grains of magnetite were detected in the ore, which explains the faintly magnetic property of some specimens. A mineral thought to be sphalerite also occurs sparingly in small grains.

Up to December, 1921, 196 tons of ore had been shipped to the Tacoma smelter from this deposit, the returns from which are stated to have averaged:

Copper	12·82 per cent
Gold	0·63 oz. per ton
Silver	3·27 ozs. per ton

Though this ore was hand-picked, much of it was shipped just as taken from the mine. A sample that was mostly chalcopyrite is said to have given the following results:

Copper	31·65 per cent
Gold	0·08 oz. per ton
Silver	4·32 ozs. per ton

A sample that was largely pyrite is said to have contained:

Copper	5·50 per cent
Gold	1·16 ozs. per ton
Silver	8·84 ozs. per ton

Along the western contact of the narrow strip of volcanics on the Venus and Venus Fraction claims, a certain amount of mineralization occurs in several pits and trenches. Wherever this mineralization, which consists of disseminated pyrite with small amounts of chalcopyrite, has been found the quartz diorite is crushed and sheared, and the pyrite and chalcopyrite are confined to the sheared parts.

On Hill 60 mineral claim there is a deposit remarkable for its straightness and continuity, to which for lack of a better term the name "mineralized zone" has been applied. This zone is usually from 2 to 4 feet wide and can be traced continuously for 900 feet by means of a depression down to 2 feet deep which it forms on the surface. This depression is marked by the difference between the amount of vegetation growing in it, and that on the adjoining rocks. All along the depression the growth of sallal is noticeably more luxuriant than elsewhere in the vicinity. Its course is also marked by a hedge of small jackpines which are doomed to early decease if one may judge from the *chevaux-de-frise* of their dead predecessors lying along the depression, none of which attained a height of more than 10 feet. The broken material comprising the zone lends itself readily to the soil-forming processes of disintegration and decay. Once a depression was initiated the concentration of moisture in it accelerated the process, at the same time providing in itself an agent favourable to the growth of vegetation.

This mineralized zone crosses quartz diorite and volcanic alike, and is, therefore, a post intrusion feature. No sign of offsetting could be detected where it intersects any of the quartz diorite-volcanic contacts, and it must be a shear or crush zone rather than a fault. Two pits have been sunk on it where the zone is in quartz diorite. In the pit at the northeastern end the shearing is 40 degrees east of north, and dips 83 to 85 degrees southeast. A section across the zone from northeast to southwest at this point is as follows:

	Thickness Ft.	In.
The hanging-wall is broken but not greatly sheared.		
Loose sugary pyrite; decomposed to gossan for 6 feet from surface	up to 6	
Greatly crushed quartz diorite..		0 5
Massive quartz diorite much iron stained and with disseminated pyrite..		4
Sheared quartz diorite with malachite stains..		5
Vein of pyrite and chalcopyrite..		0·5 to 1
Cracked quartz diorite..	3	
Oxidized pyrite and quartz..		1
Cracked quartz diorite..	2	4
Quartz stringer..		0·25
Cracked quartz diorite..	1	8
Pyrite and quartz..		0·25
	7 ft. 11·5 ins. to 8 ft. 6 in.	

The foot-wall is cracked quartz diorite with paper-thin quartz stringers. A sample of picked material from this pit taken by W. M. Brewer,[1] contained: copper, 14·4 per cent; gold, 0·38 ounce per ton; silver, 1·8 ounces per ton. Northeast of this pit the rocks for several hundred feet are obscured by alluvium and vegetation and the extension of the mineralized zone in that direction cannot be traced. At a distance of 650 feet along the zone from the pit just described another open-cut in the quartz diorite affords the following section of the zone.

The strike of the shearing here is 45 degrees east of north, and the dip 85 degrees northwest, the opposite direction from the dip at the first pit.

	Inches
The hanging-wall is strongly sheared.	
Soft chlorite gouge..	4
Loose, sugary pyrite..	4
Very soft, clayey gouge..	1·5
Incoherent pyrite..	0·75
Sheared quartz diorite..	2
	12·25

The foot-wall is cracked quartz diorite.

The southwestward extension of this zone, like the northeastward, is concealed by vegetation and alluvium. Mr. Henry Lee, Managing Director of the Lasqueti Island Mining Company that is developing the property, makes the interesting suggestion that there may be a genetic connexion between this mineralized zone and the crushed zone on the St. Joseph claim. The strike of the zone just described, if produced, meets the crushed zone at the St. Joseph tunnel, but the rocks in the intervening distance of 2,000 feet are concealed.

St. Joseph Group

The St. Joseph group, adjoining the Venus group on the east, consists of three claims, two of which are shown on the accompanying plan (Figure 10). The workings consist of an adit just above high-water mark, with a length of 116 feet; an inclined shaft from the surface intersects the adit and is said to extend to a depth of 100 feet, from which point a level parallel to the adit extends for an unknown distance. These workings were made previous to 1908, and since that year the property has not been operated. This deposit lies in a crushed zone in the volcanics which are here more than ordinarily massive, as if the movements in the vicinity had all been localized in one place. The crushed zone is from 2 to 4 feet wide, strikes 30 degrees east of north, and dips 62 degrees northwest. The mineralization

[1] Brewer, W. M., Ann. Rept. Min. of Mines, B.C., 1920, p. 213.

consists of irregular patches and small shoots of pyrite and chalcopyrite apparently occurring as replacements in the crushed volcanics. There is no indication of any of these shoots having been as large or as rich as the one at the Venus mine. On the steep shore, 80 feet west of the portal of St. Joseph adit, a vertical dyke, probably a quartz diorite porphyry, 10 feet thick, strikes north 30 degrees east. This dyke cuts massive volcanics and along its southeastern contact lies a mineralized streak in a crushed zone 6 to 8 inches thick. This zone contains lenticles of pyrite 12 inches long by ½ inch thick, together with some chalcopyrite and malachite stains. The dyke itself contains some sparingly disseminated pyrite, and it is possible that it has caused the mineralization alongside of it. It is possible, too, that the mineralization of the St. Joseph tunnel is connected with this dyke.

A pile of hand-picked mineralized rock lying at the entrance of the adit was sampled by W. M. Brewer in 1920, and the result of the assay gave:

Copper	11·4 per cent
Gold	0·82 oz. per ton
Silver	2·2 ozs. per ton[1]

Origin

The mineralization and mode of occurrence leave no doubt that both of these occurrences are instances of primary deposition. The location of the Venus deposit near the end of a tongue of quartz diorite projecting into the invaded rock, and its intimate association with shearing in the quartz diorite, lead to the conclusion that the mineralization was caused by some of the later magmatic emanations which were evolved from deeper-seated parts of the quartz diorite mass after the marginal zones had solidified sufficiently to be sheared and crushed. A similar origin can be assigned to the mineralized zone on the Hill 60 claim.

There are two possible modes of origin for the St. Joseph deposit. It, too, may be connected with the quartz diorite, in which case its relative leanness may be due to the greater distance of travel of the metallic minerals, and their localization in the volcanics rather than in the intrusive rock. On the other hand, it may be genetically connected with the porphyry dyke described above.

[1] Brewer, W. M., Ann. Rept., Min. of Mines, B.C., 1920, p. 213.

PLACER MINING IN BARKERVILLE AREA, BRITISH COLUMBIA

By W. A. Johnston

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INTRODUCTION

Placer mining has been carried on intermittently in Barkerville area ever since the discovery, over sixty years ago, of the gold-bearing creeks—Antler, Williams, Lightning, and several others—which have rendered the district famous. In the early days of mining in the district, the gold was, for the most part, recovered by drifting, and at a later period by hydraulicking; and some of the hydraulic mines have been in operation nearly every year for the past forty years. In recent years attempts have been made to interest capital in the possibilities of gold-dredging, a phase of mining which as yet has not been attempted in the Barkerville area, although it has been successfully carried on in many other placer regions.

Parts of Cariboo district were examined geologically by G. M. Dawson in 1876 and 1894. The results of his work and summaries of the history of placer mining in the region are given in the report of Progress of the Geological Survey, Canada, 1876-77; in the Annual Report for 1887-88, part II, and in the Summary Report, 1894. Cariboo mining district was topographically and geologically mapped in 1885 and 1886 by Amos Bowman, assisted by James McEvoy. The first part of Bowman's report, dealing chiefly with the general geology and the possibilities of lode mining in the district, was published in the Annual Report of the Geological Survey, Canada, 1887-88. The second part, in which it was intended that detailed descriptions of the principal auriferous creeks should be given, was not published. A number of detailed maps of the creeks were prepared by Mr. Bowman, but in June, 1894, he died without having written any descriptive matter to accompany these maps. The maps, however, were published in 1895 by the Geological Survey and were accompanied by an explanatory note by G. M. Dawson.

In 1918 B. R. MacKay, of the Geological Survey, began an investigation of the Cariboo gold region and continued his work during parts of that and the succeeding year. The results of part of his work are contained in the Summary Reports of the Geological Survey for those years. In 1920, a topographic map of the Barkerville area, embracing 210 square miles, was made by D. A. Nichols of the Topographical Division, Geological Survey. The map will be published on the scale of 1 mile to the inch, with a contour interval of 100 feet.

Much valuable information regarding mining operations in the district is given in the reports of the Minister of Mines of British Columbia, which have been issued annually since 1874. The report for the year 1902 is of special interest, as it contains a comprehensive description by Wm. Fleet Robertson, Provincial Mineralogist, of the placer deposits and the mining operations then in progress. In the report for 1914, the mining operations of the district were described by J. D. Galloway, Assistant Provincial Mineralogist, and a report is now submitted annually by Mr. Galloway as resident engineer of the district. In other years the general progress of, and information about the district have been given by the gold commissioner.

The history of mining in the district prior to 1878 is given in considerable detail by Bancroft in his "History of British Columbia" published in 1887, and also by F. W. Howay and E. O. S. Scholefield in "British Columbia From the Earliest Days to the Present," published in 1914. Interesting data on the subject are to be found in numerous other publications and manuscripts, including the early reports of the gold commissioners, which are available for reference in the excellent Parliamentary library at Victoria, British Columbia. A few rare volumes and manuscripts on Cariboo are available for reference in the Public Archives at Ottawa, also. These old reports, as well as the later reports and Bowman's maps, are of interest and importance because they furnish the main evidence as to which creeks were thoroughly tested in the early days of mining, a question which because of the peculiar condition existing in Cariboo—the presence of glacial drift overlying the gold-bearing gravels—has arisen many times in the past, and will doubtless arise in the future.

Two papers by J. B. Tyrrell, dealing with the geology and placer mines of Cariboo, have been published recently. One of these, entitled "Was There a Cordilleran Glacier in British Columbia?" appeared in the Journal of Geology, vol. 27, 1919, and the other, "Notes on the Placer Mines of Cariboo, British Columbia," was published in Economic Geology, vol. 14, 1919.[1]

The writer spent two months in 1921 in an examination of the placer deposits of Barkerville area and other parts of Cariboo district, continuing the work of B. R. MacKay who resigned from the Geological Survey in 1920. Attention was directed mainly to Williams, Antler, and Grouse creeks, and detailed maps were made of parts of these. No attempt is here made to give a general account of the possibilities of placer mining in the area, for in the short time devoted to its study it was possible to gain only a general knowledge of the history of the mining of a few of the numerous creeks, and of the mode of occurrence and origin of the pay gravels.

The writer is indebted to Mr. John Hopp for information regarding the results of Keystone drilling on Williams creek; and to Mr. J. G. McLaren for information regarding the results of drilling on Antler creek. Acknowledgments are due also to Mr. Lawrence Muller, manager of the Hopp mines, to Mr. C. W. Moore, manager of the New Waverly hydraulic mine, to Mr. L. A. Dodd, gold commissioner, to Mr. L. A. Bonner, and to many other mining men of the district.

GENERAL CHARACTER OF THE DISTRICT

ACCESSIBILITY

Barkerville area may be easily reached by the Pacific Great Eastern railway from Vancouver to Quesnel or by steamer from Prince George to Quesnel, and thence 60 miles by stage to Barkerville, or by automobile stage from Ashcroft to Barkerville. The Keithley district, 30 miles southeast of Barkerville, is reached by a road passable for automobiles from Williams lake to Quesnel Forks and thence 18 miles by a rough wagon road to Keithley. A pack trail connects Keithley and Barkerville, and wagon roads connect most of the important creeks in the Barkerville area.

[1] A paper on "Cariboo Placers and Lodes" by J. A. Macpherson also appeared in the Min. and Eng. Record, vol. XXIV, 1919.

CLIMATE

Records of climatic observations at Barkerville are available from 1888 to 1921.

The mean annual temperature at Barkerville is 35·7 degrees, nearly the same as that of southern Manitoba. The temperature extremes throughout the year are, however, less than in southern Manitoba, the summers being cooler and the winters milder. The mean temperature for July, the warmest month, is 54 degrees, whereas at Winnipeg it is 66·2 degrees. The mean temperature for January, the coldest month, is 17 degrees, whereas at Winnipeg it is −4 degrees. The temperature rarely rises above 80 degrees in the warmest month or below −20 degrees in the coldest month and in some years these extremes are not reached.

The average annual precipitation (rainfall and melted snowfall) at Barkerville is 34·5 inches and is well distributed throughout the year. The monthly average for the summer months June, July, and August is 3·2 inches and is slightly greater than for the winter months. The average winter's snowfall is 185 inches. It varies greatly from year to year. In the winter of 1904-05 it was only 97 inches; in the winter of 1916-17 it was 258·3 inches.

It is probable, so far as climatic conditions are concerned, that dredging could be carried on in the area throughout nearly the whole year.

PHYSICAL FEATURES

Because of the considerable relief, Barkerville area is generally described as mountainous, but, as pointed out by G. M. Dawson[1], it is perhaps more correct to regard the region as a deeply dissected, high-level plateau, the plateau level being preserved only in the interstream areas. The Cariboo Mountain range, characterized by rugged peaks covered with perpetual snow, lies about 20 miles east of Barkerville and forms the eastern boundary of the plateau. In the vicinity of Barkerville, the plateau level is 6,000 to 6,200 feet above the sea. Most of the important gold-bearing streams (Figure 11), Antler, Grouse, Williams, Jack of Clubs, and Lightning, rise in the Bald Mountain plateau—so-called because it is largely above timber-line—above which rises mount Agnes, an isolated peak about 300 feet above the general plateau-level. Only the creeks flowing north, northeast, and northwest from Bald mountain are gold-bearing except some of the tributaries of Swift river. The creeks descend rapidly from the plateau-level, so that within a distance of 5 to 10 miles from their sources they flow in valleys, the bottoms of which are in places over 2,000 feet below the plateau-level. The valleys are narrow and steep-sided in the upper parts, but in places have the U-shaped cross-section characteristic of glacially eroded valleys. They broaden out in the lower parts, where they are deeply drift-filled and have alluvial flats with a general elevation of about 4,000 feet.

The remarkably flat-topped summits on the interstream areas, and the fact that the nearly level surface is formed by the truncated edges of a highly folded and steeply dipping series of sedimentary rocks—which were nearly horizontal when deposited—shows that the area was once mountainous and was worn down nearly to a plain. The deep valleys have been cut down below the plateau-level and are evidence of still further erosion of the bedrock, so that it is evident several thousand feet of rock have been eroded away in places. One of the conditions for the formation of rich placer deposits was, therefore, fulfilled, the others, also fulfilled, being that the rocks eroded were in part gold-bearing and the gold placers were preserved from erosion.

The area is well wooded except on the summits, and an abundance of timber, chiefly spruce, is available. The area in the immediate vicinity of Barkerville, as shown by old photographs, was almost entirely denuded of forest in the sixties, but has since become reforested (*See* Plates II A and B).

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[1] Geol. Surv., Can., Ann. Rept., vol. III, pt. II, 1887-88, p. 30 R.

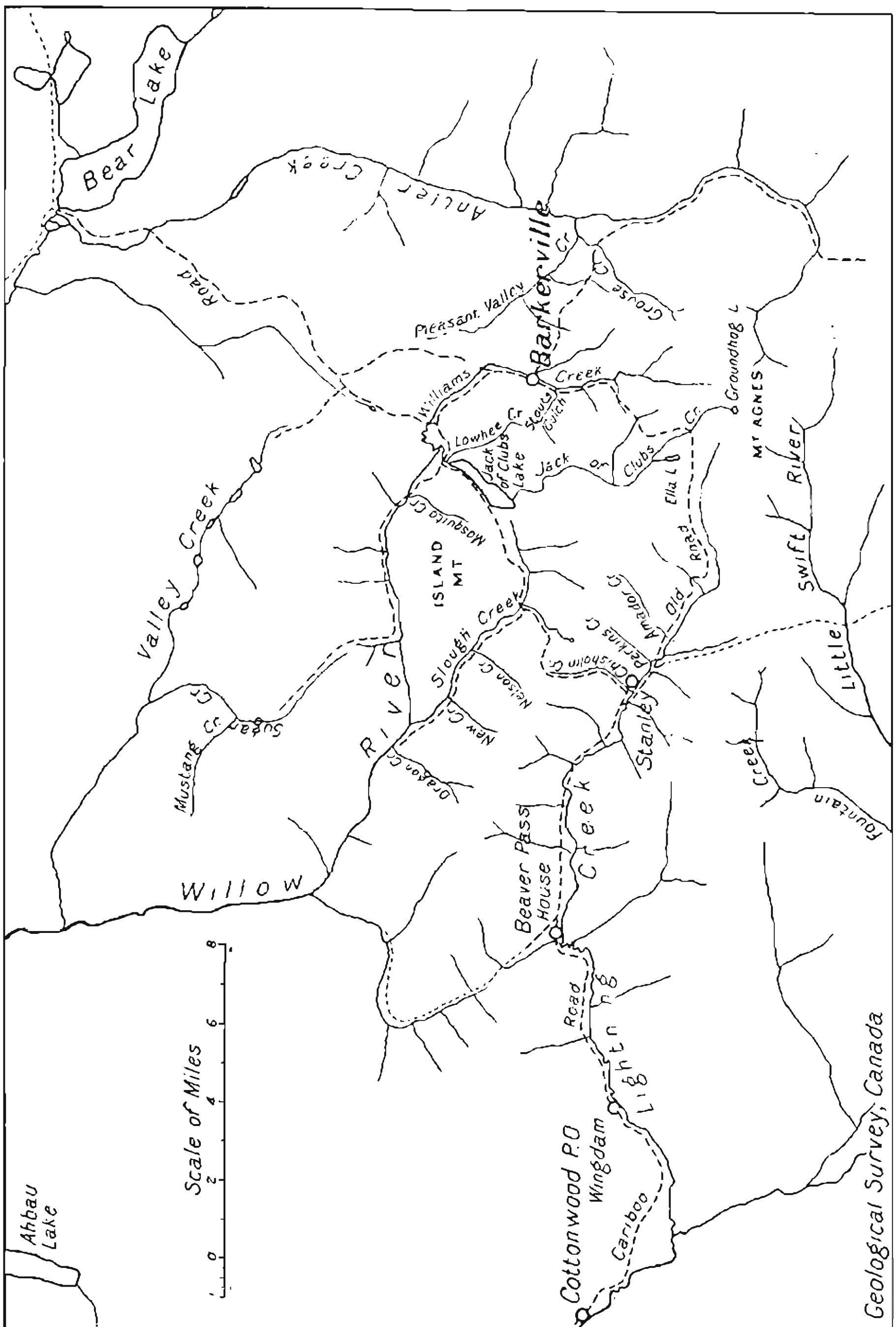

Figure 11. Barkerville district showing location of streams.

GENERAL GEOLOGY

GLACIATION

A remarkable fact and one difficult of explanation is that, although the region was glaciated, the gold placers were not destroyed nor materially eroded. The gold-bearing gravels are in part post-glacial, but by far the most important deposits are preglacial or Tertiary. Their preglacial age is obvious from the fact that the placer deposits are largely buried beneath glacial drift, and because only by the erosion of considerable thicknesses of the bedrock, and concentration of the gold by stream action, could the gold placers have been formed.

Glacial drift is abundant in the area, and in places fills the valley bottoms to a depth of 100 to 250 feet. In many cases, it mantles the sides of the valleys up to over 1,000 feet above the valley floors and, in some places—as on Proserpine mountain—true boulder clay occurs at an altitude of 5,500 feet. At higher altitudes the drift is mostly very thin or is absent, but, as pointed out by MacKay,[1] erratics occur on some of the highest summits, at altitudes of nearly 6,500 feet. The glacial drift in the valleys is nearly all of local origin, but foreign boulders occur. For example, large boulders of conglomerate are fairly abundant in the upper part of Williams creek. Glacial striæ are well developed in places and are particularly distinct on both sides of Williams creek, a short distance above the canyon between Barkerville and the old town of Richfield. Here the striæ trend downstream and show that the ice eroded the bedrock of the valley sides, but did not affect the valley floor which retained very rich placer ground. A considerable area of bedrock, glacially striated and grooved, has been exposed by mining on Cunningham creek. It is stated that considerable quantities of gold were obtained from fissures and depressions in the bedrock at this locality, showing that erosion by the glacier had not been sufficient to remove entirely the preglacial deposits. Striæ also occur at other places in the area. In the valleys they nearly all trend downstream and were, therefore, probably formed by valley glaciers. Moraines formed by the valley glaciers occur in Lightning Creek valley near Stanley, and in Slough Creek and Grouse Creek valleys. These moraines were formed during the closing stage of glaciation, for they are well preserved and occur at the surface in the valley bottoms. There is, therefore, as was recognized by Tyrrell,[2] comparatively little evidence of the presence or effects of an extensive ice-sheet in this region during Pleistocene time. Nevertheless, the presence of erratics and boulder clay at high altitudes, and the foreign derivation of some of the drift in the several valleys, and the occurrence of boulder clay at altitudes too great to be referable to valley glaciers, all go to show that an ice-sheet of considerable thickness did exist.

The glacial drift consists in part of boulder clay and moraine material; in part of stratified sand and silt—the "slum" of the placer miner; and in part of stratified gravels and bouldery deposits. The boulder clay in most places consists of an upper yellowish unstratified clay containing few boulders, and a lower bouldery clay, occurring chiefly in the valley bottoms. The upper clay, probably, was formed from materials included in the ice and deposited after its melting; the lower clay was formed beneath the ice. The moraines are composed of materials deposited at the ends of the glaciers. In many places the stratified sands, silt, and gravel occur chiefly beneath the boulder clay and rest directly on the preglacial gravels and "slide-rock" of the valley floors. The stratified silt and sand above the general drainage level in some of the valleys and beneath the boulder clay, show that in the early stages of glaciation the northward drainage was blocked—probably by an advance of glaciers from Cariboo mountains—and formed glacial lakes. The sands and gravels protected both the preglacial gravels and the bedrock from erosion by the later glaciers.

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[1] Geol. Surv., Can., Sum. Rept., 1918, p. 42 B.

[2] "Was There a 'Cordilleran Glacier' in British Columbia?" Jour. of Geol., vol. 27, 1919, p. 57, J. B. Tyrrell.

The main reasons, therefore, why the placers were not eroded by the glaciers are: (1) that they were partly protected by glacial outwash deposits; and (2) that the ice-sheet which covered the whole region was nearly stagnant. If valley glaciers alone had persisted throughout the Ice-age, the preglacial gravels would probably have been entirely removed, for valley glaciers as agents of erosion are much more effective than an ice-sheet—even of wide extent—that has a low surface gradient. Valley glaciers, however, did exist at the close of the Ice-age and they accomplished some erosion, especially in the upper parts of the creek valleys, which accounts for the absence in places of gold in the gravels.

The glaciation of the area is, in addition, mainly responsible for the exceptionally long life of this placer camp—long, that is to say, compared with that of many other alluvial fields. Although the early prospectors sometimes found the gold-bearing gravels only thinly covered by drift, they also found that in most places the gravels lay beneath a heavy burden of glacial deposits that obscured the ancient rock channels, and owing to their thickness and water-bearing character rendered difficult the recovery of the gold. A considerable part of the gold, therefore, was never touched. Had the area been unglaciated, almost all the gold would probably have been recovered within a few years after it was first attacked.

An interesting feature in connexion with this glaciation is that, so far as is known, only the one boulder clay or till sheet occurs and, as preglacial gravels are known to occur, it is probable the glacial period was—so far at least as the higher parts of the region are concerned—a unit.

ECONOMIC GEOLOGY

PLACER DEPOSITS

The placer deposits may be broadly divided into post-glacial and preglacial gravels, the preglacial being by far the more important. The post-glacial gravels form the surface gravels (except where buried by tailings) in the valley bottoms and in a few places on benches. Their gold content was derived partly by stream erosion of the glacial drift, which contains small amounts of gold included in it, and partly from erosion of the preglacial gravels and bedrock into which the present streams have cut in a few places. The area is largely drift-covered—especially the valley bottoms—and erosion, since the disappearance of the glaciers, has been limited. It is evident, therefore, that the post-glacial gravels cannot be of much importance, except locally.

The preglacial gravels consist of bench and creek gravels largely buried beneath the drift deposits, but some occur near the surface. Most of the Barkerville output was derived from them. The preglacial gravels cannot easily be distinguished from the glacial even where good sections are exposed down to bedrock, for both consist mainly of gravels derived locally and both may be well oxidized or may not. The preglacial gravels are mostly only a few feet in thickness, and are in places characterized by heavy iron minerals, and pebbles or boulders of galena and barytes, and occasionally scheelite. Many of the deposits too, are characterized by large angular slabs of rock known as "slide-rock," apparently an ancient talus. Blocks of this rock, and slightly waterworn gravel and boulders, are partly embedded in disintegrated bedrock or yellowish or bluish clay. The gravels are, in a few places, cemented by iron oxide. The gold in places extends downwards for several feet along the bedding planes and fissures in the bedrock. Residual gravels, that is gravels consisting principally of a resistant rock such as quartz, are present only in small quantities. The preglacial gravels are made up of schists, limestone, quartz, and igneous rocks, derived mainly from the Cariboo schist series named and described by Bowman.[1] The absence

[1] Geol. Surv., Can., Ann. Rept., pt. C, 1887.

of residual gravels is probably due to the youthful character of the present valleys in which the streams have naturally a fairly high gradient and the present valleys coincide, approximately, with the ancient valleys. Residual gravels can be formed only in valleys having a very low surface gradient, for in valleys having a high gradient, fresh rock material is constantly being added to the gravels, which are eroded and carried away.

Bench deposits which occur on many of the creeks at various levels are nearly all confined to the present valleys and seldom cross the present drainage, for, as pointed out by Dawson[1], the courses of the ancient and present streams are very much the same. There are, however, many places where diversion—and even reversal—of stream drainage took place as the result of stream capture in preglacial time. In places, also, the irregular deposition of glacial drift has diverted the streams into new channels, a striking example of which is Black Jack canyon on Williams creek. A characteristic feature of several of the new channels—indicated by their narrow, steep-sided character—is that they rarely contain much gold. Some of these are mainly post-glacial in age, others are preglacial and are partly due to stream capture and possibly also to rejuvenation of the streams by uplift of the region. They contain little gold unless they have been cut down directly beneath the older higher channels, for any gold they happen to contain is the result of erosion of only a small thickness of rock, whereas the concentrations in the old channels are the result of the wearing down of great thicknesses of rock. The gold in the area is mostly coarse, so that little of it is now transported by the streams. Part of it has probably moved downwards, vertically, nearly as far as it has been transported horizontally. The current through the canyons being rapid, any gold fine enough to be transported by the stream would probably be carried through the canyon.

Very little flour gold or even fine scale gold is present; for apparently the streams in preglacial time had sufficient gradient to transport the fine gold out of the region to the lower Fraser, where it has gone to enrich the placers of that region. There is little difficulty, therefore, in saving the gold in the Barkerville district.

Boulder-like masses or pockets of the preglacial gold-bearing gravels are included in the boulder clay in places, especially in its lower, bouldery part. The upper, clayey part is almost free from gold as are also the stratified sands and silts and fine gravel known to the miners as "chicken feed"; but occasional nuggets are scattered through the glacial drift. There have been some notable instances in the district of the finding of masses of gold-bearing gravels included in the boulder clay, but because of their mode of occurrence, such masses are as a rule found only accidentally in hydraulic mining. Where the boulder clay is tight on the bedrock, and contains little gravel, there is little gold. This fact was well known by the early miners, and isolated masses of boulder clay in the upper part of Williams creek remain untouched to this day, although all the surrounding ground was worked. Many of the creeks contain, in their upper reaches, considerabe quantities of coarse bouldery deposits, in places rudely stratified. They are apparently glacial outwash deposits and are as a rule nearly barren of gold.

An instance of the sporadic occurrence of gold in this area was noted during the past summer. Two miners, George Moore and Joseph Spratt, working on the upper part of Walkers gulch, which empties into Williams creek at the old town of Richfield, recovered 7 ounces of gold in three days hydraulicking. The material washed was largely boulder clay, and averaged over $3 a cubic yard, the gold being derived apparently from gravels included in the boulder clay. There was very little gold on bedrock. It is probable that there are many such occurrences in the district.

Antler Creek

Antler creek, discovered in 1860, was the first creek of the Barkerville area found to be auriferous. The rich placers of the Barkerville area were not found by

[1] Geol. Surv., Can., Ann. Rept., vol. III, pt. II, p. 31 R.

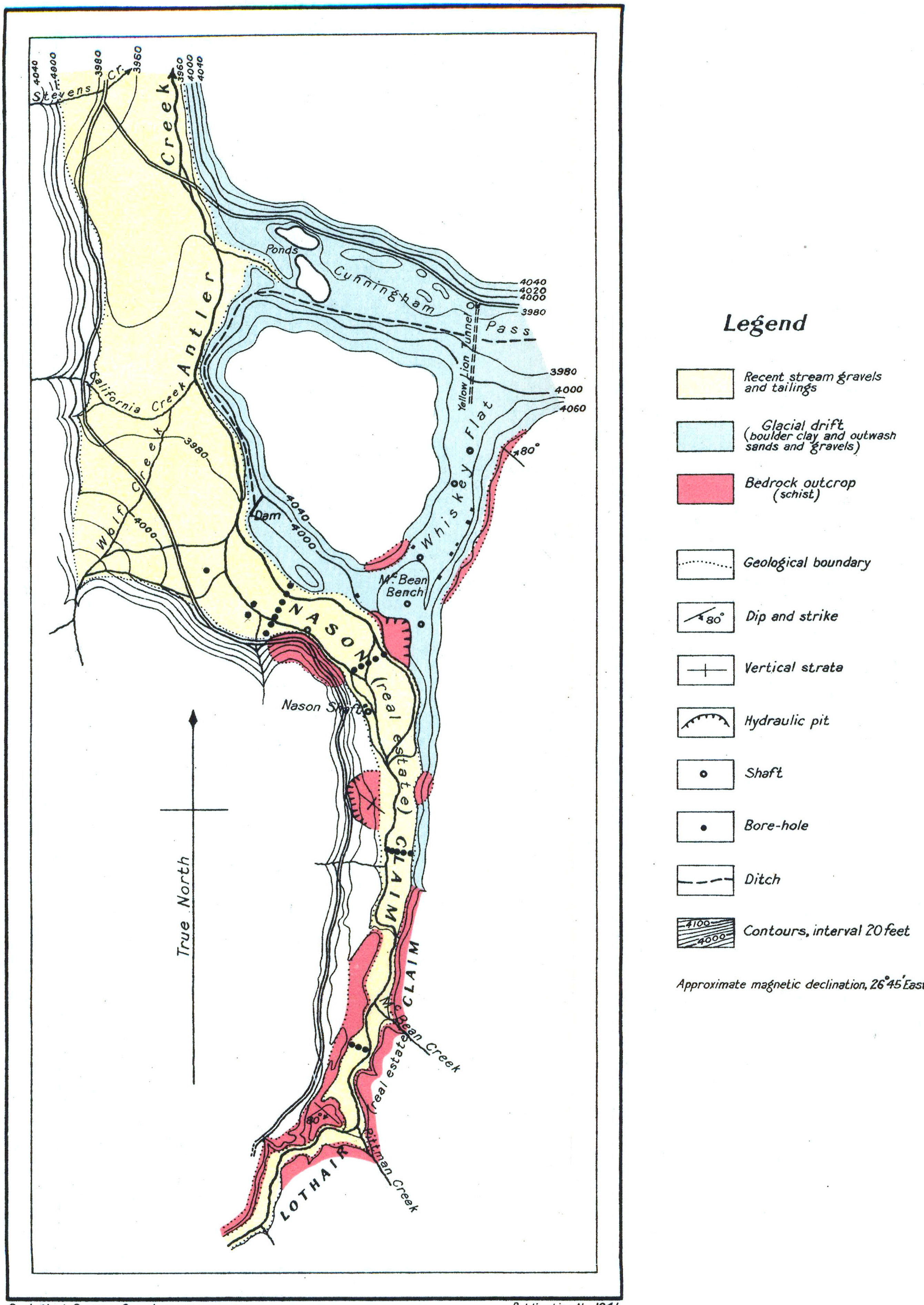
following the trail of fine gold up the Fraser and its tributaries, directly to this area. However, the theory of the miners that this fine gold had its source in a region where coarse gold would be found was undoubtedly the impelling force, as has been frequently pointed out, that led to the rapid discovery of the main placer fields. The theory was more or less sound in respect to Keithley, Harvey, and Cunningham creeks, southeast of the Barkerville area. In 1859, while placer mining was active along Quesnel river as far up as the Forks and Quesnel lake, a number of prospectors made their way up the north fork of the Quesnel, but lost the trail of fine gold at the falls, 5 miles below Cariboo lake; and it was not until the following year that Keithley creek, flowing southeast into Cariboo lake, was discovered. Late in the autumn of 1860 a party of prospectors, among whom were Rose, an American, and McDonald, a Canadian, crossed over the divide at the headwaters of Keithley creek and discovered gold on Antler creek. Little work was, apparently, done on the creek in 1860. The success of the miners becoming known at Keithley, a mid-winter rush ensued and when Gold Commissioner Nind arrived at Antler creek early in March, 1861, he found the snow 6 or 7 feet deep and the miners living in holes dug in the snow, and subsisting on the scanty supplies brought from Keithley.[1]

Antler creek rises in Bald Mountain plateau, flows southeast for several miles to Sawmill flat where it is joined by a tributary from the south, and then flows nearly north to form the headwaters of Bear river. Four miles north of Sawmill flat the creek turns to the west around a hill, to the right of which an old channel, partly drift-filled, extends to the headwaters of a branch of Cunningham creek in Cunningham pass (*See* Map 1941). This old channel is about 80 feet above the bedrock in the present stream channel of Antler and is a continuation of a bench that extends upstream along the left limit of Antler creek for about 3,500 feet and then crosses to the right bank. Above this point a small canyon extends for nearly a mile to the wide, shallow part, where most of the mining in 1861 was done. The remarkably rich and easily mined part of Antler creek was shallow ground extending for about 1½ miles along the stream above the canyon and below Sawmill flats. The daily output of the creek during the summer of 1861 is reported to have been over $10,000 and much of the ground is said to have yielded $1,000 to the square foot.[2]

The benches along the creek below the canyon and down as far as Cunningham pass have been mined, at intervals, partly by drifting and partly by hydraulicking. The early miners recognized that the present stream gravels would be enriched at those places where the present stream valley has been lowered by erosion and has cut across the more ancient stream valley, represented in part by the benches. One of these was at the mouth of the valley known as Whiskey flat where the Nason Company sank two shafts on the left bank of the stream and attempted to drift out into the channel. They are said to have spent, prior to 1875, $20,000 in unsuccessful efforts to test their ground. Work was resumed by a company of the same name in 1884 and was carried on nearly every summer until 1893, but with little success because of the porous, water-bearing character of the river gravels and the absence of any clay that would hold back the surface water. In 1888 the company succeeded in driving part way across the creek bottom, and obtained round, heavy gold at the rate of $1.50 to the bucket; but they were of the opinion that they had not struck the main lead.[3]

The old shaft of the Lothair Company, whose claim adjoins the Nason claim on the upstream side, was located, as shown on Bowman's map of Antler creek, nearly opposite the mouth of McBean creek. This company also appears to have been unable to mine the bedrock gravels in the present stream valley. The Bulger bench on the left limit of Antler a short distance below the mouth of McBean creek was mined in 1861. The Pittman and Porter bench claims on the right limit in the upper part of the Lothair were mined in 1861-62, but no information is available regarding their output. In Whiskey flat the best known claim was McBean bench. In

[1] Bancroft's Works, vol. XXXII, History of British Columbia, pp. 472-494.
[2] Ibid, p. 492.
[3] Ann. Repts., Minister of Mines, B.C., 1875-1893.



Geological Survey, Canada. Publication No. 1941

Part of **Antler Creek**, Cariboo District, British Columbia.

Scale of Feet: 1000 500 0 1000 2000

To accompany report by W. A. Johnston, in Summary Report, Part A, 1921.

Geology and Topography by W. A. Johnston, 1921.

Cunningham pass, at the lower end of Whiskey flat, the Yellow Lion Company found gold on bedrock in 1881. The claim is said to have paid well for several years.[1]

Wolf, California, and Stevens creeks which flow into Antler from the west, in the wide part below the Nason property, were all gold-bearing.[2] Tailings from hydraulicking in the tributary valleys form a part of the filling of the valley of Antler in this wide part.

The dredging ground of Antler creek consists of the Nason (real estate) claim, the Lothair (real estate) claim, and the Macdonald lease. It embraces the comparatively shallow part of the present stream bed, which begins to widen out in the lower part of the Nason claim. Keystone drilling, to determine the depths and gold values of the ground, was done by the Yukon Gold Company in 1915. A few borings were also made subsequently by the New Waverly Hydraulic Mining Company. The results of the drilling showed that the known dredging ground has a length of at least 4,000 feet; the pay gravels have an average width of 140 feet and an average depth of 48 feet, giving a total of 1,000,000 cubic yards. The ground is deepest in the Lothair claim where it has a maximum depth of 69 feet. The average value per cubic yard is 66·3 cents which is reduced to 45 cents to allow for gravels sliding into the pond and for other factors, the total recoverable gold content being estimated at $540,000. One bore-hole in the line near the Nason shaft showed a value of $6.74 per cubic yard. A check hole put down 2 feet away showed a value of $1.34½ per cubic yard and this figure was used as a basis in calculating the average value of the line of holes. The values show that this part of the stream channel is enriched by gold derived from the ancient channel as pointed out above. Twelve hundred and fifty feet of the upstream part of the property has not been drilled, but the values should approximate the general average and should bring the total recoverable gold up to $700,000. The gold is largely coarse and is mostly on or near the bedrock. The bedrock consists of steeply dipping schists which could be dredged without difficulty.

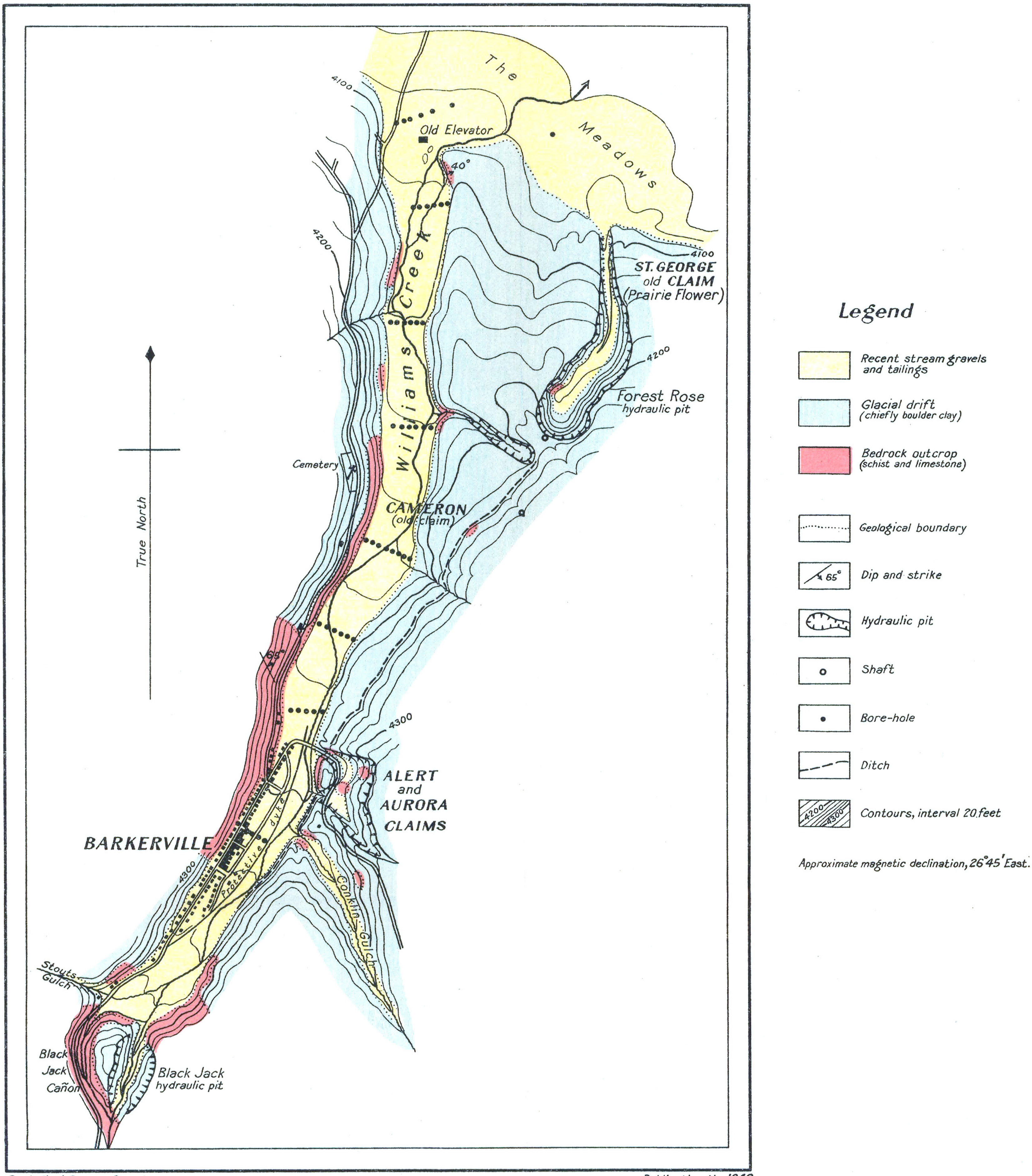
The creek has a grade of 1·4 per cent for 3,000 feet above the Nason shaft and 0·8 per cent from the Nason shaft down to the mouth of Stevens creek. The gravel is mostly fine, with few boulders over 6 inches in diameter and clay is absent. The absence of clay, in fact, has been the chief reason why it has not been found possible to mine the bedrock gravels by drifting. It is possible that a part of the nearly barren upper gravels might be removed by "booming." An excellent site for a dam is in the upper part of the Lothair claim, by means of which large volumes of water could be impounded and the water released automatically to flush out the upper gravels.

The fact that the present channel of Antler creek cuts across the ancient gold-bearing channel in the Nason, and upper part of the Lothair, claims suggests the inference that the ground will dredge up to the drillings. It is possible that the exceptionally rich ground, as shown by the borings on the lower part of the Nason, extends for some distance upstream.

Williams Creek

Williams creek, on which the town of Barkerville and the old town of Richfield (a mile upstream from Barkerville) are situated, heads in Bald mountain and flows north for 5 miles to "The Meadows" where it turns west and forms the headwaters of Willow river. The gold-bearing part of the creek, extending for 1¾ miles above Barkerville and 1 mile below, is naturally divided into two parts, of different characteristics, by the Black Jack canyon, about half-way between Barkerville and Richfield. The canyon is narrow and rock-walled, about 50 feet deep and 1,000 feet long. It forms a bend in the stream around a rock island, on the east side of which the preglacial stream flowed in a narrow valley. The filling of the old valley by glacial drift caused the present stream to be diverted into the new channel. This fact, too, was

[1] Ann. Repts., Minister of Mises, 1881-84.
[2] Dawson, G.M., Geol. Surv., Can., Ann. Rept., vol. III, pt. II, 1887-88, p. 123 R.



Geological Survey, Canada. Publication No. 1942

Part of **Williams Creek**, Cariboo District, British Columbia.

Scale of Feet

1000 500 0 1000 2000

To accompany report by W. A. Johnston, in Summary Report, Part A, 1921.

Geology and Topography by **W. A. Johnston**, 1921.

known to the early miners and in 1862, one year after the discovery, the Black Jack tunnel was begun for the purpose of locating the old channel. In 1867 the property was worked as an hydraulic claim, the first in the area, and it was still being worked in 1890.[1] The drift deposits were eventually almost entirely washed out from the old channel and the stream now flows partly in one channel and partly in the other.

Discovery claim, at the lower end of the canyon, was located in 1861 by William Dietz after whom the creek was named. It proved to be one of the poorest claims on the creek.[2]

The part of Williams creek above the canyon is comparatively narrow and steep-sided. The first important discoveries of gold were made in this part of the creek between the canyon and Richfield. The post-glacial gravels were worked first, the underlying boulder clay being regarded as the bedrock; but the main "pay" was soon found on the Abbott claim by sinking through the boulder clay to the bedrock. It was probably the comparatively lean character of the upper gravels that led to the first naming of the creek as Humbug creek. The main "pay" on the Steele claim consisted of a blue clay layer 6 feet thick containing decomposed slate and gravel, the overburden being 8 to 18 feet thick.[3] This part of the creek was eventually worked by open-cuts from the surface to the bedrock. A poorly-defined bench 50 to 100 feet above the creek bottom occurs along the east side above the canyon and was also worked. The bench has a lesser gradient downstream than the present creek, and—a short distance above Richfield—is nearly at the level of the present creek. The upper part of the creek was found to be barren; the pay stopped abruptly about three-quarters of a mile above Richfield, but was again met with considerably higher up in the tributary valley, McCallum gulch.[4]

The lower part of the creek, below the canyon, is comparatively wide and flat-bottomed, the valley flat averaging about 400 feet in width (*See* Map 1942). Here, the ground is deep, and was mined by shafts, 40 to 80 feet deep, and by drifts. One of the first shafts in this part of the creek is still to be seen in Barkerville. It was put down early in 1862 by Billie Barker, after whom the town was named, and was 52 feet deep.[5] As in the upper part of the creek, here also there were two pay-streaks, one in the post-glacial gravels and the other in preglacial gravels on bedrock. The latter gravels are separated from the upper by glacial deposits consisting in part of boulder clay and in part of stratified silt and gravel. The post-glacial gravels are concealed by tailings that average possibly 20 feet in thickness, and were chiefly derived by hydraulicking in Stouts gulch which enters Williams creek from the west at the lower end of the canyon. The preglacial gravels were mined chiefly in the sixties and were largely worked out from the canyon down nearly to the meadows, where the excessive pressure of groundwater prevented mining. These gravels were remarkably rich. According to the estimate given in the Report of the Minister of Mines, British Columbia, for 1896, this part of the creek produced between $8,000,000 and $9,000,000. The post-glacial gravels also were found in places to be rich. At the famous Cameron claim, about one-half mile below Barkerville, the ground was sufficiently rich to be worked in a series of levels from the surface to bedrock.[6] The claim was located on the east side of the valley flat, the depth to bedrock being 40 feet.[7] There were a few rich claims below the Cameron claim, but farther downstream near the meadows, where the ground was about 80 feet deep, the gold was light and scaly.[8] The richest part, as noted on Bowman's map of Williams creek, was opposite the mouth of Conklin gulch and for about 1,500 feet downstream.

[1] Ann. Rept., Minister of Mines, B.C., 1890, p. 360.
[2] Bancroft's History of British Columbia, p. 497.
[3] Ibid, p. 496.
[4] Bowman's map of Williams creek, Geol. Surv., Can., Ann. Rept., 1895.
[5] Howay and Scholefield, "British Columbia from the Earliest Times to the Present," vol. II, p. 83, 1914.
[6] Milton and Cheadle, "The Northwest Passage by Land," p. 362.
[7] Bowman's map of Williams creek.
[8] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 112.

There were also several rich claims above Barkerville, where the ground was originally 60 feet deep and in 1885—because of the accumulation of tailings—was 80 feet deep.[1]

The most important tributary of Williams creek below the canyon is Conklin gulch, which enters from the east opposite Barkerville. It was mined by drifting throughout a distance of nearly 2 miles, the ground varying in depth from 20 feet, in the upper part, to 90 in the lower.[2] The famous Ericsson and Sawmill claims were located in the lower part, near Williams creek, and the equally famous Aurora was on a bench on the right side, near the mouth. On the right limit of the gulch, near its mouth, are two benches, above the level of Williams Creek flat, and the present stream flows between rock rims nearly at the level of the flat. The deep channel, graded to the bottom of Williams Creek valley, is buried beneath drift. The three claims mentioned above are credited with having produced $1,500,000 in gold.[3]

The Forest Rose property, which was originally mined by a deep shaft and by drifting, and was later worked as an hydraulic mine for over thirty years, is a buried channel running nearly parallel to Williams creek in its lower part, and lies a short distance to the east of this stream (*See* Map 1942). The first hydraulic work on the property began at the St. George cut at the meadows. The St. George property was originally the Prairie Flower, as shown by records in the office of the gold commissioner at Barkerville. The bedrock in the cut was not reached until after several years' work and not until the cut had been carried for some distance up the old channel.[4] The old rock channel is wide, has a low gradient, and is about 50 feet above the bedrock in the adjacent part of Williams creek. It is evidently an old channel of the latter, as is generally recognized by the miners, and not, as was formerly held, a high-level channel extending along the east side of Williams creek from Conklin gulch.[5]. The channel apparently leaves Williams creek at about the location of the old Cameron claim. The part between the head of the Forest Rose pit and Williams was probably mined by drifting in the early days. The small hydraulic pit extending from near the Forest Rose shaft to Williams creek was made in recent years in an attempt to remove the overburden from part of the old channel by washing it directly into Williams creek, for it was found that the grade of the bedrock in the Forest Rose pit was too small to permit of a working gradient for the sluice boxes. Hydraulicking was abandoned in 1912. Although there is little evidence of a high channel occurring between the Forest Rose and Conklin gulch, it is stated by William Brown, of Jack-of-Clubs creek, that the California tunnel shaft 600 feet south of the Forest Rose shaft (shown on Map 1942) was 40 feet deep and that 40 ounces of gold were recovered by drifting from the bottom of the shaft. As the bottom of this shaft is nearly 100 feet above the bedrock in the Forest Rose channel it is evidently in a different channel. However, little gold appears to have been found in other workings along the supposed high level, buried channel between the Forest Rose and Conklin gulch, and it is possible the gold in the California tunnel workings was in a small creek channel tributary to Williams creek.

The Prairie Flower is stated to have had an output of $100,000 and the Forest Rose $480,000, prior to 1896.[6] The latter has produced considerable amounts of gold since 1896. William Brown states that attempts were made in the early days to mine the bedrock gravels in the Forest Rose channel at the meadows, but unsuccessfully, owing to the pressure of underground water. The facts that this channel is about 50 feet above the channel of Williams creek and that it was apparently richer in its lower part than the channel of Williams creek near the meadows, indicate that dredging ground may be found at the lower end of the Forest Rose. This ground has not been tested by borings.

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1 Bowman's map of Williams creek.
2 Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 135.
3 Ann. Rept., Minister of Mines, B.C., 1896, map of Williams creek.
4 Ann. Rept., Minister of Mines, B.C., 1886, p. 196.
5 Geol. Surv., Can., 1895, Bowman's map of Williams creek.
6 Ann. Rept., Minister of Mines, B.C., 1896, map of Williams creek.

The reasons why Williams creek was the richest creek in the region and why certain parts of it were richer than other parts are fairly obvious when the history of mining on the creek and the physical characteristics of the creek are considered. The creek valley trends at an angle of about 45 degrees across the strike of the schists and through a belt in which occur numerous quartz veins, from which the gold was probably derived. The veins are mostly nearly parallel to the strike of the rock, and are apparently most numerous in the zone along the part of the creek where the placers were richest. The barren upper part of the creek was due, probably, in part to glaciation. In the rich part of the creek above the canyon a bench occurs, but it was partly cut away by the present stream. The present stream channel was enriched by gold from the bench and coincides very closely with the ancient channel. At the canyon the old channel was rich and the new channel for reasons already pointed out was of little value. Below the canyon there are no important ancient channels occurring as benches of the creek except the Forest Rose channel. There are, however, several gold-bearing channels tributary to the creek. The present channel, as far down as the old Cameron claim, coincided with the ancient channel, so that large quantities of gold derived from the wearing away of a great thickness of rock were concentrated in it; and the structure and character of the bedrock throughout the creek bottom were ideal for retaining gold. The remarkably rich character of the post-glacial gravels at the Cameron claim was due probably to the present stream cutting into the bench of the Forest Rose channel.

Attempts have been made, notably by the Cariboo Gold Fields Company (using at first an hydraulic lift and later a bucket elevator) to mine the whole of the gravels of the part of Williams creek below the canyon, for it was generally held that because of the crude methods of mining and of saving the gold at the time when nearly all the mining was done on this part of the creek, and because of the large amounts of gold recovered, there must be a considerable amount remaining. In this connexion, the following observation of G. M. Dawson[1] is of interest. "I do not think it would be an extravagant statement to say that the quantity of gold remaining in the part of Williams creek which has been worked over, is about as great as that which has been already obtained." It was also known that there were in places upper pay-streaks which were not mined in the early days because the bedrock gravels were much richer and because of the high cost of mining. The attempts by the Cariboo Gold Fields Company to mine the gravels failed because of mechanical difficulties in the operation of the lift and elevator.[2] The location of the elevator is shown on Map 1942.

The dredging ground on Williams creek extends from the lower end of the canyon or mouth of Stouts gulch to the meadows, a distance of 8,000 feet. The ground was tested by Keystone drilling in 1914 and 1915, eight lines of bore-holes being put down at fairly regular intervals across the valley.

The results of the borings showed that the pay gravels average nearly 240 feet in width and have a maximum depth of 76 feet, with an average of 59 feet. The average value is 31 cents per cubic yard, which would probably have to be cut down 2 or 3 cents to allow for gravels sliding into the pond and for other factors. The total amount of pay gravels is approximately 4,000,000 cubic yards. Owing to lack of borings there is some doubt as to the yardage and values in the part above Barkerville.

For the reasons stated above it is surprising that the results of the drilling did not show higher values, and it seems possible, when the ground is actually dredged, that in places it will produce higher values. It is possible, also, for the reasons stated above, that dredging ground may be found at the lower end of the Forest Rose, and in places in the Williams Creek and Willow River flats. It is known that the ground in the flats or meadows is for the most part too deep for dredging. There are, however, favourable localities such as the flat or the mouth of Mosquito creek, and at

[1] Geol. Surv., Can., Rept. of Prog., 1876-77, p. 114.
[2] Ann. Repts., Minister of Mines, B.C., 1889, p. 621, and 1903, p. 60.

the mouths of Eureka and McArthur creeks which empty into Williams creek at the meadows. At these places the post-glacial gravels were, probably, enriched by gold from the tributary creeks.

The bedrock of Williams creek consists of schist and limestone beds dipping steeply towards the northeast. The rock is mostly soft and could be easily excavated in dredging.

Possible objectional features of the Williams Creek dredging ground are the depth of the deposits, the timbers in the old underground workings and in the bedrock drain which was built in 1865-66 and extends throughout the area, and the presence in places of boulder clay. It is possible that much of the underground workings has caved. The gravel deposits contain few large boulders and the boulder clay occurs only in places. It is possible, too, that a considerable part of the tailings which form a nearly barren overburden might be removed by "booming." An excellent site for a dam is at the lower end of Black Jack canyon, in which large volumes of water could be impounded to flush out the tailings. The creek, from the lower end of the canyon to the meadows, has a surface gradient of 2·6 per cent. During the past few years the creek itself has cut down the tailings in places as much as 4 feet. The lowering of the creek bed at Barkerville, which is protected from creek floods by a bulkhead, would also make it possible to work Conklin gulch to the best advantage, either by hydraulicking or by dredging, for, as already pointed out, the ground is deep in the lower part near Williams creek and this was the richest part of the gulch.

There is, possibly, dredging ground on Lightning creek and at other places in the district also. The writer's investigations, however, were confined chiefly to the areas described above.

SUMMARY

Gold dredging has not as yet been attempted in Barkerville area, although it has been known for many years as a suitable dredging proposition. But the high cost of machinery, of supplies in general, and of transportation, has so far been a deterrent to speculation. There is, however, a probability of dredging being started soon on Antler creek, and possibly, at other places in the region. The results of Keystone drilling on Antler and Williams creeks have shown that, in parts of the creeks, gold to the amount of at least $1,800,000 exists, of which the greater part is recoverable. In this paper an attempt has been made—by reciting the history of mining on the creeks and describing their physical characteristics—to show that the estimates of gold values, as evidenced by the borings, are moderate and that the known dredging ground may possibly be extended.

GEOLOGY OF THE NORTH THOMPSON VALLEY MAP-AREA, B. C.

By W. L. Uglow

CONTENTS

Illustrations

INTRODUCTION

The North Thompson Valley area extends from Fishtrap rapids, 27 miles north of Kamloops, to the vicinity of Boulder (Figure 19). The east and west boundaries of the area are from 3 to 10 miles on each side of the river, sufficiently far apart in most cases to include the slopes of the Thompson trench and a part of the adjoining plateau. The Canadian National railway fringes the east bank of the North Thompson throughout the length of the sheet.

Canada
Department of Mines

Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister.

GEOLOGICAL SURVEY

W. H. Collins, Director.

Issued 1922

PRELIMINARY MAP

LEGEND

QUATERNARY
- RECENT — Q — *River gravel, sand, silt ("White silt")*
- PLEISTOCENE — *Glacial drift*

TERTIARY
- MIOCENE — T2 — Skull Hill formation *(hornblende and augite andesites)*
- EOCENE — T1 — Chu Chua formation *(conglomerate, arkose, shale, coal)*

MESOZOIC (?)
- JURASSIC ?
  - 6 — Peterson Creek syenite
  - 5 — Baldy biotite granodiorite and granite
  - 4 — *Biotite granodiorite and quartz diorite sills*
  - 3 — *Micropegmatite pyroxenite sills*
  - 2 — Darlington hornblende granodiorite and granite

PALÆOZOIC OR PRECAMBRIAN
- A2 — Barrière formation *(quartzite, sericite schist, argillite, limestone, chlorite schist)*
- 1 — Fennell formation *(greenstone sills and pillow lava)*
- A1 — Badger Creek formation *(micaceous quartzite, quartz slate, biotite schist, hornblende schist, dolomite)*

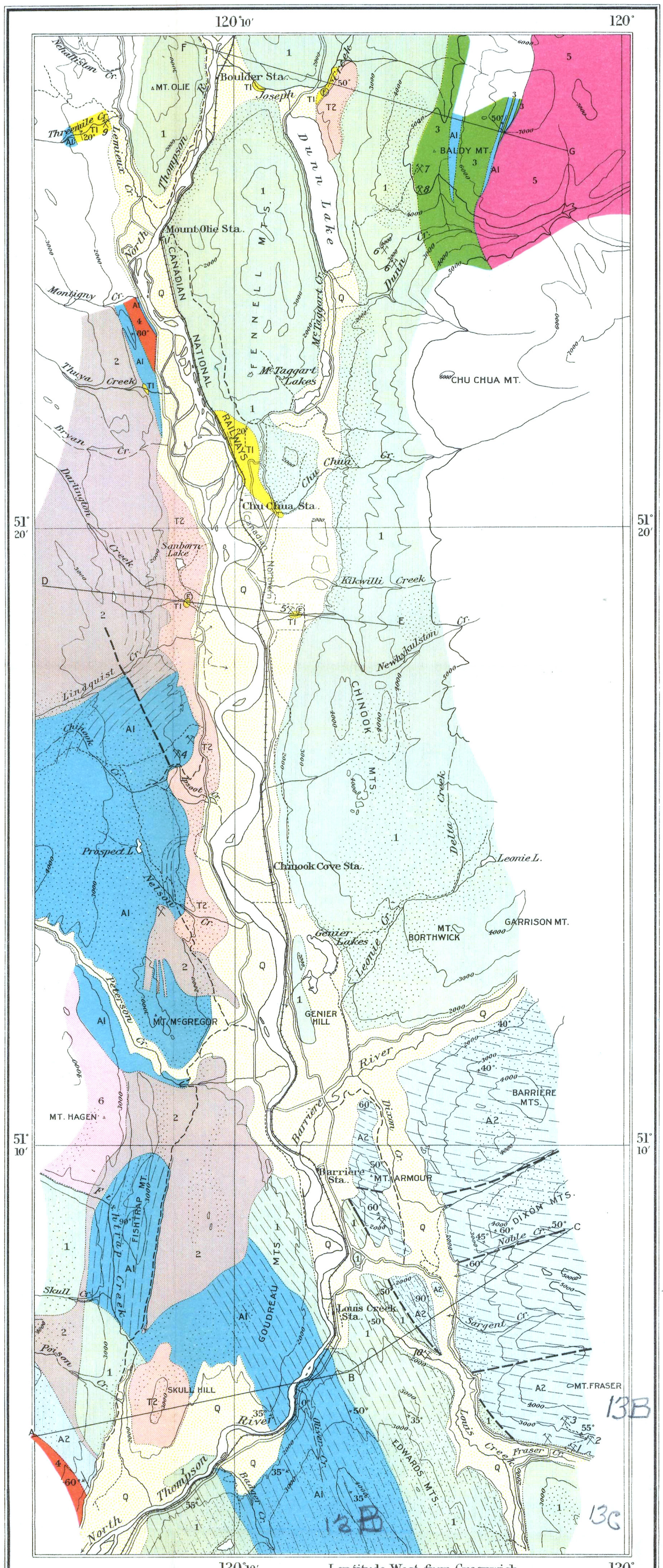
Symbols

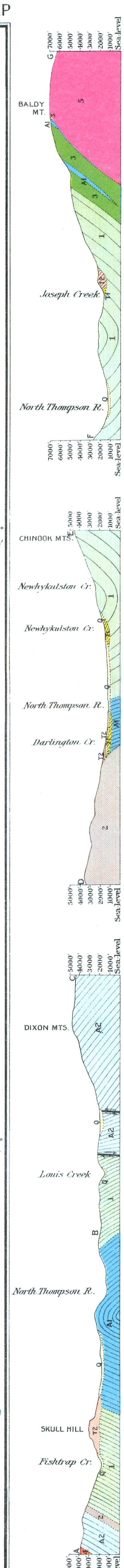
- Geological boundary *(defined)*
- Geological boundary *(approximate)*
- Fault
- Regional strike of bedding
- 35° Dip and strike
- (F) Fossil locality
- ⚒5 Mine, prospect, or placer digging
- Road
- Road not well travelled
- Trail
- 5000 Contours, interval 1000 feet

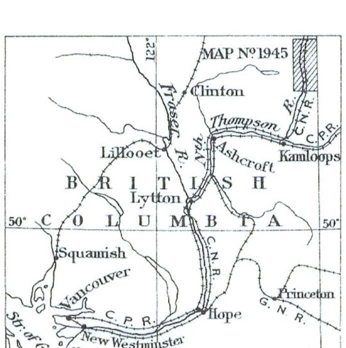
Approximate magnetic declination, 25°30' East

MINES, PROSPECTS, OR PLACER DIGGINGS

1. FORTUNA
2. PLATO
3. SKOOKUM
4. ALLIES
5. CHU CHUA COAL-FIELD
6. GOLD HILL
7. WIND PASS
8. SWEET HOME
9. THREE MILE PLACER
10. LOUIS CREEK PLACER







Scale, 100 Miles to 1 inch.

C. O. Senécal, *Geographer and Chief Draughtsman.*
A. McGregor, *Draughtsman.*

Publication No 1945

NORTH THOMPSON VALLEY BETWEEN JOSEPH CREEK AND LOUIS CREEK, KAMLOOPS DISTRICT, BRITISH COLUMBIA.

Scale of Miles

1 ½ 0 1 2 3 4 5

To accompany Report by W. L. Uglow, in Summary Report, Part A, 1921.

Sources of Information
Geology by W. L. Uglow, *1921.*
Base-map prepared from topographical map-sheets of the North Thompson Valley, by D. A. Nichols, *1918, 1919.*

The geology was plotted on an excellent topographical base map made by D. A. Nichols, Geological Survey, during the seasons of 1918 and 1919. The rugged character of most of this country, and the thick timber, made mapping difficult, and it is a pleasure to acknowledge the extent to which the base map facilitated the work of the geologist.

The geological mapping was done on a scale of 4,000 feet to 1 inch. Traverses were run by the Brunton compass and aneroid method. Three and one-half months during the summer of 1921 were occupied by this work. Special attention was paid to the coal and mineral deposits. Short trips were taken outside the boundaries of the sheet, particularly to correlate the geology of the Adams and Barrière Lakes districts, as described by Dawson and Daly, with that of the North Thompson valley to the west.

The progress of the work was greatly facilitated by the courtesy and assistance of the settlers of the district. Special acknowledgments are due to the officers of the staff of the Chu Chua Coal Company; to W. J. Smith of Louis Creek; to J. J. Smith of Chinook Cove; and to George Fennell of Chu Chua. Very valuable assistance was given at times by D. A. Nichols, whose suggestions were the means of saving considerable time in geological mapping.

C. O. Swanson rendered efficient assistance in every branch of the work; and on occasions he was allotted semi-independent investigations. C. J. Cock also acted as field assistant.

PREVIOUS WORK

Previous geological investigations of this and adjacent areas had been made by the following members of the Geological Survey:

A. R. C. Selwyn[1] in 1871 made a traverse up North Thompson River valley from Kamloops and continued his reconnaissance beyond Tête Jaune to the Rocky mountains. He gives some preliminary notes on the occurrence of the Lower Cache Creek series, and the Tertiary lavas of the North Thompson; and on the granite gneiss and mica schist series near Raft river.

G. M. Dawson[2] in 1877 made a reconnaissance geological map covering 250,000 square miles of southern British Columbia. He reported briefly on the geology of North Thompson River valley, as far north as the Indian reservation near Chu Chua. He describes the first detailed section of the Tertiary coal measures, which are exposed in the valley of Newhykulston creek. His map, on a scale of 8 miles to 1 inch, is exceedingly general, and its northern boundary passes just south of the present village of Chu Chua.

G. M. Dawson[3], during the seasons of 1888, 1889, and 1890, geologically mapped the area of the Kamloops sheet (Figure 19). This work was done on a scale of 4 miles to 1 inch and embraced an area of 6,400 square miles. The areal and structural geology was, of necessity, done in a broad and general fashion, but with certain detailed examinations and sections in some of the crucial areas. His correlation of geological series was carried out in a tentative manner from the eastern slopes of the Coast range across the Interior plateau to the Selkirk and Rocky mountains. In many respects, it was based on the occurrence in widely separated districts of similar lithological successions of formations. Dawson describes the geology of the North Thompson valley from Kamloops to Chu Chua, and the distribution of the formations is shown in the extreme northeastern corner of his map. The structure, petrography, and economic geology of this part of the valley are dealt with in some detail. No new information is presented with regard to the Tertiary coal measures on Newhykulston creek.

G. M. Dawson, in the years following the completion of his Kamloops report, geologically mapped the area of the Shuswap sheet, which immediately adjoins on

[1] Geol. Surv., Can., Rept. of Prog., 1871-72.
[2] Geol. Surv., Can., Rept. of Prog., 1877-78.
[3] Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894.

the east (Figure 19) and slightly overlaps the Kamloops sheet. The Shuswap map includes an area of 6,400 square miles on a scale of 4 miles to 1 inch. Unfortunately Dawson was unable to complete his Shuswap report, so that the only published record of his results is embodied in his Shuswap geological map[1] and its marginal notes.

R. A. Daly,[2] in 1911 and 1912, carried on a geological survey of a belt of country paralleling the Canadian Pacific railway from Clan William on the east to a point 11 miles east of Kamloops. He extended his mapping to include the shores of Adams and Shuswap lakes, and outlined a general revision of Dawson's correlation. The work of the present writer in 1921 was extended easterly to the shores of Adams lake, and an areal connexion was thus established with the work of Daly.

TOPOGRAPHY AND CLIMATE

The North Thompson valley lies near the eastern margin of the Interior plateau. The strip of country included in the North Thompson Valley map-area is chiefly confined to the flat valley bottom and the rather steep valley slopes. In places, the map extends easterly from the lip of the valley to take in parts of the relatively flat uplands.

North Thompson river has entrenched itself from 2,500 to 3,000 feet below the level of the plateau. The gently undulating plateau country above altitudes of 3,500 to 4,000 feet is in very marked topographical contrast with the steep and in some places, rugged and rocky sides of the valley (Plate III A). The lower slopes are finely terraced, whereas the valley bottom is unusually flat and has an average width of one mile. Here and there isolated knolls and ridges stand in the middle of the valley, erosion remnants whose tops still rise very nearly to the general level of the plateau (Plate III B).

A large part of the district is drift-covered and well timbered. The chief areas of exposed rock are confined to the more rugged portions of the sides of the valley, the stream and river canyons, and the few monadnocks which rise above the plateau.

The area of the sheet lies just beyond the northeastern margin of the "Dry belt". The sage-brush country, so characteristic of Kamloops and the valley of Thompson river, does not extend northerly as far as Fishtrap rapids, a few miles south of which is a rather abrupt transition from treeless to timbered country.

The climate is warm and comparatively dry in summer with occasional rains. The precipitation is not sufficient, however, to render the flat terrace-lands arable, without irrigation; but barren-looking valley flats may be converted by irrigation into rich fruit-growing ground.

GENERAL GEOLOGY

GENERAL STATEMENT

The lower formations of the district, namely the Badger Creek, Fennell, and Barrière, consist of a series of quartzite, quartz slate, micaceous quartzite, sericite schist, chlorite schist, limestone, dolomite, argillite, argillaceous schist, greenstone pillow lava, with intrusive gabbro and diorite masses. They were included in the Cambrian system by G. M. Dawson, but later work shows this correlation to be doubtful. They are here classified as Precambrian or late Palæozoic.

These rocks are intruded by dykes, sills, stocks, and a batholith, consisting of granodiorite, granite, quartz diorite, micropegmatite-pyroxenite, alkaline syenite, aplite, and pegmatite. The age of these intrusives is not definitely known, but they belong, probably, to the period of Coast Range intrusion.

The above-mentioned formations are overlain unconformably by a series of late Eocene sediments consisting of basal conglomerate, arkose, arenaceous shale, and coal,

[1] Geol. Surv., Can., Map 604, 1898.
[2] Geol. Surv., Can., Mem. 68, 1915.

which are confined to certain protected re-entrant positions near the bottom of the North Thompson trench. They are erosion remnants of a much more widespread series of mechanical and organic sediments. These sediments are unconformably overlain by a thick cover of Miocene augite-hornblende andesite flows, which have baked and somewhat metamorphosed the Eocene sediments. These two Tertiary formations have been considerably faulted and eroded, and, later, covered by glacial drift. Post-Pleistocene lava was found in Mann creek, overlying Recent stream gravels.

The North Thompson river occupies an antecedent course inherited from Cretaceous times. Its Cretaceous valley is still preserved as a slight depression in the uplifted Cretaceous peneplain.

The North Thompson valley was developed at least to its present depth in Middle Eocene time, for the Chu Chua (Eocene) sediments are now found along its lowest slopes. The valley was later flooded by Miocene lavas, and was re-excavated during the late Tertiary. Evidences of extensive glaciation are found in the valley, and on the highest peaks up to an altitude of 7,500 feet.

Several prospects are located in or near the map-area. The most important metalliferous deposits known are the Gold Hill, carrying free gold with galena; the Wind Pass and the Sweet Home, carrying free gold, magnetite, and native bismuth; the Queen Bess, a silver-zinc-lead deposit; and the Homestake, a silver-lead-barite deposit near Adams lake. The chief economic interest of the area, from a mining standpoint, is the occurrence of coal in the Eocene measures at Chu Chua. During the summer and autumn of 1921 active development and mining was being carried on by the Chu Chua Coal Company.

Table of Formations

Formations			Rock types
Quaternary	Recent		Lava River gravels, sands, silts, "White Silts" of Dawson
	Pleistocene		Glacial drift
		Unconformity	
Tertiary	Miocene	Skull Hill	Hornblende andesite Augite andesite Andesitic breccias Amygdaloidal andesite and basalt
		Unconformity	
	Eocene (Middle or Upper)	Chu Chua	Sandy shale Coal seams Arkosic sandstone Intraformational conglomerate Basal conglomerate
		Unconformity	
Mesozoic (?)	Jurassic (?)	Peterson Creek stock Baldie batholith Sills Sills Darlington stocks	Porphyritic alkali syenite Granite, porphyritic granodiorite Biotite granodiorite, quartz diorite Micropegmatite-pyroxenite Hornblende granodiorite, hornblende granite, orthogneiss

Table of Formations—Continued

Intrusive Contact

Palæozoic or Precambrian		Barrière	Quartzite, sericitic quartzite, sericite schist, quartz pebble conglomerate, argillite, crystalline limestone, chlorite schist, schistose amygdaloidal lava.
		Fennell	Ellipsoidal (pillow) greenstone, gabbro and diorite sills, chert, volcanic breccia.
		Badger Creek	Slaty quartzite, quartz slate, biotite schist, dolomite, hornblende schist.

DETAILED DESCRIPTIONS OF FORMATIONS

Badger Creek Formation

The Badger Creek formation consists of a series of metamorphosed sedimentary and volcanic rocks, now largely schistose. They are predominantly grey, green, and greyish-black. The rocks are of the following types beginning with the highest members:

Schistose andesitic tuff, a transitional type between this and the Fennell formation.
Biotite schist.
Micaceous, thin-bedded, flaggy quartzite.
Dolomitic quartzite.
Quartz slate.
Silicified argillite.
Thin, fine-grained, dolomite and limestone beds.
Hornblende schist.

The series is intruded by small sills of granite and dykes of pegmatite which have limited outcrops, but which are believed to be connected with the Darlington granodiorite.

The Badger Creek formation is the lowest stratigraphic unit in the map-area. It is exposed (1) in the vicinity of Badger creek, where the formation crosses North Thompson river in a northwesterly direction; (2) north of Peterson creek on the west side of North Thompson river; and (3) in elongated strips in the neighbourhood of Thuya and Montigny creeks, and to the west of the crest of Baldie. These areas are unconnected and their rocks are referred to the Badger Creek formation chiefly on the basis of their lithology.

The dips vary from 0 degrees to 90 degrees, and in general the beds are steeply inclined.

In the belt which crosses North Thompson river at Badger creek,[1] the most complete section of the formation is exposed. The structure at this place is a gentle anticline, as shown in the structure section on line A_1-A_2-B (*See* Map 1945). The crest of the anticline is well exposed along the road 1½ miles northeast of the mouth of Badger creek. A section of the northeasterly limb of the anticline shows a thickness of about 3,500 feet.

In the area north of Peterson creek the rock relations are considerably obscured by a heavy mantle of timber and glacial drift, and the formation is broken up and metamorphosed by intrusions of Darlington granodiorite. This section is, therefore, only tentatively correlated with the Badger Creek formation.

In the Thuya and Montigny Creeks, and Mount Baldie areas, only narrow strips, consisting chiefly of quartz slate, thinly-bedded micaceous quartzite, and minor amounts of limestone and chlorite schist, are exposed, so that the assignment of these

[1] Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894. Plate of sections.

rocks to the Badger Creek formation is also tentative. Just west of the crest of mount Baldie, the westerly-plunging contact of the Baldie granodiorite truncates the quartzite and quartz slate beds of this formation.

Age and Correlation. No data were obtained within the map-area which would definitely aid in establishing the age of this formation. It is equivalent to the Niskonlith series (Lower Cambrian) of Dawson.[1] It has a distinct Cordilleran trend, and Dawson shows it to extend southeastwards with one gap, to the vicinity of Niskonlith lake.

Fennell Formation

This formation consists chiefly of a complex of altered basic rocks of intrusive, extrusive, and fragmental characters. It covers a larger area than any other formation within the boundaries of the sheet, and extends from its southern to its northern edges. It is classified by Dawson[2] as a lower part of his Adams Lake series.

South of Barrière river, the Fennell formation is made up of chlorite schist, slightly schistose fine-grained greenstone, with beds of schistose tuffs. These rocks conformably overlie the upper part of the Badger Creek formation and have a gradational contact with the latter. They are intruded by dykes and sills of diorite and gabbro of medium to coarse grain, in which the ferromagnesian minerals are sufficiently chloritized to give the rocks dull green colours.

North of Barrière river, the east side of North Thompson valley is bordered by abrupt, smoothly glaciated bluffs of brownish-weathering medium- to fine-grained greenstone (probably metabasalt). These bluffs constitute the Chinook mountains and Genier hill. In the vicinity of Chu Chua this formation spreads and occurs in somewhat isolated ridges in the middle of the main river valley. Examples of these ridges are Fennell mountains, mount Olie (Plate III B), and Queen Bess ridge. These ridges present the most striking topographic features of the sheet. The rocks composing them are mostly ellipsoidally weathered greenstone, associated here and there with sill-like and dyke-like masses of altered hornblende gabbro. Their most characteristic trait is their pillow structure (Plate IV A). This is exceedingly well shown on the cliff sides near Genier lake and along the Canadian National railway between Chu Chua and Mount Olie. They are interpreted as lava flows, probably of submarine origin.

Lenticular masses of thinly-bedded grey to white chert occur in association with the pillow lavas. This chert is formed, probably, by the interaction of the lava with sea water and its association recalls that of submarine lavas and chert beds of the Lake Superior iron district,[3] of county Tyrone, Ireland,[4] of the Isle of Man,[5] of Hawaii,[6] of Newfoundland,[7] and other districts.

A close examination of the "pillows" brings out the structure illustrated in Plate IV B. The outer parts of the "pillows" are dark bluish green, dense, and minutely fractured. The spaces between the broken parts of the peripheries and between adjacent "pillows" are filled with chert or chalcedonic quartz, probably of similar origin to the chert beds mentioned above. The cores of the "pillows" are slightly less dense than the outsides, and show concentric rings of much altered greenish amygdules. Coarse-grained calcite is associated here and there with the chert of the inter-pillow spaces.

In places long narrow lenses and beds of fine-grained white limestone or dolomite occur within the greenstone. These also seem to be the result of some process of interaction of the basic lavas with seawater and hence are of inorganic origin and nonfossiliferous.

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[1] Bull. Geol. Soc. Am., vol. II, pp. 165-176.
Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894, p. 31 B.

[2] Geol. Surv., Can., Ann. Rept., vol. VII, N. S., 1894, pp. 102-108 B.

[3] U.S. Geol. Surv., Mon. 52, pp. 506-512.
U.S. Geol. Surv., Mon. 36, pp. 112-124.

[4] Geikie, "Ancient Volcanoes of Great Britain," vol. I, pp. 240-241.

[5] Idem, vol. II, p. 24.

[6] Dutton, "Hawaiian Volcanoes," U.S. Geol. Surv., 4th Ann. Rept., 1884, pp. 95-96.

[7] Daly, "Variolitic Pillow Lava from Newfoundland," Am. Geol., vol. 32, 1903, p. 77.

Within this formation, at several places north of Chu Chua, long, narrow, dyke-like masses of buff-coloured siliceous ferrodolomite occur. These masses show gradational contacts with the greenstone, and are evidently the results of the carbonatization of belts of the greenstone along zones of shearing. They are important as the country rock of some of the mineral deposits, notably the Gold Hill and the Queen Bess. They are locally called dykes. Most of the greenstone has sufficient secondary calcite and dolomite scattered through its mass to produce a ready effervescence with hydrochloric acid. The liberation of calcium and magnesium carbonates during the process of the uralitization and chloritization of the ferromagnesian minerals accounts, probably, for the occurrence of at least some of the material of the ferrodolomite zones.

Structure. The exposures of the Fennell formation lying to the north of Barrière river and to the southwest of Louis creek were not found in areal connexion. The Fennell rocks which immediately overlie the Badger Creek formation southwest of Louis creek, are chlorite schists which grade upward into massive fine to medium-grained greenstones (meta-andesite and meta-basalts) in the vicinity of Blucher Hall. The lithological similarity of the greenstones immediately south of Blucher Hall, and for several miles thence in a southern direction up the valley of Louis creek, to those north of Barrière river is the reason for their correlation.

The areal geology indicates quite positively the position of a fault zone striking in a northeast direction up the valley of Barrière river (Figure 19). The block of country north of Barrière river appears as if it had been offset in an easterly direction with relation to the country south of the fault. The actual direction of the fault movement cannot be determined. With this interpretation, the belt of Fennell rocks north of Barrière river would correspond with that part lying on the western flank of the Badger Creek anticline near Skull hill (Structure section A_1-A_2-B).

As shown in the structure sections on lines C-D and E-F (*See* Map 1945) the northern part of this formation is believed to be in synclinal attitude, with the upturned edges of the underlying Badger Creek quartzites and quartz slates showing along its east and west margins.

Age and Correlation. No information tending to determine the age of this formation was obtained as a result of the season's work. The series corresponds to, and is in areal connexion with, the lower part of Dawson's Adams Lake series of Cambrian age occurring along the upper reaches of Louis creek.[1] It lies immediately below Daly's Bastion schists of Skaam bay, Adams lake, and is probably identical with his greenstones ("probably in part intrusive") of pre-Beltian age, as shown on his map of Shuswap lake.[2] It does not correspond with Daly's Adams Lake greenstones (pre-Beltian) which represent only the upper part of Dawson's Adams Lake series.

Barrière Formation

This formation consists of metamorphosed sediments, with minor amounts of volcanic flow and fragmental rocks. It is exposed chiefly in the country between Barrière river and Louis creek, and extends continuously eastward to Adams lake. A small section of these rocks occurs in the immediate southwest corner of the map, between Poison and Whitewood creeks.

The prominent petrographic types are grey and black-banded argillite, with cleavage crossing the bedding planes; brownish-weathering, fine-grained sericitic quartzite, which is characterized by the thinness (½-inch to 1-inch) and persistence of its individual beds; brownish to buff-coloured sericite schist; fine-grained, white to grey, massive limestone; dolomitic quartzite; schistose quartz pebble conglomerate; silicified argillite; talc schist; white, glistening, fissile, sericite schist; greyish green tuff; and schistose amygdaloidal metabasalt.

[1] Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894, p. 108 B.
[2] Geol. Surv., Can., Mem. 68, 1915.

Structure. The rocks of this formation on the western and southern slopes of Barrière and Dixon mountains and mount Fraser, form a very marked topographic unit. They have a fairly uniform strike varying between due east and south 60 degrees east, and they dip 35 degrees to 50 degrees to the northeast. In mount Armour, which is separated from Barrière mountains by a broad alluvial flat, the strike and dip vary as shown by the pattern on the geological map until they coincide with those of the Fennell schists at the junction of the two formations.

A vertical north and south section from Blucher Hall to Barrière river shows a thickness of over 32,000 feet of beds. The series, however, has been strike-faulted in several places in such a manner as to cause repeated duplications. Three of these faults are located on the map. Their courses could not be closely ascertained on account of the covering of timber and drift, but zones of very marked brecciation combined with topographic breaks indicate approximately the positions and trends of the fault zones. No estimate could be formed of the actual formational thickness exposed, but it is believed to be very much less than the figure above quoted.

The Barrière formation overlies the Fennell formation, but they are in juxtaposition along a fault contact near Louis creek. The drag of the Barrière quartzites, limestones, and schists against the Fennell greenstones is indicated on the map by the curving of the lines of regional strike. The relative movement along this fault and its effect in obscuring the lower parts of the Barrière formation are shown in the structural section on line A_1-B_2-B.

The Barrière River fault (Figure 19) separates this formation from the Fennell greenstones to the north.

Age and Correlation. No field evidence was obtained that would help to determine the age of this formation. The limestone members are all crystalline, and unlikely to yield fossils.

The Barrière formation was traced from Blucher Hall along the road to Adams lake, and was found to connect with the area of the Bastion schist of Daly at Skaam bay. This area is mapped provisionally by Daly as Bastion formation (pre-Beltian) for the reason that its lithology is similar to that of his type Bastion section 30 miles to the southeast[1]. On this account the present writer preferred not to use the same formational name for the series on the North Thompson.

Dawson, on the other hand, has included the Fennell and Barrière formations of the North Thompson valley and Daly's Bastion schists at Skaam bay in his Adams Lake series (Cambrian).[2] Daly restricts his Adams Lake greenstones ("effusive") to the upper or volcanic part of Dawson's Adams Lake series which overlies the Skaam Bay Bastion schists. These chlorite schists and greenstones of Daly's Adams Lake group do not, the writer believes, extend to the North Thompson map-area. They are probably cut off by the Barrière River fault and by the Baldie batholith. (Figure 19).

[1] Geol. Surv., Can., Mem. 68, 1915, p. 20.
[2] Geol. Surv., Can., Maps Nos. 604 and 143 A.

The relationships of the Badger Creek, Fennell, and Barrière formations to the formations of Dawson and Daly are represented in the following table:

	G. M. Dawson		R. A. Daly	W. L. Uglow	
	Stratigraphy shown on the Kamloops and Shuswap sheets		Stratigraphy shown on the Shuswap Lake sheet	Stratigraphy shown on the North Thompson sheet	
Cambrian	*Adams Lake series* Upper portion: green schists of volcanic origin ←	Pre-Beltian	→ Adams Lake greenstone.. ←	→ Not on North Thompson sheet	Cut off by Barrière River fault
Cambrian	(Dawson maps this limestone belt as belonging to the Cache Creek group (Carboniferous)) ←	Pre-Beltian	→ Tshinakin limestone...... ←	→ Not on North Thompson sheet	Cut off by Barrière River fault
Cambrian	Middle portion: grey schists of sedimentary origin ←	Pre-Beltian	→ Bastion schist........... ←	→ Barrière formation	
Cambrian	Lower portion: green schist and greenstone (volcanic) ←		→ Not on Shuswap Lake sheet ←	→ Fennell formation	
Cambrian	*Niskonlith series*...... ←		→ Not on Shuswap Lake sheet ←	→ Badger Creek formation	

Note: Correspondence of formations on the different sheets is indicated by double-headed arrows.

INTRUSIVE IGNEOUS ROCKS

Darlington Granodiorite

This is a medium- to coarse-grained, white to grey granitoid rock consisting chiefly of oligoclase, orthoclase, and hornblende. Much of the feldspar is clouded with alteration products, and the hornblende is partly altered to chlorite. Along its contacts the rock is locally gneissic.

Five dyke, sill, and border phases of this intrusive are met with. These are: (1) porphyritic hornblende granodiorite, in which phenocrysts of common hornblende up to 3 inches in length and ¾ inch in thickness are set in a fine-grained, greyish matrix of plagioclase and hornblende; (2) uralitized pyroxenite, which consists of a mosaic of large-sized grains of black uralite, containing small amounts of secondary intersertal calcite; (3) lenticular masses of quartz-orthoclase-muscovite pegmatite; (4) irregular-shaped masses of white to brown aplite; and (5) a border facies of fine-grained dark grey diorite.

With the exception of a fine-grained granitic sill and a pegmatite dyke, the exposures of this formation are confined to the west side of North Thompson river. The larger bodies occur as stocks to the west of Chu Chua and Barrière. These rocks intrude the Badger Creek, Fennell, and Barrière formations, but were not found cutting any other intrusive rock body. Their fabric is essentially granitoid, but towards their contacts a marked parallelism of hornblende crystal grains produces a noticeable gneissic appearance.

MICROPEGMATITE-PYROXENITE SILLS

This formation consists either of a composite sill or a differentiated sill. Lack of good exposures across the formation prevented exact determination.

The most westerly or upper part of the main sill is a coarse-grained, mottled grey rock which, under the microscope, is seen to be a granophyre, consisting of large, rectangular-shaped phenocrysts of orthoclase and acidic plagioclase, separated by important amounts of micropegmatite. Common green hornblende is an important accessory, and minor amounts of free quartz occur.

The lower part of the sill or sills, which is exposed on the western flank of the crest of mount Baldie, is a brownish-weathering, medium-grained pyroxenite consisting almost entirely of greenish diallage with accessory magnetite.

The sills occur on the western flank of mount Baldie, interbedded with the Badger Creek and Fennell sediments and lavas. Outcrops of a similar rock occur on the plateau northeast of Chinook Cove just beyond the edge of the map, and are believed to be the southerly extension of these sills. In a deep ravine at the head of one of the westerly-flowing tributaries of Joseph creek, and near the crest of mount Baldie, these sills and associated sediments are seen to be truncated below by the Baldie batholith.

BIOTITE GRANDIORITE SILLS

Megascopically these sills are medium-grained, porphyritic, grey to brownish grey rocks consisting of glassy and buff-coloured feldspars, quartz, and hexagonal-shaped "books" of biotite. They were classified in the field as granodiorites. Phenocrysts of plagioclase up to one inch in length and width are common constituents and the reflection of light from their mirror-like faces is a striking field characteristic. These phenocrysts are poikilitically studded with grains of biotite and quartz.

A typical specimen of the rock proved under the microscope to be a porphyritic biotite quartz diorite with the following characteristics: large broken phenocrysts of andesine-oligoclase, showing marked albite twinning, zonary structure, and alteration in spots to zoisite and colourless mica; phenocrysts of biotite and quartz; and a groundmass or mosaic of quartz and twinned plagioclase.

Only two sills of this rock were found in the area, one about 2 miles south of the village of Mount Olie, and the other 1 mile west of the mouth of Fishtrap creek. They are placed together in the legend because of similar lithology. They stand in an almost vertical attitude, but their longitudinal extent was not determined. Their relationship to the other intrusive rocks of the district is not known.

BALDIE GRANITE

Megascopically this rock is coarse-grained, porphyritic to granitoid, and pale pink to light grey in colour. The chief constituents are clear glassy quartz, large cleavage grains and rectangular-shaped phenocrysts of pinkish feldspar, in which Carlsbad twinning is common, and minor amounts of biotite.

Under the microscope, the rock is seen to be an acidic quartz monzonite consisting of large grains of quartz, albite-oligoclase, and microperthite (the intergrowth being orthoclase and albite-oligoclase). The accessory constituents are chiefly biotite and magnetite.

This rock occurs in the form of a batholith whose western contact crosses the top of mount Baldie in a general north-south direction and swings away from the North Thompson valley in northeasterly and southeasterly directions. The batholith underlies a large stretch of country to the east, and is continuous with Dawson's Shuswap granite where it is exposed on Adams lake (Figure 19).

Where the western contact of the granite crosses the most southern tributary of Joseph creek, it plunges in a westerly direction at an angle varying from 35 degrees to 50 degrees, thus undercutting the adjacent members of the Badger Creek formation and their intercalated micropegmatite-pyroxenite sills. On the northwestern shore of Adams lake, the granite is in intrusive relations with Daly's Adams Lake greenstones, which are stratigraphically higher than the Barrière formation.

The relationship of this granite to the stocks of Darlington granodiorite on the west side of the North Thompson valley is not known, so that their respective positions in the legend are provisional.

PETERSON CREEK SYENITE

In the field this rock is white to greyish white and porphyritic; and consists almost entirely of a network of lath-shaped crystals of feldspar with minor amounts of common hornblende, in a fine-grained, greyish matrix. The structure is markedly trachytic.

Under the microscope the rock is seen to be an alkaline syenite consisting largely of microcline, microperthite, and albite-oligoclase, with minor amounts of hornblende.

A stocklike mass of the syenite is found just south of Peterson creek at the western boundary of the map. It is intrusive into the stock of Darlington granodiorite with which it is in contact.

AGE OF INTRUSIVE ROCKS

No direct evidence was found in the map-area as to the time of intrusion of the igneous rocks. They are all probably younger than the rocks of the Barrière group, and older than the Eocene. The following points suggest that the intrusives are chronologically related to the Coast Range intrusion of late Jurassic times, rather than to the Precambrian.

Their general lack of foliation except in the vicinity of main contacts.

The lithological similarity of the Darlington granodiorite to the granodiorite of the Coast Range batholith.

The lithological similarity of the Baldie granite and granodiorite to the Nelson granodiorite, of which a series of stocks follows a general northwesterly course from near Nelson to the main line of the Canadian Pacific railway. The Baldie batholith may be another link in this chain of Mesozoic intrusions.

Tertiary

MIDDLE OR UPPER EOCENE—CHU CHUA FORMATION

This formation consists of a series of sedimentary beds ranging in composition from conglomerate through arkosic sandstone and highly feldspathic arkose to sandy shale, and containing coal seams. All the rocks are consolidated. The lowest member of the series is the basal conglomerate (or agglomerate). It consists of a heterogeneous mixture of rounded, sub-angular, and angular fragments of the older country rocks of the immediate vicinity. Some of these fragments are very large, whereas others resemble pebbles from stream gravels. The matrix of the fragments is a fine- to coarse-grained grit. Where the underlying rock is the Fennell greenstone, the larger part of the conglomerate is made up of large, irregular, talus-like pieces of that rock, associated with which are stream-rounded pebbles and boulders of granite and granodiorite. The basal portion of this conglomerate passes gradually by an increase in the quantity of fragments into the underlying rock, so that it is often difficult, if not impossible, to trace a definite contact surface between the two formations. The thickest section of the basal conglomerate exposed in any one place in the sheet is 150 feet (near Chu Chua station).

The intermediate and upper members of the formation consist of massive beds of coarse pebbly sandstone or fine-grained stratified conglomerate, and a considerable thickness of thin-bedded arkose and sandy shale. There is commonly an abrupt change in the grain in adjacent beds, and frequently a 3 to 4-inch layer shows fine-grained, sandy shale at its margins with fine-grained conglomerate at its centre. Several seams of sub-bituminous coal occur in the upper part of the formation, associated with the sandy shale and feldspathic sandstone.

The basal conglomerate is well consolidated and is grey to green in colour according to the relative abundance of the constituent fragments. The arkose and sandy shale are as a rule greyish white. Where these sediments are capped by Miocene lava flows, by which they have been considerably indurated, the shales are buff to brown, very markedly banded, and quite coherent.

Distribution. The Chu Chua sediments were found in the following isolated localities in the northern part of the map-area:

The sides of the lower part of Newhykulston valley.
The southeast bank of Joseph creek, about 100 yards from the road bridge.
The gorge of Threemile creek, one-quarter of a mile above its junction with Lemieux creek.
Cliffs along the Canadian National railway for one mile north of Chu Chua station.
The gorge of Thuya creek, about 600 yards west of the road bridge.
The gorge of Darlington creek, about 300 yards upstream from the road bridge.
The east bank of North Thompson river at low-water level, one-quarter of a mile north of Chu Chua station.

Stratigraphy and Structure. The stratigraphy and structure of the Chu Chua formation are shown in the accompanying sections (Figures 12-16).

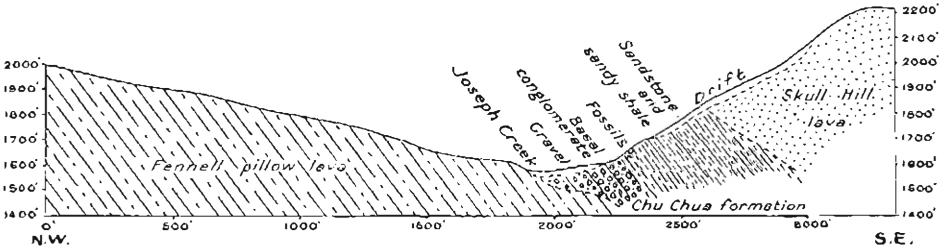


Figure 12. Vertical section across Joseph creek above road bridge, showing relations and structure of Fennell, Chu Chua, and Skull Hill formations.

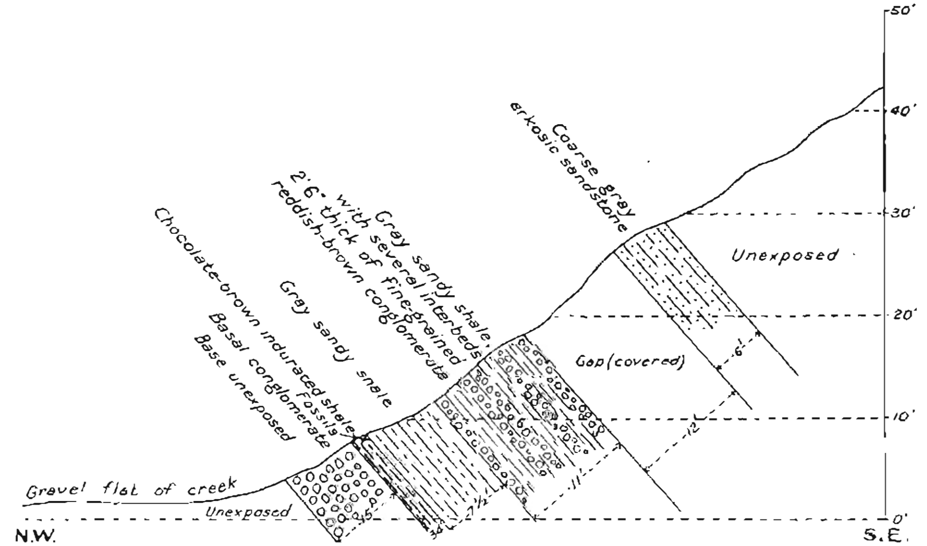


Figure 13. Detailed vertical section of the lower part of the Chu Chua formation shown in Figure 12.

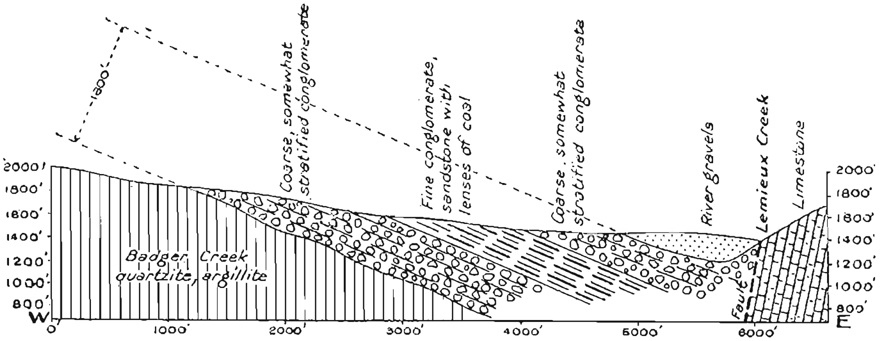


Figure 14. Vertical section along grade of Threemile creek, showing relation and structure of the Chu Chua formation.

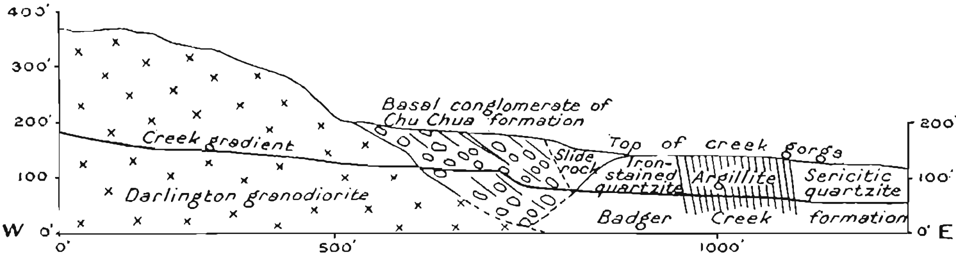


Figure 15. Diagrammatic vertical section showing relation of Chu Chua and Badger Creek formations and Darlington granodiorite, in Thuya Creek gorge.

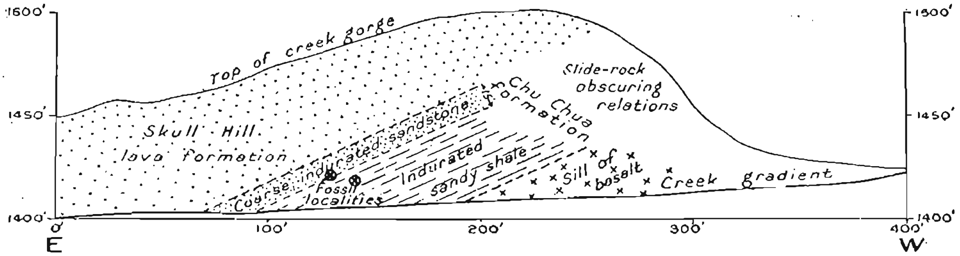


Figure 16. Diagrammatic vertical section showing relation of the Chu Chua and Skull Hill formations on south side of Darlington Creek gorge.

The following features are of particular interest.

The exposures are confined to the beds and lower slopes of North Thompson river and some of its tributary streams, and mostly occur below the 2,000-foot contour.

The longitudinal extent of the outcrops of the formation is in each case a short one. In the Newhykulston Creek area, for example, the only outcrop of these sediments is in the cut-banks of the stream valley. A low ridge, rising to a uniform height of a little over 2,000 feet (or 800 feet above the river), extends in northerly and southerly directions from the locality of the Chu Chua coal mine for distances of 2 miles and 1½ miles respectively. The topography of this ridge suggests that it is underlain by the Chu Chua formation, but, although it is traversed by several other stream valleys, no exposures of this formation were seen except those on Newhykulston creek.

The basin of Chu Chua rocks exposed in Threemile creek may also continue longitudinally in northwest and southeast directions for 4 or 5 miles, but the only evidence in favour of this possibility is the topography.

The beds dip (uniformly) to the east and southeast at angles varying from 29 degrees to 50 degrees. The strike in all cases is parallel to the general trend of North Thompson valley.

The basal conglomerate has the appearance of a tumultuous deposit, or the consolidated product of a mixture of talus fragments and large stream boulders.

There is a total absence of limestone, and of well-assorted fragmental sediments. The shales are sandy and the sandstones are feldspathic.

The most continuous section of the Chu Chua formation is found along the sides of Newhykulston creek. Here the thickness represented between the lowest and highest seams of coal is 600 feet. The bottom of the basal conglomerate is at least 1,650 feet below the lowest seam of coal. A considerable thickness of Chu Chua sediments is believed to exist above the highest coal seam, but these are not exposed. Consequently, if there is no duplication of beds by strike faulting, the formation in this locality is probably 2,500 feet thick.

It is probable that the Chu Chua sediments extend underneath the lavas of the Skull Hill formation on the west side of North Thompson river between Chinook cove and Thuya creek, and have thus been protected from post-Miocene erosion.

The isolated patches of Chu Chua rocks are erosion remnants of a much more extensive formation which filled the Eocene North Thompson valley to a height of possibly 2,500 feet above its bed.

Age and Correlation. Suites of fossil flora were obtained from the localities indicated on the structural sections (Figures 12, 13, 16) and were submitted to Professor D. W. Berry, of Johns Hopkins University, for examination. Only a few specimens were obtained from Darlington creek, and these were not in very good condition. The Joseph Creek locality is abundantly fossiliferous, and the fossils are excellently preserved. The zone at this place is 3 to 4 feet thick, and fortunately it occurs less than 5 feet above the top of the basal conglomerate. The fossils from Newhykulston creek are from a shale at the top of the chief coal seam. The discoveries at these localities fix rather closely the age of the Chu Chua formation, from its base to the top of the main coal seam. Extracts from the reports by Professor Berry, establishing the age of the Chu Chua formation as Middle to Upper Eocene, are as follows:

Newhykulston Creek Collection

The following nine species were identified. The great bulk of the collection represents the sterile and fertile fronds of the fern genus *Woodwardia*. The presence of numerous fragments of dicotyledonous species on the backs of the thicker slabs of shale indicates that the number of such species would be greatly increased by further collecting.

1. *Woodwardi maxoni* Knowlton.
2. *Phragmites sp.*, Newberry, which is probably the same as *Phragmites alaskana* Heer.
3. *Poacites tenue-striatus* Heer.
4. *Musophyllum complicatum* Lesquereux (probably not a *Musophyllum*).
5. *Betula grandifolia* Ettinghausen.
6. *Corylus macquarrii* (Forbes) Heer.
7. *Grewia crenata* (Unger) Heer.
8. *Petcrospermites alaskana* Knowlton.

Nos. 1, 2, 6, and 7 are Fort Union Forms. No. 4 is Green River. Nos. 2, 3, 5, 6, 7, and 8 are Kenai forms. The material is unquestionably of Eocene age and shows a mingling of Fort Union with the Arctic Tertiary flora which is now usually considered to be of Upper Eocene age. There is little resemblance to the Eocene floras of the John Bay basin in Oregon. Although the evidence is not conclusive, I would be inclined to consider the Chu Chua horizon as Middle or Upper Eocene and considerably younger than the so-called Canadian Upper Laramie, or Paskapoo.

9. *Taxodium occidentale* Newberry. Twigs of this species are not uncommon to the collection. The type was from the Fort Union, but is also recorded from the Lance, and from the Eocene of Mackenzie, Souris, Red Deer, and Blackwater rivers and Porcupine creek in British Columbia. Penhallow also recorded it from Quilchena, Tanquille, and Horsefly rivers, B.C., but his identifications are not very reliable.

Joseph Creek Collection

This collection includes the following forms:

Acer macropterium Heer.
Acer fruits.
Alnus sp.
Alnus cones.
Betula sp.
Carpinus sp.
Comptonia, new species.
Corylus macquarrii Heer.
Diospyros sp.
Ginkgo adiantoides (Unger) Heer.
Glyptostrobus europaeus (Brongniart) Heer.
Leguminosites borealis Heer.
Hicoria, 2 species.
Liriodendron sp.
Myrica, new species.
Pinus trunculus Dawson (leaves and seeds).
Pinus, cone scales.
Phragmites alaskana Heer.
Populus, new species.
Quercus grœnlandica Heer.
Quercus, new species.
Sassafras selwynii Dawson.
Sequoia sp.
Taxites sp.
Taxodium dubium (Sternberg) Heer.
Taxodium occidentale Newberry.
Ulmus, 2 species.
Viburnum antiquum (Newberry) Hollick.
Equisetum similkamense Dawson.

This material contains one or two Paskapoo species, but it is in the main identical with the facies of the Kenai flora of Alaska. It shows but slight similarities to the flora of the Puget group, and I have no hesitation in saying that it is probably of Upper Eocene age.

Darlington Creek Collection

The identifiable forms comprise:

Corylus macquarrii Heer.
Pinus trunculus Dawson (both leaf fascicles and seeds).
Ulmus sp.

I regard this collection as of practically the same age as that at Joseph creek, namely Upper Eocene.

These collections of fossil flora establish the occurrence of a late Eocene coal-bearing formation in south-central British Columbia. This occurrence—the first authentic discovery of Eocene sediments in the Interior plateau—indicates some interesting physiographic relations (*See* pages 89 and 90).

Dawson classified the coal-bearing sediments of Newhykulston creek as Oligocene and correlated them with the Coldwater group.[1]

MIOCENE—SKULL HILL FORMATION

This formation consists of a series of volcanic flows, minor amounts of flow breccias, and a few sills in the Chu Chua formation. Microscopic examinations of thin sections prove the flows and sills to be very constant in mineralogical composition and petrographic type. They are black, brown, and greyish-green, the black and brown predominating. The lavas are mostly highly amygdaloidal, the amygdules consisting of chalcedony, agate, hyalite, zeolites, calcite, serpentine, and some native copper.

Hornblende-andesite is the common type. Its characteristics are so marked that they may be used as a basis to differentiate the Skull Hill lavas from other flows in this area. The groundmass consists of a fine to medium-grained, felted mass of plagioclase laths of the composition of andesine-labradorite with interstitial augite

[1] Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894, p. 229 B.

and hornblende. Its structure varies from pilotaxitic to hyalopilitic. Fluxion structure is not very marked except in the vicinity of the phenocrysts. These are predominantly basaltic hornblende whose outlines are usually six-sided. The peripheries of the phenocrysts consist of a mass of grains of a black opaque mineral, probably magnetite, which appears to be the result of interaction between the hornblende and the surrounding magma. All stages from incipient to complete transformation of the basaltic hornblende to magnetite may be seen in the sections. Other phenocrysts, not so commonly present, are augite and andesine-labradorite. Hourglass structure occurs in some of the augite, and twinning is not unusual. Zonary structure is very common in the plagioclase phenocrysts. Magnetite is a fairly abundant accessory constituent.

The amygdaloidal parts of the formation are mostly much decomposed, especially where they have been soaked by percolating water from the artesian flow and the streams which traverse them.

Distribution. The formation occurs in three localities within the map-area:

On Skull hill, where it produces the mesa-like top of the mountain.

Along the west bank of the river commencing 6 miles north of Peterson creek and continuing to a point opposite Chu Chua. In this reach it constitutes a rock-defended terrace, fringing the base of the main valley slopes.

As a capping to the Chu Chua formation at the northeast end of Dunn lake.

More extensive exposures are found in the region of Clearwater river, but this area was not studied carefully during the season, and the details of the occurrence were not noted.

Structure. The andesites of Skull hill are in a nearly horizontal attitude. The lower part of them, including their contact with the underlying formations, is obscured by talus and glacial drift, so that the greatest exposed thickness is 1,100 feet. It is not known whether any part of the Chu Chua formation is buried beneath these flows, or whether they lie directly on the Fennell greenstones and green schists.

In the Dunn Lake area only the upper part of the lavas is exposed, but 400 feet is believed to be a conservative estimate of their thickness. The flows appear to dip to the southeast less steeply than the underlying Chu Chua sediments, but this point could not be definitely determined.

In the area on the west side of North Thompson river the rocks of the Skull Hill formation are largely concealed under the glacial overburden. Sections of them are obtained along the gorges of the various streams running easterly. Exposures are, however, quite abundant locally on both sides of the main road from 1½ to 3 miles north of Chinook Cove.

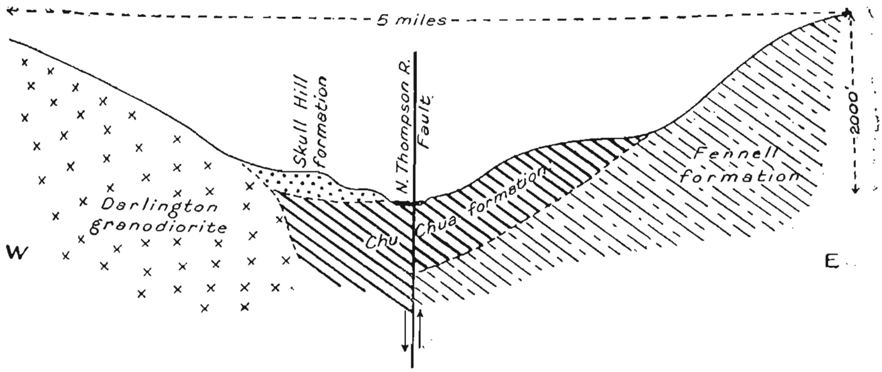


Figure 17. Generalized cross-section showing the faulting of the Tertiary formations in North Thompson valley. Vertical scale greatly exaggerated.

For 7½ miles along this side of the river, the rock terrace continues, and on it some of the richest agricultural land of the district is located. This terrace is ar erosion remnant of the lava flood-plain, which formerly filled the North Thompson valley to a height varying from 600 to 2,000 feet above the present river grade.

In many places these andesites are notably sliced or traversed by a series of closely-spaced parallel fractures that correspond in strike to the trend of the main trench. These fractures give the rock the appearance of a schist, but there is no evidence of recrystallization or of the development of platy minerals.

The strip of Skull Hill lava on the west side of the main river trench and the stratigraphically lower Chu Chua sediments on the east side, just opposite, suggest the occurrence of post-Skull Hill faulting parallel to the trend of the trench along which the western side has dropped relatively to the eastern side (Figure 17). The fracturing and slicing mentioned in the previous paragraph are believed to be a result of this faulting.

Age and Correlation. No sediments older than the Pleistocene and overlying the lavas were found within the sheet. The Skull Hill formation is, therefore, only provisionally referred to the Miocene.

Quaternary

PLEISTOCENE

Glacial Drift. A large part of the area mapped, particularly the lower slopes of the valley and the uplands of the plateau, is covered by glacial drift. Glacial striæ were found on some of the rocky knolls on the plateau and D. A. Nichols found well-marked striæ on Granite mountain, northeast of the geological map (No. 1945) at an altitude of 7,500 feet.

RECENT

White Silts. Terraces of the White Silts (of Dawson) occur in many parts of North Thompson valley and on its main tributaries. They are found at altitudes up to 2,000 feet. As stated by Dawson[1] the White Silts were probably a lacustrine deposit of the finer parts of the material made available just after the last glacial retreat.

River Deposits. These consist of stratified stream and river gravels and silts occurring on the valley flats and as terraces rising to over 500 feet above the level of North Thompson river.

Lava. A highly vesicular andesitic lava, probably of post-Pleistocene age, is found in the canyon of Mann creek and about 1½ miles above its mouth. This district is outside the limits of the present sheet and it was not examined in detail. A section of the occurrence is given in Figure 18.

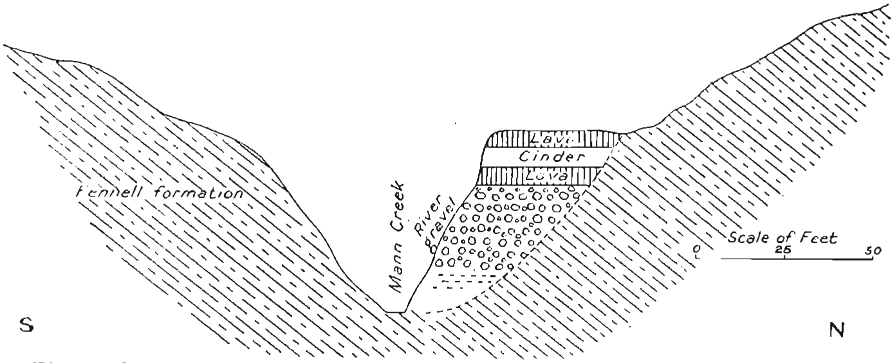


Figure 18. Section showing mode of occurrence of post-Pleistocene lava covering Recent gravels in gorge of Mann creek.

This lava, of which two 10-foot flows, exposed in the cliff face, are separated by 10 feet of cinder, covers unconsolidated, assorted coarse stream gravel. The gorge itself is of post-glacial age.

[1] Geol. Surv., Can., Ann. Rept., vol. VII, N.S., 1894, pp. 283-291 B.

DEVELOPMENT OF NORTH THOMPSON VALLEY AND SUMMARY OF THE GEOLOGICAL HISTORY

The following inferences are based on the field facts obtained within the North Thompson map-area and do not necessarily apply to the Interior plateau as a whole. The country mapped is entirely within the drainage basin of North Thompson river—it is indeed confined to the immediate slopes of the valley—and some rather interesting facts were obtained relating to the physiographic history of this particular trench.

Owing to the absence of any recognized sediments of the Mesozoic era, and possibly of the Palæozoic era, the geological history of this area in pre-Tertiary times is difficult, if not impossible, to decipher. At the beginning of the Tertiary period, the rocks had already been at least once severely faulted, folded, rendered schistose, and intruded by magmas of the batholithic, sill, and stock types. In general, the strike of these pre-Tertiary rocks is northwest, indicating a control by the forces which developed the Cordilleran structure.

The panorama obtained from an altitude of about 4,000 feet reveals two main facts: (1) The uplands between 3,500 and 4,000 feet show a gently undulating type of topography with a very even skyline. This continues for many miles in all directions, and presents the appearance of an uplifted peneplain. Above this peneplain, there are several isolated peaks and ridges, some of which rise to altitudes of 8,600 feet. Examples of these are mount Baldie (7,500 feet), Dunn peaks (8,600 feet), and Poison hill (5,370 feet) (Plate III A). They are evidently monadnocks. (2) Commencing 3 to 5 miles on either side of the present North Thompson river, this peneplain gently slopes towards the axis of the valley. If the present river trench were obliterated these two opposite upland slopes would smoothly curve downwards and would unite over the trench at a height of perhaps 2,000 feet above the bottom of the present valley. This exceedingly flat northerly trending depression in the peneplain is believed to represent the late Cretaceous valley of the ancestral North Thompson river. Since this valley is preserved in a state of physiographic old age, it was, probably, the course of the old North Thompson as it meandered with a very low gradient over the peneplained southern interior in late Cretaceous time, previous to the Laramide revolution. It was evidently the master drainage course in those times, and the bottom of its valley was the lowest point of that late Cretaceous topography. The depth of erosion since that time would, therefore, be represented by about 2,000 feet, or the distance between the bottoms of the Cretaceous and present-day North Thompson valleys.

It is interesting to note that the present North Thompson river which, as already stated, inherits the valley of its ancestor, in many places crosses the prevailing Cordilleran structure.

The sediments of the Middle or Upper Eocene (Chu Chua formation) are confined to the lower parts of the present valley. They are found below the present water level and to a height of 800 feet above it, but higher parts of them may have been removed during the post-Eocene or post-Miocene erosion cycle. The evidence is, therefore, conclusive that the depth of the North Thompson trench in Middle or late Eocene times was approximately the same as now. Between the time of the uplifting of the Cretaceous peneplain and of the deposition of the Chu Chua formation, the North Thompson valley was eroded to a depth of probably more than 2,000 feet.

The Eocene sediments are a regularly bedded series of coarse to medium-grained fragmental rocks, in which the arkose and greywacke types prevail. These indicate rapid erosion of the lands from which they were derived. The occurrence of these Chu Chua beds on both walls of the present trench and throughout a considerable distance in northerly and southerly directions, the general lack of crossbedding, and the presence of many shale horizons suggest that they are of lacustrine origin. The flooding of a large, youthful valley in this manner accounts for the character of the

Chu Chua basal conglomerate, which, as mentioned above, resembles a consolidated mass of talus and coarse stream gravel, such as was probably lying in the lower parts of the old North Thompson at the time of the formation of the lake. Repeated fillings of the lake basin, at several stages of its development, by fragmental sediments, and the growth of luxuriant and somewhat modern vegetation account for the occurrence of the coal seams.

The angular discordance which is evident in places between the beds of the Chu Chua formation and the overlying Miocene lavas points to a minor disturbance probably in Oligocene times. The Chu Chua formation seems to have been block-faulted along lines parallel to the general trend of the North Thompson trench. The beds in the various blocks dip 20 degrees to 40 degrees to the east.

Erosion during the Oligocene bevelled the upturned edges of the Chu Chua sediments.

During the Miocene great subaerial flows of andesitic lava spread over the country. Outside the boundaries of the North Thompson Valley sheet, these lava flows buried the uplifted peneplain; within the North Thompson valley they capped the Chu Chua sediments to a thickness of upwards of 1,100 feet, and filled the river valley from side to side. The drainage of the river was consequently blocked and locally altered. The lavas flooded the Clearwater valley to the north, but post-Miocene stream-cutting has removed part of them and has exposed cliffs, 100 feet high, of highly decomposed and bleached granite. These exposures afford very picturesque evidence of the depth and character of early Tertiary weathering.

Diastrophism—following the extrusion of the Miocene lava—raised, tilted, and faulted the flows and underlying rocks within North Thompson valley. The effects were mostly those of faulting (Figure 17). Dawson[1] describes the occurrence of tilted lava flows on parts of the plateau.

In Pliocene times, following the post-Miocene diastrophism, a long period of erosion ensued until the upturned edges of the lava flows were bevelled, and until the river had re-cut its channel down into the Chu Chua sediments.

The Pleistocene ice-cap which covered this part of British Columbia to a considerable depth glaciated and grooved the rocky hills and slopes and scoured and deepened the valley.

On the retreat of the ice great quantities of loose rock were supplied to the river, which spread the material across its valley in a great valley train. Subsidence of the land followed and great thicknesses of white silts probably of marine deposition covered the drift and glacio-fluvial gravels to depths of several hundred feet.

Post-Pleistocene emergence rejuvenated the river and caused it to re-cut its channel in the same course, leaving the glacio-fluvial gravels and white silts as terraces perched on the valley sides at heights up to 1,000 feet above the bottom. The North Thompson was again entrenched to a depth approximately the same as that of early Eocene time.

Lavas of unknown extent were extruded during Recent time.

GENERAL STRUCTURE OF THE BONAPARTE LAKE-CHU CHUA-ADAMS LAKE REGION

A sketch showing the relation of the geology of the map-area to that of the adjoining districts to the east and west is shown in Figure 19. On it the following relations are illustrated:

The North Thompson map-area and the North Thompson trench lie between two batholiths: that of the Darlington granodiorite and its associated intrusives to the west, and that of the Baldie granite to the east. The difficulty of working out a correlation of the North Thompson rocks becomes evident, when it is realized that they are a much metamorphosed part of the batholithic roof.

[1] Bull. Geol. Soc. Am., vol. 12, 1901, p. 81.

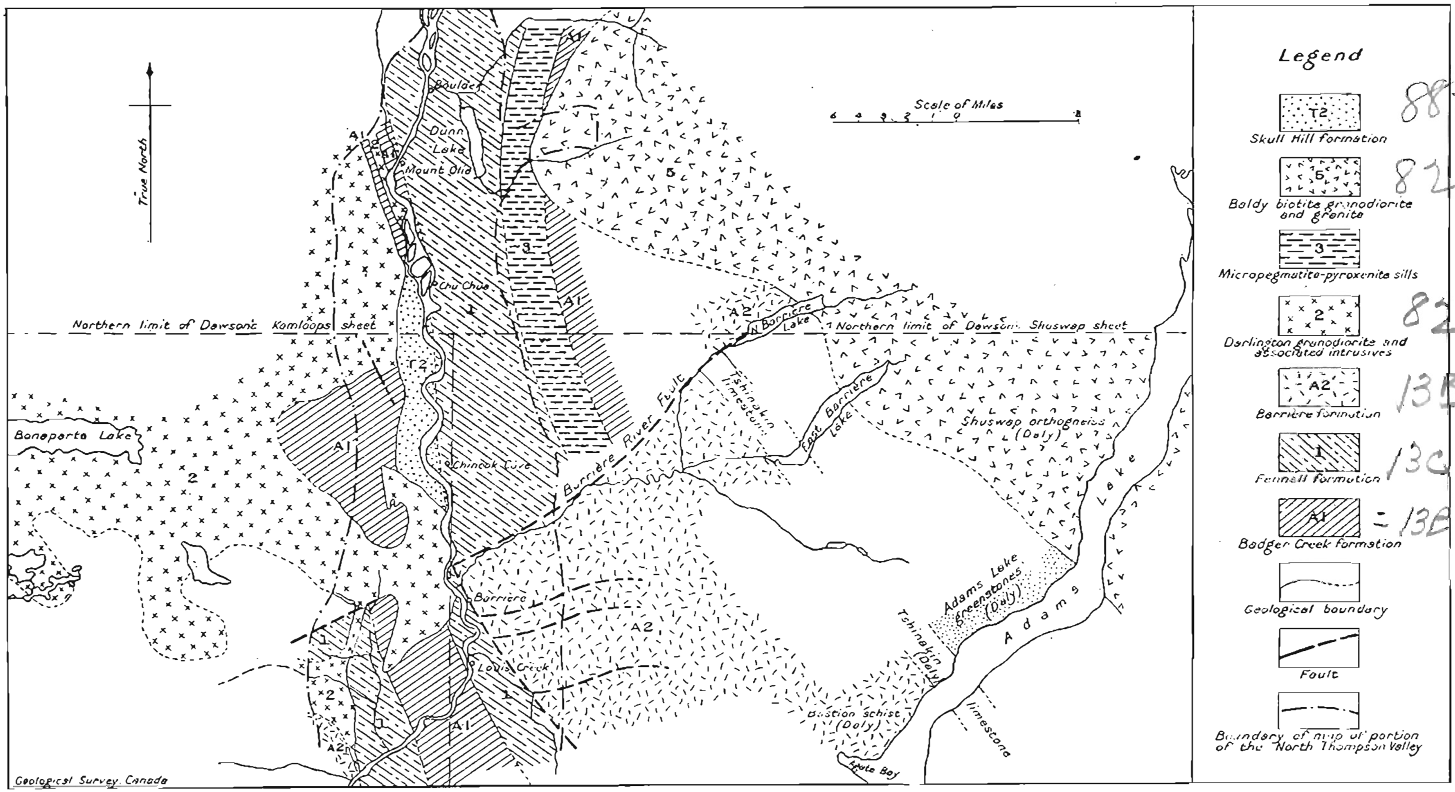


Figure 19. Diagram showing general geological structure of North Thompson valley and adjacent districts and relationship between the areal geology of G. M. Dawson and R. A. Daly and that of the map-area of a part of North Thompson valley.

The Baldie granite of this map-area is seen to be continuous with the Shuswap granite and orthogneiss of Adams lake which Dawson and Daly have classeified as Archæan.

Daly's Tshinakin limestone continues with few interruptions as a very noticeable white ridge from the northwest shore of Adams lake to North Barrière river. Here it stops abruptly, as shown. His Adams Lake greenstones are similarly cut off. The northwest shore of North Barrière lake consists of the Barrière formation.

The areal connexion of the Barrière formation with Daly's Bastion schists of Skaam bay is shown.

The position of the Barrière River fault zone crossing the Cordilleran trend and truncating the Badger Creek, Fennell, Barrière, Tshinakin, and Adams Lake formations is clearly illustrated. The fault zone was not found to cut the batholith.

ECONOMIC GEOLOGY

COAL

Coal has been known for a great many years to occur on the lands of the Indian reservation near Chu Chua. The exact locality of the occurrence is in the gorge of Newhykulston (Coal) creek three-quarters of a mile above its mouth. The exposures are at altitudes of 1,400 to 1,500 feet. A road running down the valley for 1,200 yards to a siding on the Canadian National railway makes the coal readily accessible.

Stratigraphy and Structure

The coal measures are of Middle or Upper Eocene age as determined from the flora found at the top of the main seams. A detailed section of the coal measures is given below. The beds strike north 20 degrees east and dip 23 degrees to 25 degrees southeast (Figure 20 A and B).

Coal Seams

There are three main seams which are referred to as the Gray, the Smith (A and B), and the Thomas (A and B) seams. Several other thin seams are shown on Figure 20 A and B as the A, B, C, D, E, F, G, H, J seams. For the thickness and physical characters of the minor seams, attention is directed to the stratigraphical section.

The coal is usually frozen to the bands of sandstone that occur within the main boundaries of the seam, but it breaks free from the capping and floor.

The capping is rigid, and requires very little timbering.

There is an absence of fire-clay at the base of the coal seams.

The seams thin and thicken, roll, split, and unite in short distances laterally. Such an occurrence makes an estimate of reserves exceedingly difficult to make.

Thomas Seam. Until the end of the summer of 1921, practically all the development had been confined to this horizon. It is a double seam, the upper part being the A, and the lower the B. In the outcrop along the side hill, these two parts of the seam are separated by 9 to 10 feet of arkosic sandstone and arenaceous shale. At the time of the writer's examination, they were seen to be not more than 3 feet apart in the bottom of the slope. At a lower level they may unite and form a seam 4 to 5 feet thick.

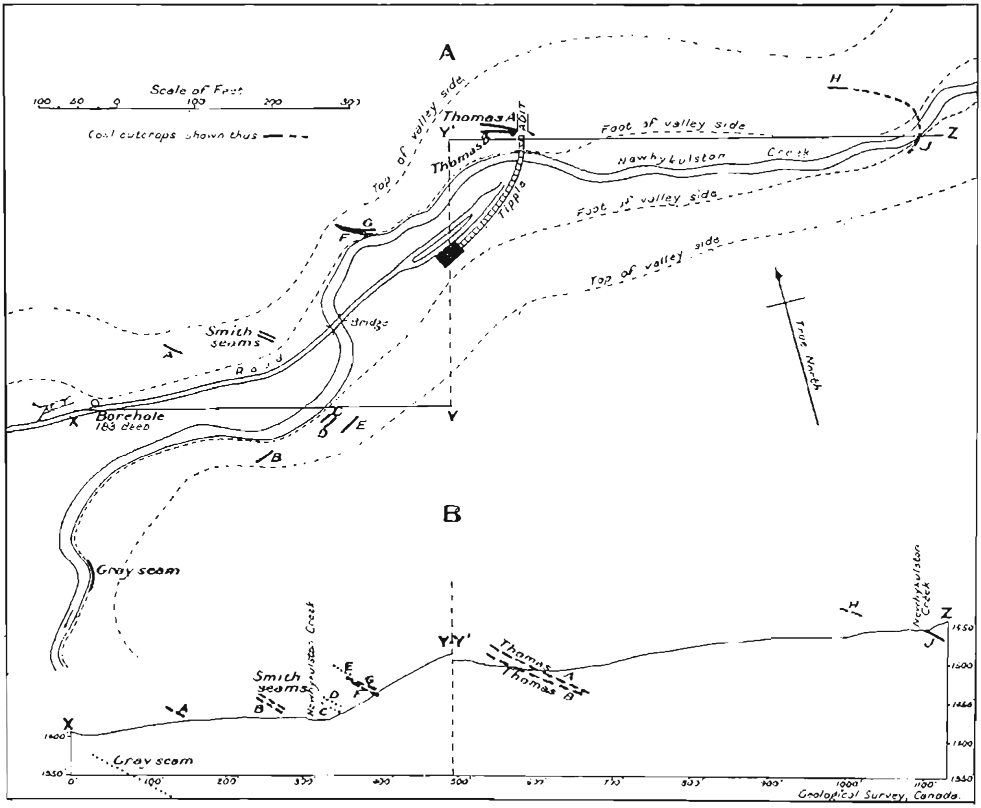


Figure 20. A. Plan showing outcrops of coal on the property of the Chu Chua Coal Company.
B. Representation of outcrops of coal seams in a vertical plane along lines XY-Y'Z. Coal seam outcropping on the line of section is shown in solid line; coal seams on north side of line are shown by broken line; and coal seams on south side of line are shown by dotted line.

The two parts of this seam vary in physical character and thickness within very short distances along the beds. The following sections reveal in detail the nature of the seams:

(1)

Sandstone roof
12 inches hard, black, lustrous coal (streak brown)
1½ inches sandy shale
1 inch hard, lustrous coal
3 inches grey sandstone
10 inches hard, black, lustrous coal (streak brown)
3½ inches sandstone
7 inches coal
2 feet sandstone floor
Total coal: 30 inches.

(2)

Sandstone roof
8 inches hard, massive, lustrous coal
2 inches shale
1½ inches coal
1 inch shale
7½ inches coal
2 inches sandy shale
5 inches coal
Sandstone (smooth floor)
Total coal: 22 inches.

(3)

Sandstone roof
30 inches coal—Thomas A seam
36 inches sandstone
30 inches clean coal—Thomas B seam

(1) Vertical section of Thomas B seam on south wall at the bottom of main slope.
(2) Vertical section of Thomas A seam on north face, lower level.
(3) Vertical section of Thomas A and B seams, 20 feet north of No. 1 chute, lower level.

Smith Seam. This is also a double seam and is exposed in a short slope. A section down the slope is given in Figure 21.

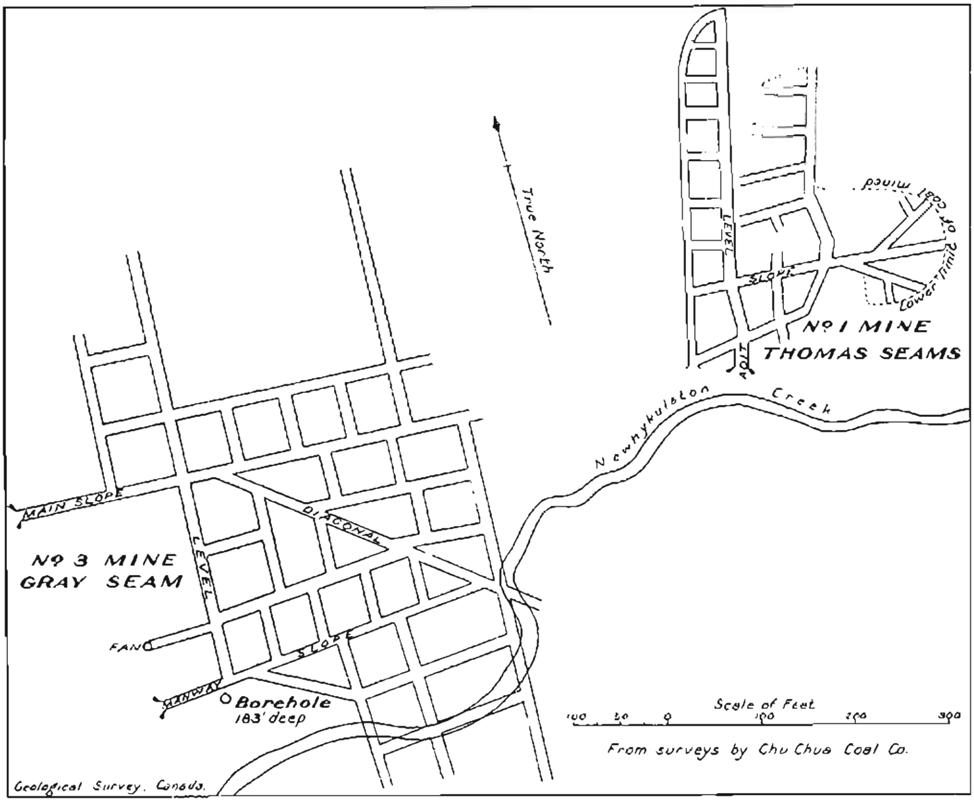


Figure 21. Plan of underground workings of Chu Chua Coal Company.

The detailed stratigraphic section at the portal of this slope is as follows:

Massive pebbly sandstone capping.
18 inches to 20 inches hard, thinly laminated, fairly clean coal.
20 inches to 48 inches hard, massive grey sandstone.
6 inches shale with coaly partings.
10 inches coal with shale partings.
Fissile grey (arenaceous) shale floor.

Gray Seam. This is the lowest coal so far discovered in the measures. It was uncovered at the time of the stream freshet in June, 1921, by the sapping of a thick mantle of glacial drift. At the suggestion of the writer a small excavation was made at this point and revealed the structure and relations shown in Figure 22. This outcrop was much weathered and it was difficult to determine how much clean coal was in the seam.

Physical Characteristics and Grade of Coal. The coal is a hard, black, lustrous, thinly laminated variety with a dark brown streak. It is very friable but it does not readily blacken the fingers. The seams lack the perpendicular prismatic jointing so characteristic of bituminous coal, but possess instead the thinly laminated structure found in lignites. The coal weathers rapidly and becomes coated with a yellowish-white alteration product. It burns readily with a long yellow flame, and it is said to be an excellent steam-producing fuel.

Small lenses, blebs, and irregular-shaped masses of a semi-transparent, amber-yellow material occur within the seams. This is the fossilized form of some of the resins of the coal-forming trees. As a result of the biochemical and dynamochemical changes which took place during the formation of the coal, the woody parts of the seam were much carbonized and fractured, whereas the resins resisted the biochemical changes to the last.[1] Being plastic, the fossilized resins accommodated themselves by

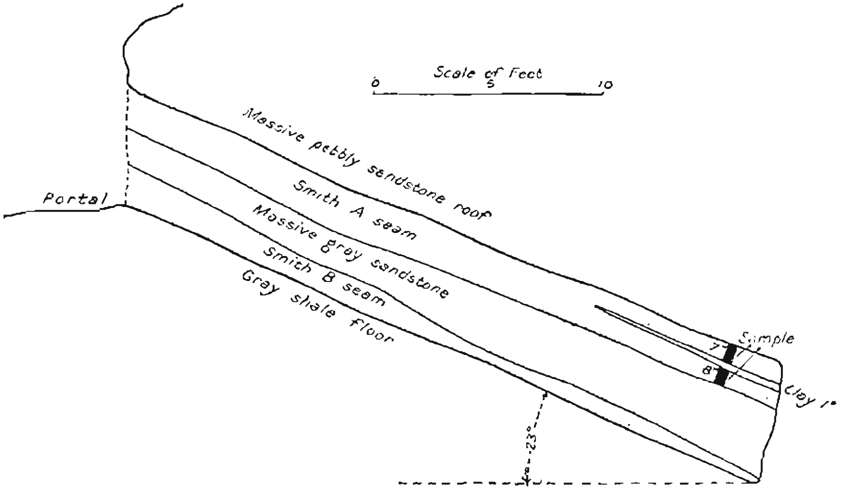


Figure 22. Vertical section through slope on Smith seam, Chu Chua Coal Company.

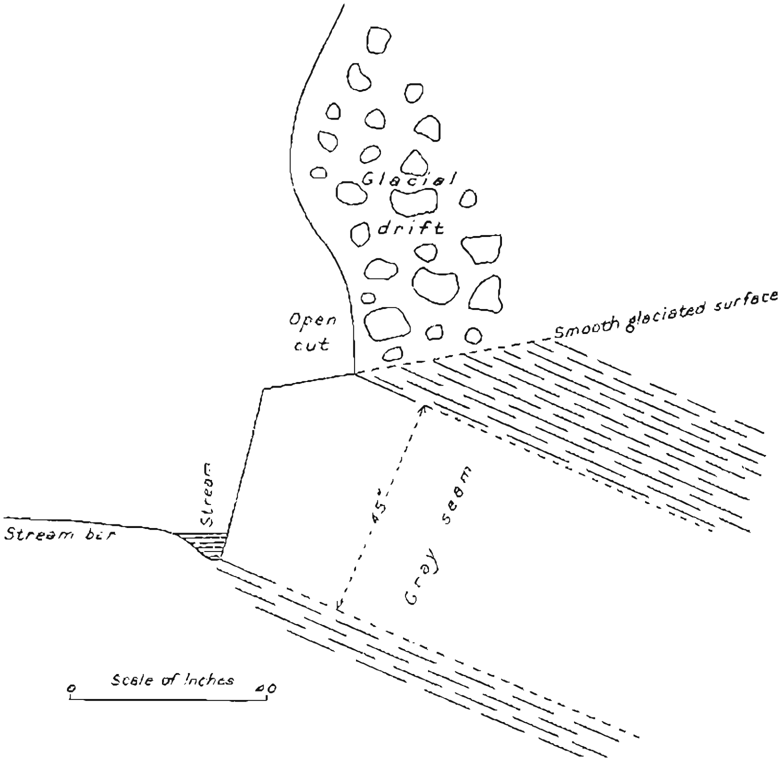


Figure 23. Vertical section parallel to dip on Gray seam, Chu Chua Coal Company.

[1]U.S. Geol. Surv., Prof. Paper 85, 1914.

flow to the shapes of the fractures in the coal, and now they occur in cracks and cavities of all shapes; and in places they present the appearance of having replaced the coal.

Four samples of coal from the seams were submitted to the Mines Branch, Ottawa, for analysis. The samples were analysed as received (R) and as dried at 105 degrees C. (D). The results are given herewith:

—	(1)		(2)	
	R	*D*	*R*	*D*
	Per cent	Per cent	Per cent	Per cent
Moisture	4·0	....	3·7	....
Ash	24·0	25·0	37·3	38·8
Volatile matter	36·1	37·6	29·4	30·5
Fixed carbon	35·9	37·4	29·6	30·7
Fuel ratio	0·99	0·99	1·01	1·01
	Sample made poor coke in very small lumps		Sample agglomerates	
British thermal units	10,290	10,700	8,230	8,550

—	(3)		(4)	
	R	*D*	*R*	*D*
	Per cent	Per cent	Per cent	Per cent
Moisture	3·6	....	4·0	....
Ash	13·8	14·3	22·1	23·0
Volatile matter	37·9	39·3	37·9	39·5
Fixed carbon	44·7	46·4	36·0	37·5
Fuel ratio	1·15	1·15	0·95	0·95
	Small lump fair coke		Small lump poor coke	
British thermal units	12,040	12,490	10,780	11,230

(1) Sample represents a channel of 15 inches in length across the Smith A seam, at a point 30 feet down the slope from the portal (Figure 21).
(2) Sample represents a channel 41 inches in length across the Gray seam. It includes 4 inches of coal shale, 8 to 10 inches of hard lustrous coal, 1 inch of clay, followed by weathered soft, shaly coal to the bottom.
(3) Selected sample of the best grade of coal from the upper 8-inch part of the Thomas A seam.
(4) Selected sample of the best grade of coal from the Thomas B seam.

These results show that the coal should be classified as low grade, low rank bituminous, or low grade, high rank sub-bituminous.[1] The fuel ratio is that of a low rank bituminous coal; the moisture content suggests a high rank bituminous; the large amount of ash makes it a low grade coal; and the lack of prismatic structure and the tendency to split into sheets parallel to the bedding indicate a sub-bituminous coal.

It seems probable that the original lignitic coal seams of this district were raised to sub-bituminous rank by thermochemical means; the heat having been supplied by Miocene lavas which, it is believed, formerly covered the coal measures. These lavas have since been completely removed by erosion.

Development. During the summer of 1921 development was confined to the Thomas seams, on which there was an adit 125 feet long, with workings which continued down the slope for about 200 feet. About twenty-five men were being employed by the Chu Chua Coal Company, the only operators. During the winter of 1921-22 underground development was carried out on the Gray seam. A short slope on the Smith seams, driven several years ago, was abandoned (Figure 20 B).

[1] U.S. Geol. Surv., Prof. Paper, 100-A, 1917, p. 3.

Production. During September, 1921, this property produced from one to two cars of coal a week. Towards the end of the year the Chu Chua Coal Company reported a production of about 40 tons a day.

Extent of Basin. As stated above in the discussion of the Chu Chua formation, owing to lack of exposures very little information is available regarding the longitudinal extent of the coal measures. They may extend 5 to 6 miles in a north-south direction underneath the low ridge that parallels the base of Chinook mountains.

Down the dip, the seams will, of course, be cut off where they overlap the surface of the Fennell greenstones, which represent the old shore-line of the lake.

In the detailed stratigraphic section of the coal measures in Newhykulston creek there is shown an interval of about 1,500 feet between the Gray seam and the basal conglomerate. In this interval, other seams of commercial value may occur.

The most important point to be determined by the present operations is, however, the longitudinal extent of the basin and this can be done only by intelligent drilling.

Coal may also be found in other parts of the North Thompson or tributary valleys where erosive agencies have not entirely removed the rocks of the Chu Chua formation.

Section of Chu Chua Formation on Newhykulston Creek

	Ft.	In.	
South Side of Creek—			
Black carbonaceous shale		3	
Coarse grey sandstone with black shale parting	5	0	
Coal shale		6	
Crossbedded shaly sandstone	1	6	
Coarse grey sandstone	4	0	
Grey shale	1	6	
Coarse grey sandstone, massive	3	0	
Grey shale and sandstone, interbedded	3	0	
Hard, massive, fine-grained grey sandstone	2	0	
Grey and black sandstone and shale interbedded	9	0	
Black carbonaceous shale		9	
Grey sandstone with shale partings	1	9	
Grey shale		6	
Black carbonaceous shale		6	
Coal, fissile, clean—J seam		7	
Shaly sandstone		6	
Black carbonaceous shale		6	
Massive grey sandstone	1	6	
Gap	200±		
North Side of Creek—			
Grey sandy shale, weathers blotched white	8	0	
Fine-grained grey sandstone	2	0	
Grey, sandy shale	4	0	
Grey shale, with sandstone at top, and 6 inches carbonaceous shale at bottom	2	0	
Grey shale, carbonaceous at base, sandy at top	1	3	
Loose sandstone with 6 inches of fine conglomerate in centre	2	0	
Grey, flaggy shale, weathers blotched		8	
Massive, fine-grained grey sandstone	1	9	
Fissile, carbonaceous shale		12	
Massive, fine-grained grey sandstone		12	
Fissile grey shale		8	
Coal and shale, interbedded		4	
Brownish-grey, thinly laminated, fissile shale, fossiliferous		6	
Coal, clean		8	Thomas A seam
Coal shale with 1-inch to 2-inch seams of coal		12	
Coal, clean		11	
Brown carbonaceous shale		4	
Coal shale with 2 inches of *coal*		7	
Grey, friable, thin-bedded shale	10	0	
Coal shale		6	Thomas B seam
Coal	1	4	
Gap—Buried	20	0	
Coarse sandstone and fine pebble conglomerate	10	0	
Grey sandy shale		12	
Fine conglomerate	1	6	
Coarse grey sandstone	7	0	
Gap—buried	30	0	
Massive, coarse grey sandstone	[illegible]0	0	

Section of Chu Chua Formation on Newhykulston Creek—Continued

	Ft.	In.	
North Side of Creek—Con.			
Grey fissile shale	5	0	
Massive grey sandstone bed	2	5	
Fissile grey shale		4	
Shaly *coal*, weathered—G seam		12	
Massive grey sandstone	3	0	
Fissile grey shale		9	
Coal, thinly laminated, weathered—F seam		11	
Hard, fine-grained, greenish grey clayey sandstone	1	3	
Fissile carbonaceous shale	2	0	
Grey sandy shale	1	10	
Hard, massive grey sandstone		12	
Fine-grained crossbedded pebble conglomerate	10	0	
Coarse, grey, crossbedded sandstone	12	0	
Grey flaggy shale	5	0	
South Side of Creek—			
Black carbonaceous shale	1	6	
Grey sandstone	2	0	
Grey sandy shale		12	
Coal shale } D		3	
Coal, thinly laminated } seam		9	
Grey, massive sandstone with 6 inches shaly sandstone at top	6	0	
Gap—Buried	3	6	
Coal } C		5	
Coal shale } seam		12	
Gap—Buried	20		
Shaly *coal*—Upper Smith seam	1	10	
Sandy shale		12	
Hard, grey, massive sandstone	3		
Shaly *coal*		4	Lower Smith seam
Coal, brittle, thinly laminated rusty weathering		12	
Shaly *coal*		4	
Grey fissile shale		6	
Hard, buff, massive sandstone	2	6	
Grey fissile shale		12	
Buff sandstone with sandy shale	4	0	
Massive grey sandstone	2	7	
Black carbonaceous shale		5	
Shaly sandstone		12	
Coal shale		4	
Grey sandy shale	1	3	
Carbonaceous shale	3	8	
Coarse, pebbly grey sandstone, massive	16	0	
Grey sandstone	2	0	
Conglomerate		12	
Black carbonaceous shale		7	
Gap—Buried	4	6	
Shaly sandstone	2	0	
Shale		12	
North Side of Creek—			
Coarse, pebbly grey sandstone with three interbeds of conglomerate	4	6	
Gap—Buried	6	6	
Coarse, pebbly sandstone with few black and grey shale partings	8	6	
Grey sandy shale		12	
Coal } A-seam		1	
Carbonaceous shale } A-seam		3	
Coal } A-seam		4	
Buff sandy shale		6	
Gap—Buried	10		
Massive grey sandstone, coarse to fine	12	6	
Grey sandstone with thin beds of conglomerate	2	6	
Gap—Buried	45		
South Side of Creek—			
Coal—Grey seam	3	9	
Gap—Buried	1,500±		
Basal conglomerate	150+		
Base unexposed.			

Gold Hill

The Gold Hill and Gold Hill Fraction are located on the southern and southeastern slopes of Gold Hill ridge. The chief mineralized zone, which is described below, occurs at altitudes varying from 2,720 feet to 3,425 feet. It is reached by a trail about 1½ miles long which leaves the main road three-quarters of a mile south of the south end of Dunn lake. The nearest railway station is Chu Chua, 5 miles from the lower end of the trail.

The property is recorded in the names of George Fennell and Henry Skoney, of Chu Chua.

The country rock is the greenstone pillow lava of the Fennell formation. This rock is traversed in a general east-west direction by shear zones which have been altered to cream and buff-coloured masses of siliceous ferrodolomite, through which ramify veinlets and irregular masses of white quartz. In many cases the quartz is broken and the fragments are cemented by ferrodolomite. The contacts between the ferrodolomite and greenstone are, as a rule, transitional. The width of the main ferrodolomite zone varies up to 20 feet. The quartz stringers carry appreciable amounts of fine and medium-grained galena, associated with less amounts of chalcopyrite, pyrite, and sphalerite. Free gold occurs scattered through these veinlets, and seems to be associated with the galena. Individual grains of gold were seen as large as pin heads and a few the size of small peas. Much invisible gold is scattered through the quartz and also in the ferrodolomite. Small pieces of rusty quartz when panned produce a very decided yellow streak, due to fine particles of gold. The quartz is rather intimately impregnated with small grains, and traversed by tiny veinlets of ankerite. The easy cleavage of this mineral makes the quartz very friable, and produces by its oxidation a buff to brown colour in the zone. Limonite is abundant as an oxidation product of the ankerite, and malachite and azurite as alteration products of the chalcopyrite.

Very little work has been done to determine the extent and value of the ferrodolomite zone. At least eight trenches and shallow open-cuts intersect the mineralized zone, and these are spaced through an horizontal length of at least 1,500 feet. It is not certain that the mineralization extends for this distance or that the ferrodolomite zone is continuous, but the evidence suggests that this is the case.

These ferrodolomite zones have irregular transitional contacts with the greenstone, and the evidence points to a replacement of the greenstone along broken or shear zones. The origin of the carbonate minerals is uncertain. Some of the material may be derived from the alteration of the ferromagnesian minerals of the original lavas by hydrothermal processes. The source of the heat, and perhaps of some of the solutions, may have been the Baldie granite intrusive which outcrops about 2 miles to the east, but which may underlie the Fennell formation of Gold Hill at a relatively shallow depth.

No systematic sampling has been done to determine the values, but the presence of free gold scattered over such a length of deposit suggests that the zone might warrant careful investigation.

Wind Pass

This property is located on the plateau, 2 miles southwest of the crest of mount Baldie, at about 5,300 feet. It is now reached by a zigzag pack trail which leaves the main road near the south end of Dunn lake. The property is recorded in the names of Oscar Hargen, Olie Johnson, and Thos. Campbell.

The country rock of the vein is the upper micropegmatite facies of the micropegmatite-pyroxenite sill which trends in a north-south direction just east of the boundary of the Fennell formation. The deposit consists of a quartz vein with a general east-west strike and a northerly dip varying from 35 degrees to 80 degrees.

The walls are definite and relatively smooth. The vein is offset in at least two places by crossfaults of small displacement. It varies in width from a few inches up to 36 inches, and averages probably 15 to 18 inches. It is characterized by pinches and swells both vertically and horizontally.

The west end of the vein consists of a highly fractured quartz filling, in which there are scattered minor amounts of chalcopyrite and pyrite. Grains of native bismuth occur here and there through the quartz, and almost any of the vein stuff pans fine gold. In some of the oxidized and broken material from the sides of the vein, leaves of native copper occur binding the fragments together.

The eastern half of the vein differs considerably in mineralogy and structure. It is much less quartzose and much less regular than the western part, and consists largely of discontinuous lenses of the solid bluish lodestone variety of magnetite, which is coated with limonite along all its fractures. Free gold may also be panned from this lodestone.

The intermediate part of the vein shows a gradation between these two types.

The vein has been followed by stripping, trenching, and open-cutting for about 200 feet. At its west end the vein enters a thin-bedded chert zone of the Fennell formation and becomes barren. At the east end it spreads into a number of lenticular lodestone masses. Deeper exploration may prove it to be continuous. At the bottom of the deepest pit on the vein—27 feet measured on a dip of 35 degrees—the vein is 36 inches wide.

The mineralization took place, probably, under deep-seated conditions, and was the result of contributions from the Baldie granite which outcrops 1¼ miles to the east. As the contact of the Baldie batholith plunges westerly it may not be very deep below the Wind Pass outcrop.

No systematic sampling was done by the writer, but the owners report as follows:

(a) Assays of solid lodestone showed values in gold of $81 and $232 per ton.
(b) A 15-inch channel sample in one of the pits across solid lodestone assayed $67 per ton in gold.
(c) In 1916, 31½ tons of mineral were shipped to Trail, from which the following assay was reported: 2·48 ozs. of gold, 0·8 oz. of silver, and 1¼ per cent of copper.
(d) In 1917, 29¼ tons were shipped to Trail, from which the folowing return was obtained: 2.14 ozs. of gold, 1.5 ozs. of silver, and ½ per cent of copper.

Sweet Home

This vein occurs at an altitude of 5,000 feet and is located about 600 yards south of the Wind Pass. It is reached by a trail running south from the main Wind Pass trail. The property is controlled by the owners of the Wind Pass.

A quartz vein 8 to 15 inches wide crosses the contact of the micropegmatite pyroxenite sill and the banded chert of the Fennell formation. The strike varies from north 60 degrees west to due east, and the dip from 30 degrees to 40 degrees north. The vein, towards its eastern exposures, seems to become dissipated in the micropegmatite.

The vein is impregnated with pyrite, trivial amounts of chalcopyrite, small grains and minute specks of gold, and a few grains of native bismuth. It has been exposed by trenching and open-cutting for a distance of 400 feet, and the deepest pit is about 10 feet. No assay results are available to indicate the value of this lode. The vein is small, and the gold values would have to be high to make it worth mining.

The Sweet Home deposit is believed to have an origin similar to that of Wind Pass vein.

Allies

This prospect is on the west side of the river, half a mile west of the main road and 2 miles north of Chinook Cove. A wagon road from the highway leads almost to the property. The altitude is 2,000 feet above sea-level or 750 feet above river level. The two claims are recorded in the name of Maria d'Yongh Smith.

The deposit occurs in rocks of the Badger Creek formation. A series of thin-bedded rusty weathering quartzites, striking north 50 degrees west and dipping 35 degrees southwest, is injected concordantly with a number of buff-coloured brownish-weathering sills, varying in thickness up to 10 feet. The larger sills carry rectangular-shaped phenocrysts of an undetermined feldspar in a dense buff groundmass. The narrower sills resemble felsite, and are markedly banded parallel to their contacts. These intrusives are impregnated with large numbers of cubo-pyritohedrons of pyrite. A series of at least three white quartz veins with crush zones filled with dolomite or ankerite cement, strike parallel with the stratification of the quartzites. They mostly occur immediately adjacent to the sills. The country rock close to its contact with the veins contains serpentine and dolomite, and has a decided greenish tinge.

Small amounts of pyrite, galena, and chalcopyrite are disseminated through the quartz veins. Systematic sampling of these veins was not done by the writer, but the owner reports attractive assay results.

Glacial drift and forest obscure the veins, which are exposed only in a few trenches, the deepest of which is 8 feet. At the bottom of this pit, a strike fault cuts off the quartz vein. The mineralization seems to be due to contributions from the sills. This inference, however, is based on areal relations only. The age and parent magma of the sills could not be determined on account of lack of exposures.

Homestake

This prospect is located on the north slope of the valley of Jamieson creek, 2 miles west of the river road. It does not occur on the North Thompson Valley geological sheet, but a special trip was made to examine it. It was under bond to J. T. Robinson and associates, of Kamloops. The outcrops are found at altitudes of 2,500 to 2,600 feet in a rolling park-like country sparsely clothed with jackpine. A serious handicap is the lack of water nearer than Jamieson creek.

Dawson examined this property in 1888, and briefly describes the local geology and the veins. He reports assays from 0·583 ounce of gold and 2·525 ounces of silver to 1·108 ounces of gold and 34·243 ounces of silver.[1]

On the property, brownish-weathering, highly fractured porphyritic quartz monzonite cuts biotite schist and argillite of the Cache Creek group. White quartz veins, and branching stringers occur along joint planes and prominent fractures in the intrusive rock. These are mineralized with scattered grains of pyrite, galena, arsenopyrite, and sphalerite. In certain cases there is a concentration of these minerals near the foot-wall. Five veins have been opened up by means of shallow pits and a shaft 75 feet deep. The veins strike north 15 degrees to 30 degrees west and dip from 90 degrees to 60 degrees west. They vary in thickness from 6 inches to 15 feet, but their longitudinal extent could not be determined. The shaft—on the largest vein—follows the hanging-wall down to 75 feet, at which depth the quartz appears to be barren. The writer suggested that a crosscut be driven 15 feet southwest into the foot-wall, and that this crosscut be carefully sampled. The veins seem to be genetically associated with the intrusive and to have been dependent upon it for the supply of their metalliferous contents.

GOLD: PLACER

Louis Creek

Small amounts of placer gold have been obtained from lower Louis creek.[2] No exploration of the gravels has been carried out that warrants the statement that pay dirt might be encountered in appreciable quantity. During 1921, W. J. Smith, of

[1] Geol. Surv., Can., Sum. Rept., 1888, p. 337 B.
Geol. Surv., Can., Ann. Rept., vol. VII (N.S.), 1894, p. 337 B.
Geol. Surv., Can., Ann. Rept., vol. IV (N.S.), 1891, p. 60 R.
[2] Geol. Surv., Can., Rept. of Prog., 1877-78, p. 155 B.

Louis creek, and five men, were engaged in diverting the creek to a new channel, so as to sluice the gravel of the present bed. Small amounts of gold were recovered from the gravel excavated from the diverting ditch. The gold was probably originally derived from the disintegration of quartz veinlets in some of the schists of the Shuswap region.

Threemile Creek

During the season, M. B. Roper and four or five men were exploring the gravels of Threemile creek, a tributary of Lemieux creek, a short distance north of Mount Olie. A shaft sunk 45 feet through the river gravel to reach bedrock, encountered a flow of water that seriously handicapped the work.

The upper 5 or 6 feet of the gravel is very coarse, and is reported to carry values up to $1 per cubic yard. It is underlain by lighter, better assorted gravel which carried much lower values. It seems probable that the lower, lighter gravel is a part of the valley fill of the larger Lemieux creek, and that the top heavy gravel is a deposit from the rapidly flowing Threemile tributary.

Above the shaft the stream emerges from a gorge cut through a heavy deposit of roughly stratified boulder conglomerate of the Chu Chua formation. The gold in the top gravels seems to be a concentration from the breaking down of this conglomerate. Small flakes and minute grains of gold can be readily obtained by panning the surface gravels in the locality of the shaft.

SILVER-LEAD-ZINC

Queen Bess Mine

The Queen Bess mine is located on the steep eastern slope of the North Thompson valley about 600 yards east and 720 feet above Auldgirth (Blackpool) station on the Canadian National railway and is outside the map-area. A chute connects the main workings with the mill which is built at the foot of the slope, and on a level with the railway track. The property is now under the management of O. A. Thomas, consulting engineer, of Seattle.

The country rock consists of the greenish pillow lavas of the Fennell formation. These are traversed by east-west buff-coloured shear zones, locally called dykes, highly charged with ankerite and dolomite. These zones are of irregular width, and show transitional contacts with the greenstone. The pillow structure of the lava is exceedingly well exemplified near the face of the crosscut tunnel, where the oval-shaped pillows are completely altered to buff ferrodolomite, whereas the matrix of the pillows is still green. Much of the ferrodolomite is decomposed to an iron-stained clay difficult to handle.

Two main veins, the Cameron and Bigelow, occur on levels Nos. 2 and 3. The Cameron strikes north 45 degrees to 50 degrees east and dips 50 degrees to 70 degrees northwest. The Bigelow, 130 feet to 200 feet southeast of the Cameron, strikes north 20 degrees to 30 degrees east and dips from 80 degrees northwest to vertical. The veins have in most cases definite walls. The fissures in which the vein material occurs maintain a fairly uniform trend in the unaltered greenstone, but where they enter the shear zone of ankeritic greenstone or ferrodolomite, they break up into a network of branching fractures. The veins vary in width from 1 inch to 5 feet, but average probably not over 12 to 15 inches. Where they traverse the greenstone, they are as a rule bordered by 2 to 6 inches of hard, buff-coloured rock of similar origin to the main zones of ferrodolomite.

Tabular to lenticular masses of nearly solid sphalerite and galena occur within the veins. The sphalerite is a beautiful coarse-grained resin variety mixed with a much smaller amount of fine- to medium-grained galena. Minor amounts of tetrahedrite occur. Lean parts of the veins contained disseminated particles of the sulphides in a quartz and quartz-dolomite gangue. In one stope a tabular mass of solid sulphides, up to 38 inches in thickness, was encountered. Minor amounts of these sulphides occur disseminated through the larger ferrodolomite masses near the positions of some of the vein fissures.

In the upper workings, several well-mineralized veins contain chiefly the oxidized minerals of zinc, lead, and copper. Cerargyrite is reported from these workings, but the writer did not recognize any in the field. No recent development has been carried on above level No. 2, so that little can be said regarding these oxidized zones.

The material mined as ore is said to average about 5 per cent of lead and 6 ounces of silver per ton. The first mill run of approximately 720 tons is reported to have given the following concentrates:

27 tons of lead concentrates assaying 40 to 50% Pb, 12% Zn, and 48 ozs. Ag per ton.
and
78 tons of zinc concentrates assaying 48% Zn, 7 to 8% Pb, and 14 ozs. Ag. per ton.

The Queen Bess is primarily a zinc blende deposit.

The only suggestion that can at present be offered regarding the origin of the veins is that they are genetically related to bodies of intrusive rock which cut the Fennell formation to the east. This occurrence is similar to that at the Gold Hill prospect.

The veins have been explored on three levels. The lower or No. 3 level, 720 feet above the railway, is 600 feet long, and enters the hill in an easterly direction. At 180 feet it cuts the Cameron vein which has been followed for about 80 feet on either side of the crosscut. From the southwest drift, a winze was sunk 100 feet on the vein, and at the 50-foot level in this winze an intermediate level was driven on the vein and the ore was stoped. The Bigelow vein, which the crosscut intersects at 300 feet, was drifted on for about 100 feet, beyond which the vein becomes a mere fissure or else anastomoses. Considerable stoping has been done on each of these veins.

No. 2 level is 300 feet above No. 3. The Bigelow vein on this level has been drifted on for over 100 feet, and a small amount of stoping has been done. The minerals are both sulphides and carbonates.

The mine has been closed since July, 1920.

Homestake Mine

The following notes have been contributed by C. O. Swanson, who made a special study of this property:

The Homestake mine is situated on the northern slope of the Sinmax Creek valley, about 3 miles west of Skaam bay, Adams lake (Figure 19). The main adit is in the rocky gully of a small stream emptying into Sinmax creek from the north, and is about 800 feet above the bottom of the creek. A wagon-road runs from Louis creek to Skaam bay and passes within a mile of the workings.

The deposit occurs in the Bastion schist (of Daly), which is part of the Barrière formation of this report. Near the mine the country rock is a quartz-sericite schist, impregnated with pyrite, which on oxidation gives the rock a decidedly yellow colour. The planes of schistosity, which are parallel to the original bedding, strike north 60 degrees west and dip 25 degrees to 40 degrees northeast. A high degree of fissility characterizes the schist, producing the appearance of a phyllite. The disintegration and creep of the schist, combined with the oxidation of the pyrite, account for the large talus slopes of yellowish platy fragments.

In the schist are intercalated two tabular bodies of fine-grained barite. The upper body is 12 feet thick at the outcrop, and the lower one 9 feet. They are separated by 150 feet of schist containing some barite. The lower deposit has been traced along the strike for 80 feet.

The barite is greyish-white and has a marked thinly-laminated structure parallel to the planes of cleavage of the schist. It does not cleave readily, however, along these bands. The analysis of an average specimen from the barite zone shows the presence of 85 per cent barite, 5 per cent silica and alumina, 8 per cent metallic minerals (galena, sphalerite, pyrite, tetrahedrite, and chalcopyrite), and 2 per cent undetermined material.

In close association with the barite zone and cutting it in places are many narrow quartz veins, which are usually barren, but which here and there contain barite, galena, and pyrite.

At first glance the barite appears to be syngenetic with the schist. But a detailed examination of the field relations and a study of many thin sections and polished surfaces shows that both the barite and the metallic minerals are a replacement of the schist. Some of the features leading to this conclusion are as follows:

The deposits occur in a more or less vertical zone characterized by the presence of barite, which does not appear elsewhere in the country rock to any extent.

Pyrite is clearly a replacement of the schist, and where pyrite and barite occur together, they appear to be of simultaneous origin.

The presence of galena and tetrahedrite, both high in silver, suggests that they were deposited by ascending solutions.

There is no evidence to show that the barite had a different origin from the metallic minerals. It occurs with them in quartz veins, and the fabric of the ore does not show the metallic minerals distinctly replacing the barite, as, for instance, the pyrite replaces the schist.

For these reasons amongst others, the origin of the deposits is held to be hypogene. The source of the solutions which contributed the barite and the metallic minerals is doubtful, as no intrusives outcrop near the mine. However, certain structural relations suggest the possibility of a body of younger granite underlying the district.

In 1893-94 twenty tons of ore averaging 80 ounces in silver were shipped from the property. Most of the development was done about 1917. A crosscut intersects the lower barite body 170 feet from the mouth, and from it drifts were run each way. The western opening met a fault beyond which the ore was lost. From the eastern drift a raise was driven in barite to the surface. A short drift running west from a point 40 feet up this raise encountered a fault, probably the same as the one mentioned above.

According to the statement made by R. W. Thompson, in the Annual Report of the Minister of Mines for British Columbia, for 1917, the general average of the ore in sight is: silver 9·75 ounces per ton, copper 0·22 per cent, and gold 0·02 ounce per ton. Assays of ore specimens and mineralogical determination of the constituent minerals show that the silver is mostly contained in the tetrahedrite.

MISCELLANEOUS MINING CLAIMS

Fortuna

The Fortuna property is located at Blucher Hall in the southwest corner of the map-area. The lower workings are a few feet above the level of the road. The nearest railway siding is at Louis Creek, 8 miles distant along a good wagon road. Mr. W. J. Smith, of Louis Creek, is part owner, and local representative of the company.

The country rocks belong to the Barrière formation and consist of argillaceous schist, with greyish streaks and fragments, and lenticular masses of quartz; massive white quartzite impregnated with pyrite; sericite schist; schistose quartzite; and a zone of greyish, medium-grained dolomite. These sediments strike about north 80 degrees west and dip 45 degrees to 55 degrees north.

A 12-foot bed of medium-grained grey dolomite lying between quartzite walls is impregnated with coarse-grained cubical pyrite. About one-half of the dolomite by volume has been replaced by the pyrite. Traces of copper mineralization are present, and minor amounts of galena. Some quartz stringers also carry small quantities of galena. W. J. Smith reports the presence of pyrrhotite and arsenopyrite, but none was recognized by the writer.

W. J. Smith states that analyses of parts of the pyritized zone showed platinum up to 0·2 ounce a ton and $2 a ton in gold. Shipments of this material have been made from time to time to Pittsburgh, Pa.

The character and mineralogy of the deposit do not in the least suggest the presence of platinum. In order to determine this point, a few picked samples, taken under Mr. Smith's supervision, were submitted to the Mines Branch, Ottawa, for assay, but not one of them gave even a trace of platinum or silver, nor more than a trace of gold.

The trivial amount of gold and the entire absence of arsenic seem to confirm the absence of platinum.

Development consists of two crosscut tunnels, a lower one (255 feet long) at an altitude of 2,005 feet; and an upper one 500 feet long at an altitude of 2,115 feet. The upper one cuts the pyritic zone at 420 feet from the portal. Some open-cutting has been done along the outcrop at an altitude of 2,350 feet.

Skookum Claim

This is a small prospect with workings between altitudes of 3,300 and 3,365 feet, located half a mile north of the Fortuna. An open-cut with a 7-foot pit has been excavated at the higher location and a crosscut tunnel 143 feet long goes into the hill at the lower elevation, but does not reach the zone of mineralization.

The deposit consists of a 3-foot zone in the Barrière quartzites impregnated with pyrite and some chalcopyrite. The width of the mineralization varies from 20 to 36 inches at the outcrop, and there is reported to be 15 inches of solid pyrite in the bottom of the pit. The strike is north 80 degrees west and the dip 30 degrees north. Stripping and trenching at different points farther east suggest that this zone might have a considerable longitudinal extent.

The average value across a mineable width would probably be below commercial grade.

The property is recorded in the name of W. J. Smith of Louis Creek.

Mann Creek

A small prospect was being explored by Alfred Mann, of Auldgirth (Blackpool), on the south bank of Mann creek about 1½ miles from its mouth.

Some stripping and shallow open-cutting show a black graphitic schist associated with the Fennell greenstones and abundantly stained with blotches and traversed by filaments of azurite and malachite. A barren-looking quartz vein cuts through the formation at this locality. No sulphide minerals were seen, and insufficient work had been done to determine even the trend of the deposit. Its origin is quite obscure.

North Barrière Lake

Several small prospects are located near North Barrière lake. This district is several miles east of the sheet, but two days at the end of the season were spent in examining the prospects (Figure 19).

The only prospects worth mentioning are the Anaconda group, belonging to the Johnson brothers, Fosborg, Bilen, and H. D. Macdougall, located on Berk creek; the Lucky Boy group, belonging to Joe Conway and associates, on the northwest shore of the lake: and the Wah Wah claim of Bendeline and Hillyard, also on the northwest side of the lake.

The Anaconda is a pyritic replacement in a dolomite zone in the quartzites of the Barrière formation, and consists of very low grade material. Minor amounts of galena and zinc blende occur with the pyrite. There is nothing to suggest any possibility of commercial value. Traces of copper and gold are the only indications.

The Lucky Boy group is the merest prospect. A tunnel was being driven into the hill through the Barrière argillaceous sericite and chlorite schists. Blotches and irregular masses of the copper carbonates stain the walls and back of the tunnel various shades of green and blue. An open-cut farther to the northeast revealed the same low-grade mineralization. The source of these oxidized copper minerals was not recognized, and no definite trend could be discovered for the mineralization.

The Wah Wah claim is located at an altitude of 3,360 feet on the northwestern slope of the lake trench. An open-cut and some stripping reveal a solid mass of pyrrhotite with small amounts of chalcopyrite and pyrite. The enclosing green schists are similarly mineralized, but to a much less extent. It is possible that the sulphides carry an appreciable amount of gold.

This district is favourably located geologically for prospecting, being within 2 miles of the contact of the Baldie granite batholith, but for mining its distance from a railway would be a handicap.

LIMESTONE

Some of the white limestone beds of the Barrière formation just east of mount Armour have been explored to ascertain their value as sources of lime. Some of these consist of relatively pure calcium carbonate. No assays were made.

GENERAL CONCLUSION REGARDING MINING PROSPECTS ALONG NORTH THOMPSON RIVER

The southern part of the North Thompson map-area seems unfavourable for the discovery of valuable metalliferous deposits. It is too far from the seat of igneous intrusion. The northern part of the area, especially beyond the limits of the map, seems more favourable, however, and the country within a couple of miles of the contact of the Baldie batholith should be carefully prospected. A thick covering of glacial drift and a dense forest mantle very greatly enhance the difficulties of the prospector.

LARDEAU MAP-AREA, BRITISH COLUMBIA

By M. F. Bancroft

CONTENTS

The field work in Lardeau map-area (Figure 24) in 1921 consisted of further systematic mapping of the geology, and investigation of ore deposits. The writer's field work had covered, by the autumn of 1920, a wide strip of country between Slocan mining area and the 20-mile railway belt out from Camborne. The section of the railway belt on the northwest side of Lardeau area is exceedingly rugged and practically devoid of trails, and only part of the topography has been mapped.

Field work was commenced at Revelstoke in the latter part of June. Snow remained on the summits until late in the season and the autumn rains set in about the middle of August, permitting only a short working season. Efficient assistance in the field was rendered by two student assistants, H. T. James and G. F. Barnwell. Three local men were engaged to help in back packing and axe work. The writer wishes to acknowledge in particular the interest taken in the work by Arthur Johnson, Gold Commissioner, A. G. Langley, Resident Mining Engineer, and Walter Bews, Mayor of Revelstoke.

GENERAL GEOLOGY

The different rock formations underlying the Lardeau map-area southeast of Incomappleux river were summed up in the table of formations in the Summary Report, 1920.[1] The same formations or their equivalents are to be found in the 20-mile railway belt on the west side of Selkirk mountains. The field data obtained in 1921 relate to the distribution and structural features of these rocks.

Both stratified rocks and igneous rocks occupy wide areas in the Lardeau map-area. The stratified rocks form a thick cover into which granite and similar rocks have been intruded. Some of the igneous bodies reached high enough in the earth's crust to establish intrusive contacts with the uppermost strata found in the region. Deep erosion has laid bare these igneous bodies over wide areas in the Selkirk region northward from the International Boundary. The batholiths are exhumed to a stage at which they are seen in contact, in some places with the basement rocks, and at many other points with the upper formations of the region. Areas of metamorphic rocks occur in proximity to the igneous bodies; and progressive metamorphism is shown in the stratified rocks upward from the intrusive contacts.

STRATIGRAPHY OF THE SEDIMENTARY FORMATIONS

All the stratified formations have been compressed into wide folds. Folding and erosion of the sedimentary cover have exposed all the different stratigraphic

[1] Geol. Surv., Can., pt. A, p. 99.

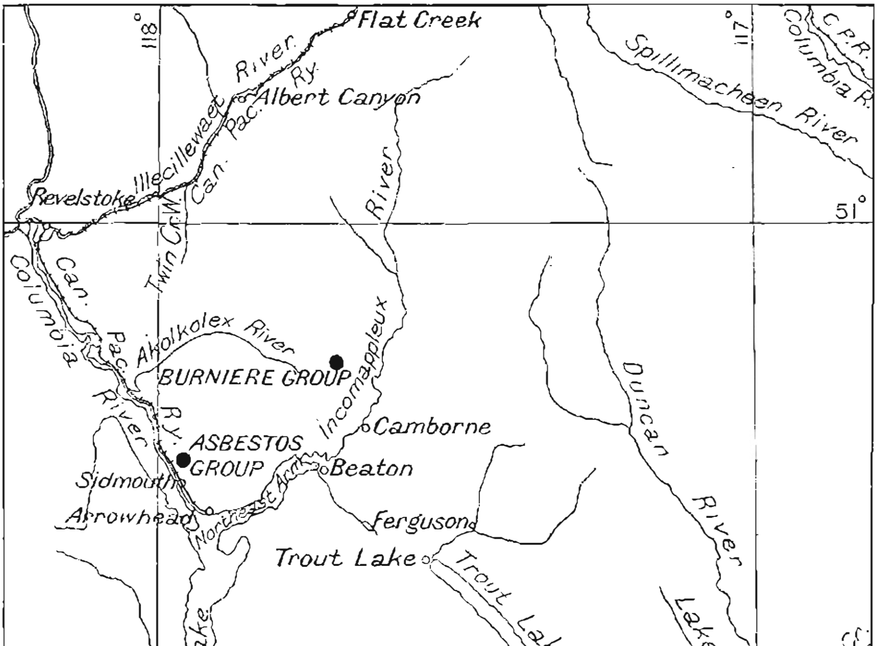


Figure 24. Index map of Lardeau area, Kootenay district, B.C.

horizons; and crystalline basement rock types may appear in the same upland surface flanking much younger and less altered formations. The total thickness of sediments thus exposed aggregates several miles.

The stratified formations of Lardeau area fall into two distinct groups, a basal series consisting of quartzites, siliceous argillites and limestones and their metamorphosed equivalents, and a younger sedimentary series of carbonaceous marine beds, dominantly composed of argillites but including persistent limestone beds that are most numerous towards the base of the series. These correspond respectively to the Shuswap series and Niskonlith series into which Dr. G. M. Dawson in 1889, when examining mining areas in Kootenay district, divided the stratified rocks on the west side of the Selkirks. His mapping of the Shuswap series southeast of Revelstoke is consistent with the structure, in so far as older stratified beds appear in this section, in Illecillewaet and Columbia valleys. Dawson mapped a Shuswap-Niskonlith contact in the mountains on the west side of Kootenay lake which has proved to be continuous into Lardeau area. He inferred that a similar contact crossed the main line of the Canadian Pacific railway near Albert Canyon station, where metamorphosed rocks of the Shuswap series appeared to emerge from beneath the carbonaceous schists and argillites found in the railway section between Albert creek and Flat creek.

There can be no doubt that a considerable time interval is represented by the contact between the basement rocks and the Slocan (Niskonlith) series. There are possibly other gaps of lesser time value that have been overlooked, but the bulk of the sedimentary formations in Lardeau area must be regarded as either Carboniferous or pre-Carboniferous in age. Definitely Carboniferous marine fossils were obtained in 1917 from limestone and argillaceous beds of the Slocan (Niskonlith) series in the southern part of Lardeau area near mount Cooper.

STRUCTURE OF THE SEDIMENTARY FORMATIONS

The major structures in the stratified rocks are folds paralleling the Cordilleran trend. These folds are complex and show a great variety of minor flexures. The folds in the formations on the west side of the Selkirks in general trend northwest to southeast.

Open folding is characteristic of the basement formations which are composed of competent beds of quartzite and indurated siliceous argillites and limestones. The younger and softer beds infolded above the basement series are often tightly compressed in close folds. Some of the composite folds in the basement rocks attain several miles in width. West of Albert Canyon station well stratified metamorphosed beds appear at the track-level, rising abruptly 4,000 feet above the valley on the south side in the vicinity of the Albert peaks and continuing southwestward to form the height of land on the east side of Columbia valley. This structure represents a broad upwarp or arch in the basement formations, an unsymmetrical anticlinorium possibly more than 40 miles in width. This structure is continuous in the mountains on the west side of the Columbia beyond the limits of Lardeau map-area.

Warping of the major structures transverse to the trend of the region has given rise to minor folds favouring east to west axes. These folds affect the whole stratified series. Where the major folds plunge to the north or pitch to south, east to west folds represent the minor bucklings in the strata around the ends of these folds.

Faulting in Lardeau area is of minor importance to the folding. A break occurs in the formations near the headwaters of Twin Creek West. The creek appears to mark the fault line, for prominent limestone beds have been dropped down in the section on the east side of the creek and carried northward for a mile. The vertical displacement is only a matter of a few hundred feet. Faults in this mountainous region mostly show downthrow of the formations to the east and the displacement appears in this case to have occurred with a shift to the north of the fault block on the east side of this break.

Igneous Rocks. The igneous rocks found in Lardeau area are all younger than the Carboniferous strata of the region. The first igneous invasion recorded includes gabbros and other basic rock types. Numerous sheet-like dykes of greenstone appear in the central part of the Lardeau syncline. These intrusives correspond to the Kaslo schists and form parallel bands following the trend of the folded formations. They are compact rocks that stood up in the weathering and erosion of the region to form the summits of ridges and peaks. They are most prominent in the region southeast from the headwaters of Akolkolex river. These basic igneous bodies preceded the invasion of the Nelson granodiorite. Many of them are greatly altered to chlorite schists, talcose schist, carbonate rocks, and in some localities to serpentine.

The granodiorite area in the vicinity of Revelstoke and extending up Illecillewaet valley appears to be in alignment with the wide belt of granite rocks that crosses the Lardeau area southeast of the Albert peaks. Northwestward beyond the Lardeau sheet a similar granodiorite belt extends through the Eagle Pass mountains and is shown on the Shuswap map-sheet (No. 604) extending as far as Adams lake.

The intrusive contacts of this batholithic area west of Revelstoke appear for the most part to be outlined in the basement rocks of the region. The contact extending along the south side of Illecillewaet valley between Revelstoke and Albert canyon pitches steeply to the south in the stratified formations, basement to and below the Slocan series. All the stratified formations above this intrusive contact are metamorphosed, and the contact pitches so steeply that few minor intrusives appear in the immediate vicinity to penetrate the overlying stratified rock cover. This intrusive contact and the stratigraphic contact crossing the height of land on the south side of Illecillewaet converge eastward so that the belt of basement rocks narrows and the igneous body is brought in close vertical relation to the upper formations in the Albert Peaks section.

ECONOMIC GEOLOGY

The mineral deposits in Lardeau area are closely associated with igneous intrusives. Wherever there are mineral indications there are at least minor igneous bodies outcropping in the same locality. The principal intrusive contacts bordering the granodiorite areas in Lardeau are similar to contacts southward in the Selkirk region and are probably well mineralized, but for the most part these contacts cross the mountains in the remoter parts of the area and have been little prospected. Few substantial efforts have been, or are being, made to prove the value of the mineral resources of this area. At the time the Slocan area was being prospected many claims were staked at widely scattered points, and some along well-defined mineral zones in this part of the Selkirk region, yet only very limited mining developments materialized. The majority of the mineral claims are in the Slocan formation, extending diagonally across the area between the head of Kootenay lake and Revelstoke. Some properties were located in the early days east of Albert canyon near Illecillewaet and on Incomappleux river, south of Flat creek. No important mineral discoveries have yet been made in the mountains along the south watershed of Illecillewaet river, though there are places where the rocks are impregnated with rusty-weathering sulphides, containing pyrite, pyrrhotite, and some chalcopyrite. A few mineral occurrences have been reported from the Akolkolex drainage basin just south and east of this watershed, within the bounds of Revelstoke mining division. The geological formations found in this section are the extension northwestward of the rocks crossing Lardeau, Trout Lake, Ainsworth, and Slocan mining divisions.

The metalliferous ores mined in the Selkirk region carry values in gold, silver, lead, zinc, and copper.

GOLD

The gold quartz veins found in the central mineral belt from Cascade creek on Lardeau river through to Camborne on Incomappleux river merit investigation. The gold quartz at Poplar resembles the gold quartz in the mineral belt crossing Incomappleux river. Associated with the quartz are green patches of material made up of several hydromicas varying from colourless to bright green, the green being due to the presence of a small amount of chromic oxide. These hydromicas have the optical and other physical properties of the mineral mariposite. The veins are associated with a carbonate rock which appears to be in general an intimate mixture of quartz, carbonate minerals, and hydromicas of the mariposite group. Some quartz showing the green hydromicas was found by the writer this season in the talus slopes about the head of Greely creek, but none of the carbonate rock was seen in that locality.

NICKEL

Specimens of the gold quartz and carbonate rock from the Berniere property were found by R. A. A. Johnston to contain minute specks of metallic sulphides that gave traces of nickel; some of the specks may be millerite (nickel sulphide), but others are probably nothing more than nickeliferous pyrite. The carbonate constituents in the rock associated with the gold quartz from the Berniere are somewhat complex. The principal base metals noted are iron, calcium, magnesium, and nickel; traces of manganese and cobalt show in some of the trials; but qualitative experiments indicate rather wide variations in the proportions of the bases mentioned even in different portions of the same sample. The status of the nickel content of the carbonates is a matter of uncertainty, but its behaviour towards reagents points very strongly to the presence of zaratite, a hydrous carbonate of nickel often found in emerald green crusts.

MANGANESE

Carbonates that show on weathering a considerable content of manganese occur in grey quartzites bordering a body of serpentine rock on the west slope of Sproat mountain. The serpentine carries a certain amount of carbonate material, and manganese carbonates occur as local replacements or fissure fillings in the sedimentary formations on the east side of the serpentine belt. The ground in this locality was staked several years ago for asbestos, which occurs in the altered serpentine rock.

Several small open-cuts have been made showing the character of the manganese ore. Samples taken from the surface this season by the writer were reported on by Eugene Poitevin as follows: "The material consists for the most part of granular, compact, greyish to pinkish carbonates of manganese, iron, calcium, and magnesium. These carbonates probably form isomorphous series. Some of them are near rhodochrosite in composition, others nearer to mangancalcite or mangansiderite. The specific gravity varies from 3·30 to 3·40, and the optical properties indicate that the material is not of uniform composition. About 20 per cent of the material is unattacked by hydrochloric and nitric acids. The microscopic residue appears to be quàrtz. A few quartz crystals coated with manganese oxides appear encrusted on one of the specimens.

The hydrous manganese oxides coating the carbonates are admixed with certain quantities of limonite. It is evident that the manganese oxides were derived from the transformation of the carbonates."

ASBESTOS

Asbestos Group. The property mentioned above is known as the Asbestos group of claims and sit situated to the east of the Columbia river, about 1½ miles in direct line from the Canadian Pacific Railway track at Sidmouth, a flag station 3 miles north of Arrowhead. The claims are at an elevation of 4,200 feet above sea-level, approximately 2,800 feet above the railway.

Assessment work in the early part of the summer disclosed some high-grade asbestos of the fibrous chrysotile variety in open-cuts made in the serpentine. The owners are R. Armstrong of Sidmouth and J. T. Lauthers of Revelstoke.

Chrysotile veinlets may be found in almost any serpentine area. The surface showings where chrysotile is mined in Quebec are seldom conspicuous. The Asbestos group of claims is located on a belt of serpentine rock that represents a very much altered basic igneous intrusion. This igneous body has the form of a wide dyke or elongated stock that cuts across a series of quartzites, crystalline limestones, and argillaceous schists. The original igneous massive has been altered to serpentine and talcose schists.

In the ground covered by the Asbestos group the serpentine forms an escarpment or series of rocky bluffs starting at an elevation about 2,600 feet above the railway on the northwest slope of mount Sproat. The outcrops of the serpentine occur over a vertical distance of 350 feet on a 25-degree slope, so that the belt has a width of about 1,000 feet and is continuous for some distance along the strike.

Good samples of both cross fibre and slip fibre may be obtained from the open-cuts on the Asbestos group. Mr. A. G. Langley examined the property, and samples submitted by him to R. A. A. Johnston proved to be chrysotile or serpentine asbestos. The specimens of cross fibre collected by Mr. Langley showed a fibre length of $\frac{1}{2}$ inch to $\frac{3}{4}$ inch. Mr. Johnston states that these specimens are quite as good as, if not superior to, much of the South African stock now being used in increasing amounts as a filler.

The writer visited the property in August and obtained a variety of specimens of different grades. The best cross fibre in these specimens is straw-yellow and would yield a product of fair length, strength, and silkiness that would find a ready market.

A specimen showing the best quality of slip fibre consisted of fine, silky fibres 4 to 5 inches in length. This was pronounced by Mr. Harvie, who has been working in the Quebec asbestos area, to be very desirable material, corresponding to certain varieties of material from South Africa.

Some of the specimens of cross fibre were found to be somewhat harsh and brittle and would lack the tensile strength for a good spinning fibre; it should, however, make a good filler for textiles. The very short-fibred material could be used to advantage in compositions such as wallboard, tile, and roofing.

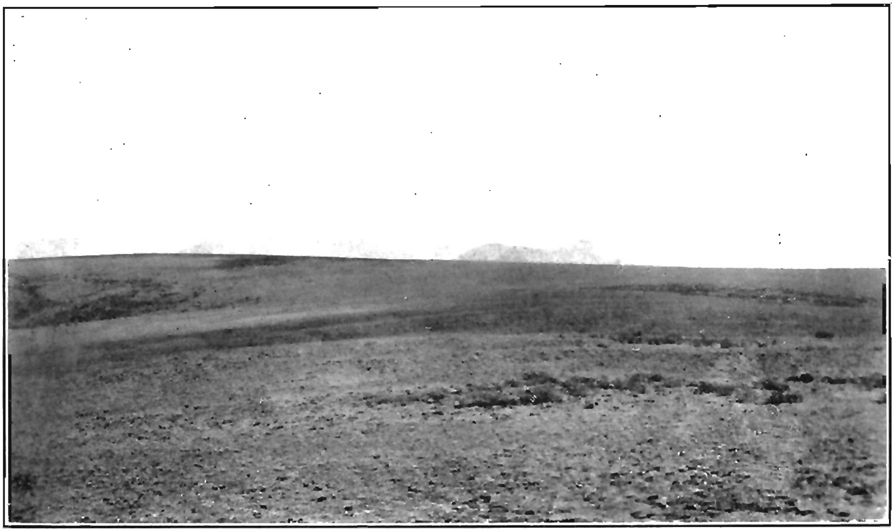
The serpentine on the Asbestos group of claims is a very much altered type of rock. A considerable part of it is altered to compact talc schists. Other minor alteration products are calcite and magnesite; possibly some of the green patches in the rock may be actinolite. Associated with the cross-fibre asbestos is the brittle, fibrous, green mineral picrolite.

Talc. Some of the talc in this serpentine might prove of commercial value, since the property is close to transportation. Varying amounts of either talc or serpentine asbestos are found in the small open-cuts that have been made on the property. The talc, where it occurs in quantity, is light grey, but soft, yielding a white powder. Some of the samples show material that would make a medium-grade talcum powder or might be useful as a paper filler and in compositions.

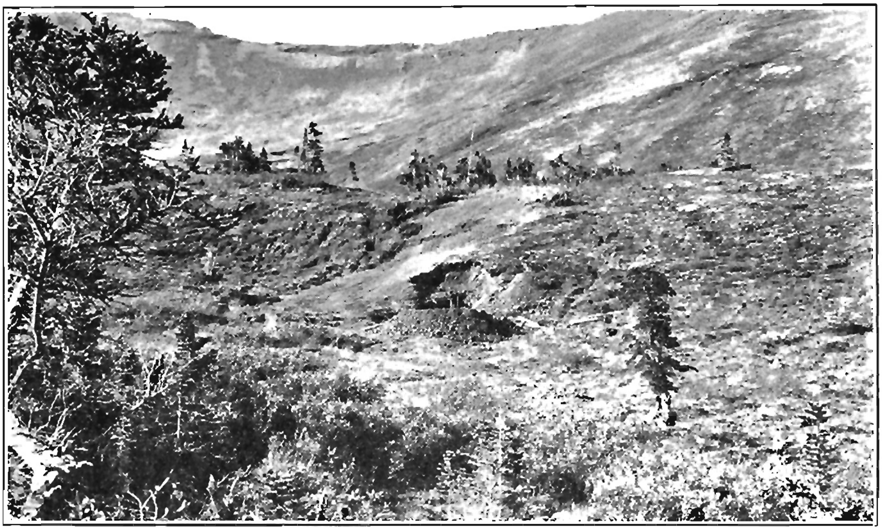
The Mount Sproat section appears to warrant further exploratory work to determine whether chrysotile, talc, or manganese occur in workable deposits. The Asbestos group has yielded the best samples of chrysotile so far found in British Columbia.

Iceland Spar. R. W. Brock, reporting on Lardeau area in 1903, pointed out that a small piece of calcite, so clear and unchecked as to belong to the Iceland spar variety, had been found near Whiskey point on the northeast arm of Upper Arrow lake. It was also pointed out that if this material could be found in quantity it would be a most valuable discovery, as this form of calcite is in demand for optical purposes and the known deposits are almost exhausted.

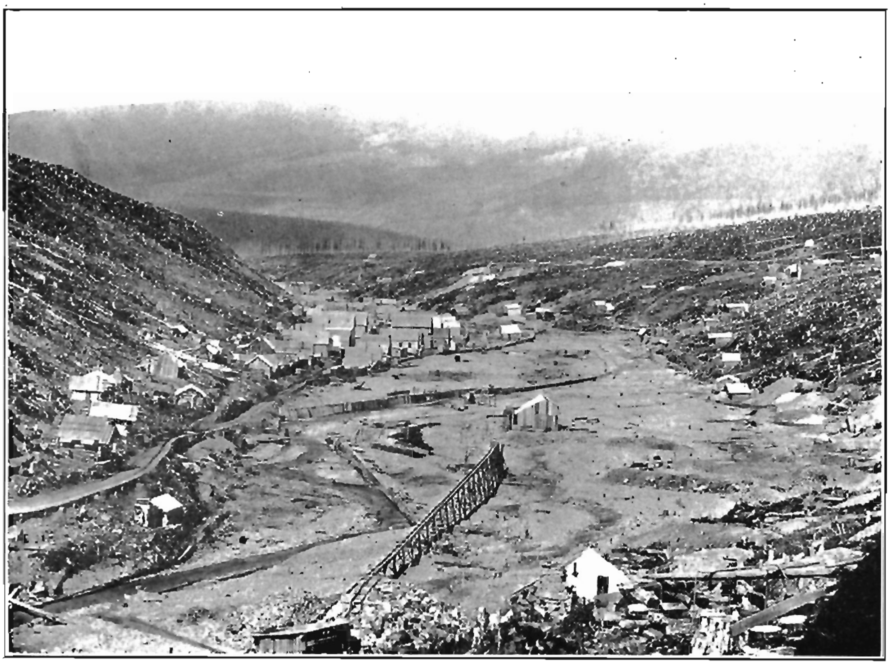
A discovery of Iceland spar was reported this season near the headwaters of Lake creek, a tributary of Lardeau river. This locality is on the northeast side of Lardeau area, where the limestone formations that occur near the base of the Slocan series strike northwest and southeast across the country. The writer was unable to examine the deposits, but samples obtained from outcrops give promise that the right sort of material has been found in place.



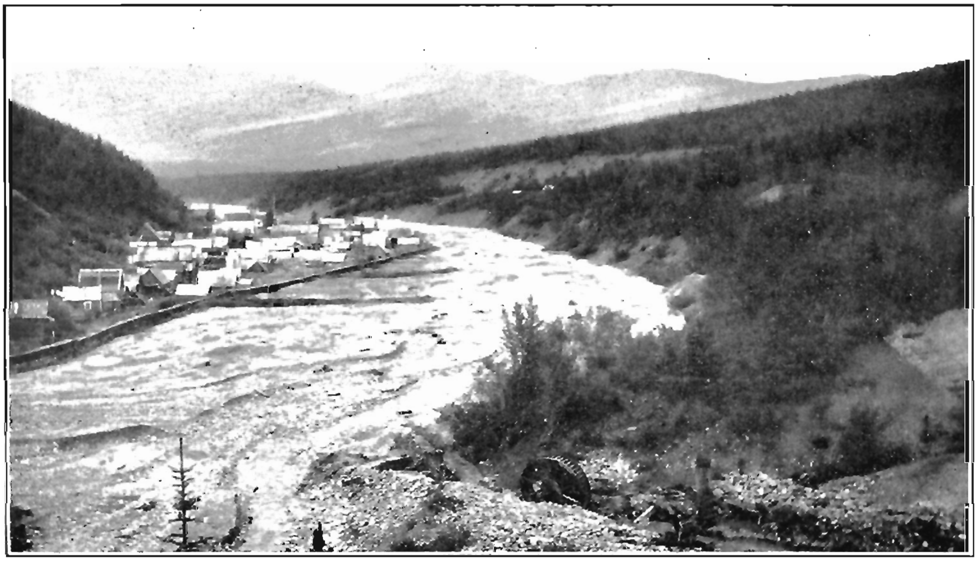
A. View of the upland surface, showing the flat-topped character of the plateau. (Page 3.)



B. Workings of the Mount Cameron property. The outcrop of the vein may be seen in the silde of broken material in the middle of the picture. (Page 6.)

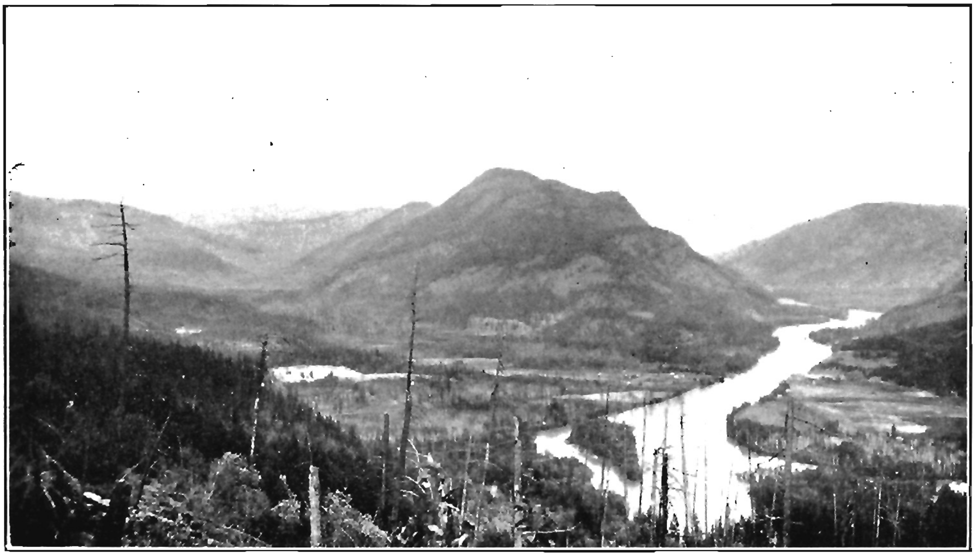


View down Williams creek from Black Jack cut, Bakerville area, B.C. (Photo, 1868, by R. Maynard, Victoria, B.C. (Page 61.)



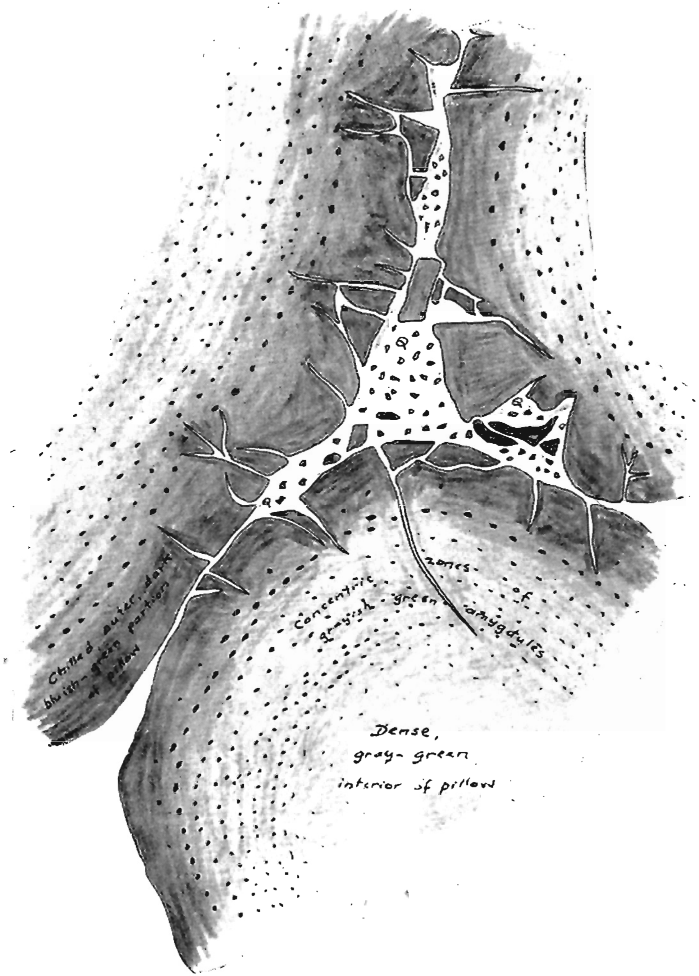
B. View down Williams creek from Black Jack cut, Barkerville area, B.C. (Photo, 1921.) (Page 6.)

A. View eastward across North Thompson valley from point 2 miles south of Mount Olie village. Picture shows the youthful topography of the North Thompson trench, the old-dissected peneplain above, the topographic unconformity between these two, and Dunn peaks in the far distance, which are monadnocks standing above the uplifted peneplain. (Pages 74, 89.)



B. View up North Thompson valley showing Mount Olie village and "roche moutonnée" character of Fennell pillow lava on Mount Olie ridge. (Page 74.)

A. Fennell greenstone showing pillow structure, in Canadian Northern railway-cut north of Chu Chua, (Page 77.)



B. Sketch of parts of three contiguous pillows, to illustrate the brecciation of their peripheries, the fillings of chalcedonic quartz (Q), and the zonal arrangement of the amygdules. Natural size, approximately 11 inches. (Page 77.)

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[1]NOTE: All localities not otherwise designated are in British Columbia.