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DEPARTMENT OF MINES

SIR JAMES LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR.

Summary Report, 1920, Part A

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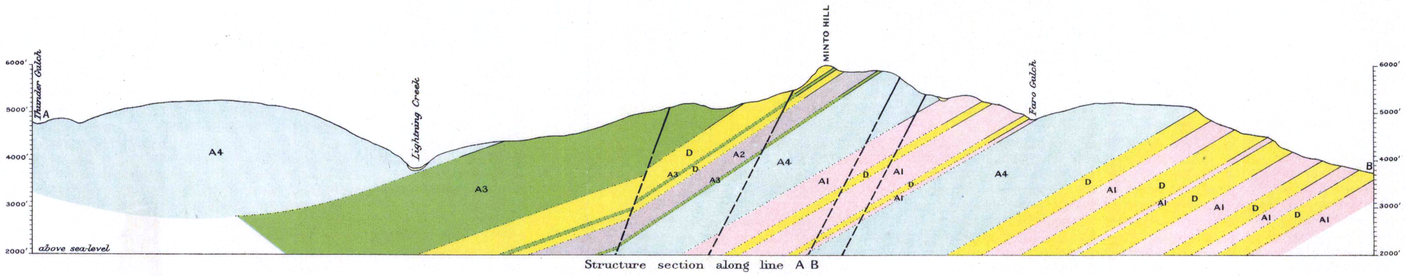


Structure section along line A B

LEGEND

TERTIARY TO PALÆOZOIC MESOZOIC(?) — QUATERNARY

RECENT AND PLEISTOCENE
- Q — Superficial deposits *gravel, soil, silt, muck, glide-rock, and boulder clay.*

T-M — *Rhyolite, quartz porphyry, granite porphyry.*

DEVONIAN (?)
- D — *Andesite, diorite, diabase.*

PRECAMBRIAN — NASINA SERIES
- A4 — *Quartzite*
- A3 — *Black schists (mica and graphite)*
- A2 — *Green schists (sericite and chlorite)*
- A1 — *Schists (not differentiated.)*

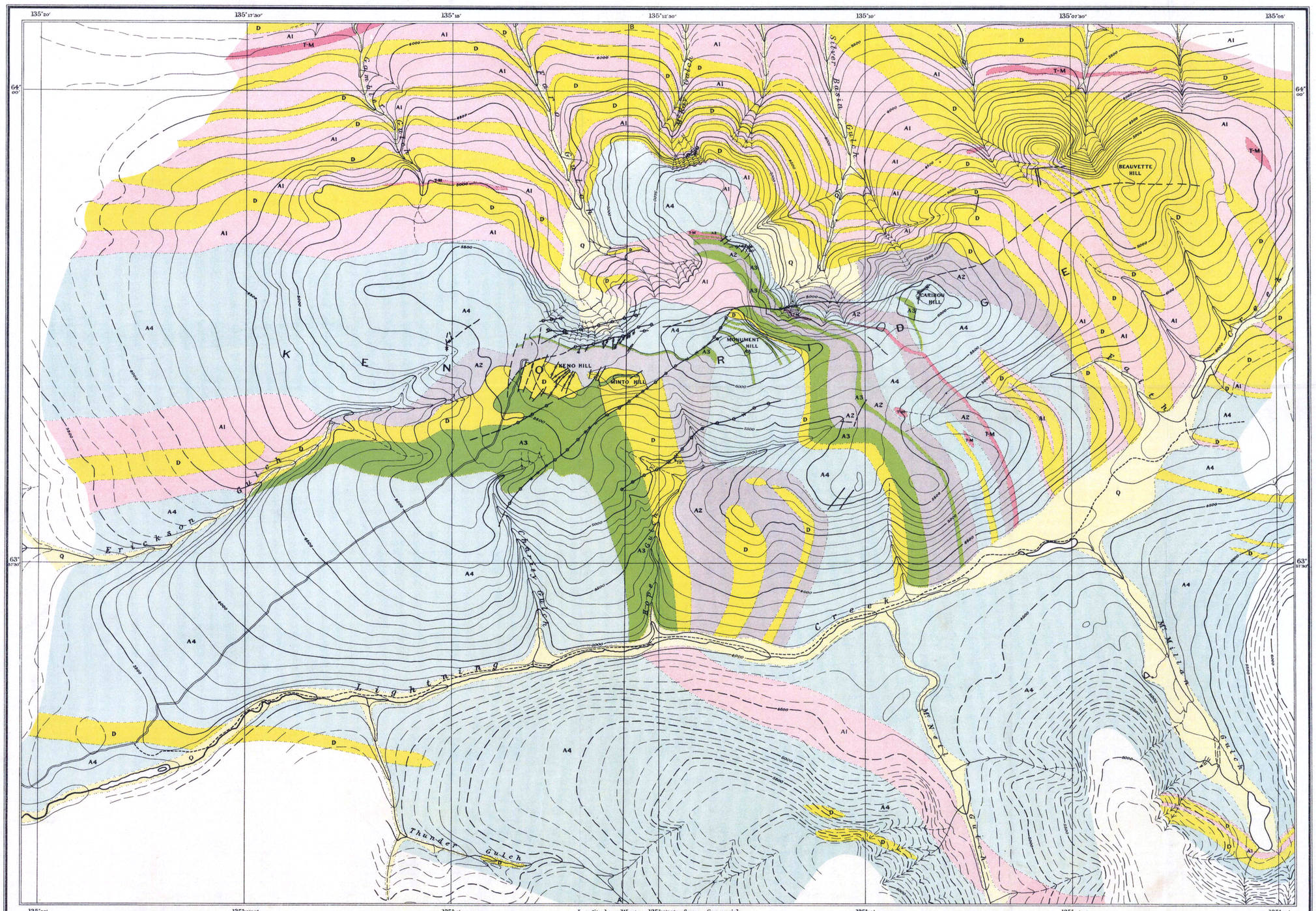
Symbols

- Geological boundary *(observed.)*
- Geological boundary *(assumed.)*
- Fault *(located.)*
- Fault *(galena, iron, manganese mineralization.)*
- Fault *(quartz, arsenopyrite mineralization.)*
- Fault *(assumed.)*
- Dip of fault
- Roads
- Trails
- Rivers and lakes
- Watercourses *(with intermittent flow)*
- Contours *(showing land forms and elevations above sea-level) Interval 100 feet.*
- Contours *(showing land forms approximately)*

Geology south of Lightning creek of reconnaissance type.

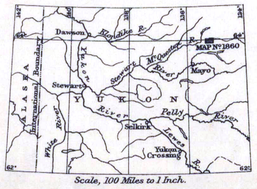
Geographical position subject to revision.

Approximate magnetic declination, 37° 20' East.



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

Publication N° 1860



Scale, 100 Miles to 1 Inch.

KENO HILL AREA, MAYO DISTRICT, YUKON TERRITORY.

Scale of Feet
1000 0 1000 2000 3000 4000 5000 6000

Sources of Information

Geology by W.E. Cockfield, 1920.

Topography from reconnaissance surveys by W.E. Cockfield, 1920; from maps of the Topographical Surveys Branch, Department of the Interior, and of the Yukon Gold Mining Company, Limited.

Map compilation by W.E. Cockfield, 1920.

Keno Hill, Mayo District.
5-1-11
A, Geol.

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1860

To accompany Report by W.E. Cockfield, in Summary Report, Part A, 1920.

SUMMARY REPORT, 1920, PART A

SILVER-LEAD DEPOSITS OF THE KENO HILL AREA, MAYO DISTRICT, YUKON

By W. E. Cockfield

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INTRODUCTION

A detailed geological investigation of the ore deposits of Keno hill, Mayo district, was made in the summer of 1920. Two and a half months were spent on the field work, and the writer was ably assisted by P. F. Armstrong, W. G. Cuttle, and C. A. Merritt. The work included the preparation on a field scale of $\frac{1}{12,000}$ of the topographic map that accompanies this report.

The writer wishes to acknowledge his indebtedness to the officials of the Yukon Gold Company for information freely placed at his disposal and for many other courtesies.

Location and Accessibility

Mayo district takes its name from the town of Mayo, which is situated on upper Stewart river, 180 miles above its confluence with the Yukon. All parts of the area are readily accessible. During the summer months a regular passenger and freight service is maintained by the White Pass and Yukon route.

The position of Keno ridge with respect to Mayo is shown in Figure 1. It is a ridge about 10 miles long and 5 miles wide lying between Christal and Lightning creeks and Ladue river. The distance from Mayo by wagon road is about 42 miles.

The rates charged for freight vary greatly. From Dawson to Mayo the freight rate is from $50 to $60 per ton, depending upon the stage of water in Stewart river. The freight rate from Mayo to the summit of Keno hill is 15 cents a pound by wagon and about half that amount by sled in the winter. Ore is usually handled by contract and can be shipped from Keno hill to smelters on the Pacific coast for about $60 per ton.

TOPOGRAPHY

Mayo district lies entirely within the physiographic province known as Yukon plateau. It is characterized by being subdivided into isolated mountain groups, separated by broad, flat-bottomed valleys. The interstream areas are mostly flat-topped and stand at an average elevation of 5,000 feet, the elevation increasing slightly toward the east. These upland areas are parts of a former plain-like surface, which has been uplifted and dissected.

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

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By far the greater part of the area is floored by the crystalline schists of the Yukon group[1] which are thought to be Precambrian. In Mayo district these belong chiefly to the oldest subdivision of the group, namely, the Nasina series,[2] and con-

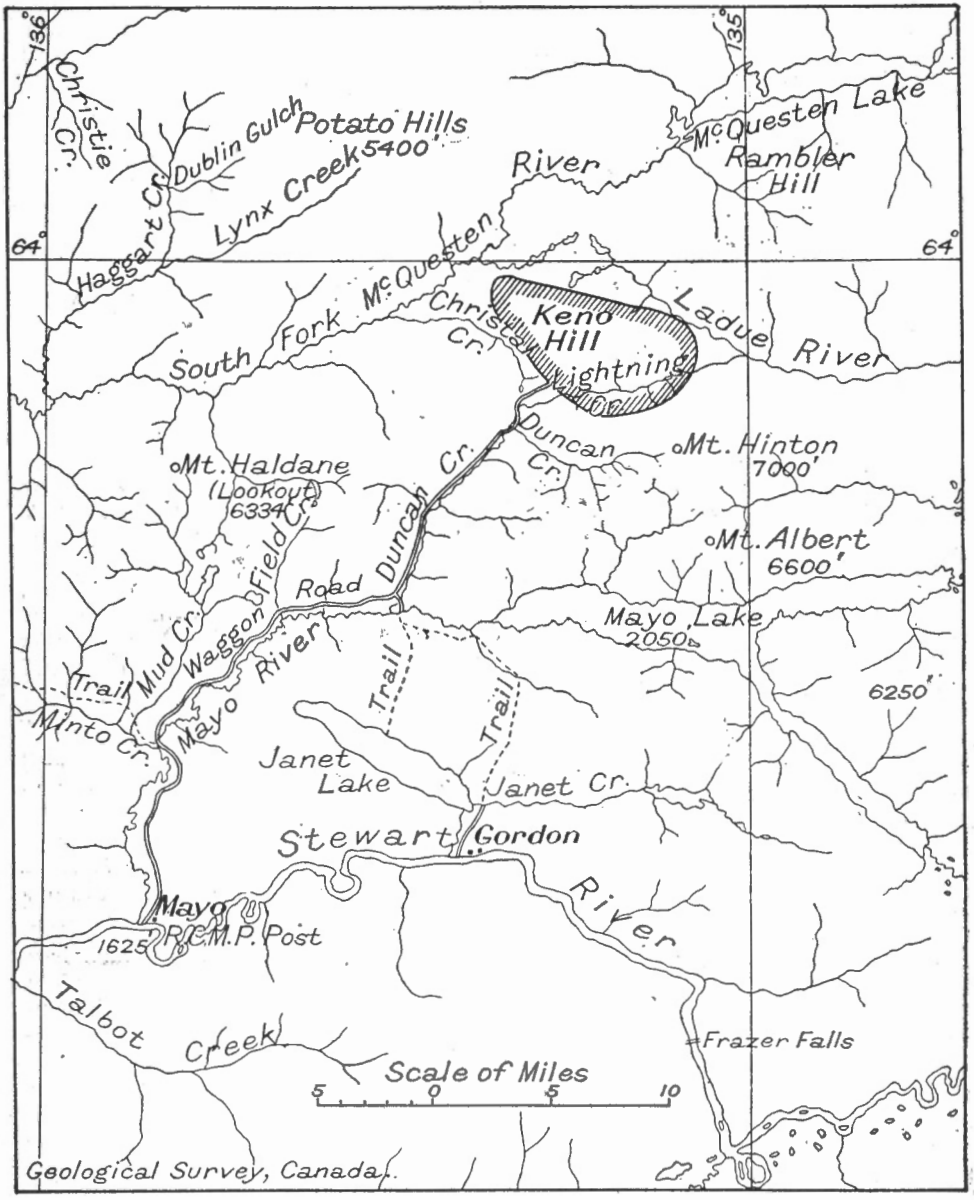

Figure 1. Index map showing location of Keno Hill area, Mayo district, Yukon.

sist of gneissoid quartzites, quartz-mica schists, mica schists, graphite schists, hornblende schists, and crystalline limestone. These schists are cut at some localities by later igneous rocks, chiefly greenstones and granite.

[1] Cairnes, D.D., "The Yukon-Alaska International Boundary", Geol. Surv., Can., Mem. 67, 1914, pp. 38-44.

[2] McConnell, R. G., "Report on the Klondike gold fields", Geol. Surv., Can., Ann. Rept., vol. XIV, 1901, pp. 12 B-15 B.

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The area mapped during the past summer consists of a ridge about 10 miles long and 5 miles wide, lying between Christal and Lightning creeks and Ladue river. The ridge is long and wedge-shaped, with a flat top and is surmounted by five hillocks rising a few hundred feet above the general level. These are known as Keno hill, Minto hill, Monument hill, Caribou hill, and Beauvette hill. All except the very lowest slopes of the ridge is above timber-line. The summit of the ridge stands at an elevation of 6,346 feet above sea-level, and the bulk of the properties on which work has been done lie quite close to the summit.

The northern slope of the ridge is very steep, but is broken by a series of benches, formed by outcrops of the harder formations. These benches slope gently toward the hill, but their outer limits are bounded by steep, even precipitous, slopes. A prominent sill of greenstone projecting almost 100 feet above the surrounding rocks forms the summit of Keno hill. This sill has a cliff face to the north and forms a topographic feature that can be recognized for long distances.

A number of small gulches drain outward from the ridge, and are tributary to the larger drainage courses. These gulches are steep in grade and mostly rise abruptly in semicircular basins. The more important gulches draining to the north are Gambler, Faro, and Silver Basin; draining to the south, Faith, Hope, and Charity; and to the west, Erickson.

GENERAL GEOLOGY

The greater part of the area is underlain by crystalline schists which are intruded by sills of greenstone and dykes and sills of quartz porphyry and granite porphyry.

The crystalline schists consist of a banded blue and white gneissoid quartzite, grading in places into a quartz-mica schist, sericite schist, graphite schist, and crystalline limestone. These occur in bands more or less continuous across the mapping sheet. The greenstone is intruded as sills, usually into the softer schist formations. These sills are conformable in strike and dip with the intruded schists. Like the schists they have undergone deformation, but have suffered less in this respect than the rocks they intrude. In places they have a decidedly schistose appearance, but in general are quite massive, though possessing a pronounced cleavage in one direction. The greenstones vary considerably in colour, texture, and composition, ranging from a diorite to a diabase. Owing to their superior resistance, they form important topographic features.

The quartz porphyry and granite porphyry occur as dykes and sills which in general conform in strike to the bedding of the rocks they intrude, but in some instances they cut across it, and in such cases clearly show that they are the latest consolidated rocks of the region. They are believed to be apophyses of a large granite body which outcrops 10 miles to the east, and which undoubtedly extends widely beneath the known strata of Mayo district.

Overlying all the consolidated rock formations there is a mantle of superficial deposits, which nearly everywhere masks the underlying rocks and renders prospecting difficult.

The general trend of the strata is in an east-west direction, and they dip to the south at relatively low angles. However, near the hillocks known as Keno hill, Minto hill, and Monument hill, the strata undergo a sharp flexure, bending nearly at right angles, and continue in a southerly direction across Lightning creek where they gradually resume their former course. This flexure is believed to be the cause of the numerous small local faults which occur in the vicinity, and which have such an important bearing on the ore-bodies.

ECONOMIC GEOLOGY

Ore-Bodies

The ore-bodies are found in fissure veins and are consequently bound up with the systems of faulting. Two of these systems have been recognized. Owing to the

main system having a general trend of north 30 to 40 degrees east (magnetic)[1] and running in a general way parallel to the trend of the formations, these systems will be called for purposes of reference, longitudinal faults. The main system is composed of one main fault, which crosses from Beauvette hill on the east to Caribou hill and thence across the top of Silver Basin gulch, a distance of over 2 miles. Near Silver Basin gulch this fault diverges into three branches, one of which crosses Minto and Keno hills and the others the top of Faro gulch. Towards the western portion of the mapping sheet these die out or their effect is obscured by the mantle of superficial deposits. Traces of other faults parallel to these have been found but they could not be traced any distance for the same reason.

The second system of faults will be referred to in this report as transverse faults because they are, in general, found cutting across the strike of the formations. Their strike is from north 5 degrees west to north 15 degrees east (magnetic), and as a rule they are short and of comparatively slight displacement. As already pointed out these faults are exceedingly numerous in the vicinity of the local folding referred to above.

The longitudinal faults are mineralized with quartz, arsenopyrite, siderite, manganese, and galena; the transverse faults are mineralized with quartz, calcite, galena, blende, manganese, and siderite, and enriched with a silver salt, not yet positively identified but believed to be freibergite (4 (Cu Ag)$_2$S.Sb$_2$ S$_3$), a sulphantimonide of copper and silver.

The principal ore-shoots already discovered lie in the transverse faults and consequently work on these faults has progressed to a greater extent than on the longitudinal faults. From what has already been learned it may be established as a general rule that where a transverse fault taps one of the longitudinal faults and passes upward out of a hard stratum such as quartzite or greenstone into schist, an ore-shoot is usually found in the vein beneath the schist, as if the latter had acted as an impervious barrier to the ore-bearing solutions and had forced deposition of their load at that point. Development has not yet been carried to the point where it can be affirmed that the schist is barren of ore, and that ore-shoots occur only beneath schist cappings, but it is well established that such places are exceedingly favourable for ore-bodies.

In the longitudinal veins ore deposition has taken place at localities where the veins have been opened by a distinct fracture, i.e., probably contemporaneous with the formation of the transverse faults. At other points, however, the ore is of a disseminated character and may possibly have been introduced at the time of formation of the longitudinal faults. Consequently no general rule for the distribution of ore-shoots in longitudinal veins can be formulated at present.

No samples for assay were taken by the writer as the content of the ore is well known. The galena usually occurs fairly pure, i.e. free from mixture with gangue minerals. In such cases it assays from 200 to 500 ounces of silver a ton, but in places it goes much higher, reaching 2,000 ounces. In such cases, however, it usually contains freibergite. The lead assays usually average about 60 per cent. These values it must be understood are for samples of the ore-shoots and are not for the full width of the veins.

Mining Operations

Upwards of 600 claims have been staked on Keno hill and in its vicinity. Naturally on the majority of these only representation work has been done. Serious development work has been performed on only two or three groups.

The Yukon Gold Company secured options on a number of claims, which they have been prospecting vigorously. Their main group consists of the Roulette, Keno, Scotty, Solo II, Pinochle, Wolverine, and Rico, and in addition a number of outlying claims are being prospected such as the Caribou, Gold Hill, Ladue, and Lucky Queen.

[1] Declination 1920, 37° 20′ east.

The principal workings of the Yukon Gold Company lie above timber-line at an approximate elevation of 5,800 feet above sea-level, on the small knoll known as Keno hill and on the steep slope at the head of Faro gulch. They comprise a series of shafts, tunnels, and surface trenches. The three branches of the main longitudinal vein and a number of transverse veins cross the property.

The most northerly of the longitudinal veins is known as No. 1. This vein strikes north 35 degrees east (magnetic) and dips 60 degrees to the southeast. It is from 3 to 7 feet in width, mineralized with quartz and arsenopyrite, and has been explored by three tunnels 230 feet, 140 feet, and 150 feet long. These tunnels are about 60 feet apart along the dip of the vein and the upper two are connected by a winze. These tunnels have tapped an ore-shoot which has an approximate length of 60 feet and thickness of 14 inches, formed in a distinct fracture in the vein.

A second longitudinal fracture runs along close to the top of the slope of Faro gulch. This vein is in a general way parallel to No. 1. It strikes north 40 degrees east (magnetic) and dips 45 degrees to 50 degrees to the southeast. It is similar in type to No. 1 vein, i.e. a quartz-arsenopyrite vein, but no decided ore-shoots have been found in it up to the present. A number of transverse veins intersect it, however, and give rise to some of the more important veins of the property. These are Nos. 3, 7, 8, 9, and possibly also Nos. 4 and 5. No. 3 vein strikes north 23 degrees east (magnetic) and is practically vertical. It has been explored to a depth of 80 feet by a shaft. It averages 3 feet in width and is well mineralized with galena. No. 4 vein is considered to be the continuation of No. 9, a flat underlain by schist, through which the vein has not been traced, intervening between the two. This vein which is approximately 3 feet wide, strikes north 10 degrees east and dips 75 degrees to the southeast. An ore-shoot showing 2 feet of massive galena occurs on the slope overlooking Faro gulch. No. 7 vein strikes north 15 degrees east and dips at 47 degrees to the southeast. It has a thickness of 3 feet. No. 8 vein is in reality a sheeted zone with a thickness of 3 feet.

A third longitudinal vein crosses the southeastern edge of Keno hill and the western edge of Minto hill. It shows the typical quartz-arsenopyrite mineralization with some galena.

The Caribou claim is situated on Caribou hill. The workings consist of surface trenchings. On the summit of the hill the vein is about 5 feet in width striking south 45 degrees east and dipping 72 degrees to the northeast. The mineralization consists of 5 to 8 inches of galena in a gangue of carbonates, oxides, and quartz. The outcrop may be traced along the northern slope of Caribou hill. A considerable body of disseminated ore is found below the intersection of this vein with a flat-dipping one.

McKay and Erickson's Workings. Mining work is in progress on two groups of claims owned by McKay, Erickson, and Beauvette. One of these groups situated at the head of Erickson gulch, comprises the Shamrock, Reno, Kid, Lion, and Tiger claims. Development work consists of 200 feet of drifts and a 15-foot winze. There are two main veins varying in width from 2 feet maximum to a seam, the dips varying from 45 to 90 degrees. There are in addition a number of small slip faults. The mineralization consists chiefly of galena, carbonates, and iron oxide. About three tons of galena was stoped from these workings and shipped but returns were not available at the close of the season's work. Very little unaltered galena was encountered in these workings which are, however, within 40 feet of the surface.

Nabob Claim. McKay and Erickson are also operating the Nabob claim, at the head of Faro gulch, immediately to the east of the Rico claim of the Yukon Gold Company. The vein here is the one described as the central longitudinal vein on the Yukon Gold Company's property. An incline 10 feet in depth has been sunk and considerable disseminated galena was encountered. The property also has several transverse faults intersecting this main vein and it is considered likely that ore-shoots will be found in these as development work continues.

Rasmussen's Property. Rasmussen's claims are situated on the western side of Silver Basin gulch and consist of the Silver Basin, Silver Basin IV, Diorite, and Silver Gulch. A main longitudinal fault striking north 30 degrees east and dipping 65 degrees to the southeast cuts across the property. This has the typical quartz-arsenopyrite mineralization, with some galena. Four transverse faults intersect this main fault and pass upward from the quartzites into the schists. The chances for mineralization at these points have already been pointed out. The work done consists of some open-cuts and trenches, but is insufficient to show the true value of the property.

On a number of other claims, assessment work has been done, but in most cases this has not progressed far enough to expose the veins in place.

Conclusions. The high-grade ore in the transverse fissure offers little difficulty either in finding or extracting. On the upland surface these fissures can frequently be traced by the iron, manganese, and galena float, which is usually close to the outcrop of the vein. As the superficial deposits are generally thin, the task of finding the veins is comparatively easy. On the lower slopes of the ridge, however, where the drift cover is thicker and where the float may be some distance from the outcrops, the prospector's task is more difficult. Good results may be obtained by ground-sluicing with snow water in the spring. The extraction of the ores also offers few difficulties, as most of them are rich enough to pay for mining by hand methods, and in most cases concentration is unnecessary.

In considering the future of the camp it must be remembered that some of the transverse fissures are quite short and are not likely to continue to great depths, but this is compensated for, to some extent, by the large number of these veins. The longitudinal veins, on the other hand, are more persistent, and are more likely to prove continuous with depth. As these fissures undoubtedly served as the main channels for the circulation of the ore-bearing solutions, there is some likelihood of ore-bodies being found in them. Whether these will be of the same high grade character as the ore found near the surface cannot be foretold. It is believed, however, that the permanency of the camp depends to a large extent on the character and size of the ore-bodies contained in these fissures.

SALMON RIVER DISTRICT, BRITISH COLUMBIA

By S. J. Schofield and George Hanson

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Summary and conclusions	12

Illustration

Figure 2. Diagram showing the geology along Premier wagon road, Salmon River area, Cassiar district, B.C. .. 10

INTRODUCTION

In order to complete the study of the geology and ore-deposits of the Salmon River district, Portland Canal Mining Division, commenced by J. J. O'Neill,[1] in 1919, the writers carried on field work in the above-mentioned district.

R. G. McConnell[2] made a reconnaissance of the Salmon River basin in 1911 and his results comprise, in general, the first comprehensive account of the geology of the

[1] O'Neill, J. J., Geol. Surv., Can., Sum. Rept., 1919, p. 7 B.
[2] McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1911, p. 50. Geol. Surv., Can., Mem. 32, 1914.

mineralized belt along the eastern contact of the Coast Range batholith, north of Skeena river. The reports of the Minister of Mines for British Columbia, since 1906, contain valuable and detailed descriptions of the mining properties of the district.

The Geological Survey expresses its indebtedness to the owners of the various mining properties in the district, and especially to Mr. Dale Pitt, General Manager of the Premier Gold Mining Company, for many courtesies extended in the performance of the field work, and also to Mr. P. Racey, General Leckie, and Mr. A. Harris for valuable information concerning the properties under their control. To Mr. Charles Bunting and Mr. P. S. Jack, Stewart, B.C., the writers' thanks are due for their kindness in presenting fossil collections from the district under examination. The topographic map constructed by F. S. Falconer of the Geological Survey, served as a base for the geological investigations. Valuable assistance in the field was rendered by I. M. Marshall and C. H. Crickmay.

Not all the properties examined are described in this report but representatives of each type are given.

The district is contiguous to the International Boundary between Alaska and British Columbia, about 14 miles north of the head of Portland canal. It has an area of about 60 square miles, and lies entirely within the drainage basin of Salmon river, which flows into Portland canal at Hyder, Alaska.

GENERAL GEOLOGY

The geological formations represented in the Salmon River district may be summarized as follows:

Quaternary	Pleistocene and Recent		Flood-plain gravels and glacial drift
		Unconformity	
Mesozoic	Upper Jurassic.	.....	Granite dykes.
		Intrusive contact	
		.....	Augite porphyrite stock.
		Intrusive contact	
		Coast Range batholith	Granodiorite.
		Intrusive contact	
		Premier sills	Quartz porphyry.
		Intrusive contact	
		Nass formation	Slates (fossiliferous), thickness 1,000+ feet.
		Salmon River formation	Conglomerates, thickness 300± feet.
		Bear River formation.	Agglomerates and tuffs, thickness 2,000+ feet.
		Base unexposed	

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

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

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

Premier Sills. These are tabular masses of quartz porphyry intruded between the bedding planes of the tuffs of the Bear River formation. Their maximum thickness is in the neighbourhood of 1,300 feet. The rock is grey-coloured, massive in character, and in hand-specimens shows in some cases phenocrysts of orthoclase and small, irregular masses of quartz in a fine-grained groundmass. The sills were intruded prior to the mountain-building, and, therefore, while the tuffs were horizontal. Since the time of intrusion, they have been subjected to folding along with the containing rocks, and now occupy varying positions which deviate from the horizontal.

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

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

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

Pleistocene. The Pleistocene is represented by drift and fluvioglacial deposits.

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

[1] McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 14.
[2] McConnell, R. G., Geol. Surv., Can., Mem. 38, p. 22.

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

ECONOMIC GEOLOGY

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

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

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

Base Metal Type

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

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

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

Indian Group. The country rock in the immediate vicinity of the ore-body is a quartz porphyry of the Premier type which intrudes tuffs and tuff-conglomerates. The ore occurs in a sheared and brecciated zone which follows closely a quartz diorite dyke. The main tunnel has been driven for a distance of 400 feet along this sheared zone and exposes three ore-bodies, the same, probably, that were developed on the surface above by open-cuts. The two ore-bodies first encountered in the tunnel are very siliceous and do not carry very heavy sulphide mineralization. The ore-body exposed in the face of the tunnel shows very heavy sulphide mineralization for a width of over 15 feet. The predominant minerals are sphalerite, galena with smaller amounts of pyrite, and chalcopyrite.

Silver-Gold Type

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

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

Premier Mine. The geology in the vicinity of the Premier mine is complex, as shown in Figure 2. The main feature is the occurrence of sill-like masses of quartz

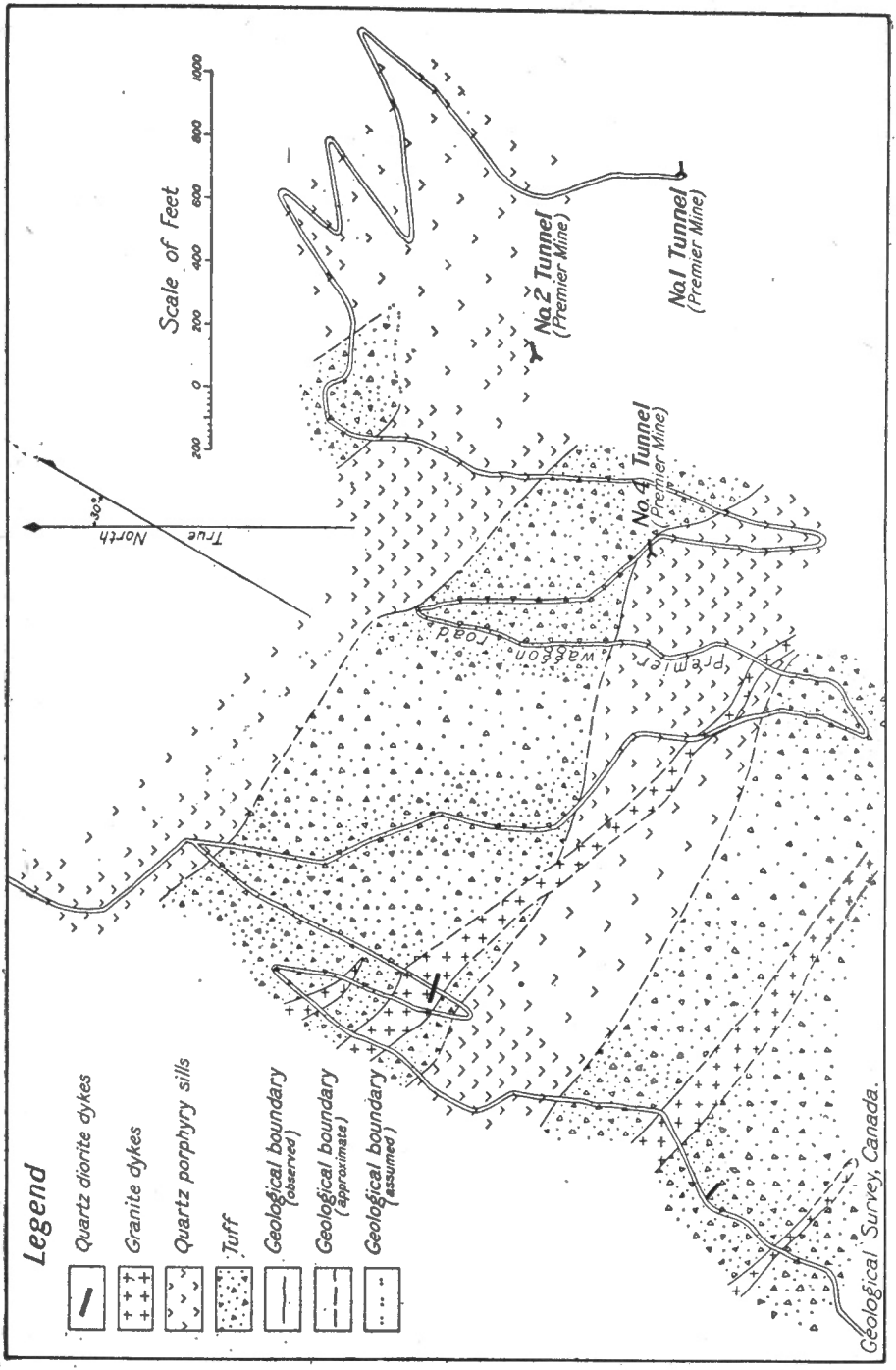

Figure 2. Diagram showing the geology along Premier wagon road, Salmon River area, Cassiar district, British Columbia.

porphyry, called the Premier sills, intruded between the bedding planes of the tuffs of the Bear River formation. Since the dip of the rocks corresponds in large measure

both in direction and amount with the slope of the hillside, it is difficult to locate the contacts between the sills and the tuffs, especially when the greater part of the surface is covered with drift which supports a heavy vegetation.

The ore-bodies in the Premier mine follow closely the contact between the quartz porphyry and the tuffs, both of which are highly altered. Up to the present no ore has been found entirely enclosed in the tuffs, but several lenses occur in the quartz porphyry. The chief locus of the ore-bodies, however, is the tuff-porphyry contact. The ore-chutes are in the form of lenticular veins, in most places about 10 feet in thickness. They have been formed partly by fissure filling and partly by replacement of the tuff and the quartz porphyry.

Minerals identified in the ore-bodies are: pyrite; sphalerite, chalcopyrite, galena, tetrahedrite (grey copper), freibergite (silver tetrahedrite), polybasite, silver copper sulph-antimonide, pyrargyrite (dark ruby silver), argentite (silver sulphide), and native silver. Stephanite (silver sulph-antimonide) and native gold have been recorded. [1]The predominant gangue mineral is quartz. Most of the ore is heavy sulphide, but some of it consists of quartz with isolated patches of sphalerite, tetrahedrite, and silver minerals. The wall rocks have been intensely altered and in most cases extensively silicified.

The ore-bodies, which strike north 75 degrees east and dip 70 degrees to the north, are cut by several faults and shear zones. The movement along the faults has caused a block of the country rock to be displaced so that a portion of the vein is offset to the south about 40 feet. This explains the position of No. 4 stope which is offset about 40 feet from No. 1 and No. 2 stopes.

The native silver is found almost entirely associated with these faults and shear zones and was not seen in the unfractured vein material. In addition, the fractures show a strong downward movement of water and contain considerable amounts of limonite. The silver occurs as thin leaves or plates filling small cracks in the ore. Some occurs in hair-like forms (wire silver) and nuggets in small quartz druses. The localization of the silver to the immediate vicinity of the fractures points to a secondary origin for the native silver or, in other words, the native silver is due to secondary enrichment. Dolmage, in the paper mentioned above, believes that secondary enrichment played a very minor role in the development of the rich silver ores in the Premier mine. Dolmage, however, had not visited the occurrence in the field and based his conclusions on a careful microscopic examination of ore furnished by Mr. C. Bunting.

From the metallographic study of specimens obtained during the examination of the mine it is seen that the native silver occurs in minute veinlets cutting and replacing the other minerals and hence was probably deposited later than these minerals and giving a structure which has been accepted, in large measure, as one due to secondary enrichment.

Evidence in regard to the pyrargyrite and argentite is not so striking. Probably, however, these minerals are in large measure of secondary origin.

It is believed that the silver in the primary ore will be carried chiefly in the galena and tetrahedrite. The values in gold will not be affected by secondary enrichment.

Silver Tip. The Silver Tip property is located in the "Belt of dykes" crossing the northern part of the district. Development consists of numerous open-cuts and a few short tunnels. The ore occurs in narrow, discontinuous veinlets cutting a quartz porphyry dyke. In this part of the district the dykes penetrate the Naas slates, and where veinlets in the dyke reach a slate wall the mineralization spreads along the slate-dyke contact. The minerals are chiefly sphalerite, galena, chalcopyrite, tetrahedrite, silver minerals, native silver, and covellite. Quartz is the principal gangue mineral. The values are in silver.

[1] Dolmage, V., Can. Min. Jour., vol. 41, 1918, p. 454.

Gold Type

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

SUMMARY AND CONCLUSIONS

The ore deposits fall into three main groups:

(*a*) a low-grade, complex type, with values in the base metals, copper, lead, and zinc. (Big Missouri, Hercules, Forty-nine, etc.)

(*b*) a type rich in silver minerals, including tetrahedrite, freibergite, pyrargyrite, argentite, and in some cases native silver. (Premier, Silver Tip, certain ore-bodies in Forty-nine, Big Missouri, and Mineral Hill.)

(*c*) a pyritic siliceous type, with high gold values. (An ore-body in Premier mine.)

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

(*a*) in the quartz porphyry.

(*b*) at the contact of the quartz porphyry with the tuffs.

(*c*) in certain beds of the tuffaceous conglomerate.

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

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

The native silver is considered to be of secondary origin.

WEST COAST OF VANCOUVER ISLAND BETWEEN BARKLEY AND QUATSINO SOUNDS

By V. Dolmage

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INTRODUCTION

The field season of 1920 was spent in making a geological map of the west coast of Vancouver island between Barkley and Quatsino sounds. This work joins up that done by the writer in Quatsino sound, 1918, with that done by him in Barkley sound, 1919; and, together with Dawson's[1] work north of Quatsino and Clapp's[2] work south of Barkley, forms a complete shore-line map of the whole of the west coast.

Owing to the absence of other topographic maps, the geology was plotted on Admiralty charts and the mapping had, therefore, to be confined chiefly to the shore-line. However, the coast is so indented and the islands are so numerous that it is possible from a complete map of the shore-line to draw fairly accurate conclusions regarding the geology of the whole region.

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., 1886.
[2] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912.

The only geological work previously done in this region is that of E. Haycock[1] and A. Webster[2] who made a trip up the coast in 1902, landing where it was possible and describing the formations there observed. The work of the present writer, however, is to a great extent a continuation of Clapp's and Dawson's work.

R. C. Emmons ably filled the position of student assistant. The work was also facilitated by Captain Charles Spring who proved not only a capable navigator but also a useful guide in finding certain mineral and fossil localities.

GENERAL DESCRIPTION

The coast between Barkley and Quatsino sounds, consisting as it does, of three large sounds with numerous inlets and islands, among which may be found many excellent harbours, is the most irregular part of the west coast of Vancouver island. It differs markedly from the rest of the west coast, which is so straight and regular that it offers almost no protection to coasting vessels.

The shore, in general, is bold and rocky, and sparsely timbered with stunted conifers; but in a few places, such as Estevan point and in the vicinity of Wreck and Long bays, long, sandy and bouldery beaches are developed at the base of low perpendicular cliffs.

This part of the island is thinly populated, chiefly by Indians of a most primitive type; a few white people are engaged in fishing and canning, and to a slight extent in mining, lumbering, and ranching.

The only means of communication is by the C.P.R. steamer, *Princess Maquinna*, which makes the round trip from Victoria to Quatsino three times each month.

GEOLOGY

The following table of formations summarizes the geology of this part of Vancouver island.

Table of Formations

Age	Formation	Character
Recent		Stream and river gravels.
	Unconformity	
Pleistocene	Wreck Bay formation	Stratified sands, gravels, and clays.
	Unconformity	
Lower Cretaceous or upper Jurassic	Cretaceous sediments	Sandstone and conglomerate.
	Unconformity	
Jurassic	Coast Range batholith	Granodiorite, quarts-diorite, diorite.
	Intrusive	
Triassic	Vancouver group	Andesites, tuffs, tuffaceous argillites, and limestones.

[1] Haycock, E., Geol. Surv., Can., Ann. Rept., 1902-3, pp. 76 A.
[2] Webster, A., Geol. Surv., Can., Ann. Rept., 1902-3, pp. 55 A.

Vancouver Group

The oldest rocks of the district are those of the Vancouver group and these are also the most widely distributed, not only in this district but throughout the island. The group consists almost entirely of volcanic rocks, chiefly andesites, but contains also many intercalated beds of tuffaceous argillite and limestone—some of which attain a thickness of 2,000 feet or more. Clapp,[1] in describing the rocks of this group as observed in the southern portion of the island, subdivided it on grounds of lithology, distribution, and structure, into the Nitinat formation, the Vancouver volcanics, the Sutton formation, and the Sicker series. It was not, however, found desirable to extend these names and subdivisions in the northern coast region of the island, but instead, to divide the group on lithological grounds only, into the volcanic rocks, the tuffaceous argillites, and limestones.

The volcanic rocks comprise by far the greater bulk of the group, and underlie fully nine-tenths of the area under discussion. Andesites are the prevailing types, but dacites and basalts are also found, and considerable quantities of tuffs, breccias, and agglomerates. The andesites consist essentially of plagioclase ranging from andesine to labradorite, augite and glass, with magnetite, and occasionally some quartz. Porphyries, having feldspar phenocrysts, are common among them, and they are in the majority of cases amygdaloidal, the amygdules containing epidote, quartz, opal, chalcedony, and occasionally albite. Flow structures are common and the amygdules are frequently observed to be pulled out in the direction of flow. The andesites, however, like the other rocks of the group, are seldom found in a fresh condition. They usually contain high proportions of chlorite, actinolite, and epidote, giving the rocks a dull greenish colour, or else they contain considerable hematite which gives them a decidedly reddish to brownish tint. Secondary calcite is also common.

The basalts consist of labradorite, dark brownish augite, decomposed olivine, and considerable magnetite.

The dacites are usually very fine-grained, light-coloured rocks, consisting of a felted feldspathic groundmass, containing crystals of quartz and pyroxene, and spherulites of chlorite, often associated with calcite and leucoxene.

Tuffs are plentifully distributed throughout the group. They are usually well bedded and clearly indicate the attitude of the beds of the formation. They present a great variety of colour, from dark purple through shades of brown and red to light grey, but very commonly also assume various shades of dull green. They vary likewise in texture from coarse agglomerates through many gradations down to material so fine that its components can be resolved only by the use of a microscope.

They are composed of various proportions of glass fragments, crystal fragments, and rock fragments, and may be classified as vitric tuffs, crystal tuffs, and lithic tuffs, according as the glass, crystal, or rock fragments form the predominating component. The vitric tuffs are usually light grey or reddish in colour, the glass fragments being always more or less devitrified. Crystal tuffs are only rarely found, though all the tuffs contain many broken and partly decayed plagioclases. The lithic tuffs are the most common, usually consisting of a wide variety of rock fragments, most of which have volcanic characteristics, and can be correlated with the rocks of the Vancouver volcanics.

The tuffaceous argillites, the least abundant rocks of the group, are always associated more or less closely with the limestones, and are confined to relatively thin beds occurring north of Kyuquot sound. The best exposures were found in Malksope and Ououkinsh inlets which lie about 10 miles north of Kyuquot Indian village. In Malksope inlet a highly fossiliferous horizon was discovered and a collection of fossils was made. Similar rocks were found by the writer in greater abundance in Quatsino sound, and by Dawson on the north coast of the island about 6 miles east of cape Scott, on certain islands in the gulf of Georgia, and on Graham island. All these rocks are of the same age.

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[1] Clapp, C. H., Geol. Surv., Can., Mem. 96. Geol. Surv., Can. Mem. 13.

In hand specimen they are fine-grained to dense, finely banded, usually black, but often grey, brown, or dark green, and have a distinct cleavage parallel to the bedding. When black they are almost invariably fossiliferous. Some of the thin layers are heavily impregnated with minute crystals of pyrite.

Under the microscope they were seen to consist of tiny, sharply angular fragments of rock, quartz, feldspar, glass (more or less devitrified), calcite, carbonaceous and argillaceous materials. The fragments are beautifully sorted into thin layers of coarser and finer material.

Interest in these rocks is centred chiefly in the fossils, which help to determine the age of the Vancouver group. Among the fossils collected the outstanding species was *Pseudomonotis subcircularis*, concerning which F. H. McLearn of the Geological Survey, Canada, says:

"This is a widely spread species and, having a restricted vertical range, indicates a quite thin zone in the upper Triassic. The beds containing it can be correlated with the highest of the Triassic beds exposed in the upper Peace valley, B.C., and also with beds on Pine and Stewart rivers. It has a wide distribution in Alaska, e.g., the McCarthy formation in the Chitina valley. It occurs also on Queen Charlotte and Vancouver islands. To the south it is found in California and Nevada. In Europe and Asia it is correlated with the Upper Noric.

"It would be interesting to determine on Vancouver island, if possible, the stratigraphic relation of this zone to the Sutton formation of the Vancouver group. Shimer and Clapp placed the Sutton formation in the lower Jurassic. G. C. Martin, however, questions this correlation, suggests the possibility of an upper Triassic age, and would make it a little earlier than the zone with *P. subcircularis*."

The only limestones that might correspond in this district to the Sutton formation of southern Vancouver island are some thin beds from 2 to 50 feet thick which are interbedded with this fossiliferous horizon. These are, of course, of virtually the same age as the "*subcircularis*" horizon, but they contain no fossils within their own limits, and there are at present no facts to prove they are the same age as the Sutton limestones. Both limestones, however, lie well towards the centre of the group, and it seems unlikely that they should differ greatly in age.

Beds of limestone, varying from a few feet to 2,000 feet or more in thickness, were found at many places, interbedded conformably with the andesites and tuffs of the Vancouver group. Thin beds of limestone were observed in Kennedy lake, Bedwell sound, Herbert arm, Sidney inlet, Kokshittle arm, Malksope inlet, and Ououkinsh inlet. Very thick beds were found in Deserted creek which is an offshoot of Tlupana arm of Nootka sound, and in Tasis canal, also of Nootka sound. The beds exposed in these localities are several thousand feet thick, and belong, probably, to the same horizon.

These limestones for the most part are very pure, light grey to bluish-grey in colour, and have been metamorphosed into a medium coarse, even-grained marble. Impure varieties, however, occur in many places and contain varying amounts of pyroclastic, carbonaceous, bituminous, and argillaceous material, grading on the one hand into calcareous tuffs, and on the other, into calcareous argillites, and varying in colour from light grey to brownish-black.

The purer crystalline marble makes excellent material for building and ornamental purposes, and during the years 1908 and 1909 a considerable amount of this material was quarried from the massive beds on Deserted creek.

The limestones, where cut by plutonic intrusives of the Coast Range batholith, are intensely metamorphosed into rocks containing garnet, epidote, pyroxene, quartz, wollastonite, tremolite, and actinolite, with which are associated large quantities of copper, in some places forming valuable deposits of magnetite, and in others equally or more valuable deposits of copper.

Structure. All the members of the Vancouver group which were observed in this district are, in general, conformable with one another. The contacts between the

various members are often quite irregular owing to a number of natural causes; for example, the lava flows vary considerably in thickness, and often flow out over very uneven surfaces, and their contacts with the limestones frequently show intrusive relations. The limestones also vary greatly in thickness, sometimes within relatively short distances; and none of the limestone beds, not even the thicker ones, are continuous for any great distance. Local unconformities, may, therefore, be expected in many places, but in general the various members are conformable.

The Vancouver group is folded into steep anticlines and synclines whose axes strike north 60 to 65 degrees west, and faulting on a small scale is common, but no large faults were encountered in this region.

The members are intruded in numerous places by the granitic rocks of the Coast Range batholith. Their age, as has been mentioned above, is, in part at least, upper Triassic.

Coast Range Batholith

A great many intrusions of diorite and granodiorite, some of considerable extent, occur in this district cutting the rocks of the Vancouver group, and are believed to be related to the Coast Range batholith. They are distributed throughout the district in the form of small batholiths, stocks, dykes, and occasionally in the form of sills. In the southern part these intrusions consist of two types distinctly different in composition and age; a diorite consisting of oligoclase to andesine plagioclase, little or no quartz, and a relatively high proportion of hornblende and biotite; and a granodiorite consisting of orthoclase, oligoclase, quartz, and a relatively low proportion of ferromagnesian minerals, chiefly biotite. The diorite is cut by many dykes and apophyses of the granodiorite and fragments of diorite are frequently found enclosed in the granodiorite, which proves the diorite to be the older. These types may be correlated with the Beale diorite and Saanich granodiorite described by Clapp[1].

In the northern part, however, these two types become so intimately intermixed that it is impossible to map them separately on the scale adopted. There is also a change in the colour of the rocks from light and dark greys to pinks and reds. In Kyuquot all these intrusives have a decidedly reddish tint due to the colour of the feldspar which they contain. This change in colour is accompanied by a slight change in the composition of the feldspars, which have more alkali and less lime.

A number of large intrusions of a very fine-grained, light grey, plutonic rock, resembling a diorite in composition, were found in the vicinity of Elk river and the northern extremities of Kennedy lake. These intrusions cut the rocks of the Vancouver group and the granodiorite of the Coast Range batholith. They are the only known intrusives in the district younger than the granodiorite, and they presumably belong to the latest phase of the batholithic intrusions. They are important from the economic standpoint because they have, associated with them, some rather rich gold-bearing quartz veins.

The intrusions of the Coast Range batholith in this region are thought to be upper Jurassic in age.

Cretaceous Sediments

A few small areas of sandstone, fine conglomerate, and shale on the farthest outlying points and islands of this part of the coast form a narrow and broken fringe of sediments on the very edge of the island. They were first encountered on Flores island in the vicinity of Rafael point, where they extend along the shore for several miles, and inland for a mile or less. Another short, narrow band of similar rocks occurs just west of Refuge cove. The largest area of these rocks is on the large, broad peninsula lying between Kesquiat harbour and Nootka sound. They outcrop again on Nootka island in the vicinity of Bajo reef, forming a narrow strip along the shore. They were last encountered on Barrier islands off the entrance to Kyuquot sound.

[1] Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912.

For the most part they consist of fine-grained, buff-coloured, massive sandstones containing well-rounded grains of quartz, calcite, highly weathered feldspars, and small fragments of weathered volcanic rock. There is also considerable pyrite evenly distributed in the form of small crystals throughout the rocks, the weathering of which to limonite accounts for their brownish and buff colours. In certain places the pyrite, and some marcasite, become exceedingly abundant, and constitute the major part of the rocks. Such a locality occurs at Bajo reef where the fine-grained fossiliferous sandstone and shale are almost completely replaced by marcasite. Some of the fossils of this locality now consist of a solid mass of exceedingly fine-grained marcasite but still have their forms well preserved.

Fine conglomerate, interbedded with sandstone, occurs at Rafael point on Flores island, and thick beds of coarser material were observed near Bajo reef on Nootka island. The pebbles of the fine conglomerate consist entirely of volcanic rocks and are obviously derived from the various members of the Vancouver group. Fairly thick beds of dark grey shale near point Estevan are lying almost flat and probably underlie the whole of that peninsula.

These rocks are only slightly folded, the strikes are all nearly parallel to the shore, i.e. north 45 to 60 degrees west, and the dips are to the southwest or seaward from 10 to 25 degrees, excepting on Grassy and One Tree islands where they steepen up to 50 degrees. They overlie the Vancouver group unconformably. Though the strike is more or less parallel to that of the Vancouver volcanics the dip is much flatter. No rocks were found cutting these and none overlying them.

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

Aucella cf. *piochii*
Belemnites sp.
Intermediate ammonite.

The *Aucella* forms were sent to Dr. Stanton of the U. S. Geol. Surv., for comparison with the more complete sets of Aucella there. Dr. Stanton identified the forms as "*Aucella piochii* var *ovata*. Stanton."

Concerning the age of *Aucella piochii* Dr. Stanton says[1], "The typical form occurs in the lowest known beds of Knoxville (Lowermost Cretaceous). It ranges through several thousand feet of strata, and in the upper part of its range is associated with the variety *ovata*. The latter is the predominant form at an horizon about 2,000 feet below the top of the Knoxville and above the horizon of its culmination it is gradually replaced by *Aucella crassicollis*.

"The Aucella collected by Geo. M. Dawson on the Skagit river, British Columbia, in 1875, seem to belong to *Aucella piochii* var *ovata*. Those from other British American localities that I have been enabled to examine, through the kindness of Mr. F. J. Whiteaves, are all *Aucella crassicollis*, under which name the localities will be enumerated. Judging from the range of these forms in California only the upper part of the Aucella-bearing beds have been found in British Columbia."

Aucella beds of Jurassic age, however, containing the forms related to *Aucella bronni* associated with *Cardioceras*, have been found in British Columbia.

In 1918 the writer examined some Cretaceous beds about 10 miles in from the mouth of Quatsino sound on the southern shore. These beds yielded fossils e.g. *Aucella crassicollis*, which Mr. McLearn says belong to the Upper Knoxville (Lower Cretaceous) of California, and represent a stage a little later than *A. piochii* and considerably earlier than the Lower Cretaceous of the Haida formation of Graham island.

[1] U.S. Geol. Surv., Bull. 133, pp. 44.

Wreck Bay Formation[1]

The only rocks in this district younger than these Cretaceous beds are deposits of glacial till which cover most of the country, recent river gravels found at the mouths of all the larger streams, and a formation of considerable extent composed of unconsolidated gravels, sands, and clays which lies between Ucluelet and Clayoquot sound. This formation extends along the shore from the southern end of Wreck bay up into Clayoquot sound, and reaches inland as far as Kennedy lake, a distance of 10 miles. The sands, gravels, and clays are well sorted into thin beds which lie horizontally on a rough, uneven surface of Vancouver volcanics. They have a maximum thickness of about 50 feet, the upper surface forming a uniformly level plain about 50 feet above sea-level.

The gravel consists of well-rounded pebbles, varying in size from a fraction of an inch to 4 or 5 inches in diameter, and composed of a variety of volcanic rocks, granodiorite, diorite, quartz, and a few of limestone. Very few boulders occur either on the beach or on the upper surface of the formation. The sand is medium fine, and yellowish. The clay is found in thin, bluish bands, and in some places is very fine, whereas in others it is coarser and becomes sandy. Considerable quantities of magnetite sand on the beach have been concentrated by wave action, and carry small quantities of fine gold.

All that can be said regarding the age of this formation is that it appears to be of marine origin and of so recent a date that it shows no signs whatever of consolidation or folding. It has been uplifted so recently that the streams have as yet cut into it only to a limited extent, and it appears from the absence of any overlying glacial material to have been elevated by an uplift subsequent to the glacial period.

ECONOMIC GEOLOGY

Gold, copper, iron, marble, and manganese occur in this region, but for some years there has been no mineral production of any kind. In the past, however, small quantities of gold from Wreck bay, copper from Sidney inlet, and marble from Deserted creek have been produced. Very soon, considerable copper will be shipped monthly from the Tidewater Copper Company's mine at Sidney inlet. No other minerals are likely to be produced on a commercial scale in the near future.

Gold

Gold in small quantities is found in the beach placers of Wreck bay and in small quartz veins cutting the Vancouver volcanics in the vicinity of Elk river which flows into the east arm of Kennedy lake. The Wreck Bay placers have been described in two previous reports.[2]

Gold-bearing quartz veins were known as early as 1898 to occur in the Elk River section. The most notable vein is on a group of claims known as the Rose Marie, situated on the east side of the river about 3 miles above its mouth. Several attempts were made to develop this vein, and eventually a small concentrator was erected, but owing to a number of reasons it was never put on a successfully producing basis.

According to D. G. Forbes,[3] who examined the property in 1899 and 1912 and 1913, the vein was traced by open-cuts for several thousands of feet, and exposed by the almost perpendicular bank of the river for a vertical distance of over 1,500 feet. At an elevation of about 1,600 feet, a drift adit was driven into the vein for 438 feet. The vein has a persistent width of from 15 to 24 inches and a very regular strike of north 34 degrees east with a dip of about 60 degrees to the northwest. It is composed of quartz streaked with pyrite, and a small amount of arsenopyrite.

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[1] Geol. Surv., Can., Sum. Rept., 1918, pt. B.
[2] Dolmage, V., Geol. Surv., Can., Sum. Rept. 1918, pt. B.
Geol. Surv., Can., Sum. Rept., 1919, pt. B.
[3] Forbes, D. G., Ann. Repts., Minister of Mines, B.C., 1899, 1912, 1913.

Samples taken at various times and at different places across the vein gave values in gold of from $12 to $30 per ton. It was the opinion of Mr. Forbes that it might be worked profitably if attempted on a small scale, but no work has been done recently.

A similar vein was recently discovered by Mr. Lachlan Grant of Tofino on the west shore of the east arm of Kennedy lake near the mouth of Elk river. This vein, examined by the writer this season, seems to be a similar occurrence to that of the Rose Marie.

It is situated in a small gulch about one-quarter of a mile from the shore, at an elevation of about 300 feet above the level of the lake, and has been included in two claims, the Wanderer and the L. Grant. Up to date development work consisted of a few open-cuts, some stripping, and two small adits. The vein is thus traced for several hundred feet, and the steep hillside through which it passes shows that it has a vertical extent of at least 200 feet and probably much more. Its width, however, averages only about 5 inches.

It consists of fairly pure, coarsely crystalline quartz through which is sparingly scattered small grains of pyrite, galena, tetrahedrite, and in some places free visible gold. Assays taken across the vein at three different places by W. M. Brewer[1] gave, respectively:

Gold, 0·32 oz.; silver, 0·4 oz.
Gold, 0·64 oz.; silver, 0·8 oz.
Gold, trace; silver, trace.

These veins occur in the andesite of the Vancouver group in the close vicinity of large intrusions of a very fine-grained, dark grey diorite, with which the veins are thought to be genetically connected. The andesites are somewhat sheared, but except in the immediate vicinity of the intrusions of diorite and the veins, are comparatively fresh. Where altered they consist largely of chlorite and secondary quartz, and near the contacts of the veins contain considerable pyrite. The diorite was not observed except in the vicinity of Elk river and the northern extremities of Kennedy lake, and showed—by the fact that it formed dykes in the granodiorite of the Coast Range batholith—that it belongs either to an exceedingly late phase of the batholithic period or to some subsequent period of intrusion. No evidence could be found to determine which. The veins are all small, that on the Rose Marie being the largest. They have a common and persistent attitude, striking about north 45 degrees east and dipping northwest 70 to 80 degrees. They consist of coarsely crystalline quartz containing many vugs, and small grains of pyrite, galena, zinc blende, tetrahedrite, and gold which is sometimes visible.

These gold-bearing quartz veins constitute a type of mineral deposit which is different from any previously described in connexion with the west coast of Vancouver island, and although they have not yet proved to be of commercial importance, they do in places carry good gold values, and may with further prospecting and developing turn out to be valuable.

From an examination of the Wreck Bay formation and of the intervening topography it seems almost certain that the gold content of those gravels originated in the quartz veins of this district.

Copper

Copper occurs at numerous places along this part of the west coast. The occurrences are, without exception, of the contact metamorphic type, and are formed near the contacts between the limestones of the Vancouver group and the intrusions of granodiorite or diorite of the Coast Range batholith. At, or near, every observed contact of these two rocks copper and iron minerals were found in the altered limestone, and in some places in large amounts. At the diorite contacts less copper and

[1] Ann. Rept. of Minister of Mines, B.C., 1918, pp. 262.

more iron are found, but at the granodiorite contacts copper predominates. Most of these deposits, however, would be worked for copper rather than iron, but there are some composed of almost pure magnetite. Copper deposits of this nature were found at the following localities:

Clayoquot river near its entrance into Kennedy lake.
Deer creek at the head of Tofino inlet.
Tranquil creek, Tofino inlet.
Disappointment inlet, Mears island, Clayoquot sound.
Bear river, Bedwell sound.
Flores island near Matilda creek.
Sidney inlet.
Muchalat arm, Nootka sound.
Head bay, Tlupana arm, Nootka sound.
Tasis canal, Nootka sound.
Kokshittle arm, Kyuquot sound.
Kloskino inlet.

All of these deposits except the ones at Sidney inlet and in Disappointment inlet are as yet merely prospects in an early stage of development, and little can be said of their possibilities until more work has been done. They are all situated near limestone-granodiorite contacts, but owing to the marked irregularity of all the deposits of this type found on the west coast, much development work is necessary before their extent can be even roughly estimated.

The deposit in Sidney inlet has already passed through one successful stage of operation, and appears now to be entering upon another. The deposit in Disappointment inlet, known as the Kallapa mine, was operated for a time, but at a considerable loss, and has been abandoned.

The deposits may be found within a few feet of the granitic contact, or at a distance of several thousand feet. They may be formed in thick beds of metamorphosed limestone free from any volcanic rock or, as is more often the case, they are in thin beds of limestone between beds of volcanic rocks which are also highly metamorphosed and metallatized. In the former case the ore-bodies are extremely irregular in shape and size, but in the latter their limits are more or less defined by the interbedded volcanic rocks.

The limestones are altered to epidote, garnet, pyroxene, actinolite, wollastonite, tremolite, and serpentine. The volcanic rocks are altered to chlorite, actinolite, clinoclore, and quartz. The ores consist of chalcopyrite, bornite, pyrite, pyrrhotite, magnetite, hematite, and molybdenite.

The Tidewater Copper Company's mine at Sydney inlet is situated near the summit of a mountain about 2,000 feet above sea-level and less than a mile from the shore. The concentrating mill at the beach is connected with the mine by an aerial tramline. The mill is equipped with a battery of "Peterson" flotation cells and the necessary crushers and ball mills. The power is developed by a small hydro-electric plant, fed by the waters of two small creeks lying to the east of the mine. The water supply is amply sufficient excepting during dry spells in the summer, when it is necessary to resort to steam power.

As the result of development work done during the past two years, sufficient ore of good grade has been proved to ensure the continuous operation of the mill for two years.

The mountain on which the ore-bodies are situated is composed of coarse, light grey granodiorite up to about the 1,500-foot contour, above which is a closely folded series of metamorphosed limestones and andesites, striking north 70 degrees west and dipping nearly vertically. The ore-bodies lie from 100 to 200 feet above the granodiorite contact, and are distributed on three sides of the mountain extending nearly to the summit.

The ore consists of bornite, chalcopyrite, and magnetite, and carries good values in silver and gold. The metallic minerals are found both in large segregations of

high grade material in the metamorphosed limestone, and in irregular disseminations in the altered limestone, metamorphosed andesites, and tuffs. The most abundant ore mineral is bornite, and in this respect the deposit differs from all the other copper deposits found on the west coast.

Magnetite forms a large proportion of the ore produced, and it has been reported that the company intends to install machinery to extract from the tailings the magnetite which under the present process is lost. In this way, at a very small cost, a by-product could be obtained, which could be sold at a profit, if, as is expected, an iron and steel plant should be established on the British Columbia coast. Should such a scheme prove successful, it would materially increase the value of all the copper deposits on the west coast, for, without exception, they contain large proportions of magnetite.

Another copper deposit which received considerable attention during the season is situated on a river flowing into the head of Kokshittle arm, Kyuquot sound. It lies on the east side of the river about 1¼ miles above its mouth and is owned by Charles Norstrome and associates of Quatsino.

The copper occurs in two nearly flat-lying beds of limestone which are now so completely altered to epidote, garnet, and pyroxene that their original character is almost completely obliterated. They outcrop one above the other on a steep mountain side separated by about 150 feet of barren andesite, and have a strike roughly east and west with a dip to the north and into the mountain of about 10 degrees.

The diorite of the Coast Range batholith cuts the volcanic and limestone beds at a point about one-third of a mile south and also outcrops about one-quarter of a mile to the east. The diorite has a light pinkish colour consisting essentially of pinkish plagioclase, biotite, and augite.

The upper zone—the larger and richer—has a thickness of about 10 feet, and its length has been traced for about 150 feet by open-cuts and one small shaft. Its strike is roughly east and west and the dip from 5 to 10 degrees to the north, but local faulting, which is considerable in this zone, has thrown the eastern end of it down about 20 feet. It consists of chalcopyrite, magnetite, and hematite in a gangue of epidote, garnet, quartz, and calcite. At the western end of the zone a section about 10 feet thick and 20 feet wide consists chiefly of chalcopyrite with a small proportion of hematite, and forms very high grade ore. To the east, however, magnetite predominates greatly over the chalcopyrite.

The lower zone is only about 5 feet thick and consists chiefly of magnetite with traces of chalcopyrite in it.

Iron

The sole deposit of magnetite which approaches commercial size in this district is situated about one mile up a creek flowing into Head bay at the head of Tlupana arm in Nootka sound. Mr. W. M. Brewer[1] of the British Columbia Bureau of Mines roughly estimates the tonnage of iron ore to be 250,000 tons known, 250,000 tons probable ore, and 275,000 tons possible ore.

The deposit is located in a large body of garnetized limestone at the contact of a large intrusion of fine-grained diorite. Small amounts of copper are associated with the magnetite, but by far the greater portion of it is free from both copper and sulphur.

Marble

Marble is found in Nootka sound both in Deserted creek and in Tasis canal. In 1908 the Nootka Quarries Company, Limited, began the operation of a fully equipped quarry and mill, established on the northeast shore of Deserted creek, but after operating for a year, during which $3,000 worth of marble was quarried, the plant was closed and still remains so.

[1] Brewer, W. M., Rept. of Minister of Mines, B.C., 1916, p. 293.

At this point a mass of crystalline limestone, several thousand feet in thickness, outcrops along the shore for over a mile. It strikes in a northeast direction and can be seen to extend over the summit of a mountain about a mile or more eastward. It is coarsely crystalline and varies from pure white through shades of blue and grey to black. It is steeply folded, and in places is checked by a closely spaced set of compression joints. Here and there thin flows of andesite occur interbedded, and from these many small dykes and sills extend into the limestone in several directions. The quarry is situated at a point where the marble is cut by several such dykes and sills.

Though the attempt to produce marble from these beds on a commercial basis seems to have failed, the facts remain that there is an unlimited quantity of marble conveniently situated at tide water, and that operations of the Nootka Quarries Company, Limited, proved that the marble can be quarried in sufficiently large blocks, and that it can be sawn, rubbed, turned, and polished to produce an excellent stone for building and ornamental purposes.

The quarry and plant have been fully described by W. A. Parks[1] and W. M. Brewer.[2]

Manganese

On Vargas island, about 2 miles inland from the north shore, a deposit containing considerable manganese was recently discovered by Mr. Hovelaque of Clayoquot. As yet only a small amount of work has been done, and the highest assays obtained showed not over 15 per cent manganese which is much too low to be considered of economic value.

The deposit occurs less than 50 feet above sea-level in a low swampy area underlain by a band of cherty, ferruginous tuffs of the Vancouver group, which have been sheared and slickensided, and are strongly weathered to a depth of 10 feet or more. The weathered rocks contain much limonite, and some pyrolusite which forms films on the shear planes.

The area underlain by the sheared tuffs is quite extensive, and future work may disclose areas having sufficiently high proportions of manganese to enable it to be mined at a profit. The deposit is interesting because it is the first discovery of this metal on the west coast.

"Alunite"

A peculiar, light-coloured rock thought to contain the mineral alunite, was discovered on the narrow peninsula between Easy creek and Kokshittle arm in Kyuquot sound in 1908. It was first staked as a possible gold deposit, later the British Columbia Pottery Company used the material for fire-clay and for the manufacture of sewer pipe. In 1911 the San Juan Manufacturing Company used the material for making a powdered household cleanser and mechanical soap. Prior to 1914 it was being considered as a possible source of potash and during the war when the scarcity of potash fertilizer became acute the Kyuquot deposits again came into prominence.

In 1913 C. H. Clapp[3] made a thorough investigation of the deposits, during which he found that they consisted largely of silica, pyrophyllite, and natro-alunite (i.e. the soda-bearing alunite). In spite of this report, however, still further efforts were made to interest the public in these deposits as a source of potash fertilizer; and in order to settle the matter definitely, the British Columbia Bureau of Mines sent W. M. Brewer and P. B. Freeland into the district in 1919 to sample the deposits as carefully as possible. The samples were later analysed and checked by five different chemists. The results showed that most of the material contained less than 2 per cent water-soluble K_2O, and that the very best material obtained yielded, after a thorough grinding and roasting, only about 2·6 per cent water-soluble K_2O. This, of course, is far below the limit required to make it a commercial possibility as a source of potash fertilizer. Whether the material from these deposits can be put to other uses remains to be seen.

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[1] "Report on the building and ornamental stones of Canada," Mines Branch, Dept. of Mines, Can., Pub. No. 452, vol. V.

[2] Rept. of Minister of Mines of B.C., 1916.

[3] Geol. Surv., Can., Sum. Rept., 1913.

COQUIHALLA AREA, BRITISH COLUMBIA

By C. E. Cairnes

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INTRODUCTION

The Coquihalla area covers a nearly triangular strip of territory drained by Coquihalla river, which enters Fraser river at the town of Hope, about 91 miles by rail east of Vancouver.

An excellent photo-topographic map of the area, prepared by F. S. Falconer on a scale of 4,000 feet to an inch, was used as a base for geological work. The map includes an area of approximately 295 square miles, through which Coquihalla river flows in a southwesterly direction. A glance at the drainage system of this stream, as indicated in the accompanying sketch map (Figure 3) gives a fair idea of the general outline of the basin itself.

The Kettle Valley railway, a branch line of the Canadian Pacific, runs up Coquihalla valley, keeping generally in close proximity to the river. The old wagon road up this valley has been in part occupied by the railway bed and cannot now be employed for continuous transportation. An excellent trail, serviceable as a wagon road for 23 miles from Hope, leads up Nicolum valley and thence by way of Sumallo river and Skaist and Whipsaw creeks to Princeton. The route is commonly referred to as the "old Dewdney trail" and segments of its roadbed, prepared some sixty years ago by a party of Royal Engineers, are still well preserved. Another, but more circuitous, route to Princeton leads from Hope up Silver creek and down Skagit and Similkameen rivers. A much poorer trail, impassable for horses for over 2 miles below the summit, leads up Dewdney creek to Summit Camp on the headwaters of Tulameen river. This trail could be cleared easily and would afford a very convenient route between Hope and Tulameen.

Between the mouths of Ladners and Dewdney creeks and on the northern slope of Coquihalla valley, a network of trails, some passable for horses, connects a series of gold mining properties with the railway.

The greater part of the Coquihalla area, however, is devoid of trails. This fact, combined with dense vegetation, a high timber line, and extremely rugged topography, has made prospecting very difficult and explains why this region, though comparatively near points of civilization, has been more backward in the development of its many mineral resources than other more remote, but more readily explored, areas.

Hope, the only town of importance in the Coquihalla district, is situated on the delta formed by Coquihalla river at its junction with the Fraser. Both the Canadian National and Kettle Valley railways pass through the town, and the main line of the Canadian Pacific runs along the opposite shore of the Fraser. The town has a population of about 200 and supports itself largely on the returns from mining and lumbering industries.

Prior to 1919 very little had been published on the general geology and stratigraphy of the area. In 1877-78, Dr. G. M. Dawson made a hurried reconnaissance of

the main valley and also traversed the old Dewdney trail. In the Report of Progress of the Geological Survey for these years he recorded his observations on the geological formations. He also offered tentative suggestions regarding their correlation with the formations of neighbouring areas.

Practically all later geological work has been confined to local studies of placer and lode deposits discovered in this area, the results of which have been published chiefly in the Annual Reports of the Minister of Mines for British Columbia.

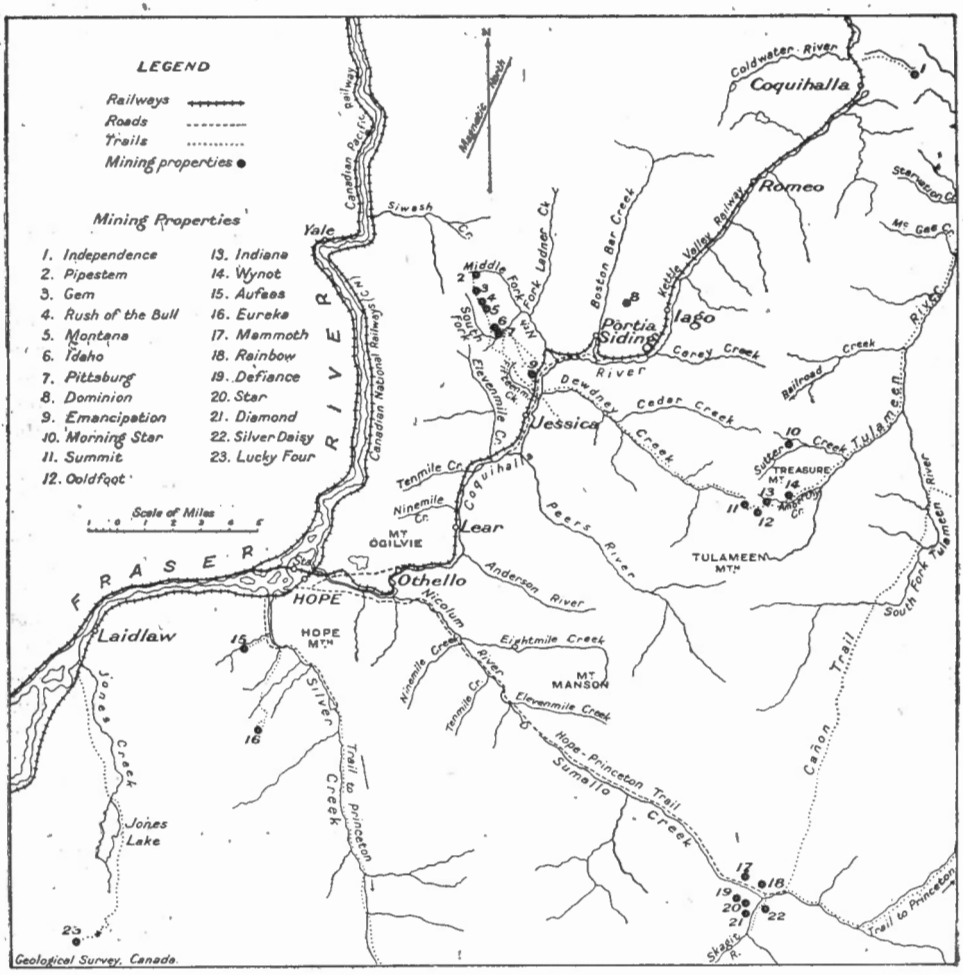

Figure 3. Diagram of Coquihalla River area and adjacent areas, Yale district, British Columbia, showing location of certain mining properties.

In the summer of 1919, however, C. Camsell spent a few weeks in the Coquihalla valley, working chiefly along the Kettle Valley railway between Hope and the mouth of Boston Bar creek. During that time he also made a brief examination of the gold claims in the vicinity of Ladners creek.[1]

The purpose of the present work is to continue the investigations begun by Camsell, and, eventually, to extend the geological observations to include the whole of the Coquihalla map-area. To complete this task in the semi-detailed fashion which

[1] Geol. Surv., Can., Sum. Rept., 1919, pt. B.

now seems desirable will require another season in the field. Exceptionally active prospecting during the past couple of years and the recent development of at least one property—the Emancipation mine—to a point of actual production, has lent additional incentive to the renewal of geological work in this area.

Some time was spent by the writer in visiting neighbouring areas where mining and prospecting were in active progress. Brief examinations were also made of older properties which, for the past few years, and largely because of poor or too expensive transportation, have been temporarily abandoned, but in which, with the advent of the Kettle Valley railway, renewed interest is being excited.

The writer wishes to express his appreciation of the cordial co-operation tendered him by the various officials, mine owners, and prospectors at Hope, and in the different mining camps. In the field work, W. E. Chantler rendered most efficient service throughout the season.

PHYSIOGRAPHY

The Coquihalla area forms a part of the most westerly prolongation of the Cascade range which, after crossing the International Boundary, fingers its way into the belt of the Interior Plateaus as far north as Thompson river. On the west, the Coquihalla district is separated from the mountains of the Coast range by the breadth of Fraser valley. On the east, it merges into the great Central Plateau region of British Columbia. To the north and south, it falls into line with the western edge of the Cascade system represented here by the Cheam and Hope mountain ranges.

The area is extremely rugged in character with a relief ranging from 200 to nearly 8,000 feet. The valleys tributary to the Coquihalla are extremely precipitous, a feature particularly pronounced in their upper courses, but often characterizing their entire length. The Coquihalla itself, in a distance of some 33 miles, falls nearly 3,400 feet, and in its tumultuous course affords one incessant roar from source to mouth.

The summits of the area bear in the main the rounded surfaces and deep scars of heavy glaciation, but where, by reason of their height, they escaped such action, they are commonly sharply pointed or edged and often difficult to ascend. A striking contrast to this rugged topography is afforded the observer who from the eastern rim of the Coquihalla basin overlooks the broad flat-topped terrane of the Interior Plateau, whose vast expanse of gently rolling dun-coloured hills offers such a dissonant background to the riotous mass of snow-covered peaks comprising the Cascade and Coast ranges.

The area, as a whole, is heavily timbered, although in this respect the underlying rock seems to have a considerable influence on the abundance of vegetation. The more strictly sedimentary areas are, generally speaking, densely forested to heights exceeding 6,000 feet, whereas the granitic tracts are more scantily covered and their plutonic character is often easily recognized from a distance by their barer slopes. Among the great variety of trees represented are included the hemlock (*Abies Mertensiana*), pine (*Pinus monticola* and *P. contorta*), red and yellow cedars (*Thuya gigantea* and *T. borealis*), spruce (*Picea engelmannii*), douglas fir (*Pseudotsuga douglasii*), Canada balsam (*Abies balsamea*), maples, yew (*Taxus Canadensis*), birch (*Betula papyifera*), and poplar (*Populus tremuloides*). A thick, mangled mat of underbrush consisting of sallal, blackberry, salmon berry, devils club, and second growth evergreens, makes progress always excessively arduous and, except where occasional trails are encountered, renders it necessary to travel on foot and to carry such provisions and bedding as may be required.

Rainfall is large and often proves a serious handicap to field work. During the season of 1920, from June 26 to October 7 inclusive, the writer noted thirty-eight days during part or all of which rain fell in considerable abundance. This total does not include several evenings and nights of rain which served to saturate the underbrush and make travelling disagreeable the following morning.

As only about half of the Coquihalla area was examined with any detail during the past season, and as practically no time was spent in comparing the formations so encountered with those of adjacent areas where the geology has been more carefully studied, the inferences drawn in the following paragraphs must be regarded as tentative and subject to partial, or complete, revision in the light of further investigation.

For convenience, the following tabulation has been prepared. It refers in particular to the formations encountered in the portion of the Coquihalla area drained by tributaries entering the main stream below the mouth of Boston Bar creek. Camsell[1] has already given brief descriptions of the formations exposed along the areas on either side reaching to the headwaters of the various tributary streams. Kettle Valley railway. The present report extends his observations to include the

Probable age	Designation	Description
Pleistocene	.....	Glacial and fluvioglacial deposits.
Lower Cretaceous	.....	Conglomerate.
Jurassic and later	Coast Range Batholithic rocks	Granites, diorites, granodiorites, pegmatites, granite porphyries, basic and acidic dykes and sills.
Carboniferous and later	Fossiliferous series	Argillaceous and calcareous slates, schists, volcanic tuff beds, grits, and conglomerates.
	Non-fossiliferous series (Hozameen)	Cherty rocks, greenstone schists, massive volcanic and porphyritic rocks, serpentine.

Non-fossiliferous Series

What are tentatively regarded as the oldest rocks in the area are included in a belt about 5 miles wide extending across Coquihalla river in a general northwest direction between the mouths of Anderson river and Dewdney creek. This series is composed mainly of two rock types. One is a massive, dark-blue, and exceedingly fine-grained cherty formation, usually minutely intersected by numerous quartz veinlets and interbedded with considerable slaty or argillaceous material and some calcareous beds. The other includes great thicknesses of volcanic rocks, of varying mineral composition, frequently exhibiting a schistose, often a more massive structure, and occasionally a porphyritic texture. They probably represent contemporary lava flows, and their schistosity, as well as the contorted structure of the associated sediments, must be largely a result of the intense dynamic metamorphism to which they have been subjected. With the dark cherty rock is often associated a lighter coloured variety, commonly occurring in thin, but regular, bands or ribbons an inch or so wide, and separated by thin, argillaceous partings. They are commonly minutely crumpled and contorted. A great similarity exists between the dark cherty formation and a corresponding member in the Hozameen series, as shown at the 23-Mile camp near the junction of the Sumallo and Skagit rivers. As this locality lies on the strike of the Coquihalla rocks, and as the cherty formation was traced, intermittently at least, from the Coquihalla to the Skagit, there seems little doubt that a correlation with the Hozameen series is justified. The associated greenstones are generally more massive in appearance in the vicinity of Skagit and Sumallo rivers, but this may be in part due to a lack of the intense compression which has developed the schistose structure along Coquihalla valley.

The general attitude of the series is apparently that of a great syncline, although this structure is frequently obscured by minor faulting and folding. One strong set of vertical joint planes, striking approximately south 65 degrees west, has resulted from the compression to which these and the neighbouring fossiliferous sediments have been subjected.

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, pp. 32-33 B.

The syncline lies in contact on the southwest with later granitic rocks of the Coast Range batholith, and to the northeast is separated from a fossiliferous series by a belt of igneous rocks varying in width—in those parts examined—from less than half a mile to over a mile and a half. With this is associated a great deal of serpentine. A field study of the complex indicates that the serpentine has resulted from the alteration and replacement of a fine-grained green volcanic of latitic composition whose age and origin are tentatively regarded as similar to that of the other greenstones in the cherty series. This volcanic rock appears to have been invaded by a coarser intrusion, probably an apophysis of the Coast Range batholith. In mineral composition this intrusive varies from a hornblende diorite to a gabbro, and it probably has had considerable influence in effecting the partial alteration of the earlier igneous body to a serpentine.

Fossiliferous Series

Considered as a whole, the sediments composing the fossiliferous series follow the same general strike, and are characterized by the high dips so noticeable in the unfossiliferous cherty and volcanic rocks. Structurally the two series might be regarded as conformable, but stratigraphically they were found to be separated by the rocks of the serpentine belt and by a narrow conglomerate bed, which very persistently, though somewhat intermittently, follows its northern flank. This conglomerate is only a few feet thick, but was noted at several points on either side of Coquihalla river, which it crosses near the mouth of Dewdney creek. It is formed of a slaty matrix in which is embedded a variety of cherty, felsitic, and some definitely igneous pebbles. In part these are indistinguishable lithically from members of the unfossiliferous rocks, but may have been derived from other sources.

In an important respect the rocks of this series differ from the members of the unfossiliferous sediments in that, as their name implies, they contain organic remains. In all the members except the coarsest conglomerates a few fossils were found, but they show no great variety, and on the whole are rather scarce. A number of small collections were made at various horizons. These were referred to the Palæontological Division of the Survey for determination, but were found to be of no definite value in fixing the age of the enclosing sediments.

Where these fossiliferous sediments cross the railway, they consist of a variety of argillites, slates, and schists, with some calcareous members. These are intruded by narrow sills, and near their contact with batholithic rocks are partly recrystallized and highly impregnated with igneous material. The prevailing dip is to the southwest at high angles. A remnant of one anticlinal fold was observed in the bend of the track south of Ladners creek, but the structure here, as elsewhere, is obscured by thrusting and faulting on a large scale. The planes of these major movements seem to strike approximately parallel with the formation, and are well marked by gouge and brecciated material up to 3 feet in width. The original thickness of this formation is also obscured by the development of a slaty or schistose cleavage which often bears but little reference to the bedding planes.

These slaty rocks are presumably part of an auriferous series, whose continuation to the northwest, down the valley of Siwash creek and across the Fraser, received considerable attention from earlier investigators.[1] Where they cross the Fraser-Coquihalla divide, they are interbedded with coarser sediments. Among these, a belt of conglomerate a few hundred feet thick is characterized by the presence of many irregular slate fragments which, during a period of partial uplift and more active erosion, may have been torn loose from the still unconsolidated slate floor. Other more rounded pebbles in this conglomerate very much resemble the cherty and volcanic members of the unfossiliferous series already described from lower down the

[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-77, p. 107.
Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, pp. 153-154 B.
Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1911.
Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 34 B.

Coquihalla valley. These coarse sediments are in part very similar to a much heavier series encountered on the headwaters of Cedar and Dewdney creeks, where the rocks range in texture from dense, cherty quartzites to coarse conglomerates, and where their total thickness must extend well up into the thousands of feet. They are characterized, under the microscope, by their comparatively fresh appearance and by an abundance of pyroclastic material. The conglomerate member occupies the divide to the northeast of the head of Cedar creek and has an apparent thickness of about 3,000 feet. Its pebbles grade in size up to a foot or so in diameter and are generally well rounded. It appears to be a basal formation, but the extremely high dips and numerous irregularities make this determination somewhat uncertain. Some of the pebbles very much resemble detritus from the unfossiliferous series of the lower Coquihalla river. Others are distinctly granitic, and may have been derived from an early intrusion of the Coast Range batholith.

Other Conglomerates

A very interesting basal conglomerate of uncertain age is exposed on the summit of Silver peak about 5 miles south of Hope. It was briefly examined in connexion with the silver ore deposit at the Eureka mine where it forms the country rock. Its occurrence as a capping 1,500-2,000 feet thick, overlying the massive plutonic rocks of the Coast Range batholith, suggests that it was deposited upon them and hence is younger. There is some field evidence, however, which tends rather to discredit this hypothesis. No definite attitude could be obtained, although in certain places the arrangement of the constituent pebbles suggested a nearly vertical dip. Some very prominent joint cracks were observed, and these have practically the same attitude as those noted in the sediments of Coquihalla valley. The pebbles are in general cherty, and in part are very similar to, if not identical with, the cherty formation previously described in the non-fossiliferous series. Some volcanic, and a few definitely granitic, pebbles were also observed, but both these occur in minor proportions as compared with the cherty varieties.

This conglomerate appears to be practically identical with a very small exposure found near the head of Cedar creek, possibly resting upon, but more likely interbedded with, the heavy conglomerate member of the fossiliferous series. It is also similar to another small outcrop found on the ridge that continues west from Tulameen mountain, and its matrix is in part macroscopically identical with some of the members of the fossiliferous series. The pebbles are very well cemented and fractures usually pass through them.

One large dyke of rhyolite quartz porphyry was found intersecting this conglomerate in the vicinity of the Eureka mine, but its relation to the batholithic rocks has not yet been studied.

Coast Range Batholithic Rocks

The chief exposures of batholithic rocks in the area occur below the mouth of Anderson river and above the mouth of Boston Bar creek. The contact of the more southern area extends from Fraser river around the south flank of Ogilvie mountain and crosses Coquihalla river about one-fourth mile below the mouth of Anderson river. Thence it continues southeasterly, crossing Nicolum river a mile or so below the mouth of Elevenmile creek. The northern contact extends from the mouth of Boston Bar creek, over the divide between this stream and the north fork of Ladners creek which it crosses 2 miles below its head. The main contact southeast of Coquihalla river has not been traced, but in this direction a belt of granitic rocks, apparently an apophysis of the main body and varying in width from less than half a mile to nearly 2 miles, crosses the Coquihalla some 2 miles above the mouth of Boston Bar creek and proceeds in a general southerly direction across Cedar and Dewdney creeks towards the headwaters of Peers river. Other areas of granitic rocks were noted near the divide at the head of Cedar creek and the South Fork of Dewdney creek.

Generally speaking, the larger areas are more coarsely crystalline, whereas the smaller exposures are commonly quite fine-grained, and frequently exhibit a porphyritic texture in which sometimes biotite, but more often hornblende, form the conspicuous phenocrysts.

Granites and granodiorites appear to constitute the bulk of these rocks, but their contacts with the older sedimentary formations are frequently marked by more basic apophyses and by the intrusion of dykes of complementary character, including almost pure quartz and very basic stringers. Elsewhere the sediments have been intruded by numerous dykes and sills of more intermediate composition.

No field evidence indicates any great difference in the time of intrusion of these varieties. The sediments of both the fossiliferous and nonfossiliferous series are intruded by them and hence are older. The occurrence, however, of granite pebbles in all the conglomerates, together with the occasional appearance of boulder-like inclusions of foreign granitic material in the batholithic rocks themselves, suggest that there may have been an earlier invasion of batholithic material, but that this has been obscured by subsequent igneous and sedimentary formation.

Lower Cretaceous

A conglomerate, tentatively referred by Camsell to this period[1], is exposed in a small, relatively unimportant, area on the west bank of the Fraser, opposite Hope. It has been regarded by some as probably of the same age as the conglomerate exposed on the summit of Silver peak on the opposite side of the river and some 3,000 feet higher. From this latter, however, it differs markedly in some respects. Its pebbles are very loosely cemented and are composed mainly of granitic and volcanic materials, accompanied by a small proportion of quartz and slate fragments. This conglomerate appears to definitely overlie, and consequently to be younger than, the batholithic rocks exposed in this neighbourhood.

Glaciation

The topography of the Coquihalla area has been greatly modified by glacial processes. All but the highest summits, those exceeding 6,000 feet in elevation, have been glaciated and exhibit the rounded outlines, polished and striated surfaces, and lee and stoss gradients characteristic of glacial activity on a continental scale.

The direction of this major glaciation, as indicated in particular by glacial grooves on the summits, appears to vary between south 45 degrees west and west, with the more southerly directions prevailing. Field evidence points to this direction of movement rather than to one directly opposite. Large erratics, commonly of granitic material and transported for distances measured by miles, are common, and appear to have been derived from northeastern rather than southwestern sources.

Owing to the rugged topography, the glacial material deposited on the slopes of the basin has tended to migrate toward the valley bottoms and from thence, in large part, has been removed by the streams or has accumulated nearer their mouths. A large part of this material was evidently supplied by more local but extremely potent mountain glaciation forces.

The greatest accumulations of glacial deposits are found in Coquihalla valley itself, and are well exposed in some of the railway cuttings. They are mere remnants, however, perched on the valley slopes, but they indicate that glacial material once occupied Coquihalla valley to a height of about 500 feet above the present bed of the river.

Camsell[1] has already drawn attention to the great mass of glacial material piled up near the mouth of Coquihalla river and its effect in abruptly diverting this stream

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 33 B.

from its original channel through Kawkawa lake to the one now occupied. There can also be very little doubt that the great mass of the delta deposit at the mouth of the river is made up of reworked glacial materials.

That the advance of the valley glaciers was accompanied by more or less sorting of the deposits by glaciofluviatile processes is indicated by the bedded character exhibited in some of their sections. That this advance was also subject to considerable oscillation is suggested by the abrupt changes and repetitions in the coarseness of the material so deposited.

Local or alpine glaciation does not now play a rôle of any importance in the area, for in spite of a heavy annual precipitation of snow, the greater part of it disappears during the summer months and little or no accumulation results.

ECONOMIC GEOLOGY

Placer mining on Coquihalla river and its tributaries has never met with that success which the presence of certain favourable auriferous formations might indicate. This is largely due to the physical difficulties encountered in sinking through the heavy mantle of glacial and fluvial drift which covers the creek bottoms. This difficulty is aggravated, too, by the great velocity of the streams and their irregular fluctuations in level.

Probably the most favourable locality for the placer miner in this area lies within the limits of the belt of slates already referred to in this report as an important member of the fossiliferous series. These slates cross Coquihalla river in a northwest-southeast direction between the mouths of Boston Bar and Dewdney creeks and are probably the same slates which, for the last sixty years, have provided rich placer returns from the Fraser River "bars" below North Bend.

In contrast with this latter region, only a few sporadic attempts have been made to wrest placer gold from the gravels of the Coquihalla and its tributaries. These attempts have always met with some measure of reward. Coarse gold in payable quantity, and in some cases a fair proportion of platinum, have usually been found. There seems in reality very little doubt that the installation of efficient pumping machinery and the construction of more permanent flumes and dams would make placer mining in these slates, and even for some distance below them, a paying proposition.

The source of the platinum is still a matter of doubt, but may be the belt of serpentine and partly serpentinized rock lying immediately below the slates.

The chief mineral deposits of the area, in the present decreasing order of importance, are gold, silver, copper, molybdenum, and manganese. This classification does not include those properties outside the limits of the Coquihalla area proper but included in the sketch map (Figure 3) accompanying this report. They will be considered independently under the caption of the respective mining camps in which they are located.

Gold

Gold is the chief ore mineral of economic importance at present being mined in the area. Its occurrence, except at the Aufeas mine, is confined to a belt of auriferous slates about 4 miles wide which strikes across Coquihalla river in a general northwest-southeast direction above the mouth of Dewdney creek. Camsell[1] remarks that the auriferous character of these slates is not peculiar to the Coquihalla basin but has been recognized in other mining districts farther to the northwest, notably in the adjoining Siwash Creek area, along Fraser river near North Bend, and on Cayoosh creek.

The chief mineral properties are situated along a line which extends across Coquihalla river near the mouth of Dewdney creek, and follows in a general way the

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 34 B.

contact between the slates and a persistent though somewhat irregular igneous belt with which is closely associated a considerable amount of serpentine. Of these properties, those lying on the western slope of Coquihalla valley are at present of most importance.

The mineral deposits themselves are almost entirely confined to the slates. They occur as quartz veins, usually parallel to the bedding or cleavage of the enclosing sediments but occasionaly cutting across them. Frequently the veins show remarkable persistence and regularity both in attitude and composition, but these are not generally considered by the miner as promising prospects as those quartz veins occupying more irregular and highly fractured zones in the slates, or those immediately associated with one or more of the numerous sills occurring in these slates. The sills themselves are very frequently well mineralized, and good gold values have been reported by claim owners from some of them. They are, on the whole, characterized under the microscope by the scarcity of free quartz and often of ferromagnesian minerals. The constituent alkalic and basic feldspars commonly assume a reticulating structure where present as phenocrysts or as constituents of the finer groundmass. Calcite is usually present in varying amounts as a replacement mineral. The general alignment of the chief mineral properties along the contact of the large serpentinized belt mentioned above has naturally led to the assumption that this igneous body has been mainly responsible for the concentration of values along its margin. With this view the writer is in part inclined to agree, but holds a tentative hypothesis that the mineralization was not effected by the serpentine itself nor by the effusion of the fine-grained latite which has subsequently been partly replaced by serpentine, but rather by a later intrusion of a plutonic rock, mainly gabbroic, which occurs in considerable amounts through the serpentinized belt.

The gold occurs both free and in close mechanical association with arsenopyrite and, to a smaller extent, pyrite. Although mainly confined within the walls of the quartz vein, the values may also extend for some distance in the adjacent country rock. They vary greatly in different portions of the same vein, tending to concentrate in shoots showing high values, and separated from each other by low-grade vein material.

There is some indication, too, either that the quartz veins are not all of precisely the same age, or have formed at somewhat different temperatures, the gold values appearing to favour the higher temperature veins. A certain amount of subsidiary faulting, observed in the workings of the Emancipation mine, is reported to be an indication of higher values in that portion of the lead.

Where the quartz leads outcrop at the surface, the upper decomposed and oxidized part frequently shows good colours and, "the discovery of the deposits has invariably been made by tracing the gold up the gulches by panning."[1] On the Idaho claim the quantity of gold contained in the surface capping of the principal lead was considered sufficient to warrant the installation of a temporary flume and sluice boxes and in this way afford some recompense for the labour and time involved in stripping.

Emancipation Mine. A brief description of this property has been given by Camsell[2] and details of its development have from time to time been published in the Annual Reports of the Minister of Mines, British Columbia.

The mine is situated about 1,100 feet above the Kettle Valley railway and almost opposite the mouth of Dewdney creek. It is now in the hands of the Liberator Mining Company of Vancouver, and when last visited by the writer, preparations were being made to operate on a much larger and more efficient scale than hitherto. An assay office installed at the mine has been of great service during the past summer. A compressor, temporarily operated by a gas engine, had been installed at the railway,

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 34 B.
[2] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 35 B.

and a pipe-line run from there to the mine workings, where a couple of machine drills were making satisfactory progress. Telephone connexions had been established between the mine and the railway, and it was expected shortly to have the line extended to Hope. A railway siding was also under construction.

The main adit, known as the 1,200-foot tunnel, has been driven 530 feet along the high-grade quartz vein from which all the ore so far shipped has been extracted. In this distance two small, but well-defined, faults were noted at approximately 310 feet and 490 feet from the portal. These show a displacement of 1 foot and 3 feet and a strike of south 65 degrees west and west respectively. Both dip to the northwest at about 70 degrees. According to assays made at the mine, the ore in their vicinity and for some distance on either side shows much higher values than elsewhere. Evidence proves the existence of a major longitudinal fault running up Tangent creek from the east side of the portal of the 1,070-foot tunnel. It is possible that the minor cross faults shown in the upper workings may be subsidiary in character to this larger movement. If this be so, it seems desirable to project the work at the mine to the point of investigating the principal ore-body at its intersection by this major fault.

The high-grade quartz lead lies near the hanging wall of a much larger and well-defined quartz vein known as the Boulder lead. This vein was the first to be prospected in this property and has been stripped at several points above the present workings. It has an average width of about 8 feet and nearly, if not quite, the same attitude as the enclosing slates. Because of its low values in gold, work has been abandoned on it for the present. Its continuity above the main workings has been proved, but its continuation farther down the hill has not been carefully investigated, except to show that considerable displacement has occurred between the 1,200-foot and 1,070-foot tunnels.

The gold values at the Emancipation mine occur both free and intimately associated with arsenopyrite and pyrite. Highly silicified fragments of country rock embedded in the quartz-vein material are often extremely rich. These fragments impart a bluish cast to the enclosing quartz, and when freshly fractured and moistened are often found to be strongly impregnated with finely disseminated gold particles. These are frequently so fine as to be invisible to the naked eye, but a touch of the blow pipe to the enriched surfaces causes the gold to coagulate into small beads which stand out on the surface and are easily discernible.

The presence of a considerable amount of feldspar in the vein material from this ore-body, taken in conjunction with the occurrence of admixed sulphides, is suggestive of at least a fairly high temperature of formation or even igneous intrusion along the strike of the lead. A contrast is noted in the case of the Boulder lead, in which no feldspar was observed, and which is composed almost entirely of pure vein quartz. In this lead, too, little or no dissemination of sulphides occurs, and calcite, which affords a common gangue mineral in the principal ore vein, is lacking. A sample taken across the face of the Boulder lead at its outcrop near the portal of the 1,200-foot tunnel was assayed by the Mines Branch at Ottawa. No gold or silver values were found. Silica constituted 92·92 per cent of the vein material. This sample, though typical, cannot be considered as representing an average of the lead as a whole.

Some enargite, chalcopyrite, and a little stibnite have been found associated with the quartz gangue on this property, but are of no economic importance. Silver is said to accompany the gold in the proportion of 1 ounce of silver to 6 ounces of gold.[1]

Idaho Group. This property was examined by Camsell in 1919[2] since which time very little has been done except surface stripping. The material so removed was in part run over a series of sluice boxes and riffles by the aid of a long canvas hose, In this way a fair amount of very fine, but little worn, gold was saved.

The Idaho Group consists of four claims, of which the Idaho only has received any considerable attention. The property is situated at an elevation of 3,400 feet, or about

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 35 B.
[2] Camsell, C., Geol. Surv., Can., Sum. Rept. 1919, p. 34 B.

800 feet abeve the bed of the South Fork of Ladners creek on the north slope of the valley. A series of trails, some passable for pack horses, connects this property with the Kettle Valley railway, about 2½ miles to the southeast.

The two principal leads occur in the slates a few hundred feet to the east of the serpentine belt. One of these is apparently bedded with the sediments, which strike about north 80 degrees west and dip 45 degrees to the north. The lead is a somewhat calcareous brecciated zone averaging 5 feet in width, which has been highly silicified and largely replaced by vein quartz material. The whole has the general appearance in the outcrop of a fine-grained sill of medium acidity which has been partly replaced by calcite and impregnated and intersected by vein-quartz material. The lead is moderately well mineralized with pyrite and arsenopyrite and contains a little free gold. The slate walls, also, are sparingly mineralized and intersected by numerous small quartz stringers for a distance of about 1 foot on the foot-wall and 3 feet on the hanging wall. The total breadth of the mineralized zone is thus about 9 feet, but it varies considerably in the distance exposed. A sample of typical, but not necessarily average, vein material from this lead assayed by the Mines Branch, Ottawa, ran 0·055 ounces in gold. No silver was present.

The other lead outcrops immediately above the workings on the bedded vein. It appears to cut the slates at an angle of 60 degrees, following the jointing rather than their bedding or cleavage planes. It has a breadth of 6 feet and is composed mainly of vein quartz, although containing numerous silicified fragments of the country rock.

Assays from these two leads were said by the owners to show an average of over $8 per ton. It is possible that a higher concentration of values may occur at their intersection.

Pittsburg Group. This group adjoins the Idaho claims to the southeast, and reaches down the northern slope of the valley of the South Fork of Ladners creek No development work was done on this property during the past summer. At the principal showing a 30-foot tunnel has been driven along a quartz vein some 10 feet wide. This vein was described by Camsell[1] as "well-defined and mineralized sparingly by pyrite and arsenopyrite. The gold appears to be associated with the arsenopyrite, but may also be obtained by panning the decomposed outcrop."

Montana Claim. In this claim which adjoins the Idaho to the northwest, an open-cut has been driven in a massive volcanic of latitic composition containing a couple of narrow quartz veins about 2 inches in width showing occasional rich specimens of free gold. The volcanic rock is mineralized with pyrite adjacent to the quartz veins, and is itself said to contain appreciable values in gold. The presence of free gold in the quartz veins intersecting this greenstone is of considerable interest, as in all the other properties examined in this section the quartz leads carrying gold are confined to the slates, or to narrow dykes and sills in the slates.

A few yards to the northeast of this open-cut the slates are encountered, and some work has been done there on a poorly-defined calcareous lead about 3 feet wide, which is apparently bedded with the slates and moderately well mineralized by pyrrhotite and pyrite.

Rush of the Bull Fraction. Adjoining the Montana claim to the north is a full claim known as the Rush of the Bull No. 1. No deposit of interest has been opened on this property, but adjoining it to the north is the Rush of the Bull Fraction, about 400 feet wide, on which some very promising discoveries have been made. Here at an elevation of about 4,500 feet and a few yards above the trail leading to the Pipestem mine, two small quartz veins averaging 4 inches in width cut across the slates and are heavily mineralized with coarse arsenopyrite and some free gold. The wall rock is impregnated with the sulphide and shows occasional specimens of free gold. More development work is necessary to prove whether these quartz veins constitute the main ore-body or are themselves off-shoots from some larger lead.

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1919, p. 35 B.

Other larger quartz veins of a bedded character have been discovered below the trail, but as yet no free gold has been noticed in these and they are in general rather scantily mineralized.

Gem Group. The three claims represented in this group are situated to the north of and adjoining the Rush of the Bull Fraction. They are traversed by the trail leading to the Pipestem mine at the head of the Middle Fork of Ladners creek, and follow more or less roughly the contact between the slates and the serpentine belt.

On the most southerly of these claims, known as the Golden Cache No. 1, six bedded quartz veins in all have been discovered. They strike about north 70 degrees west, and dip at high angles to the north and south, and are all somewhat sparingly mineralized by pyrite and arsenopyrite. The assay values in gold are, as far as known, rather low. No average, however, can be given with any degree of confidence, as but little development work has been done and no systematic sampling attempted. Adjoining this claim is the Golden Cache No. 2, in which very little of interest has been discovered. The third claim, known as the Gem, shows three open-cuts approximately in line with each other and probably all cutting the same or closely parallel leads. The ore-body is represented by a decomposed quartz vein, about 6 feet broad and filled with silicified fragments of country rock. Both the vein material and the wall rock show sparing mineralization by pyrite and arsenopyrite, the latter easily recognized by the garlic odour emitted when struck with a hammer. Occasionally the mineralization is quite heavy, and in such cases appears to favour the wall rock and in particular the hanging wall, which seems to be a highly altered and comparatively acid sill striking north 70 degrees west and dipping at about 70 degrees to the north. A prolongation of the main quartz lead would bring it very closely in line or parallel with the principal ore-body at the Pipestem mine in the adjoining claims. A red decomposed earth, overlying the most northerly of the three surface showings, gives a good display of colours on panning.

Pipestem Mine. This property is situated on the divide between the Middle Fork of Ladners creek and the headwaters of Siwash creek at an elevation of approximately 4,500 feet above the sea. The Pipestem group consists of six claims to which a trail has been constructed from the railway at Ladners creek. The trail was said to lead up the valley of this stream to the confluence of the North Fork and, after following this tributary for a mile or so, to cut across to the mine at the head of the Middle Fork.

When examined by the writer, the work at the mine had been confined chiefly to an exploration of the principal lead on the Pipestem No. 1 claim. Here two open-cuts had been made on a quartz vein which varied in width from 6 inches to 2 feet, but along the course of which the slate walls were so heavily mineralized and ran so high in gold values as to increase the actual width of the pay streak from 50 per cent to 100 per cent. A specimen of this country rock showing exceptionally heavy sulphide mineralization was assayed by the Mines Branch, Ottawa, and ran 3·76 ounces in gold. The quartz vein appears to be bedded with the slates, which here have a more massive habit than farther down the valley and are highly fossiliferous. They strike approximately north 80 degrees west and dip at high angles to the north and south. The north, and in general the hanging wall of the lead, is partly defined by a narrow belt of more fragmental material having the general appearance of a fine slate conglomerate. This, like the more typical slates, is also fossiliferous.

In line with these two open-cuts which are about 150 feet apart, a shaft 30 feet deep and approximately 130 feet farther to the northwest, has been sunk along the foot-wall of the conglomerate. As the main lead is not encountered in this shaft, some displacement or irregularity has evidently occurred between this point and the nearest open-cut. There is reason to believe that the main quartz vein will be found close to the south wall of the shaft or, at least, no great distance down the hill. A

couple of quartz stringers about 4 inches wide are intersected by the shaft. These had been assayed by the owners and were said to show $37 in gold, the slate itself at the bottom was at the same time reported to assay $5.60 in gold and 0·06 ounces silver per ton.

Pyrite in well-defined, large cubes, together with a smaller proportion of arsenopyrite, appears to be the chief gold carrier in this mine. Assays of the cube iron alone are said by the owners to run as high as $37 per ton. Gold also occurs free both in visible and microscopic quantities. It affords some very spectacular specimens, and is responsible for the high assay returns on some of the samples which run into hundreds of dollars per ton but vary within wide limits. Some silver is also present in proportions which apparently bear no fixed relation to the amount of gold with which it is associated.

Morning Group. The Morning Group, consisting of four claims, is situated on the east side of the Coquihalla and above the mouth of Dewdney creek. Like the gold properties on the opposite slope of Coquihalla valley, these claims are located in the vicinity of the contact between the slates and the serpentine belt.

The most promising showing in this group is found on the Broken Hill claim at an elevation of approximately 2,500 feet on the precipitous slope of the hill overlooking Dewdney creek. Here a quartz vein, varying in width from a few inches to 10 feet and traceable for a couple of hundred feet at least, shows in places quite a heavy mineralization chiefly by arsenopyrite. Pyrite also appears in considerable amounts, and a little galena. Quartz and calcite are the common gangue minerals. No assays have yet been reported from this prospect.

The country rock is a slate striking about north 27 degrees west and dipping 45 degrees to the southwest. Interbedded with this are a couple of andesite dykes which have undergone considerable alteration and are in part replaced by calcite. They are 15 feet and 8 feet wide respectively, and some 50 feet apart, and appear to have some genetic bearing on the ore mineralization. The upper and larger one is in intimate contact with the main quartz lead, and is itself partly replaced by several small quartz veins. Gypsum was noted on the surface of the hanging wall of the lower of these two dykes.

Lucky Bear, Summit, and West End Claims. The Lucky Bear is situated nearly opposite the mouth of Boston Bar creek on the east slope of Coquihalla valley and about 200 feet above the river bottom. The Summit and West End claims are located near the Ladners-Siwash Creek divide above the Montana claim and at an elevation of about 5,000 feet. None of these properties has yet given values of economic importance, although all are represented by quartz leads showing sulphide mineralization.

Aufeas Mine. The Aufeas mine is situated on Wardle creek, a small tributary to Silver creek, at an elevation of about 1,500 feet and about 3½ miles in a direct line southwest of Hope. A good wagon road leads up Silver creek to within a mile of the mine workings. The country rock is a part of the Coast Range batholith. In mineral composition this rock appears to be a rather coarse-textured diorite or possibly a gabbro. The only feldspar represented appears to be a plagioclase showing coarse polysynthetic twinning. This composes roughly 50 per cent of the rock, the remainder consisting chiefly of hornblende, but also containing a large amount of biotite. In the immediate vicinity of the workings, a very fine-grained, light green intrusive of highly acidic character was encountered and may represent a later intrusion into the partly or completely solidified mass of the coarser plutonic. It is closely associated with the ore deposits, is itself often quite heavily mineralized, and has been largely replaced by calcite.

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The ore-bodies apparently occupy fractured zones and fissures in the disrupted igneous mass and are composed largely of almost solid arsenopyrite associated with a considerable amount of chalcopyrite and some pyrite. Quartz is the common gangue mineral, and its proportion to the ore mineral varies widely in different veins and in different portions of the same lead.

The ore-bodies as a whole assay low, but are said to have shown no sign of falling off in values as the work proceeded.

Little or no work has been done on this property since 1914 when 140 tons of ore were mined and partly sacked. Shipment, however, has been temporarily postponed until more satisfactory freight rates are obtained.

An examination of this property was made in 1915 by Mr. Brewer who gave, in his report for that year, a careful description of the underground workings[1].

Silver

Both high-grade silver and silver-lead deposits occur in the Coquihalla area. Of these the latter are still of minor importance, although further developments are likely to occur when better transportation facilities are available. Deposits of this character are known to occur on the west slope of Coquihalla valley below Ladners creek and also near the head of Coquihalla river. They also are found in a few small workings near the head of Cedar creek on some old crown-granted claims upon which no work has been done for a number of years. Their geological associations here are very similar to those of the adjoining Summit Mining camp on the headwaters of Tulameen river to which some references are made later in this report.

The high-grade ores are confined to two localities in the Coquihalla area, both near the summit of Silver peak. These are the old Van Bremer and Eureka mines.

Eureka Mine. This property is situated about 5½ miles south of Hope in a direct line, or 7 miles by trail. A good wagon road runs for 4 miles up Silver creek to the foot of the trail leading to the mine workings which are near the summit of Silver peak.

The Eureka is the oldest mine in this area, its discovery dating back to 1871. It has the reputation of being a high-grade silver property, but better returns have been reported from the Van Bremer, about 3,000 feet south of the Eureka. The splendid assay returns from these two mines, together with the reported size and persistence of their leads, aroused great interest for some time following their discovery. A considerable amount of development work was done and ore was shipped to San Francisco, where it netted $420 per ton. Further progress was, however, retarded in part by the physical difficulties and expense involved in transport and partly by unfortunate litigation. At present, however, it is understood that a clear title to the property has been secured and that operations will shortly be continued. The trail leading to the workings from Silver creek, although very steep, is in good repair and can be travelled by pack horses.

The writer was able to spend only a few hours in actual examination of the mine and it is possible that some workings were overlooked.

In ascending the trail above Silver creek, the country rock for the first 3,000 feet appears to be almost entirely massive plutonic rocks of the Coast Range batholith. At 4,000 feet some conglomerate float was noticed on the trail and soon appeared in place, and constituted the chief formation the remainder of the distance to the summit.

At 4,900 feet elevation the trail forks. The left branch leads to an old working in a narrow precipitous gulch which continues up the side of the peak. A tunnel, driven along a fractured zone in the conglomerate, exposes a lead of decomposed vein material averaging, probably, 6 inches in width. This vein strikes south 60 degrees west, and lies between the massive conglomerate walls of the country rock.

[1] Brewer, W. M., Ann. Rept. Minister of Mines, B.C., 1915, p. 255.

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This tunnel was examined for only a short distance, owing to water, but the lead was easily traceable on the surface above the tunnel and was followed to an elevation 100 feet higher, where a second tunnel about 30 feet long shows the hanging wall with well-defined slickenside grooves, indicating that the vein material is following what is probably a joint plane along which some shearing and brecciation have taken place. The attitude of the vein here is practically the same as in the lower tunnel. The hanging wall is much fractured, and the small fissures formed in it are filled with a reddish, decomposed gouge or vein material which may contain values. The main lead is still less than a foot in width.

Continuing up the gulch along the lead by means of a series of rope and ladder arrangements, the vein was found to persist in its direction and a hundred feet higher broadens out to a width of about 14 inches. A considerable amount of yellow clay is associated with the vein material. Although the lead still continued above this point, it could not be followed because of the precipitous character of the gulch and the absence of any artificial assistance.

No ore minerals of economic significance were noted in this portion of the lead, and, if present, must occur only in minute particles. The yellowish clay above mentioned may be an indication of lead or silver values, but more probably of iron. A little green copper stain was also noted. A fragment of the vein material considered as typical, but not representing an average, was referred to R. A. A. Johnston, Geological Survey, who reports as follows:

> "This specimen has evidently been taken from a vein or pocket. The enclosing rock which is highly siliceous, has been honeycombed and impregnated with a mixture of hydrated oxides of manganese and iron. The vein matter consists of crystalline quartz with interspersed patches of specular iron (hematite)."

The right branch of the trail leads to the opposite or south side of the peak facing Holy Cross mountain. What appeared to be a continuation of the same lead examined on the north side of the hill was here picked up, and if this be the same lead, it must be 2,000 feet or more in length. Here another tunnel had been driven for about 100 feet along the lead, which is only about 3 inches wide, and as before lies between shattered conglomerate walls. The vein is composed of a greenish, soft, oxidized material, of which a sample assayed by the Mines Branch, Ottawa, yielded 658·42 ounces in silver and 26·72 per cent lead. Below the portal of this tunnel a considerable amount of limonite was found in the fractured zone of the wall rock on either side of the lead. A large proportion of siderite is associated with the limonite. The limonite shows a massive and sometimes a crude botryoidal structure. It also occurs pseudomorphic after either siderite or marcasite. Small flakes of hematite were also noted. The siderite is mainly dark brown in colour and shows large cleavage surfaces. It also appears in whitish masses of sugary texture where it is associated with small quartz crystals. Quartz is also a common gangue mineral. A small vein an inch or so in width of almost solid fine-grained marcasite was found near the east wall of the mineralized zone. The attitude of the lead is approximately the same as on the other side of the hill.

In a dump below this tunnel fragments of vein material were found, in some of which were noted small areas of a softer, light grey, metallic mineral, which upon examination in the laboratory appears to be a sulph-antimonide of lead—possibly jamesonite or boulangerite. This mineral probably carries the silver values whose concentration has formed the high-grade vein material in the tunnel above.

Copper

Chalcopyrite is the only copper mineral of economic importance in the Coquihalla area, but at only one property, the Independence mine, is it the chief ore mineral. It commonly occurs in small percentages, locally concentrated into small

unimportant deposits or minutely disseminated through the country rock. It is always found associated with one of the sulphides pyrite, pyrrhotite, marcasite, galena, and sphalerite, and is an accessory constituent in the majority of the mineral properties in this area.

At the Independence the chalcopyrite has itself furnished a deposit of commercial value. This property is situated at an elevation of 5,500 feet near the head of Coquihalla river, about 2½ miles east of the railway and on the divide overlooking Bear creek, which flows southeast into Tulameen river.

No work has been done on this property since 1908. When visited by the writer all outcrops and surface showings were obscured by several inches of snow. A brief examination of some of the principal workings served but to confirm the general conclusions already drawn by Camsell,[1] from whose report the following is quoted:

> "The ore-body, which is a granite porphyry, appears to be cut by a darker syenitic variety that is also highly mineralized with copper ores. The whole is much fractured and cut by small calcite veinlets which carry the ore minerals. Where the fracturing is greatest, the rock is richest in sulphides. Over 1,000 feet of tunnelling and 180 feet of shaft and wings have been done besides a large amount of surface prospecting. A large shoot of good copper ore has been defined by these workings."

Molybdenum and Manganese

Molybdenite is said to occur in a deposit of economic value in the massive granite of the Coast Range batholith near the summit above, and to the east of, Boston Bar creek and about 3 miles north of the railway. This property is known as the Dominion Mineral group. Molybdenite was also noted as an accessory constituent of the granite along the railway at Boston Bar creek near Portia station.

A manganese deposit of commercial importance is also reported to occur on the ridge between Cedar creek and Coquihalla river, less than 2 miles in a direct line from the railway, and about 4 miles east of the mouth of Boston Bar creek.

Summit Camp

The Summit, or Summit City, mining camp is situated on the headwaters of Tulameen river near the Coquihalla divide and across from the head of Dewdney and Cedar creeks. The chief tributaries on the Tulameen slope are Sutter and Amberty creeks. The camp may be reached from the east by pack trail from Tulameen village, about 24 miles distant, or from the west by a trail 12 miles long leading up Dewdney creek from the Coquihalla.

The writer visited the camp and examined the only property being worked, the Wynot Fraction, situated on Treasure mountain. The lower tunnel of the Wynot claim said to be 700 feet long, had caved in near the portal and could not be examined. About 400 feet higher a second tunnel had been driven 150 feet along a mineralized vein in which the chief ore mineral is a coarse galena reported to contain high silver values. A sample of this galena assayed by the Mines Branch, Ottawa, gave 242·15 ounces in silver. Associated with the galena is a considerable amount of black sphalerite and some chalcopyrite and pyrite. Quartz and fragments of country rock constitute the gangue. The ore is thought to be introduced by a bird's eye porphyry dyke about 24½ feet wide which cuts across both workings. According to the owner it forms the hanging wall of the lead with depth, the foot-wall in the upper tunnel, and at intermediate points the ore occurs on both sides. Microscopic examination of this dyke shows it to be a highly altered feldspar andesite porphyry. The country rock in the upper tunnel is a fine black conglomerate composed of small, felsitic,

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1908, pp. 63-64.

volcanic or cherty pebbles in a black, slaty, and somewhat calcareous matrix. Higher up the hill sediments varying from feldspathic grits with slate fragments to coarse conglomerates were noted. Some more or less calcareous members are present, and it is in part to the replacement of these that the ore deposits are due.

23-Mile Camp

The 23-Mile camp sprang into prominence about ten years ago, and while its properties have generally been regarded as rather low grade propositions, the camp appears to have been handicapped by difficulties of transportation rather than by lack of sufficient tonnage.

The camp is situated near the junction of Sumallo and Skagit rivers, about 23 miles from Hope. The old Dewdney trail passes through the camp, and for this distance from Hope is serviceable as a wagon road.

In 1911, Camsell visited the camp, and in his report[1] concluded that the ore-bodies were probably of contact metamorphic origin and, on the whole, low grade. Mr. Brewer visited the camp in 1915 and has given[2] a description of several of the properties.

Silver Daisy Mine

This property is situated on the east side and 200 feet above Skagit river about one-half mile below the mouth of the Sumallo. A small creek plunges down a gorge in front of the workings. The country rock is represented by the massive, dark blue, cherty member of the Hozameen series, characteristically intersected by numerous quartz veinlets. This has been intruded in the vicinity of the workings by an irregular, stock-shaped mass of a grey feldspar porphyry of doubtful composition and apparently of small areal extent.

The ore-body forms a lead about 5 inches wide in the cherty rock. Along it a lower tunnel 75 feet long, and an upper one about 20 feet long, have been driven. Sphalerite, pyrrhotite, and galena are the chief minerals present, but considerable chalcopyrite and some arsenical iron are also represented. The galena is the chief economic mineral, one assay return obtained by the owner showing $617.88 in silver and $400 in gold. Quartz is the chief gangue mineral, and its arrangement in the vein, with crystals projecting inward to form a rough comb structure, suggests the deposition of the ore in an open fissure. The wall rock has also been slightly impregnated with mineral and possibly to some extent replaced by the mineral-bearing solutions.

The vein has an attitude of about north 25 degrees east and dips to west at an angle varying from 50 degrees to 70 degrees. On the opposite side of the gorge or stream bed the vein divides, a minor stringer branching from the main lead at an angle of about 30 degrees.

A shipment of over seven tons of ore to the Trail smelter in 1916 gave the following returns in ounces per ton:

Gold 0·6, silver 89·3, zinc 12·4, iron 25·1.

Diamond Group

This property is located to the west of Skagit river about a mile below the mouth of the Sumallo. Work has been concentrated largely on stripping the surface of the principal lead, but several open-cuts have been distributed up the side of the hill at various points to an elevation of about 1,500 feet above the river.

The country rock is the Hozameen series in which a crystalline limestone plays an important part. This appears to be bedded with great thicknesses of a massive cherty rock like that observed at the Silver Daisy, and is also associated with considerable thicknesses of a massive dark greenstone.

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[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, pp. 115-123.

[2] Brewer, W. M., Ann. Rept., Minister of Mines, B.C., 1915, pp. 264-266.

The lower, or chief, showing is located about 360 feet above the river and exposes a mineral zone from 25 to 30 feet wide, striking north 15 degrees west and dipping at about 70 degrees to the southwest. The enclosing formation appears to be a complex lime silicate rock, which has resulted from the alteration of a limestone by the intrusion of a dyke, probably an andesite, underlying the deposit.

The ore consists chiefly of an aggregate of the sulphides arsenopyrite, chalcopyrite, and pyrrhotite. Some sphalerite is present, and a small amount of galena, said to be highly argentiferous in narrow stringers on the borders of the deposit. The ore minerals do not occupy the whole width of the deposit uniformly from wall to wall but tend to segregate in smaller stringers varying in width from a fraction of an inch to several inches. Certain minerals predominate in certain stringers of veins, and also in different zones in those veins. Though apparently discontinuous or grading rapidly into the country rock to the southeast, the deposit is said to follow the line of its strike for at least 200 feet to the northeast.

Above this showing and at an elevation of approximately 600 feet above the river, a large belt of crystalline limestone was encountered; and at its contact with a belt, or dyke, of andesitic rock, very typical lime silicate minerals, such as garnet, epidote, and tremolite, have been formed.

At an elevation of 1,100 feet above Skagit river, an open-cut on the left bank of a small tributary has revealed an 8-inch vein of almost solid chalcopyrite occurring in a dark blue, massive, cherty member of the Hozameen series. An analysis of a sample of the chalcopyrite obtained by Brewer[1], and considered as typical but not representing an average, gave gold 0·08 ounce, silver 1·88 ounce, copper 18 per cent, zinc 6 per cent. Some marcasite is associated with the copper ore.

Star Number One Claim

The claim is located on the north side of the Sumallo about one-half mile above its junction with the Skagit. The lower working lies about 700 feet above the river and consists of a tunnel driven 20 feet along a mineralized quartz lead from 6 inches to 12 inches in width. The country rock is a massive, hard, dark green, hornblende-andesitic rock and shows mineralization by pyrite, marcasite, pyrrhotite, and small amounts of free copper. An interesting association of pyrrhotite apparently replacing large irregular grains of tourmaline was noted in a thin section of this rock. The copper occurs along the surfaces of minute joint planes in the solid rock. The vein has an attitude of south 80 degrees west and dips to the south at an angle of about 80 degrees. It is composed mainly of arsenopyrite in a quartz gangue, but a small proportion of galena is present. This vein, although small, could, it was stated, be traced for several hundred feet above and below the tunnel. An assay reported by the owners on a sample of the arsenopyrite obtained from the vein ran $4.20 in gold and $24.83 in silver. This is not to be considered as an average value for the vein as a whole, but is quite typical of the arsenopyrite itself. Probably much higher values in silver will be found in the galena, although this mineral has so far been encountered only in very minor proportions.

An upper working, not visited by the writer, was said to be situated along the contact of a limestone belt with the greenstone. The ore there was stated to be chiefly galena associated with smaller amounts of chalcopyrite, pyrrhotite, and sphalerite. An assay was obtained by the owners on some galena from this working. It gave $113 in silver, $5.78 in gold, and $4.68 in copper.

Mammoth Group

The Mammoth group of two claims is situated on the north bank of Sumallo river opposite the Defiance and Star claims and about a mile above the junction of the Sumallo with the Skagit.

[1] Brewer, W. M., Ann. Rept., Minister of Mines, B.C., 1915, p. 266.

The lower showing appears at an elevation of 700 feet above the Sumallo in a country rock which is prevailingly the massive cherty member of the Hozameen series. With this are associated considerable bodies of the massive greenstone encountered at the lower showing of the Star Number One. The ore deposit itself occurs in a belt about 50 feet wide which appears to have originally been a limestone, but which has now been highly altered by contact metamorphic agencies into a lime silicate rock. In this the ore minerals are segregated.

The most interesting of these is a calcium tungstate or scheelite, occurring principally in a vein about 3 feet wide following the west wall of the lime belt. Associated with the scheelite is a considerable amount of pyrrhotite. This sulphide gives a very good qualitative test for nickel. The eastern wall of the lime-silicate belt is composed largely of a greenish rock suggesting a crystalline limestone. In the laboratory, it was revealed as an intimate mixture of quartz and calcite, the latter intergrown with siderite. A considerable amount of pyrrhotite and sphalerite is disseminated through the carbonate vein. The metallic constituents are mainly segregated adjacent to the inner walls of both the tungstate and carbonate leads, and tend to grade out into the central portion of the lime-silicate belt which is more sparingly mineralized. Sphalerite and pyrrhotite are the most abundant of these minerals. Others present include pyrolusite and molybdenite. The writer was informed that manganous deposits occur in bodies of considerable size higher up the hill in line with this lead. Of the contact lime-silicate minerals represented actinolite, occurring in large masses of green acicular crystals, was most noticeable. A curious occurrence of a mineral believed to be anorthite, and present in masses of large crystals was also observed.

This ore-body appears to be faulted off a few yards below this showing, but outcrops of a similar character were said by the owner to occur near the crest of the ridge about a half mile to the northeast and approximately in line with the lower workings. It is possible that a continuity may be established between these two points, in which case an ore-body of considerable economic importance might be developed.

Rainbow Claim

This property adjoins the Mammoth group to the southeast, and appears to lie not far from the contact between rocks of the Hozameen series and a large area of hornblende granodiorite which, commencing at a point about a quarter of a mile above the mouth of Sumallo river, occupies the left bank of that stream for several hundred yards. As far as could be judged from hand specimens, this rock is identical with a granitic outcrop observed at the head of Cedar creek in the Coquihalla area. This claim was not visited by the writer, but samples of the ore said to have come from the claim appeared to show that silver values of some importance may occur in a light grey metallic sulphide which, on laboratory study, seems to be a mixture of a sulphantimonide of lead, possibly jamesonite and berthierite, the latter showing characteristic hair-like structure. Other minerals occurring in a siliceous gangue include arsenopyrite, sphalerite, and pyrite.

The assay returns on a shipment of about 8⅝ tons of ore sent to the Trail smelter in 1914 gave in ounces per ton: gold 0·06; silver 15·7; copper 0·70; zinc 2·8. No work is at present being done on this property.

THE LIMONITE DEPOSITS IN TASEKO VALLEY, BRITISH COLUMBIA

By J. D. MacKenzie

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INTRODUCTION

For more than ten years it has been known that deposits of limonite of the variety known as "bog iron ore" existed in the country drained by the headwaters of the Taseko (Whitewater) river and in adjacent districts. They are said to have been staked first in 1909, and during 1914 development work was planned by the owners at that time. As a result of the general disturbance occasioned by the war these plans for developing the deposits were not carried out. Eventually the ownership of the properties changed, but nothing further was heard concerning them until 1919 when interest was revived. In August of that year a superficial examination of the area was made by Mr. W. M. Brewer of the British Columbia Bureau of Mines, and in the summer of 1920 the work which furnished the basis of this report was done. In addition to this geological investigation a topographical map of the area on a scale of one inch to one mile with a contour interval of 100 feet was made by C. H. Freeman of this department.

During July and the early part of August five weeks were spent in field work in the course of which the general geology of the district in which the deposits were situated was studied and mapped, and a careful and exhaustive examination was made of the limonite deposits themselves. Especial attention was given to measuring and estimating the quantity of bog iron and to determining the probability of extensions of the present exposures. The chances of finding other bodies of limonite were also considered. Samples were taken of the beds of limonite, the results of the analysis of which are presented below, with a description of the methods by which the samples were obtained. In connexion with the study of the occurrences of limonite a plane-table map on a scale of 1 inch to 200 feet was made of each deposit. By this means not only were the various geologic boundaries closely delimited and mapped on the spot with as great a degree of accuracy as the field facts would permit, but the relations of the limonite occurrences to the topography could be studied intimately on the ground. These maps, reduced in scale to 1 inch to 400 feet for purposes of publication, accompany this report, together with a map of the areal geology of the region

on a scale of 1 inch to 3,000 feet. Because of the shortness of the season early snow prohibited the mapping of all the area in which the deposits occur, and on this account those on McClure mountain, 5 miles down Taseko valley from the edge of the map-area, are illustrated only by the 1 inch to 400-foot plans.

Acknowledgments are gratefully tendered to the many residents of Lillooet and other localities, whose efforts materially furthered the season's work. Close co-operation was maintained during field work with the party under Mr. F. J. Crossland engaged in determining the quantity of ore in the limonite deposits for the British Columbia Bureau of Mines. C. W. Robinson proved an efficient field assistant.

No geologic work had been done in this region previous to the present investigation, with the exception of a reconnaissance in 1912 by A. M. Bateman, who traversed the valley of Battlement (Iron) creek and Taseko river. He makes brief mention of the limonite beds in his report.[1]

SUMMARY

The limonite deposits in Taseko valley are situated in its upper portion and in the valleys of several tributaries, the total area in which the beds of limonite are found being about 50 square miles. Access to the district may be had during the summer via Taylor and Warner passes from Gun valley. These passes are blocked with snow during the remainder of the year. An alternative route up Taseko river from Alexis creek may be followed. The elevation of the lowest point of the region is 5,200 feet and above this elevation steep mountains rise to altitudes of over 9,200 feet. Much of the district is above timber-line.

GENERAL GEOLOGY

The rocks underlying the limonite deposits are an assemblage of basaltic flows and pyroclastics with some quartz diorite porphyrite dykes and sills, the whole being described under the name "Taseko formation." This volcanic formation, of Tertiary age, overlies unconformably the previously eroded surface of the great batholith of the Coast mountains, which is composed of light grey, medium to coarse, even-grained quartz diorite.

The Taseko formation dips away from the batholith at angles up to 25 degrees, flattening to the east and northeast.

The Tertiary volcanic rocks also unconformably overlie another volcanic series which is apparently cut by the batholith and, therefore, is older than it. Rocks representative of this series in the map-area are termed the Denain formation.

LIMONITE DEPOSITS

The deposits known as bog-iron ore, are situated in seven different localities. They consist of sheets of brown limonite of varying shape, size, and thickness, built up of thin layers of brown, cellular, and generally loose-textured limonite, lying parallel to the surface of the ground on which they rest. The limonite when dug forms a large percentage of fines; most of it breaking into pieces of less than half an inch, and much of it breaking to the fineness of sand.

The iron is derived from finely divided pyrite which impregnates greatly silicified and sericitized tuffs of the Taseko formation. The iron sulphate solutions formed by the oxidation and leaching of this pyrite trickle down the mountain slopes and deposit at the first favourable location, building up a bed of limonite.

A concise statement of the tonnage, etc., present in the district, is given on page 68.

[1] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 186.

GENERAL STATEMENT

SITUATION AND AREA

The Taseko limonite deposits are situated in the eastern ranges of the Coast mountains nearly 100 miles by railway, wagon road, and pack trail west of Lillooet. They consist of several separate and distinct areas, in the valley of the Taseko and in the valleys of four creeks tributary to this river. Seven separate localities have been studied and mapped; of these, five are situated in an area of about 25 square miles in the upper Taseko and adjacent valleys, 6 miles separating the most accessible of these deposits from Taylor pass which connects Taseko and Gun valleys. Two more deposits are situated on the south side of Taseko river 5 miles from the west edge of the map-area. The total area in which these deposits occur is, therefore, about 50 square miles, but it must be kept in mind that in much of this area no limonite is found.

MEANS OF ACCESS

The best route to this district starts from Lillooet, a station on the Pacific Great Eastern railway in Fraser valley. Thence either railway or water transportation may be utilized to Shalalth, a railway station 15 miles from Lillooet on Seton lake at the foot of Mission mountain. Automobile or wagon transportation is available from Shalalth by a good road over Mission mountain and up the Bridge River valley for nearly 40 miles to where the excellent pack train, following Gun creek, leaves the wagon road. This trail, built during 1919, is well cut and follows an easy grade for some 25 miles up Gun Creek valley as far as Trigger lake, where a side trail branches off to Copper mountain. From here the remaining 15 miles through Taylor pass are not graded, and the trail is not so good. Taylor pass is at an elevation of 6,950 feet and is blocked with snow until July, though in some years pack horses may be taken through before this date when the snow is hard in the early morning.

An alternative route from Trigger lake is up Warner creek and over Warner pass. This is a somewhat shorter but an exceedingly rough trail; the pass is at an elevation of 7,700 feet and the trail leads over a glacier. Mr. Crossland's party had great difficulty in crossing this pass about the middle of June, 1920, and had to shovel snow for several miles. Access to Taseko valley may be had from the headwaters of Tyaughton creek by a trail into Battlement Creek valley.

The district may also be reached by a much longer though a lower route from Alexis creek on Chilcotin river by following up Taseko river. In 1919 prospectors who stayed in the valley until late in October came out this way after finding Taylor and Warner passes blocked with snow.

In the area itself a fair trail leads down the Taseko valley to and past the lake, and crossing Taseko lake at the "Narrows" leads to the Chilko Lake country. It continues to Alexis creek and the Chilcotin country down the main Taseko valley. Over these trails come the Chilcotin Indians every autumn in search of game for their winter's supply of meat. Their scaffolds used in the smoking of venison, "ground hogs" (as the marmot or "whistler" is known in this region), and other meat, as well as the curious frameworks they cover with skins inside of which to take their steam baths, are frequent along the trail. A trail leads up Battlement creek and over the summit into the headwaters of Big creek; over this route Bateman travelled in 1912, on his way to Chilko lake.

Another trail traverses the valley of Denain creek, leads over Warner pass, and joins the Gun Creek trail at Trigger lake. Characteristically these Indian trails are crooked, poorly graded, are not cut out, and seldom blazed. As a consequence except where they are well beaten they are not readily followed and in timber the overhanging branches cause inconvenience. Above timber-line they are not marked at all, and as no two parties generally follow the same route the traveller is left to his own devices to find the way. This is no hardship, however, for once above timber-line the country

is beautifully grassed and seldom boggy, so that it is possible to ride almost anywhere. On a fine summer's day these brilliantly green, grassy slopes, spangled with the gem-like splashes of colour of the profuse mountain flowers, are a delight and an inspiration. And situated as they are, in the midst of mountain scenery of a grandeur and magnificence that must be seen to be realized, the whole landscape drenched in dazzling sunshine, they make a picture whose impression persists even in the days of rain and storm, when these same slopes wear an aspect more menacing than beneficent.

TOPOGRAPHY

From a high point, the eastern Coast mountains in which the area is situated appear as a vast assemblage of snow-covered, serrate, alpine peaks and ridges stretching in all directions into the far distance. In this region a sufficient area of country was not studied to name and classify the various ranges and groups of peaks which occur in a variety which at first seems bewildering; but one or two general features of the topography can be mentioned.

The principal drainage of the region is that of Taseko River basin above Taseko lake. This lake occupies a longitudinal valley trending north and draining into Chilko river, thence via Chilcotin river into the Fraser. The divide east and north of Taseko valley sheds its water eastward and northward into Gun and Tyaughton creeks and thence to Fraser river via Bridge river, and into Big and Churn creeks whose waters also flow to the Fraser.

Taseko lake lies outside the limits of the area studied, but it was visible and its outlines were approximately sketched. Its elevation is about 4,400 feet. The lake has not the regular outlines as hitherto represented—it consists of a wider upper portion 7 miles long and from 1 to 2 miles wide connected with a narrower, more irregular, longer lake by a strait, known as the "Narrows", which is about 200 yards across. The trail to Nemaia valley and Chilko lake crosses Taseko lake at these narrows. In certain lights the opalescent milky green colour of the lake is remarkable and its former name, Whitewater, was in allusion to this appearance.

Two large streams drain into the head of Taseko lake, the one coming from a few degrees west of south for a distance of 8 to 10 miles where it heads in a complex of rugged quartz diorite peaks among which lie large snowfields and glaciers. About the same volume of water flows into the lake from this stream as comes from Taseko river, although the latter is considerably the longer stream. Taseko river has a length of about 20 miles from its source among the high quartz diorite peaks overlooking Taylor pass to where it mingles its waters with those of the lake. About 10 miles below Taylor pass three streams join Taseko river from the east within a distance of 2 miles. These are Denain, Rae, and Battlement creeks and it is in these valleys that the limonite beds, except those in Taseko valley itself, are found. The other tributaries of Taseko river are small, excepting a considerable stream that joins at grade from the southeast about 5 miles below the source, and is said to curve southeastward and head near Taylor pass. Five miles from Taylor pass a notable flattening of the grade of Taseko river begins and extends for a distance of nearly 2 miles. In this stretch the river meanders in wide, serpentine curves and has built up an alluvial flat, well shown on the topographic map, in which splendid examples of ox-bow lakes can be seen. This alluvial flat probably represents the filling up of a lake basin caused by the overdeepening of the valley at this point just below where two glaciers joined in former times.

The valleys of the region possess several features in common. They all head high up among peaks which have been greatly modified by ice action, and several of them have their source in cirque basins, some even flowing from glaciers still existing. The first part of their course is thus over a valley bottom floored with glacial deposits of the nature of ground moraines; they then, after a distance depending on the altitude and the volume of water, begin to cut into the underlying bedrock formations, and

the lower part of their course is in all cases a rock-walled canyon. While flowing on the boulder clay of the moraine their course is straight in general but crooked in detail, and these curves are superimposed on and incised into the solid rocks underneath, where the surface mantle is cut through. Denain creek forms an excellent example of this type; the rock canyon begins as a very slight trench in the underlying volcanic rocks but rapidly deepens. Three miles from where the stream dives below the boulder-clay surface it flows around incised curves in a box canyon a hundred feet deep.

The veneer of boulder clay covering the valley floors extends up the walls to an elevation in general of from 6,500 to 6,700 feet. In the lower, flatter portions of the valley the topography is dominantly of the "knob and kettle" type—knobs and hillocks from 10 to 50 feet high strewn with quartz diorite, erratic boulders, and in between them boggy, alluvial flats filling up the original kettles, some of which are still represented by small ponds. The slopes above the boulder clay veneer are, where oversteepened by glacier action, formed of rocky ledges, but elsewhere are covered by slide rocks, screes, and talus slopes. The extreme size of some of these talus slopes, notably at the head of Taseko lake, is worthy of comment.

That portion of the area lying east and northeast of Taseko river, although just as high as the portion west and south of the river, has a markedly different aspect. The rocks underlying this portion are flat-lying, bedded volcanic flows and pyroclastic varieties which, under the influence of the weather, form smooth, rounded, evenly-sloping ridges. These give an erroneous impression of lesser height than the sharp, irregularly serrate peaks of the quartz diorite ranges to the west. These smooth ridges have altitudes of over 9,000 feet, and as the elevation of the Taseko valley at the western edge of the map-area is 5,200 feet, the relief may be said to be 4,000 feet. A striking feature of the area is the great wall of bedded volcanic rocks rising 2,500 feet sheer out of Battlement Creek valley and bounding it on the north. This rampart, with only two valleys breaking its continuity, extends along the northeast side of Taseko valley, and, swinging northward, bounds Taseko lake to the east. With its curiously sculptured towers, minarets, and pinnacles formed from the volcanic beds out of which it is built this high ridge at once arrests attention.

GLACIATION

Incidental mention has been made of boulder clays and other glacial phenomena of Taseko valley. The effect of ice action is most evident here and the strongly overdeepened trunk valleys, the faceted spurs, the high hanging valleys, all of which features may be seen illustrated on the topographic map; as well as the mantle of boulder clay, the great number of erratics, and finally the ice-scored and polished surfaces bear most unequivocal testimony to the efficacy of glacier ice as an agent of surface abrasion. The question of the general glaciation of the region will not be discussed in this report; suffice it to say here that the glaciation was purely local in character, the ice having filled the valleys to an elevation varying from 6,500 to 7,000 feet, leaving large areas above this altitude standing free of ice. The glaciers from the tributary valleys joined the main Taseko glacier and the direction of ice flow was clearly northwestward down the valley.

CLIMATE

This region is situated on the inner flank of the Coast mountains, that highland which has such a marked effect on the climate of the western interior of British Columbia. The situation gives it a climate partaking of features both of the Coast region proper and of the dry belt of the interior. The experience of the one summer spent in the area and the more weighty evidence of the vegetation indicate a climate typical of the semi-dry belt with occasional incursions of weather more characteristic of the wetter region to the west. The altitude of the district in these latitudes means

that hot weather is scarcely ever experienced. Clear, warm, sunny days are the rule during the short summer, though, as is the case in all mountain regions, sudden storms are not uncommon, and there is considerable thunder during the warm weather. It is remarkable how quickly a chill comes into the air whenever the sun is obscured. Even when the rest of the sky is clear, if a cloud drifts over the sun the marked change of temperature is quickly noticed. This is ascribed to the fact that the area is almost wholly surrounded by large snowfields and from whatever direction the wind blows it comes from chill fields of permanent snow.

No personal testimony as to the winter climate is available, but the amount of the previous winter's snow lying on the ground as late as the first of August, the prevalence of snow slides, and the huge, permanent snow-fields on the higher elevated tracts indicate that the snowfall is heavy.

There are no settled inhabitants of this valley. In the summer occasional prospectors, and in the big-game season hunting parties visit the district. The semi-nomadic Chilcotin Indians traverse the valley every autumn in search of meat for the winter.

FLORA AND FAUNA

The trees of the area are nearly all jackpine, with some spruce and a few aspen. Except in some of the stands of spruce the forest growth is sufficiently open to permit of riding almost everywhere, and there is a nearly complete absence of underbrush except low bushes in the wetter areas and along stream courses.

There is sufficient grass and peavine for horse feed and the open nature of the country makes the selection of camp sites easy.

During the summer Robert Johnson collected over ninety plant specimens, but they have not yet been determined.

Big game, which once abounded in this region, is now virtually absent, although goats are still to be found in the mountains west of the valley. Bighorn sheep are very scarce, the only sheep seen this summer being a band of half a dozen which inspected the camp in Taylor pass one evening in early July from the vantage ground of the lofty crags overlooking the head of Gun valley. Deer are occasionally seen, but bear seem to have deserted this area for other hunting grounds. Two coyotes were noted during August. Among the smaller animals are whistlers in abundance, brown squirrels, a tiny chipmunk, and rock rabbits. Game birds are willow grouse, "fool hens," and ptarmigan, but they are not plentiful.

The ubiquitous mosquito during June and July, and "bulldogs" as well as several other species of flies later in the season, lend variety to existence.

GENERAL GEOLOGY

The area examined is in a region of particular geologic interest since it lies on the eastern contact of the great Coast batholith, that most impressive single feature of British Columbia geology. Westward to the coast stretches a stupendous mass of plutonic rock which until lately was supposed to consist of nothing but quartz diorites and associated batholithic varieties. Camsell's reconnaissance of the Pacific Great Eastern railway between the Coast and Fraser valley[1] showed that these mountains may contain considerable areas of included "roof rocks" which are of particular interest to the prospector in search of likely areas for mineralization. Eastward from the area studied are rocks not of batholithic origin, both older and younger than the intrusive plutonics of the Coast mountains. The inner contact of the batholith has been studied and mapped by Drysdale in the Bridge River district[2] to the southeast of the present one, and in that district it is intrusive in its relations to the adjacent rocks. This relation probably holds for a few miles west of the

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1917, pp. 12 B-23 B.
[2] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, pp. 75-85.

Bridge River sheet, but for most of the distance between here and Taseko lake the plutonic rocks, instead of being intrusive into the adjacent formations, are overlapped by them unconformably. The recognition and mapping of this contact was one of the most important results of the season's work, and its significance is this: wherever the plutonic rocks are intrusive the general geologic conditions are favourable for mineralization to have taken place; but where the granitic mass is covered by the overlap of volcanic flows there is no geologic reason for anticipating mineral deposits along the contact.

Table of Formations

Period	Formation	Lithology
Quaternary		
Recent	Limonite deposits	Bedded limonite.
	Alluvium	Stratified sand and gravel; talus cones; alluvial fans; screes.
	Glacial deposits	Lateral and terminal moraines.
Pleistocene	Glacial deposits	Till and erratic boulders.
	Unconformity	
Tertiary		
Oligocene	Taseko formation	Basalt flows and pyroclastics; quartz diorite porphyrite sills and dykes.
	Unconformity	
Upper Jurassic (or possibly Cretaceous)	Batholithic rocks of the Coast mountains	Quartz diorite and associated dyke rocks.
	Intrusive contact	
Jurassic (?)	Denain formation	Basaltic pyroclastics and flows.

DENAIN FORMATION

Distribution. In the lower portions of the valleys of Denain, Feo, Rae, and Battlement creeks; in one locality in Taseko valley within the limits of the map-area and well exposed in the canyon on Taseko river above Taseko lake are rocks to which the name Denain formation is given. The rocks are exposed virtually only in canyons on the streams mentioned, but their distribution in this manner is such that they are thought to be the bedrock formation of the area coloured as such on the map.

Lithology. The Denain formation is dominantly pyroclastic, though rocks of the flow type are found in it as well. The beds are much cracked and broken, and the opportunity thus given for weathering agents to affect them has rendered a recognition of their lithology difficult. As they are exposed largely in post-glacial canyons weathering has been especially effective in masking their original character.

The thin sections studied indicate that the tuffs of the formation were originally basaltic or andesitic. They are now dark greenish or bluish grey, fine to medium-grained rocks, usually even textured but occasionally irregular. In most cases their fragmental texture is apparent in the field; in others the aid of the microscope is necessary to distinguish between dense tuffs and flow rocks. The tuffs are much altered and now consist of a mass of decomposed plagioclase, chlorite, epidote, calcite, and perhaps other secondary minerals. Magnetite and occasionally a fair amount of

finely disseminated pyrite are found. The latter may be connected with the Tertiary mineralization described under the Taseko formation. Several of the fragments of primary rocks seen in the tuffs have fluidally arranged feldspars too small to determine; the textures of these, the general appearance, and the mineral association on the whole is the evidence on which the statement that they were originally andesitic or basaltic is made.

Agglomerates with heterogeneous textures containing angular fragments up to several inches across are found interbedded with the tuffs, and are best exposed in the canyon on Taseko river about 6 miles west of the present map-area. An exposure of agglomerate of the Denain formation on the trail near Battlement creek in Taseko valley has been studied, and will be described in connexion with the intrusive relations of the batholithic rocks.

The relative abundance of flows and pyroclastics in the Denain formation is not known, but as stated, the pyroclastics probably predominate. Only one specimen of the flow rocks has been studied in thin section. It is a grey, dense porphyry, speckled with yellowish-green patches of epidote up to $\frac{3}{16}$ inch across, and dull white, lath-like feldspars $\frac{1}{8}$ to $\frac{1}{4}$ inch long. It is very much altered but the feldspar phenocrysts can be determined as labradorite of the composition Ab_{50} An_{50}. There were originally augite phenocrysts as well, which are now completely replaced by granular epidote. The matrix is microcrystalline plagioclase and altered augite, with an intersertal texture.

On Feo creek, 100 yards above its junction with Denain creek, a 10-foot dyke of dark green diabase cuts the Denain formation, striking north 35 degrees west with a vertical dip. It is markedly chilled on both contacts. The thin section exhibits the ophitic texture of diabase, and the augite is considerably altered. A small amount of quartz, apparently primary, is also present.

Structure. The beds of the Denain formation now dip at angles from 40 degrees to vertical, the higher dips predominating, with strikes from north 50 degrees west to north 80 degrees west. The general similarity of the beds wherever exposed; their shattered, altered, and weathered nature; and the paucity of exposures has rendered any certain deciphering of their structure impossible. That they are strongly folded is known; small faults and crushed zones which may indicate larger displacements have been observed, and it is evident that the formation has been severely deformed. The attitudes of the formation as shown in the structure section are intended to illustrate the type and degree of the deformation to which it has been subjected, rather than to delineate actual folds. Of these, the syncline where the line of the structure section crosses Denain and Feo creeks was the only one observed.

Origin. The composition and characteristics of the Denain formation point to its having originated during an extensive period of volcanism, when eruptions of the explosive type predominated.

Age. Except for degree of alteration and its much greater deformation the Denain formation is not greatly different from the Tertiary Taseko formation. No contacts between the two have been seen, and the constitution of the Denain formation as a separate entity is based on the severe deformation to which it has been subjected, its marked alteration, and on strong although not certain evidence (to be given later) that it is intruded by the batholith of the Coast mountains.

The coincidence of lithological similarity and areal contiguity is such, however, that the fact must be kept in mind that the rocks included in the Denain formation are only highly deformed members of the Taseko formation. However, the volcanic rocks certainly referable to the Tertiary are nowhere known to be so severely deformed; neither are they so highly altered and decomposed, and the preponderance of evidence is such that the field facts are best explained by considering the Denain rocks to be a separate formation of pre-batholithic age. They are accordingly doubtfully assigned to the Jurassic, and a correlation of the most tentative sort is suggested with Dawson's

Porphyrite group.[1] It is just possible that they represent the rocks which Bateman[2] provisionally classes as a lower series of Lower Cretaceous age, apparently on the basis of structural conformity alone. This lower series is described by Bateman as having a thickness of 10,000 feet of predominantly volcanic rocks. Nowhere in British Columbia is there known to be such a thickness of volcanic rocks certainly referable to the Cretaceous. On the other hand, rocks which Bateman describes as conformably overlying the lower series[3] contain fossils of the very lowest Lower Cretaceous, so that the meagre evidence favours his lower series being of Jurassic age.

BATHOLITHIC ROCKS OF THE COAST MOUNTAINS

Distribution. The rocks described as the batholithic rocks of the Coast mountains occupy the southwest part of the district described, underlying the valley of Taseko river for most of its course in the map-area. South of the map-area the contact runs across the high peaks and ridges east of Taylor pass and crosses Gun valley about 5 miles above Trigger lake; westward from the map-area the contact follows down the valley of Taseko river, runs up and behind McClure mountain, and has been traced as far as the south end of Taseko lake. Southwestward from this boundary and apparently extending in that direction for many miles are the batholithic rocks of the Coast mountains.

Lithology. The great mass of the batholith is composed of quartz diorite. It is light grey, medium to coarse, even-grained, and wherever observed the appearance, texture, and mineral composition are characteristically the same. Differences of texture and proportion of minerals are found near the contacts; dykes of aplite cut the more massive quartz diorite, occasional "schliers" and cognate xenoliths of mafic minerals and certain other exceptional types have been noted, but the striking feature about this enormous volume of plutonic rocks, as evidenced not only by the ledges in place, but by the widespread erratic boulders as well, is its homogeneity.

In thin section the quartz diorite is seen to be composed of andesine and quartz, with subordinate biotite and hornblende and accessory apatite, titanite, and magnetite. Secondary minerals are chlorite, sericite, calcite, and kaolin. The indices of refraction of the andesine have been determined by George Hanson by the immersion method to be those of andesine, about Ab_{60} An_{40}, and this has been checked in thin section. It is sharply twinned, occasionally zoned, and only slightly altered. The hornblende is a green variety. The biotite is considerably changed to chlorite. The rock is only slightly altered.

Near the contact of the batholith with the Denain formation (which it almost certainly intrudes) somewhat finer and also more siliceous facies of the quartz diorite have been observed.

On the Taseko River trail 600 yards south of Battlement creek there is a small outcrop of agglomerate, intruded and brecciated by a siliceous quartz diorite porphyrite, thought to be a contact facies of the batholith. The rocks are well exposed over an area of 120 by 75 yards, but this outcrop is surrounded by drift and till, so that neither the agglomerate nor the porphyry can be traced into the formations to which they belong. Their respective lithology is such, however, that their correlation can be done with a high degree of probability.

The agglomerate is a bluish-grey, very hard rock, consisting of angular fragments up to 8 inches of bluish, fine porphyry in a dense, greenish-grey matrix containing smalled fragments and crystals like the feldspar phenocrysts of the porphyry.

This agglomerate is brecciated by the quartz diorite porphyry in an irregular contact zone from 5 to 30 yards wide, in which are found a number of very irregular veins and lenticular masses of milky quartz, apparently barren of any mineralization.

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[1] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1876-1877, p. 58.
[2] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 183.
[3] Idem, p. 184.

The intrusive porphyry at first sight resembles the quartz diorite forming the bulk of the batholith; on closer inspection, however, it is evident that the plagioclase crystals are phenocrysts in a finely granular matrix of quartz and feldspar.

These phenocrysts determined by Mr. Hanson by the immersion method are identical with the feldspar of the quartz diorite which has a composition indicative of andesine, Ab_{60} An_{40}. This determination has been checked in thin section. The andesine is in some cases fresh, but is mostly partly altered to kaolin and sericite. It is subhedral, rarely showing sharp edges against the matrix. The matrix of the porphyry is mostly quartz and brown biotite, the latter much altered to chlorite and sericite. Accessory minerals noted are the same as in the batholithic quartz diorite—apatite, titanite, and magnetite.

In thin section the agglomerate is seen to be completely altered, and is now a mass of finely granular quartz, biotite, and magnetite, the original texture of the rock being completely masked. A plagioclase feldspar occurs sparingly in irregular, altered grains, and is thought to be a residual mineral of the original rock. A thin section was studied which had been cut across the contact of the porphyry and the agglomerate. This contact is sharp, and the porphyry is distinctly finer grained in a zone parallel to the agglomerate inclusion. There is a blending of the two rocks to some extent, and the difference between them immediately adjacent to the contact consists rather in a finer grain and a larger proportion of quartz and biotite in the inclusion, with the andesine confined to the porphyry.

It is evident that a transfer of material from the intrusive to the intruded rock now represented by quartz, biotite, and magnetite has taken place on a large scale.

Light coloured, fine-grained aplitic dykes are found cutting the massive quartz diorite. In thin section they are seen to consist of equigranular mixtures of quartz and feldspar in approximately equal quantities, with accessory biotite, apatite, and titanite. Occasional micrographic intergrowths of quartz and feldspar were observed. The feldspar is almost wholly orthoclase or cryptocrystalline microcline; it is usually fresh and has very low indices of refraction. A sodic andesine occurs sparingly. It is interesting to note that orthoclase, so abundant in these aplites, has not been observed in the parent quartz diorites.

Structure. A marked jointing, approaching sheeting in some places, has been observed in the quartz diorite nearly always striking in a northwesterly direction. The jointing is so continuous and uniform that at a distance it sometimes has a strong resemblance to bedding. Although cracked and broken, no other evidence of movement in the mass itself has been noted.

Age. Mention has been made above of a locality where rocks thought to be marginal facies of this batholith intrude—and include fragments of—an agglomerate. This locality is surrounded by drift, so that neither rock can be traced from it, but the agglomerate on lithological grounds is correlated with the Denain formation.

On the summit of Wilson ridge and on McClure mountain Mr. R. Robinson has seen the Taseko formation lying unconformably on the quartz diorite batholith, in the former case occurring as outliers as well. The evidence in the present map-area, therefore, indicates a pre-Tertiary and possibly post-Jurassic age for the batholith.

These plutonic rocks are, however, correlated with the Bendor batholith of Drysdale[1] in the Bridge River map-area, southeast of the Taseko district, which in common with the larger plutonic masses of the Coast mountains is considered to be of upper Jurassic age. The plutonic rocks of the Taseko district may be traced continuously into the Bendor batholithic stocks of Drysdale, and in the vicinity of Gun creek southwest of Eldorado creek there is some evidence that may indicate a post-Lower Cretaceous age for this part of the Coast batholith.[2]

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 79, and map.
[2] See also "Report on a reconnaissance between Taseko lake and Fraser river."

TASEKO FORMATION

Distribution. The Taseko formation underlies nearly all the northeastern half of the map-area.

Lithology. The Taseko formation comprises volcanic rocks, both flows and pyroclastics, and associated intrusive types. These latter are dykes and sills; some of the dykes are shown on the areal map, but the sills are not separately distinguished, the amount of field work necessary to do this not having been considered expedient. With the exception of certain tuff beds whose alteration is exceptional and will be described in detail, the rocks of the Taseko formation have not been greatly altered. No estimate of the relative abundance of these rocks has been made, but the impression gained in the field was that flow rocks predominated, pyroclastics being next in amount, with a relatively small volume of sills. The best exposure of the Taseko formation is in the great escarpment which forms the north side of Battlement valley. Here, for a distance of about 5 miles the steep wall rises to a height of over 2,000 feet above the stream, affording a magnificent natural section. The beds are seen to be up to 200 feet thick, the thicker ones being visible for a mile or more along the strike, whereas others are lenticular and extend only a few hundred yards. Below the crest of the ridge palisaded cliffs descend very steeply for 800 feet. In this distance twenty to twenty-five separate beds can be counted, giving an average thickness of 30 to 40 feet. Some of these are exceptionally well stratified and can be traced continuously for a mile or more. They are probably pyroclastics.

The flow rocks studied consist wholly of basalt porphyrites and amygdaloids, with slight variations in texture and mineral composition. They frequently exhibit columnar jointing, a notable example occurring on Palisade bluff, where a flow 95 feet thick is jointed from top to bottom in irregularly hexagonal prisms from 3 to 5 feet across. The basalts are dark grey to black, fresh-looking rocks of dense and porphyritic textures. In thin section the phenocrysts are usually in two generations of labradorite (Ab_{50} An_{50} to Ab_{40} An_{60}) and augite, the latter frequently altered to chlorite, magnetite, and calcite. The matrix is usually microcrystalline and consists of lath-like and tabular labradorite and augite; sometimes it consists of minute feldspars in unresolvable material. Fluidal arrangement of both phenocrysts and groundmass minerals is common. Olivine has not been observed. In the amygdaloidal flows the amygdules are filled with chalcedony, epidote, chlorite, and calcite, the first named forming the lining of the cavity, the epidote and chlorite coming next, and the calcite forming the centre filling.

The pyroclastic rocks of the Taseko formation consist of both agglomerates and tuffs. On Palisade bluff, apparently forming an intercalation in the thick, columnar, jointed flow described above is a lenticular mass of agglomerate, at least 200 feet long and over 25 feet thick. It is formed wholly of angular and subangular fragments of dense basalt porphyrite up to 12 inches across, in a matrix of finer fragments of the same rock. Other agglomerates have been noted elsewhere. The tuffs are finer, more evenly stratified, and probably more continuous.

The sills differ sharply from the flows in appearance, composition, and texture and, in fact, it is on these differences that they are classed as injected types, field evidence being inconclusive. They are grey, fresh-looking quartz diorite porphyrites, with phenocrysts of plagioclase and hornblende in a clearly granular matrix. In some instances the matrix is almost of the size of grain of the phenocrysts and these resemble fine to medium, even, granular rocks. Measurements made in thin section, and also determinations of the indices of refraction by Mr. Hanson agree in assigning a composition of labradorite (Ab_{50} An_{50}) to andesine (Ab_{60} An_{40}) to the plagioclase. It is usually very fresh, equant, euhedral, up to $\frac{1}{8}$ inch across in the larger phenocrysts, zoned and sharply twinned after both the carlsbad and albite laws. The plagioclase forms about 70 per cent of the rock; the other minerals are hornblende and quartz in about equal amounts, with accessory apatite and magne-

tite, and secondary chlorite, calcite, and epidote. The hornblende is the common variety showing pale greenish-brown pleochroism, and some alteration to chlorite, etc.; the quartz is irregular and is strictly a matrix mineral, and the hornblende appears as phenocrysts as well.

The dykes which cut the Taseko formation are from 10 to 50 feet thick and lie at various attitudes. They are light-coloured, usually whitish or yellowish-grey rocks of the composition and textures of diorite and quartz diorite porphyrites. Some of them have a resemblance to the sills, for which they may have been feeders. In thin section they are seen to consist of phenocrysts of andesine and hornblende in a matrix of the same minerals, sometimes with quartz. The dykes are usually much altered, and show a great development of chlorite, calcite, and other secondary minerals. They contain accessory apatite and magnetite. One of these dykes forms a prominent landmark in Battlement ridge, where it outcrops as a light coloured streak cutting the horizontal appearing beds at a low angle. It is about 30 feet thick, and is jointed in a rude columnar manner perpendicular to its contacts. The rock is greatly weathered and the only clearly recognizable original minerals are phenocrysts of plagioclase and of quartz, the latter exhibiting rounded and embayed outlines as if they had been resorbed. Pseudomorphs of chlorite and calcite represent what were probably smaller hornblende phenocrysts. The matrix is entirely altered and consists of a matted mass of chlorite, calcite, and other indeterminate secondary minerals.

Silicified Tuffs. The beds described as silicified tuffs are an exceptional variety of altered rock. Their true nature was not at first recognized, and in the field they were thought to be rhyolites. They are important because it is from the pyrite they contain that the iron has been derived which has formed the limonite beds of the region. Two separate occurrences of these altered rocks are shown on the accompanying maps (Nos. 1842-1849), and a third occurrence is found on McClure mountain, beyond the western limit of the map-area.

These altered tuffs weather in characteristically brilliant red, orange, and yellow tints, these colours enabling them to be readily recognized and traced along the scarped mountain slopes. Ledges and talus fragments are invariably covered with a film or even a thicker crust of brightly iron-stained material, but the fresh rock is light whitish or bluish-grey, resembling chert or dense rhyolite in the field. Finely divided pyrite may be readily recognized on freshly broken surfaces, sometimes showing a greater concentration in certain bands.

The band of tuffs outcropping on Rae ridge was examined carefully, and the evidence there seen, together with that from the study of the thin sections, furnishes a clue to the nature of this peculiar rock. On Palisade bluff, near the end of Rae ridge, a section was measured across the outcropping edges of the flows and pyroclastics of the Taseko formation, which included this bed of silicified tuff. At this place it was 70 feet thick; overlain conformably by the 95-foot bed of columnar jointed basalt described above, and underlain, apparently conformably, by several hundred feet of alternating flows of basalt porphyrite and amygdaloid, and pyroclastics. It weathers, where not iron-stained, to a dead white, and the fresh interior of the rock is whitish or pale bluish-grey, with a suggestion of fragmental texture, and a marked conchoidal fracture. Pyrite is abundant in minute, evenly disseminated crystals. The upper 10 feet of the bed has weathered into paper-thin sheets, and an apparently solid piece when struck with the hammer breaks with a high degree of fissility parallel to the bedding. Farther down in the bed this extreme fissility gives place to a more irregular jointing in platy layers. The rock strongly resembles a very fine-grained, evenly laminated sediment.

The other two occurrences of this altered tuff are in the lower part of the Taseko formation, and rest directly on the batholith. The actual contact was seen by Mr. Robinson on Wilson ridge and on McClure mountain, both localities being at high altitudes.

The exceptional nature of these rocks is most apparent under the microscope, where they are seen to be composed of quartz and sericite, with subordinate amounts of pyrite, and considerable rutile. Certain other minute grains of a brownish colour and high double refraction may be siderite. The proportions of quartz and sericite vary; some varieties are nearly all quartz, and gradations into specimens having 60 per cent sericite have been noted. Pyrite forms about 5 per cent of the rock. The texture is always very fine; as noted above, the tuffs resemble chert in the hand specimen, and the average size of grain in the specimens studied ranges from 0·005 mm. to 0·06 mm. Sharp irregularities of texture are characteristic, and marked variations in size and proportions of minerals take place in the same specimen. The pyrite is usually sharp euhedral, up to 0·1 mm. across, and a close association of pyrite and sericite has been noted, crystals of the latter frequently lying flat against the crystal faces of the pyrite, and there is nearly always a concentration of sericite near the pyrite. The rutile occurs in needles and hair-like crystals barely resolved by the highest power up to rods 0·03 mm. by 0·002 mm. It also occurs in minute grains. The quartz is clear and contains rods of rutile as well as strings of exceedingly minute inclusions whose nature is not known.

On Wilson ridge the lowest beds of Taseko formation resemble quartzites. They consist almost entirely of vitreous quartz, exhibiting sharp variations in texture. In thin section a few flakes and considerable rutile has been noted in grains averaging 0·01 mm. lying in and between the quartz grains and also occurring in slender rods. Near these quartzite-like beds, but apparently in a porphyritic facies of the quartz diorite batholith at this point, is a flat lenticular vein, 1 foot long by 3 inches thick, filled with compactly arranged, divergent prisms of black tourmaline, with small amounts of quartz and calcite. In this connexion it may be mentioned that on McClure mountain, also near the lower contact of the Taseko formation, a specimen from talus consisted of finely granular, black tourmaline and quartz intimately mixed in approximately equal amounts. These tourmaline veins are regarded as being associated with the mineralization which affected the tuffs, but their relations are not well understood.

No trace of any mineral which could be considered as having been an original constituent of the tuffs has been noted in any of the specimens studied, unless some dark, indeterminate, finely granular material in one thin section be considered as such. In the alteration of these beds replacement has occurred on a scale that is simply colossal, and the original material of the tuffs, presumably basaltic—if one may judge from the associated rocks—is now represented mainly by quartz, sericite, and pyrite. Lindgren in discussing "metalliferous deposits formed near the surface by ascending thermal waters and in genetic connexion with igneous rocks" states that "more rarely sericite develops in abundance and the effusive rocks are converted over large areas to a mixture of quartz and sericite, with more or less pyritization."

The great volume of altered rocks at the base of the formation may indicate that the surface of unconformity formed an easy channel for the mineralizing solutions. In the case of the sharply defined bed of Rae ridge it may be supposed that some favourable texture which may have been connected with its extreme fissility caused this bed to be replaced completely, whereas the adjacent impermeable basalts were not affected.

Structure. The actual contact of the Taseko formation has been observed by Mr. Robinson on Wilson ridge and McClure mountain where he reports that the volcanics dip gently northeastward, in some cases lying almost flat, but generally inclined up to 10 degrees. This dip increases toward the northeast, and the general attitude of the formation near the batholith is a dip to the north or northeast of from 10 to 25 degrees. To what extent this represents an initial dip can not be definitely stated; from evidence gathered in the region east of this map-area it is apparent that the Taseko volcanics were extruded on a surface of some relief and the angle of 10 degrees mentioned above may very well be an initial dip. No certain evidence of

deposition in water has been observed; it is true that some of the tuffs are extremely well and evenly laminated, but this may happen during the subaerial deposition of finely divided explosive ejecta.[1] On the other hand an initial dip of as high as 25 or 30 degrees is not probable for so much of the formation as lies at those angles in this map-area, so that even if an original dip of 10 degrees be admitted, there is some evidence of uplift along the edge of the formation where it rests on the batholith. Farther to the eastward, beyond the limits of the map-area, the Taseko formation lies nearly flat, or is disposed in gentle, undulating folds.

The thickness of the Taseko formation exposed in this map-area is in the neighbourhood of 6,000 feet.

Origin. The Taseko formation was accumulated during an epoch of widespread volcanic action. In the area described there is little evidence to tell whether the volcanism was dominantly of the explosive or the fissure type of eruption, though the extensive tuff beds indicate that explosions on a considerable scale played at least a part in the accumulation of the beds. A few miles to the east of this map-area, on the headwaters of a branch of Tyaughton creek, a very well-preserved and typical volcanic neck occurs cutting Lower Cretaceous sediments, and it doubtless represents the feeder of one of the former vents from which the Taseko formation was poured out. The preponderance of evidence indicates that the volcanic rocks of the formation were accumulated during an epoch characterized by explosive volcanism from central vents, from which quiet emission of lava flows also took place on a large scale.

Following the accumulation of the extrusive rocks the beds were intruded by the quartz diorite porphyrite sills, and by the various dykes which have been described. At what stage the extensive metasomatism of certain of the tuff beds took place can not be stated definitely; it may perhaps be correlated with the later manifestations of volcanic action.

Age. No fossils have been found in this great accumulation of volcanic material. In this area all that can be said of its age is that it is post-upper Jurassic and pre-Pleistocene, but the volcanics have been traced eastward to Fraser river and although they do not form continuous outcrops they may be correlated with Dawson's Upper Volcanic Group[2] of the Kamloops sheet to which he assigned a Miocene age. Palæontologic evidence quoted by Daly[3] indicates that Dawson's Miocene volcanics are better referred to the Oligocene, and they are accordingly so designated here.

PLEISTOCENE GLACIAL DEPOSITS

The glacial deposits of the Pleistocene consist of a sheet of till of varying thickness covering the floor of the valleys and extending up the valley walls to an elevation from 6,000 to more than 7,000 feet, and in addition a very large number of erratic boulders strewing the surface of the till, these in most cases being quartz diorite of the local type. The till itself is largely composed of varying proportions and sizes of quartz diorite fragments embedded in a sandy or gravelly matrix. A striking feature of the erratics is the degree of exfoliation exhibited by them, causing a rounding of outline simulating the action of running water.

The surface of the till, particularly in the flatter portions of the valleys, is disposed in the irregular hillocks and hollows to which the name "knob and kettle" topography is given.

The Pleistocene till, when followed up the higher reaches of some of the valleys, finally disappears under the present day glaciers, the last survivors of a more general ice occupation of the district.

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[1] See for example, "The Katnai region, Alaska, and the Great Eruption of 1912." C. N. Fenner, Jour. Geol., vol. XXVIII, 1920, p. 596.

[2] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, pp. 73 B-76 B, 216 B, etc., and Map No. 556.

[3] Daly, R. A., Geol. Surv., Can., Mem. 68, 1915, p. 126.

RECENT DEPOSITS

As noted in the preceding paragraph the Pleistocene glacial till passes into similar deposits of recent date, these consisting of moraines of various types fringing the present day mountain glaciers. Another sort of recent deposit is found in the main Taseko valley about 6 miles from its source, where, for about a mile, the stream winds its way in well-formed meanders through an alluvial plain varying up to 600 yards wide. Reference has been made to the enormous talus slopes and screes of the region, especially in that portion of it underlain by the Taseko formation.

LIMONITE DEPOSITS

GENERAL DESCRIPTION

Location

The limonite deposits in Taseko valley are situated in seven different localities in its upper portion and in valleys tributary to it. These localities, beginning with the one first seen on entering the district, are: the Forrest deposit, located 6 miles from the source of Taseko river in Taylor pass, and half a mile east of the river; Denain Creek deposit located on Denain creek 4 miles above its junction with Taseko river; Feo, Rae, and Battlement Creeks deposits, situated on the creeks of those respective names, near their sources; the McClure Mountain deposits comprising the limonite on the Chilcotin and Limonite groups of mineral claims on McClure mountain. The relative positions of these various occurrences can be seen from the accompanying key map (Figure 4) showing the location of the Taseko River map-area, and on which they are numbered consecutively as enumerated above. The first five are shown on the areal geology map (No. 1849) as well and their significant relation to the silicified tuffs of the Taseko formation is at once apparent.

Form, Structure, and General Characteristics

The deposits are in the form of sheets of brown limonite of different shapes, generally more regular in the smaller patches but becoming more irregular as they increase in size. In area they vary from a few hundred to nearly a million and a half square feet, and each deposit as designated above comprises several separated areas of limonite which are considered and described under the heading for that particular deposit. Relative areas, internal and external, may best be apprehended by a study of the accompanying maps, Nos. 1842-1848, on a scale of 1 inch to 400 feet. In thickness the limonite sheets range from a few inches to an ascertained dimension of 9 feet, measured at right angles to the slope of the bed; and it is probable that in some instances a thickness of from 12 to 15 feet may be attained.

Structurally the sheets consist of parallel and sub-parallel layers from a fraction of an inch to several inches, seldom over a foot thick, lying conformably on the surface of the ground, or diverging from its slope at a slight angle. In some instances narrow creek valleys have been filled with a platy accumulation to a depth of more than 4 feet, and in one case an example of terrace structure in process of formation was observed.

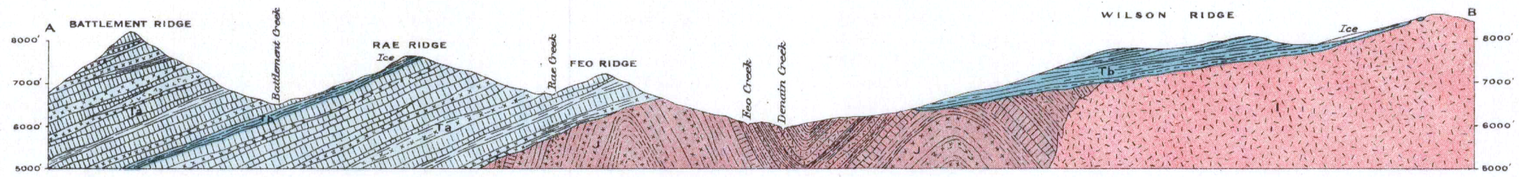
The surface of the limonite beds where free from vegetation, and not subjected to the action of one of the numerous streamlets which characterize the deposits, is covered with a loose layer of broken, flaky, angular fragments ranging from an inch in size down to the texture of sand. This gravelly ore layer is up to a foot in thickness and it is doubtless due largely to the disintegrating action of frost on the upper layers of the limonite beds. Below the loose surface layer the limonite lies in a coherent mass laminated as above described, in layers slightly thicker with depth.

Canada
Department of Mines

HON. SIR JAMES A. LOUGHEED, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR.

Issued 1921



Structural section along line A B

LEGEND

CENOZOIC — QUATERNARY — RECENT

- Q2 — Limonite deposits
- Q1 — Alluvium

CENOZOIC — TERTIARY — OLIGOCENE

- 2 — Dykes *(quartz-diorite porphyrite, etc.)*
- Ta, Tb — Taseko formation
  Ta. *basaltic flows, agglomerates and tuffs, and quartz-diorite porphyrite sills.*
  Tb. *silicified tuffs*

MESOZOIC — UPPER JURASSIC (POSSIBLY CRETACEOUS)

- I — Bendor batholith *(quartz-diorite)*

MESOZOIC — JURASSIC(?)

- J — Denain formation *(basaltic tuffs, agglomerates and flows)*

Symbols

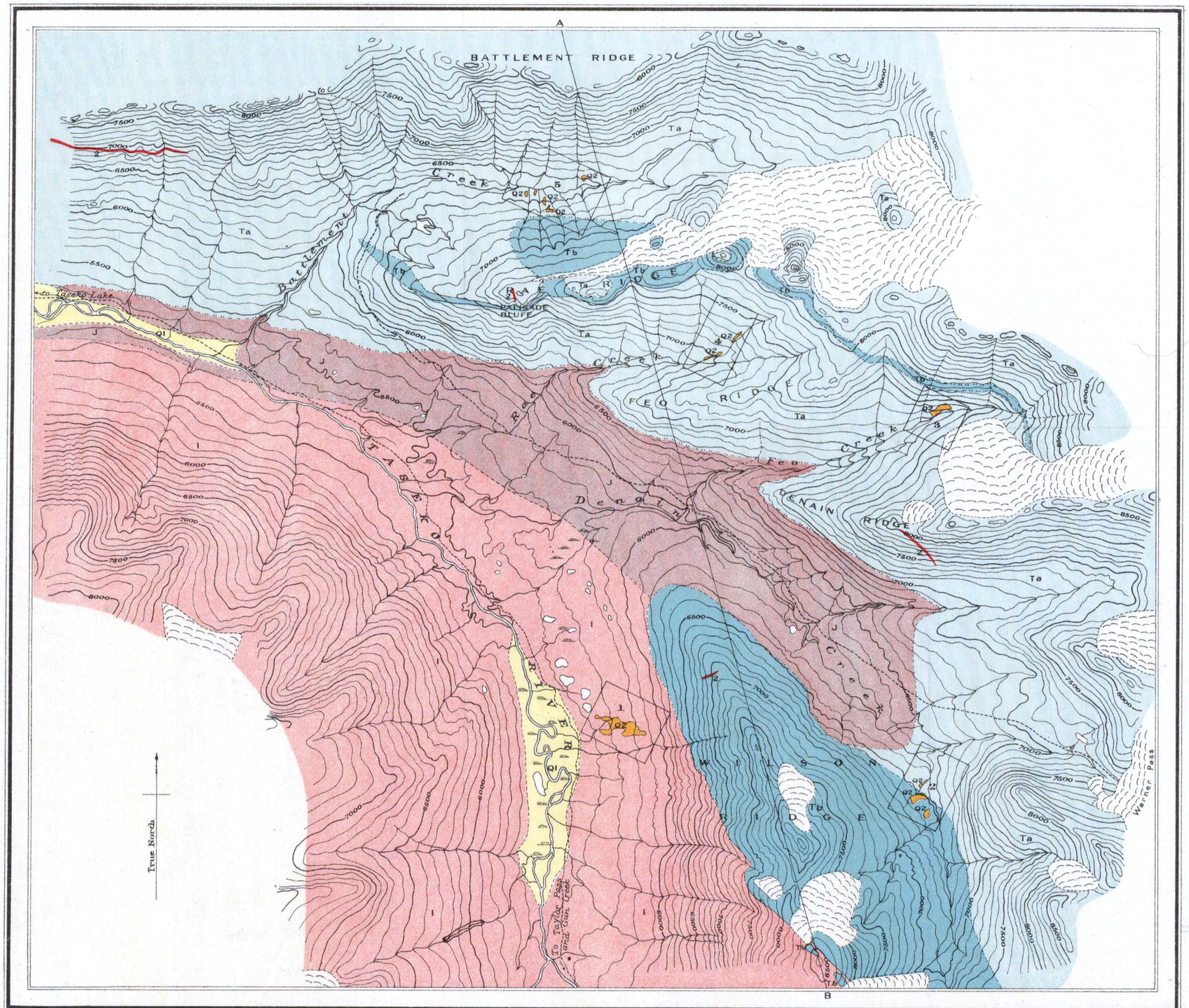
- Geological boundary *(observed)*
- Geological boundary *(located within 200 feet)*
- Geological boundary *(approximate)*
- Trails
- Rivers and ponds
- Glaciers
- Contours *(showing land forms and approximate elevations above sea-level.)* Interval 100 feet

Approximate magnetic declination, 26°30' East.

Limonite deposits

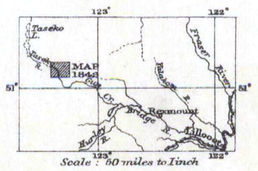
1. *Forrest Group*
2. *Denain Creek*
3. *Feo Creek*
4. *Rae Creek*
5. *Battlement Creek*

Note:- *Areas outlined on map including limonite deposits are also shown as detail plans.*



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

Publication No. 1849



TASEKO RIVER AREA

LILLOOET DISTRICT

BRITISH COLUMBIA

Scale, 1/36000

Miles 1 3/4 3/2 1/4 0 1

Kilometres 1 0 1 2

3000 FEET TO 1 INCH

GEOLOGY
Geology by J. D. MacKenzie, 1920.

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

To accompany report by J. D. MacKenzie in Summary Report, Part A, 1920.

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Taseko River Area.
(Lillooet district).
5.1.2
A, Geol.

1849

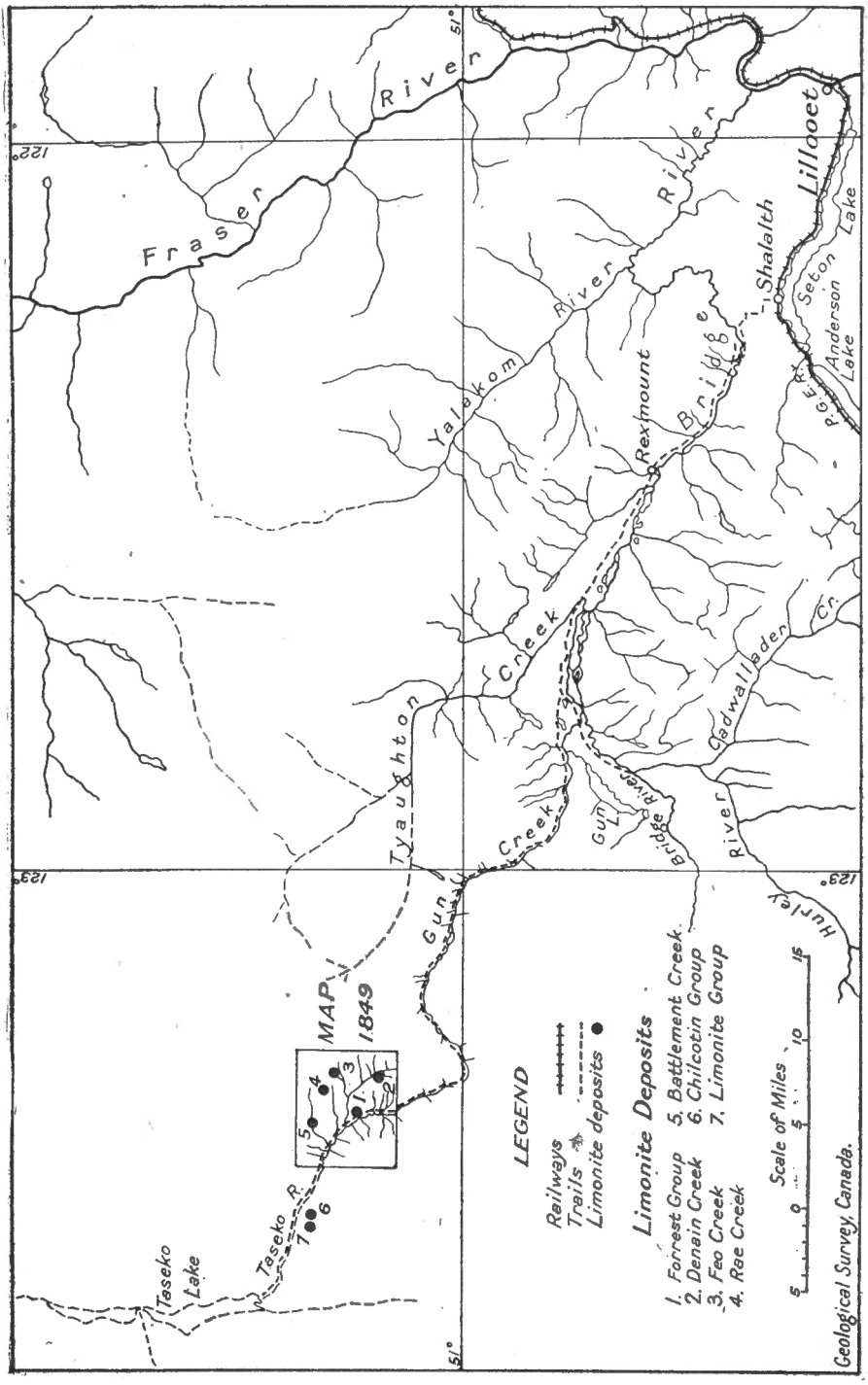


Figure 4. Diagram showing location of Taseko Valley limonite deposits, Lillooet district, British Columbia.

Occasionally through the bed are lenticular masses of harder recemented limonite seldom over a foot in thickness, and these are noticeably more frequent near the bottom of the sheet where it rests on the glacial till. Occasionally, layers in which branches of trees are abundant are found.

Although its texture may be described as finely porous, the limonite, except in some cases near the surface, is too resistant to be picked by hand, though a trench once made may readily be enlarged with an axe. The material, except when one of the recemented layers is met, rarely breaks in lumps as large as a foot across. On the whole it is only moderately coherent, and the ore in dumps from prospect trenches only a few weeks old runs heavily to fines. One such dump showed very few lumps over 6 inches diameter; few were as large as 4 inches. Over 60 per cent of the mineral was in bits under ½ inch across, and most of that was as fine as sand.

No minerals other than earthy limonite have been recognized in any considerable amount in these beds. An interesting occurrence, however, is native copper, found in loose, spongy-textured pieces from the size of an oat grain to that of a large pea. The copper has the distinctive rosy pink colour characteristic of the element when chemically pure and free from incipient surface oxidation, and occurs associated with the semi-carbonized pieces of wood found in the limonite. It has also been observed in panning the gravels of streams draining the district in which the limonite beds are found. A blue-black film with a metallic lustre, sometimes sooty in appearance, found coating the cracks in the pieces of wood in the limonite, is thought to be chalcocite.

On the upper surface of the fragments of the loose layer of broken ore which covers the top of the beds a white mineral occurring in short branching stalagmitic shapes was observed in several instances, notably on the Forrest deposit. It imparts a frosty-white appearance to the surface of the bed, and is a very recent deposit from the waters flowing over the surface of the ground and from which the limonite is deposited as well. This white incrustation has been examined by R. A. A. Johnston who writes that it is "of the nature of a fiorite or siliceous sinter. From its chemical behaviour I would think that this sinter is of very recent origin; it appears to have undergone but little dehydration since it was deposited."

The sinter has not been observed except on the surface of the limonite, yet it is altogether likely that it formed on the surface of previous layers as they were successively laid down. Its non-appearance in the interior of the deposit must be ascribed to re-solution, and its occurrence at the surface is due to precipitation by evaporation, which does not take place beneath the uppermost layer. The two samples of water whose analyses are given on page 69, contained 30 and 40 parts per million of SiO_2. From waters such as these both the limonite and the siliceous sinter were deposited.

Vegetation

The limonite deposits are for the most part bare of vegetation. In those occurrences situated above timber line there is occasionally a certain amount of moss rarely over a few inches thick, but in general the accumulation of the iron oxide has been and continues to be too rapid to permit of vegetation obtaining a start. Locally, in places where accumulations have taken place below timber-line, a few trees have found a foothold, but these are usually less than a foot in diameter and under 25 feet high.

Geologic Relations

In the description of the Taseko formation it has been mentioned that certain tuff beds have been completely altered by silicification and other metasomatic action, and that a part of this alteration consists of an impregnation of the tuffs by large amounts of finely divided pyrite. It is significant that outcropping above every occurrence of limonite studied are ledges of this silicified tuff, whose brilliant iron-

oxide stains, covering large areas of the mountain sides, are a most noticeable feature even from a great distance. In several cases large talus cones and screes of angular, freshly-broken silicified tuff are situated on the slopes immediately above the limonite deposits, and some of the deposits are considerably contaminated by this rock debris.

The detailed Maps 1842-1848 of the individual areas illustrate the fact that in most cases the iron oxide was deposited and now lies on the surface of glacial till. In a few instances the limonite has accumulated on a surface formed of angular blocks of broken volcanic rock, distributed by gravity or alluviation over the bedrock itself. This relation is found only in the higher patches of bog iron. The till has a characteristically uneven surface, as it has been left by the ice disposed in hillocks and hollows of various shapes and sizes, which have been only slightly, if at all, subdued in their relative relief. In general, however, it happens that the limonite deposition has taken place in localities where the degree of the relief of the surface of the till is not very great, and may be expressed in terms of a few feet; nevertheless it must be borne in mind that the floor of these deposits is an irregular one and furthermore that boulders of country rock are to be expected the more frequently as the bottom of the layer of bog iron is approached. This bottom is usually marked by a harder layer of recemented limonite lying on a soft layer of carbonaceous peaty mud. Both these features are connected with a more active circulation of water along the bottom of the sheet of iron oxides.

Topographic Relations

The range in altitude of the beds of limonite is from an elevation of 5,500 feet to over 7,300 feet. It is noticeable that the higher the deposits lie the thinner and smaller they are; no large beds are found above 6,400 feet. The significance of this and the reasons for it are discussed on pages 68, 69.

Deposits have been observed on slopes as steep as 21 degrees, but this is exceptional, and most of the beds lie on hillsides of less than 15 degrees slope, many of them much flatter even than this. They usually occur on the valley walls below where the steeper slope flattens out into the more gently inclined bottom of the valley—in nearly all cases below the lower limit of talus accumulations. Several of them occur on flattish benches interrupting the continuity of slope of the sides of the valley. Sufficient of the accumulations are located below draws or local shallow depressions in the valley walls to make it evident that the concentration of drainage from a considerable area of the mountain side above has had a significant effect in the localization of the limonite. In one or two instances small stream valleys have been filled to a depth of several feet, and the constant association of rivulets with the beds of bog iron is a point of special significance.

Outlines of the Deposits

In a study of this kind, designed to arrive at an accurate estimate of the quantity of bog iron in the deposits, the careful and certain delimitation of their boundaries is a matter of prime importance. It must be remembered that these limonite beds occur as patches lying on top of the ground; that they are among the very latest sort of deposit formed in the region; and, in fact, that their deposition is still in progress. Moreover, they are usually bare of vegetation, and, where locally covered, their surface expression is such that they may readily be distinguished from areas underlain by till. In the few deposits at such an altitude that they lie on screes or slide rock the element of vegetable cover is absent and the outlines of the bodies are most easily observed. The fact that these accumulations lie on top of the ground is to be emphasized; they are, in other words, not so many scattered outcrops indicating a larger, co-extensive body underneath, but they, in themselves, represent the totality of the ore present. On account of the topographic and other features of the limonite beds which have been for the most part described above, it has been relatively an easy task in the field to lay down the outlines of the deposits on the detailed plane-table

maps (Nos. 1842-1848) with a high degree of accuracy. In almost every case the boundaries of the patches are shown with solid, unbroken lines indicating that they have been actually observed on the ground, and surveyed as observed.

With these considerations in mind the calculation of the areas involved is comparatively a simple matter, and has been done by dividing the irregular patches of bog iron into rectangles or triangles of equal area and adding up the whole. A certain amount of subjective error enters here, but great care has been taken to eliminate this as far as possible, and if any error exist it is on the side of liberality. To calculate the volume of limonite present it only remains to determine the third dimension, that is the thickness of the sheets, and owing to a number of considerations this is a much more difficult matter. Were the difficulties of a very uneven floor removed, the uncertain variability of the thickness of the patches themselves would complicate the question. Nevertheless after a careful study of the different occurrences aided most materially by the prospect trenches put in by the British Columbia government the estimates of quantity of the various deposits given under their respective headings have been prepared. Further details regarding them are mentioned in each case.

From these considerations it will be evident that the tonnages stated are of that degree of accuracy connoted by the terms " actual ore," "positive ore," "ore in sight," etc., and that they represent all the limonite available in the deposits seen. Exceptions to this rule, as in the case of the McClure Mountain deposits, are stated in the descriptions of these occurrences. It is probable that other small deposits occur in various places on slopes below outcrops of the silicified tuffs now covered by vegetation, but from the nature of the deposits and the ease with which they can be recognized, it is very improbable that any considerable deposit has been overlooked.

Transportation

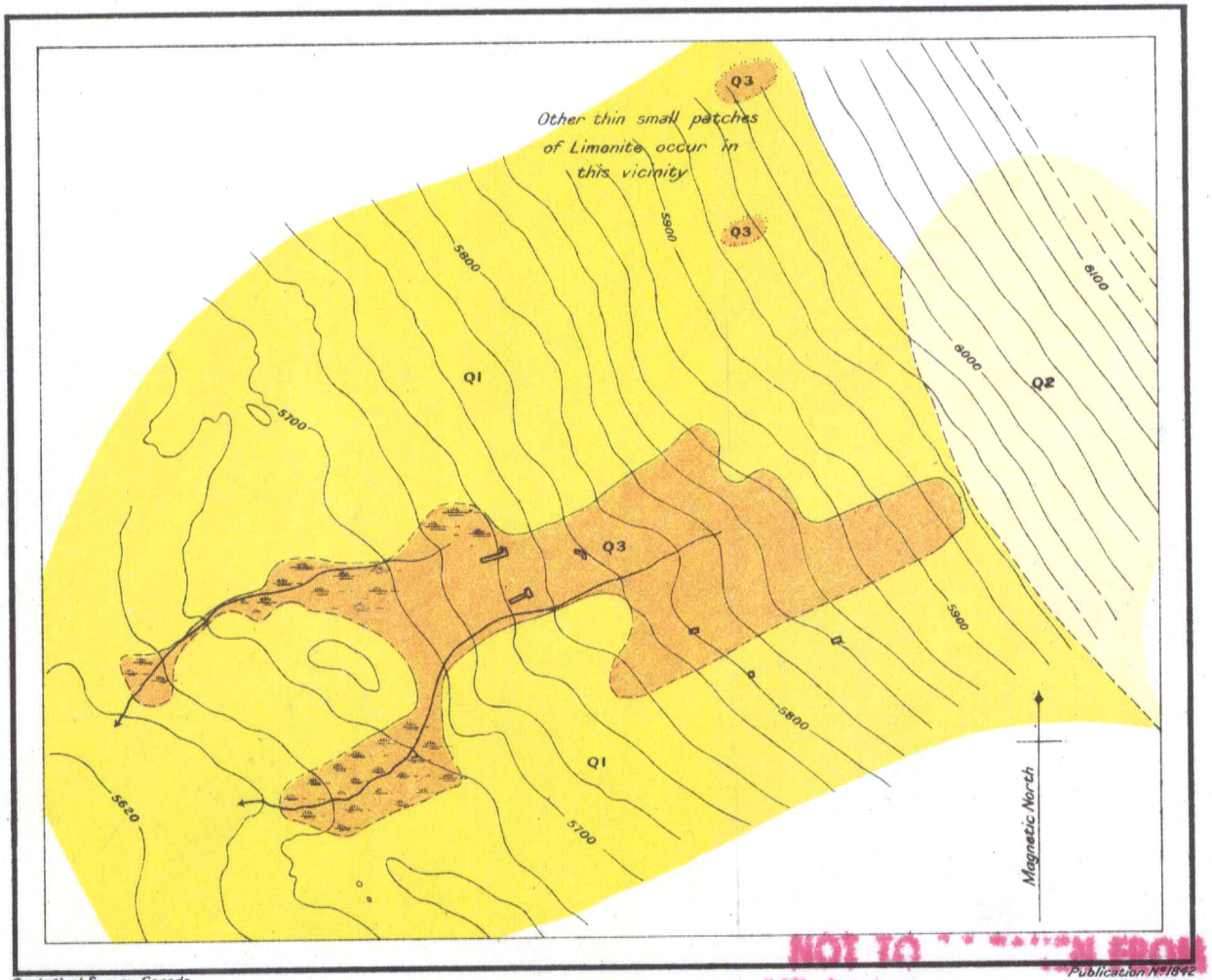
As this is virtually the first published information regarding this remote region, it may not be out of place to state certain facts bearing on transportation facilities, although it was not the province of the writer to inquire into them.

The passes into the region from the south and east, that is Taylor, Warner, and the pass into Battlement creek from the headwaters of Big creek, are scarcely practicable railway routes, not only because of the difficulties of surmounting the steep grades, but because these passes, in common with all others of similar altitude in that region, are buried in snow eight or nine months of the year. In the first week of July, 1920, there was more than 10 feet of the previous winter's snow lying on the north side of Taylor pass, and this did not leave until after the middle of the month; Warner pass is occupied by a permanent glacier. In 1920 there was 2 feet of fresh snow in Taylor pass by the middle of September, and continual heavy falls may be expected after this date in any year.

A railway to tap the upper Taseko valley would, therefore, have to be built from the other end, and as the stream has a moderate grade below the situation of the deposits, a route past Taseko lake and down Taseko river could no doubt be located without any serious engineering difficulties. From Chilko river a possible route lies past Tatlayoko lake and down the Homathco river to Bute inlet on the Pacific coast —this line was explored by one of the early survey parties of the Canadian Pacific railway. From the rugged appearance of the high, snow-covered, alpine ridges and peaks south and west of Taseko lake and from the small size of the streams draining into it, there is every reason to consider that region as impassable for railway purposes.

Weight per Cubic Foot

To determine the tonnage of limonite in the various deposits it is necessary to ascertain with some degree of accuracy the weight of a given volume of the material. To do this in the case of each bed was impracticable and unnecessary, so the Forrest deposit was selected as being typical and sufficiently thick and well-prospected to allow of results of general application to be obtained from it.



Legend

Quaternary

- Q3 Limonite
- Q2 Talus, alluvium
- Q1 Till

- Geological boundary (observed)
- Geological boundary (located within 20 feet)
- Geological boundary (approximate)
- Open cuts and trenches

Elevations subject to revision

Geological Survey, Canada.

Publication No. 1842

Forrest Group limonite deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet
100 0 500 1000

To accompany Report by J.D. MacKenzie, in Summary Report, Part A, 1920.

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Forrest Group.
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A, Geol.
1842

In the side of one of the 9-foot deep trenches cut in this layer of bog iron a channel 2 feet by 6 inches in horizontal and 6 feet in vertical dimensions was cut accurately and the 6 cubic feet of ore thus obtained was collected carefully and weighed in a balance constructed in the field. It was found to weigh exactly 800 pounds, which works out at 15 cubic feet per ton, and represents limonite as extracted from the bed and partly air dried.

DETAILED DESCRIPTION OF LIMONITE OCCURRENCES

Forrest Deposit

Location. The Forrest deposit is situated between the 5,600 and 5,900 contours, about half a mile from the east side of Taseko river, 6 miles from Taylor pass, and about 13 miles above Taseko lake. Stripped of its former covering of vegetation by a snowslide which took place several years ago, it now shows as a bare brown patch on the hillside over which trickle several tiny streamlets. Above it rise the bare, brightly coloured talus slopes and rock ledges of the Taseko formation in Wilson ridge.

Form, Structure, and Characteristics. By referring to the detailed map (No. 1842) it will be seen that the Forrest deposit covers an irregular area elongated down the hillside, and that it has been localized in its formation by low ridges in the till surface on which it lies.

Figure 5 is a drawing of the south wall of the more northerly trench marked on the map, which was sunk in what was taken to be the thickest portion of the bed. That part of the sketch in solid lines indicates what was actually seen in the trench; the broken lines indicate the inferred relations of the sheet of limonite to the underlying till. It is evident that the material is in layers parallel to the hillside or nearly so. Laterally the layers have a tendency in the upper portion to dip gently from the centre of the bed toward the edges. The section illustrates the fact that in the upper portion the laminæ are thinner than those below; it also shows the occurrence of the harder recemented layers; the twigs and branches found are indicated as well.

The character of the limonite has been already described: it is generally porous in texture, crumbling quicker under the influence of the weather, and forming a large percentage of fines.

Analyses

	1	2	3	4	5	6	7
Iron, metallic (Fe)	45·61	45·76	43·96	41·0	41·4	46·6	47·6
Silica and insoluble residue (SiO_2,etc.)	4·92	5·24	4·81	2·2	3·2	4·0	5·2
Sulphur (S)	1·52	1·55	1·64	2·24	2·46	0·88	0·86
Phosphorus (P)	0·046	0·033	0·025	Trace	Trace	Trace	Trace
Manganese (Mn)	.....	.....	.....	.....	.....	.....	Nil.
H_2O at 110° C. for 2 hours	.....	.....	.....	.....	.....	.....	6·7

1, 2, and 3. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch.

1. From the southerly trench marked on the map. It represents the run of the deposit, a shovelful having been taken every 2 feet, from the top of the 50-foot dump, broken and quartered to about 8 pounds.

2. From the same trench as No. 1, taken from the bottom of the dump on the opposite side, in the same manner.

3. From the northerly pit marked on the map. Taken by cutting a 2-foot by 6-in. channel 6 feet vertically from the surface into the deposit, giving a good average of it, broken and quartered to 6 or 8 pounds.

Analyses 4, 5, and 6. Collector, W. M. Brewer; analyst, D. E. Whittaker, B.C. Bureau of Mines.

4. Grab sample taken near the upper end of the exposed limonite.

5. Grab sample taken near the lower end of the exposed limonite.

6. Grab sample taken from a mound of limonite on north side of the exposure.

7. Collector, F. J. Crossland; analyst, D. E. Whittaker, B. C. Bureau of Mines. The metallic iron percentages on seven other samples collected by Mr. Crossland were determined by Mr. Whittaker to be 50.0%, 46.0%, 47.2%, 51.0%, 44.6%, 46.4%.

(Analyses were made on air-dried material).

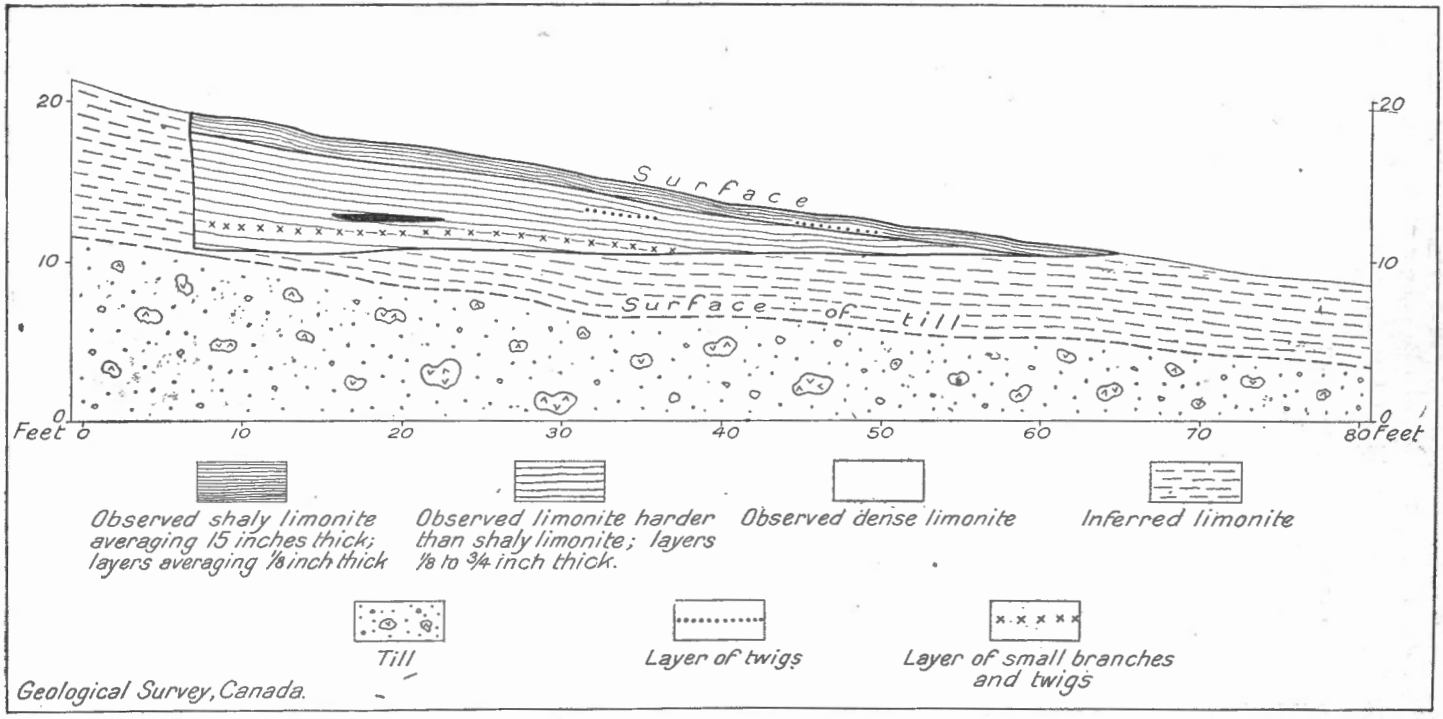
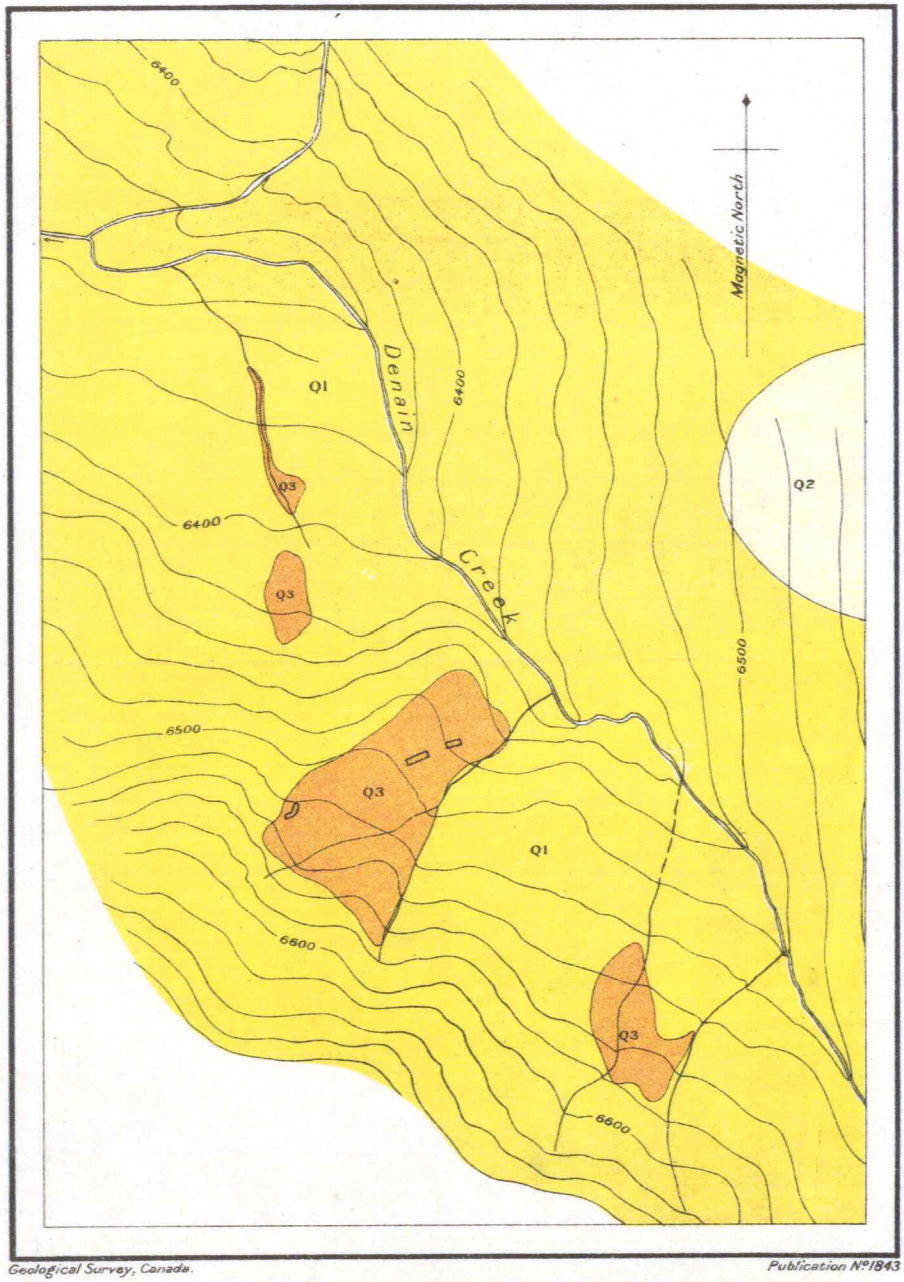


Figure 5. Prospect pit in Forrest Group limonite deposits, showing section of limonite bed resting on till.



Legend

Quaternary

- Q3 Limonite
- Q2 Talus
- Q1 Till

Geological boundary (observed)

Open cuts and trenches

Elevations subject to revision

Geological Survey, Canada.

Publication No 1843

Denain Creek limonite deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet.
100 0 500 1000

To accompany Report by J.D. MacKenzie, in Summary Report, Part A, 1920.

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Denain
5·1·2
A, Geol.
1843

Area, Thickness, Volume, and Tonnage. In estimating the tonnage of limonite in the deposits no account was taken of the irregular, swampy areas at the lower end where the deposit is thin, nor were the small patches north of the main body included. This loss of area is more than compensated by the thicknesses assigned to the portions measured.

Several test pits and trenches have been sunk in this deposit, and the greatest thickness proved was between 8 and 9 feet, from the surface to the bottom of the limonite. The area having this thickness has been liberally estimated at 100,000 square feet. For the remainder—an area of 202,000 square feet—a thickness of 24 inches is indicated by the pits. These figures give a volume of 1,304,000 cubic feet of limonite. It has previously been stated that the partly air-dried limonite runs 15 cubic feet to the ton. Allowing a loss of between 6 and 7 per cent water to bring it to the condition of thoroughly air-dried material a figure of 16 feet to the ton results. Using the figure thus determined, the quantity of limonite in the Forrest deposit is 81,450 tons.

Denain Creek Deposit

Location. The Denain Creek deposit is located on the creek of that name 4 miles above its junction with Taseko river. It is on the south side of the valley, immediately above where the creek that comes from Warner pass joins Denain creek, and is just above timber-line at an elevation of 6,500 feet.

Form, Structure, and Characteristics. The beds of limonite in this locality occur in four separate patches whose shape, size, and relations may be understood best by referring to the accompanying map, No. 1843. Six hundred yards down the valley on the same side is another thin, rudely rectangular patch of bog iron about 200 by 300 feet in area.

The limonite is generally similar to that on the Forrest deposit, but occurs in slightly thicker layers and is perhaps a little denser. It is not so clean, however, and certain streaks and layers are charged with angular rock debris. The surface of the till in the vicinity of the beds is thickly covered with quartz diorite boulders to 6 feet diameter and as similar ones are found in the prospect trenches there is no doubt that the iron has accumulated around and over them. The surface of the till, where not covered with limonite, is rough and hummocky. The surface has the usual loose mantle of flaky fragmental limonite.

Analyses

	1	2	3	4	5
Iron, metallic (Fe)	47·26	44·0	45·0	50·0	47·67
Silica and insoluble residue (SiO_2, etc.)	7·24	7·0	8·0	2·1	
Sulphur (S)	1·32	1·38	1·03	1·06	
Phosphorous (P)	0·128	0·23	Trace	0·21	

1. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch. Sample from the dump of a prospect trench 2 feet wide by 15 inches deep, by 40 feet long, sampled by taking a shovelful every 2 feet and quartering to about 8 pounds.

Analyses 2, 3, and 4. Collector, W. M. Brewer; analyst, D. E. Whittaker, B. C. Bureau of Mines.

2. A sample of the loose surface limonite.

3 and 4. Samples of more solid limonite about 1 foot below the surface.

5. An average of eight determinations of iron made by D. E. Whittaker, of the B. C. Bureau of Mines, on samples collected by F. J. Crossland.

(All analyses were made on air-dried material).

Area, Thickness, Volume, and Tonnage. The two smaller patches of limonite have together an area of about 21,000 square feet and a liberal estimate allows them an average thickness of 12 inches. In the two larger patches which comprise an area of

166,600 square feet the limonite is thicker, trenches proving 25 inches. Allowing an average of 2 feet, which is liberal as it takes no account of bottom irregularities, or boulders, a total volume of 354,200 cubic feet of limonite is obtained. At 16 cubic feet to the ton the deposit is slightly over 22,000 tons.

Feo Creek Deposit

Location. The deposit on Feo creek is situated on a flat, glacially-carved bench on the north side of the creek 2 miles above its junction with Denain creek, which it joins 2 miles above Taseko river, flowing from the northeast. The bog iron is near the head of the valley, and is surrounded by high, rusty, red, and yellow ridges from which descend large talus slopes. It is at an elevation of 7,200 feet, which places it about 800 feet above timber-line.

Form, Structure, and Characteristics. The limonite lies in a thin, even sheet of rectangular outline near the edge of the post-glacial trench the stream has excavated, in two places spilling over the side of the bench into the stream gorge. In general the limonite is like that previously described.

A special feature is the number of large boulders up to 6 feet in diameter which litter its surface to the number of twenty or thirty, and also the amount of talus and slide rock fragments mixed with the limonite, especially near its edges. This has been transported by snowslides and sudden rushes of water following quick melting of the snows.

Analyses

—	1	2	3
Iron, metallic (Fe)	47·17	48·0	48·0
Silica and insoluble residue (SiO_2, etc.)	1·71		
Sulphur (S)	2·47		
Phosphorus (P)	0·045		

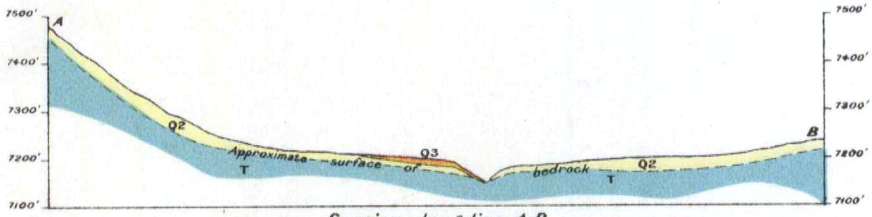
1. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch. Taken by cutting a plate of limonite 6 feet by 12 inches by 2 inches deep and quartering to about 6 pounds.
2 and 3. Collector, F. J. Crossland; analyst, D. E. Whittaker, B. C. Bureau of Mines.
(All analyses were made on air-dried material.)

Area, Thickness, Volume, and Tonnage. The Feo Creek deposit owing to its regular shape lends itself to accurate measurement. It underlies an area of 140,000 square feet to a depth varying up to 3 feet in the deepest of several test pits. Using 24 inches as a reasonable average the volume is found to be 280,000 cubic feet, this at 16 cubic feet to the ton giving 175,000 tons of limonite. A considerable percentage of this tonnage consists of the rock fragments mentioned above.

Rae Creek Deposits

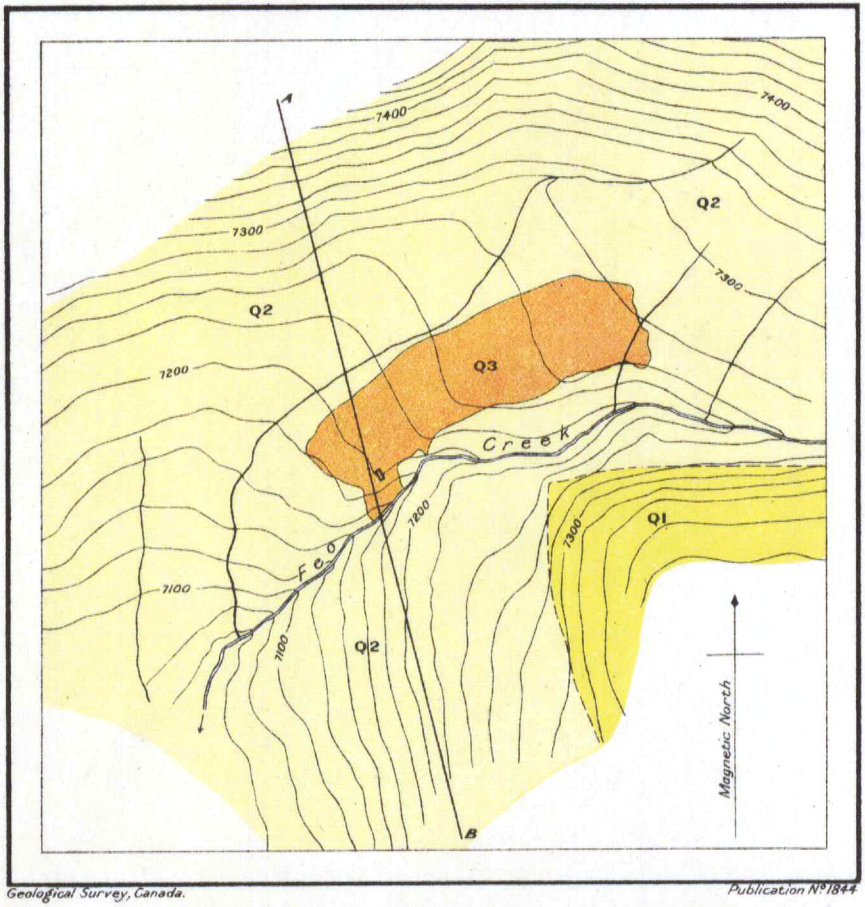
Location. The Rae Creek deposits are located on a small tributary of Rae creek, near its head, and 3 miles from where it joins Taseko. They lie in the shallow valley of the small stream which cascades down the steep mountain side, and range from 6,900 to 7,300 feet in altitude, being the highest of all the occurrences of bog iron in this district.

Form, Structure, and Characteristics. The deposit consists of the two elongate patches mapped, and a third elliptical patch 140 feet by 210 feet and under 2 feet thick which lies 1,000 feet down Rae valley from the lowest iron shown. The higher patch, lying on a slope of 21 degrees, is very thin and outcrops of the underlying Taseko formation are found protruding through the upper end of the bed. The limonite is much contaminated by pieces of talus and rock debris, an inevitable feature of these deposits at such an elevation and on such a slope. All over the



Section along line A-B

Note. The thickness of the Limonite bed is somewhat exaggerated



Geological Survey, Canada.

Publication No 1844

Legend

Quaternary

- Q3 — Limonite
- Q2 — Talus, alluvium
- Q1 — Moraine (recent)

Tertiary

- T — Taseko formation

- Geological boundary (observed)
- Geological boundary (located within 20 feet)
- Open cuts and trenches

Elevations subject to revision

Feo Creek limonite deposit,

Taseko Valley, Lillooet District, British Columbia.

Scale of Feet

100 0 500 1000

To accompany Report by J.D. MacKenzie, in Summary Report, Part A, 1920.

Feo Creek
5-1-2
A, Geol.

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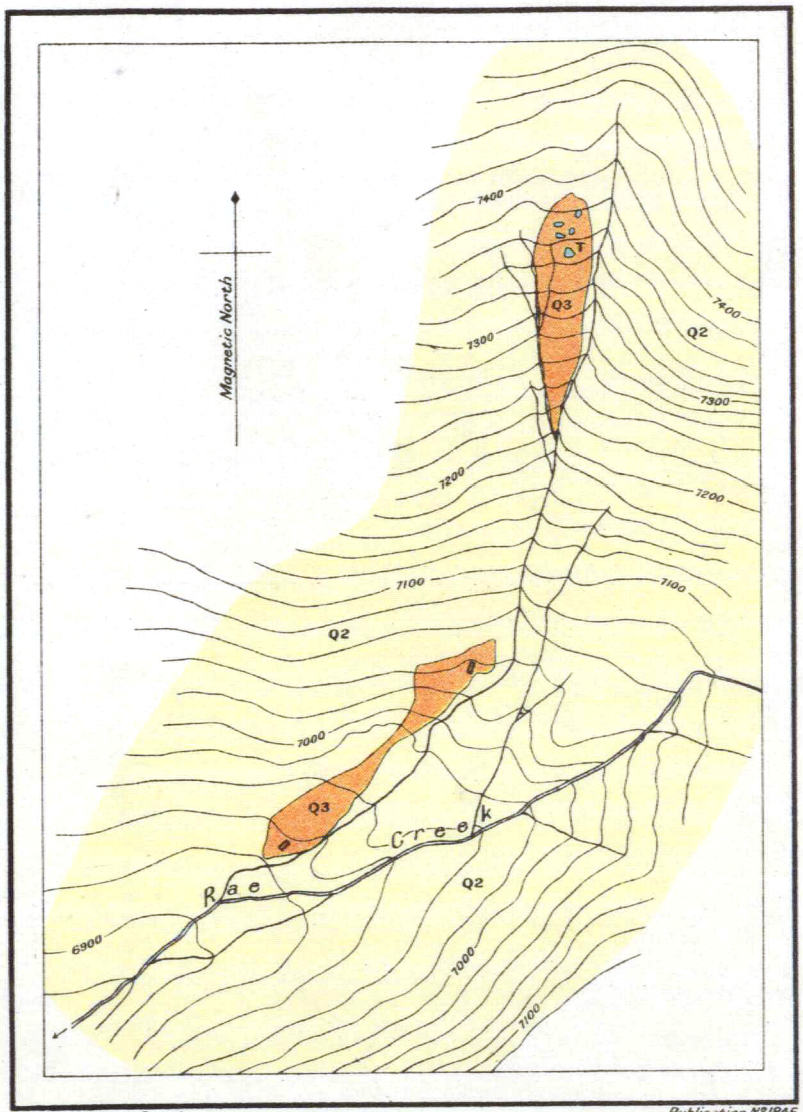
1844



Legend

Quaternary
- Q3 — Limonite
- Q2 — Talus, alluvium

Tertiary
- T — Taseko formation

Geological boundary (observed)

Open cuts and trenches

Elevations subject to revision

Geological Survey, Canada.

Publication N°1845

Rae Creek limonite deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet
100 0 500 1000

To accompany Report by J.D. MacKenzie, in Summary Report, Part A, 1920.

1845
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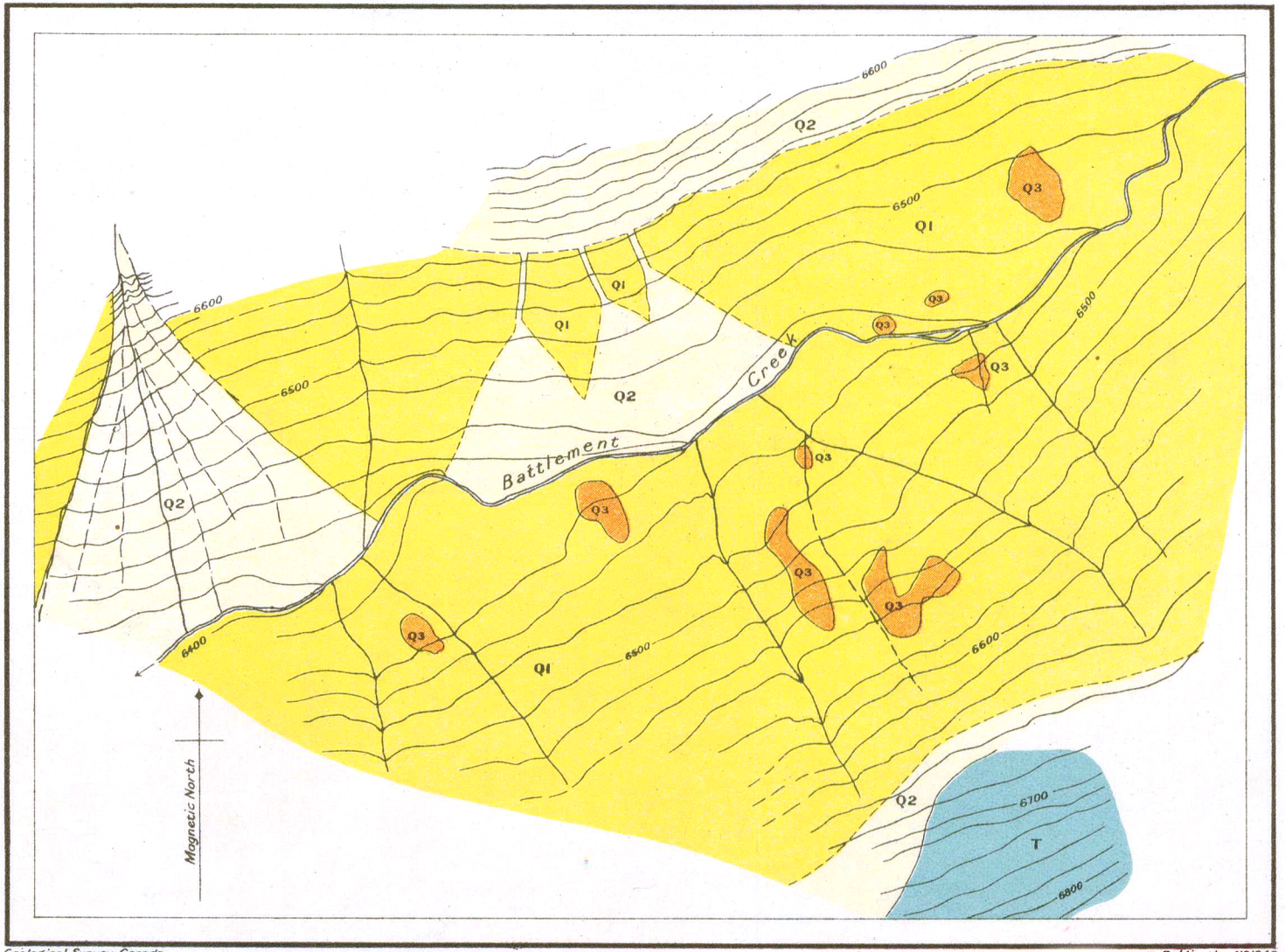
Rae Creek
5·1·2
A, Geol.



Geological Survey, Canada.

Publication No 1846

Battlement Creek limonite deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet

100 0 500 1000

To accompany Report by J.D.MacKenzie, in Summary Report, Part A, 1920.

Legend

Quaternary
- Q3 Limonite
- Q2 Talus, alluvium
- Q1 Till

Tertiary
- T Taseko formation

Geological boundary (observed)

Geological boundary (located within 20 feet)

Elevations subject to revision

This map has been reprinted from a scanned version of the original map

Reproduction par numérisation d'une carte sur papier

surface of this deposit is a layer of fine, broken, loose ore from 2 to 10 inches thick, forming about one-third of the whole quantity of bog iron in the deposit. The surface limonite has a reddish colour and a sub-metallic lustre, simulating hematite, and it is possible that the surface is formed in part of this mineral. Lying on a steep, south-facing slope, at the high altitude of 7,200 feet, the heat and intensity of the summer sun may explain this partial dehydration.

Analyses

—	1	2	3	4	5	6
Iron, metallic (Fe)	50·34	44·2	48·0	48·8	51·6	51·0
Silica and insoluble residue (SiO_2), etc	2·90	13·3	4·1	1·6		
Sulphur (S)	1·17	1·05	0·60	1·34		
Phosphorus (P)	0·021	0·52	0·85	Trace		
Manganese (Mn)	.....	.....	.....	Nil		
H_2O at 110° C. for 2 hrs	.....	.....	.....	7·1		

1. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch. Sample of loose surface limonite free from rock debris. A shovelful taken every 4 feet for 100 feet and quartered to about 8 pounds.
2 and 3. Collector, W. M. Brewer; analyst, D. E. Whittaker, B. C. Bureau of Mines.
2. Grab sample of loose surface limonite.
3. Grab sample of hard limonite from knoll at upper end of deposit.
4, 5, and 6. Collector, F. J. Crossland; analyst, D. E. Whittaker, B.C. Bureau of Mines.
(All analyses were made on air-dried material.)

Area, Thickness, Volume and Tonnage. In the mapped deposits on Rae creek an area of 54,000 square feet is considered to contain limonite moderately free from rock debris, and the unmapped patch has an area of about 30,000 square feet. Pits showing 18, 21, and 24 inches of platy limonite with the usual characteristics have been sunk in this deposit and a thickness of 24 inches over the areas given above is a very generous estimate. The volume is, therefore, 168,000 cubic feet and at 16 feet per ton the tonnage is 10,500.

Battlement Creek Deposit

Location. The deposits on Battlement creek are situated on both sides of the stream in the bottom of the valley 2½ miles from its mouth. Their elevation is about 6,500 feet above sea-level. Another small patch occurs about a mile down the valley, on the south side.

Form, Structure, and Characteristics. The deposit consists of nine separate and distinct patches of limonite lying on a rough till surface similar to that on Denain creek. The limonite exhibits the usual platy structure parallel to the surface on which it rests. In the two larger patches a layer of limonite 8 inches thick was observed to be denser and harder than usual.

Analyses

—	1	2	3	4
Iron, metallic (Fe)	51·25	47·0	47·6	49·2
Silica and insoluble residue (SiO_2, etc.)	1·40	4·1	6·0	4·7
Sulphur (S)	1·41	0·44	1·85	1·06
Phosphorus (P)	Trace	0·04	Trace	Trace
Manganese (Mn)	.....	.....	.....	.....
H_2O at 110° C. for 2 hrs	.....	.....	6·5	6·9

1. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch. From the largest and thickest patch, a shovelful dug out of the solid limonite every foot for 60 feet and quartered to 8 pounds.

2. Collector, W. M. Brewer; analyst, D. E. Whittaker, B. C. Bureau of Mines. Hard limonite from the face of a trench in the deposit farthest down Battlement Creek valley not shown on the large scale map).

3 and 4. Collector, F. J. Crossland; analyst, D. E. Whittaker, B.C. Bureau of Mines (All analyses were made on air-dried material.)

Area, Thickness, Volume, and Tonnage. The area of limonite on Battlement creek having a thickness of 1 foot is 5,200 square feet; the area estimated at 2 feet is 64,900 square feet, and 3-foot iron occupies an area of about 23,600 square feet, all these thicknesses being based on test pits. These dimensions represent a volume of 205,800 cubic feet which, allowing 16 cubic feet to the ton, gives slightly under 12,900 tons.

McClure Mountain Deposits

The deposits considered to this point are scattered over an area of from 15 to 20 square miles in Taseko valley and in smaller higher valleys tributary to it. The McClure Mountain deposits lie on the northern flank of the mountain of that name on the south side of Taseko river 5 miles below the junction of Battlement creek with that stream. These deposits are much larger in area and are thought to be considerably thicker than the ones already described, but the prospecting done on them is entirely insufficient to allow an estimate of the tonnage commensurate in accuracy with the stated figures for the other localities.

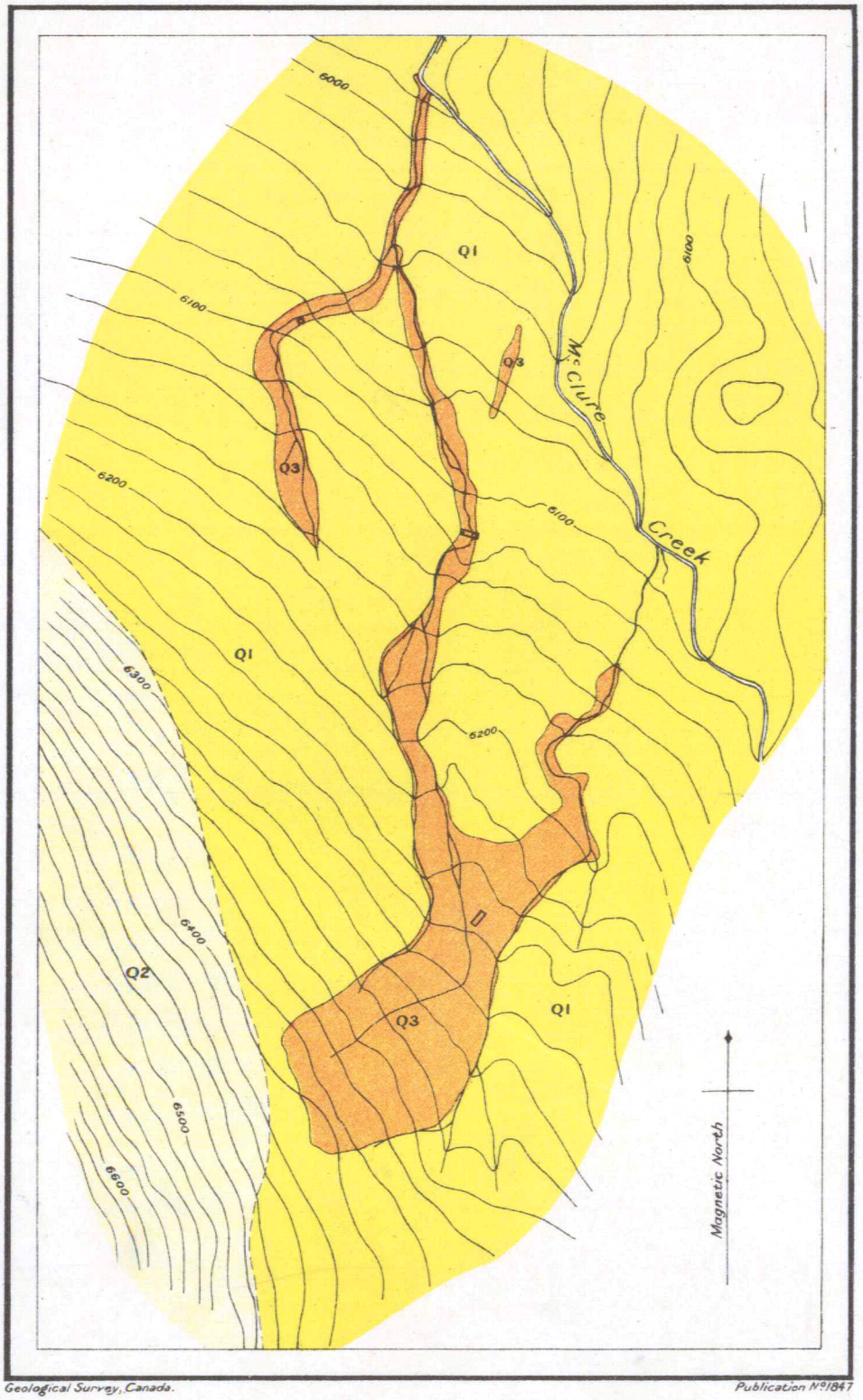
The limonite is found in two separate areas, one on the Chilcotin group of mineral claims and the other on the so-called Limonite group.

It is stated by one of the owners of the McClure Mountain properties that on the flat bottom of the valley near the river below McClure mountain there is a patch of limonite 600 by 100 feet occurring in a swamp.

Chilcotin Group

Location. The Chilcotin group is situated on the west bank of McClure creek about a mile from Taseko river which it joins about 5 miles above Taseko lake. The elevation of the deposit is from 6,000 to 6,400 feet above sea-level, and the lowest iron is about 1,200 feet above Taseko stream.

Form, Structure, and Characteristics. The deposit consists of a roughly rectangular body lying on the sloping hillside and from which two long tongues extend down into and partly fill two small valleys beneath. Its shape, the manner in which the limonite is localized by depressions in the till surface, and the way in which it fills them are shown in the detailed map No. 1847. The limonite is of the usual platily-bedded, rather loose-textured sort, and is very similar to that found on the Forrest deposit. It is free from the admixture of rock fragments so characteristic of the other deposits at higher elevations.



Geological Survey, Canada.

Publication No 1847

Legend

Quaternary

- Q3 — Limonite
- Q2 — Talus
- Q1 — Till

- Geological boundary (observed)
- Geological boundary (located within 50 feet)
- Open cuts and trenches

Elevations subject to revision

Chilcotin Group limonite deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet

100 0 500 1000

To accompany Report by J.D. MacKenzie, in Summary Report, Part A, 1920.

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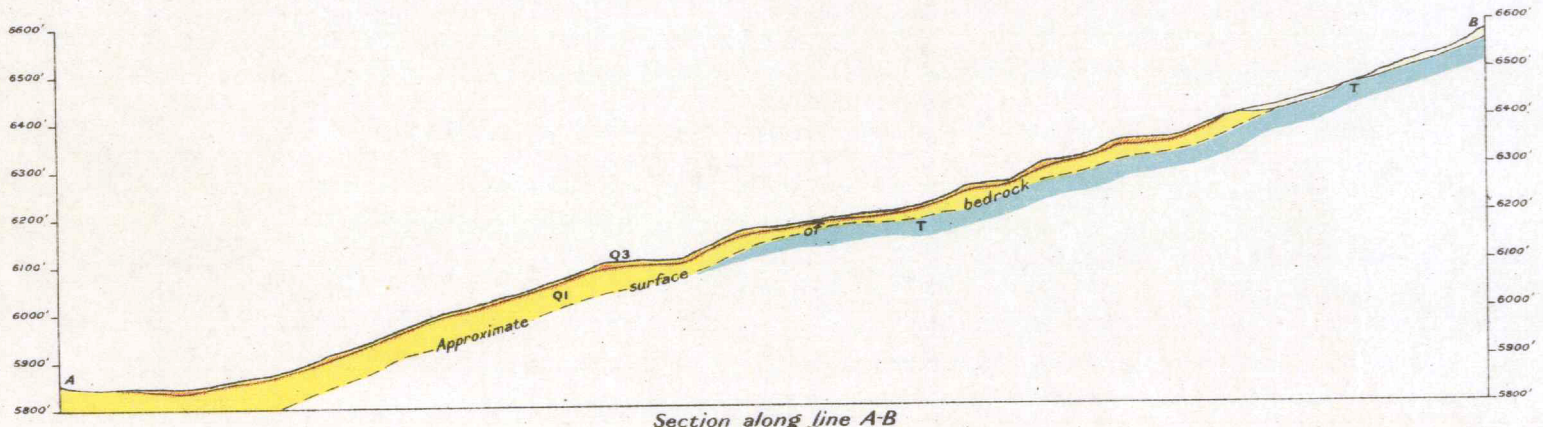
Chilcotin Group

5.1.2

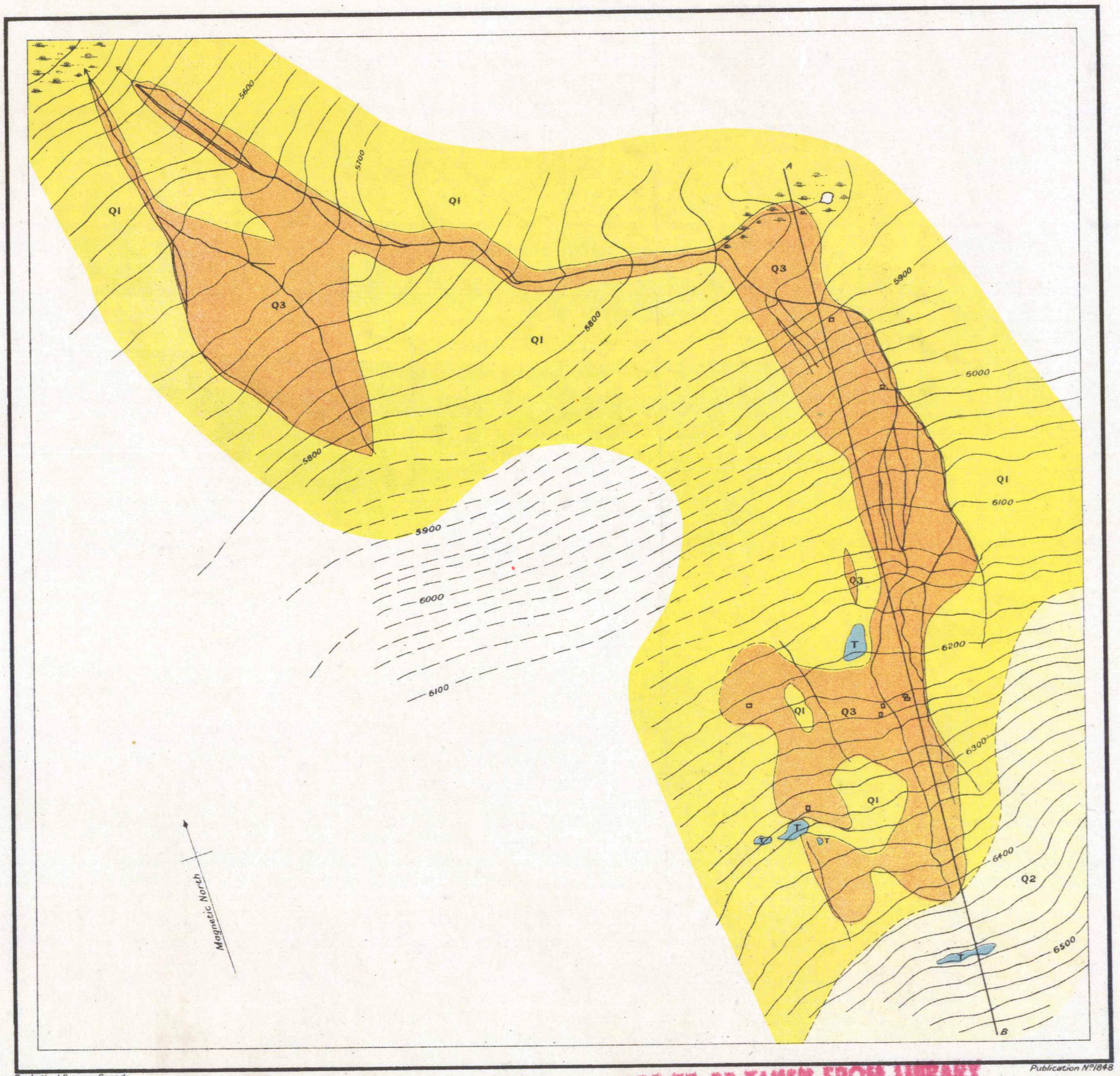
A, Geol.

1847



Section along line A-B

Note; The thickness of the limonite bed is somewhat exaggerated



Legend

Quaternary
- Q3 — Limonite
- Q2 — Talus
- Q1 — Till

Tertiary
- T — Taseko formation

- Geological boundary (observed)
- Geological boundary (located within 50 feet)
- Open cuts and trenches

Elevations subject to revision

Geological Survey, Canada.

Publication N°1848

Limonite Group deposits,
Taseko Valley, Lillooet District, British Columbia.

Scale of Feet

100 0 500 1000

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1848

Limonite Group.
5·1·2
A, Geol.

To accompany Report by J.D.MacKenzie, in Summary Report, Part A, 1920.

Analysis

Iron, metallic (Fe)	49·0
Silica and insoluble residue (SiO_2, etc.)	2·5
Sulphur (S)	1·6
Phosphorus (P)	Trace
H_2O at 110° C, for 2 hours	7·1

1. Collector, F. J. Crossland; analyst, D. E. Whittaker, B. C. Bureau of Mines. (Analysis made on air-dried material.)

Area, Thickness, Volume, and Tonnage. The total surface underlain by limonite in this group is about 403,450 square feet. The variable depth, and the fact that the deposit is only slightly prospected, increase the difficulties of estimating the tonnage of such a large area over an irregular floor. However, judging from its size, the manner in which it has formed bulges on the hillsides and filled up small valleys, as well as from the shallow holes which have been dug, a conservative estimate of an average thickness of 5 feet of limonite is made.

This gives a volume of 2,017,250 cubic feet which, at 16 cubic feet to the ton, assigns slightly over 126,000 tons to the Chilcotin group. This may be termed the "highly probable" limonite; it may be as much as 30 per cent greater, but is not likely to be less.

Limonite Group

Location. The Limonite group is situated on the north slope of McClure mountain overlooking Taseko valley. The deposit consists of a strip of limonite of varying width and direction stretching down the steep mountain side from the 6,400 to the 5,500 contours, the lowest outcrops of the mineral being about 500 feet above Taseko river.

Form, Structure, and Characteristics. The detailed map, No. 1848, shows that the limonite has been deposited in close association with a small stream which trickles down the mountain at this point. The relation of the iron to actual outcrops of the silicified tuff is well shown and also the influence of ridges and hillocks in the till in localizing the mineral. The profile section of the deposit illustrates the interrelation of bedrock, talus, till, and limonite, and also the terraced shape of the hillside accentuated to some degree by the thicker deposition near the edge of the flatter portion of the bench. In the narrow isthmus of limonite connecting the two large bodies is a very pretty example of terrace structure caused by rapid deposition of the iron oxide. Here the mineral lies on a 12 degree slope in a number of overlapping terrace basins, 1 inch to 12 inches high, 2 to 4 feet wide, and up to 20 feet long transverse to the slope. At this point the limonite is clearly at present in process of deposition.

Analyses

	1	2	3
Iron, metallic (Fe)	50·79	50·8	47·0
Silica and insoluble residue (SiO_2, etc.)	3·31	2·5	9·0
Sulphur (S)	1·46	1·77	1·58
Phosphorous (P)	Trace	Trace	Trace
Manganese (Mn)	.....	.....	.....
H_2O at 110° C. for 2 hrs	.....	7·1	6·1

1. Collector, J. D. MacKenzie; analyst, A. Sadler, Mines Branch. A picked sample from a dump near the middle of the longer strip.
2 and 3. Collector, F. J. Crossland; analyst, D. E. Whittaker, B.C. Bureau of Mines. (All analyses were made on air-dried material.)

Area, Thickness, Volume, and Tonnage. The difficulties of arriving at the quantity of limonite in the Chilcotin group are also present in this case, for here also,

prospecting has been insufficient to demonstrate the tonnage present. From general considerations, however, it is probable that in this deposit there is thicker limonite than elsewhere in the district. The deposit has been divided into several areas, and thicknesses varying from 1 to 10 feet have been assigned to them. The volume of limonite thus obtained is 6,147,000 cubic feet and at 16 cubic feet to the ton the tonnage is slightly over 384,000. As in the case of the Chilcotin group, this may be regarded as "highly probable" tonnage. Though there may be more, it is not likely that there is less.

The patch of limonite below the Limonite group in the valley bottom previously mentioned may contain in the neighbourhood of 15,000 tons.

Big Creek Deposits

Deposits of limonite similar to those described are reported from the vicinity of some of the headwaters of Big creek which flow from the divide east of the Taseko drainage. Prospectors who have seen these beds state that they are thin and of small extent.

Total Tonnage

Deposit	Area	Volume	Tonnage
	Square feet	Cubic feet	
Forrest	302,000	1,304,000	81,450
Denain Creek	187,600	354,200	22,000
Feo Creek	140,000	280,000	17,500
Rae Creek	84,000	168,000	10,500
Battlement Creek	93,700	205,800	12,900
Limonite Group	1,493,100	6,147,000	384,000[1]
Chilcotin Group	403,450	2,017,250	126,000[1]
Swamp claims	60,000	240,000	15,000
Totals	2,763,850	10,716,250	669,350

[1]The method by which the thicknesses of this tonnage are calculated is included with the description of the deposit.

ORIGIN

Mode of Accumulation

The close association of the limonite beds with streamlets flowing down slopes below outcrops or large accumulations of talus of silicified and pyritzed tuffs has been mentioned and is a feature evident on all of the accompanying maps. In order to deposit iron oxide these streamlets must be sufficiently constant in flow to carry a continuous supply of the iron salts which finally deposit as oxide and which, from the analyses and taste of the water, are plainly present in considerable quantity, yet they must be sufficiently shallow to allow of fairly complete aeration of their waters, and they must not be so swift or so large as to transport all the dissolved iron out of the locality before it is deposited as the oxide. A nicely balanced set of factors is thus necessary before any accumulation can take place, and the required conditions are usually found where the first flattening of slope below the steeper talus cones takes place. Here, especially if a bench or terrace results on the hillside, the necessary topographic conditions are most likely to be fulfilled.

The adverse effect of high altitudes on the occurrence of thick and large beds has been mentioned. The first adverse effect is because in the higher regions there is less catchment area above the first break in the slopes where the limonite occurs, causing a smaller flow of water for leaching purposes, and there is also a smaller volume of rock to be leached. Once the water passes the first or second easing of slope it has invariably gathered itself into a sufficiently large stream to excavate a channel in the till or bedrock, and once the solutions reach such a water course they are hurried out of the locality without any chance for deposition. The second

adverse effect of altitude is a lessened flow of water due to freezing at nights—this inhibition of drainage occurring earlier in the autumn and lasting longer in the spring, as well as happening on some nights even in the summer when waters lower down are still flowing. And third, at the higher altitudes there is less vegetation, and vegetation affects deposition by preventing a quick run-off. Where mosses and grasses cover the ground the streamlets are broken up and distributed and these thin sheets of percolating water are more easily oxidized.

The mechanism of deposition is as follows. Given suitable topographic and geologic conditions, a streamlet charged with iron salts begins to deposit the ferric oxide known as limonite along the wrinkle or depression in the till or moss or on whatever floor it is flowing. This deposit gradually fills up the depression occupied by the rivulet; forced out of its erstwhile bed it may divide or shift to one side or the other or do both—the ultimate effect is a lateral change of the locus of deposition of the iron oxide. This sort of thing goes on, several streamlets usually working in a given zone until the lateral progress is stopped by a ridge in the hillside. Against such a barrier the water deposits a fringe of iron oxide and this of itself forces the channel to reverse its direction of lateral migration. In this way the beds studied have been built up; where the supply of iron oxide is small, as in all the higher deposits seen, the resulting beds are small and patchy and thin; where the supply is larger the deposits spread out laterally until the major depression in the hillside is filled as on the Forrest, Chilcotin, Limonite deposits, and others, or they may fill a narrow valley to a considerable depth as on the Chilcotin and the Limonite groups. In one case only in such a narrow valley on the Limonite group, deposition was so preponderant over transportation that a series of imbricating terraces has been formed. Much larger terraces of this same type were observed by the writer in a somewhat similar deposit of limonite on one of the headwaters of the Zymoetz river, a tributary of the Skeena.[1]

Source of the Iron Oxide

The ultimate recognizable source of the iron oxide of these deposits is assigned without hesitation to the vast quantities of pyrite which exists finely disseminated through the silicified and otherwise altered tuffs of the Taseko formation. Wherever the beds of limonite occur outcrops of this light-coloured brilliantly stained formation are found above them—the surface coated with a film or even a crust of iron oxide and the fresher interior invariably giving back the glint of the myriad minute cubes of pyrite with which it is impregnated, and which in its finely divided state is so readily susceptible to a process of natural leaching. The surface waters descending from these pyrite-bearing beds are sufficiently charged with iron salts to give them a bitterly astringent taste, and analyses of them are given below.

Partial Analyses of Surface Waters Flowing over Limonite Deposits

	1		2	
	Parts per million	Per cent solids	Parts per million	Per cent solids
SO_4	206	66·03	156	62·15
Ca	42	13·46	57	22·71
Fe	24	7·69	8	3·19
Al				
SiO_2	40	12·82	30	11·95
	312	100·00	251	100·00

Both samples collected by J. D. MacKenzie and analysed by E. A. Thompson, Mines Branch.
1. Water seeping through the iron deposit 8 feet beneath the surface in a test pit.
2. Water from a small streamlet 100 yards below the edge of the limonite deposit farthest down the hillside, and flowing from it.

[1]MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1915, p. 67.

Neither sample contained ferrous iron, nor free sulphuric acid. Both are high in iron and in the sulphate radicle for waters of the surface type. The noticeably lower iron content of No. 2 may be ascribed to the deposition of much of its iron content in the deposit which lies on the hillside above the point where it was collected.

Field observation was sufficient to determine that replacement of organic matter, which played such a large part in the deposition of the Zymoetz limonite[1] is here of negligible importance and no certain instance of it was observed. The occurrence of considerable quantities of wood in the form of branches and twigs in certain zones often deep in the bed of limonite and quite unaltered except for a blackening of the outer layers is evidence that the iron solutions are not of a nature to replace vegetable matter with limonite.

The actual deposition of the iron oxide from the sulphate solutions consequent on the oxidation and leaching of the pyrite may be in part due to the agency of iron bacteria. The question has not been fully investigated, but minute, rod-like bodies resembling broken threads of the iron bacteria have been observed under the microscope in several specimens of the consolidated limonite, though it is possible that these are diatoms. Similar forms and also much longer threads, resembling some of the bacteria figured in Harder's excellent report on these organisms,[2] have been noted in samples of slimy ochreous scums collected near the edges of the deposits and from pits cutting them. Apart from the possible bacterial action, direct precipitation by chemical action may have played a considerable part in the building up of the limonite; the relative influence of these two processes, to which the actual deposition is due, is a matter for future investigation.

A RECONNAISSANCE BETWEEN TASEKO LAKE AND FRASER RIVER, BRITISH COLUMBIA

By J. D. MacKenzie

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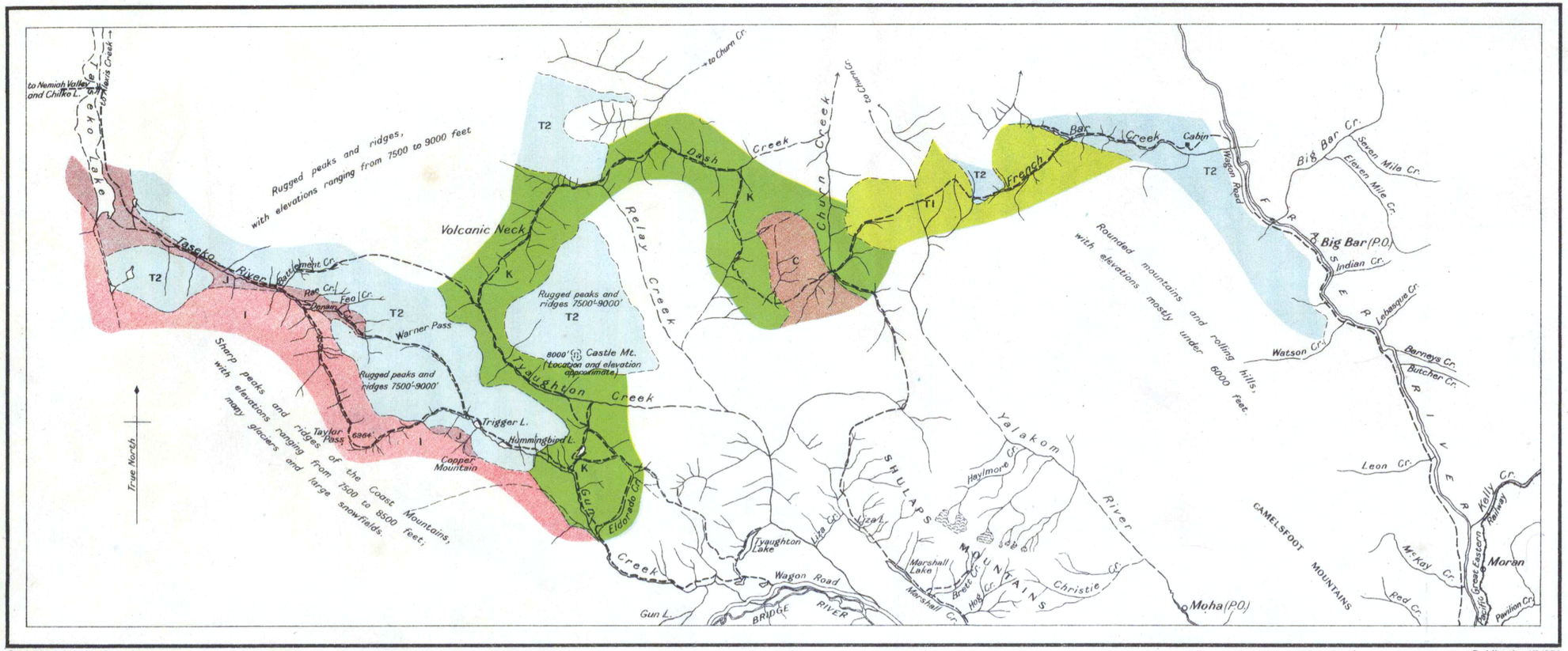
INTRODUCTION

That portion of British Columbia lying between Fraser river and Taseko lake is a region of considerable geologic importance. Rocks of the Palæozoic, Mesozoic, and Cenozoic eras are found here, and they are in part fossiliferous. Sufficient evidence has now been obtained to indicate that their relations, which have not yet been defined clearly, will be definitely known when certain parts of this area are studied in detail.

[1] Op. cit.

[2] Harder, E. C. "Iron depositing bacteria and their geologic relations." U.S. Geol., Surv., Prof. Paper 113, 1919.



Geological Survey, Canada.

Publication No. 1859

Route map of country between
French Bar creek (Fraser river) and Taseko lake, Lillooet District, British Columbia.

Scale of Miles
5 0 5 10 15

To accompany Report by J.D.MacKenzie,
in Summary Report, Part A, 1920.

Legend

Cenozoic	Oligocene(?)	T2	Taseko formation
		T1	French Bar formation
Mesozoic	Lower Cretaceous	K	Eldorado series
	Upper Jurassic(?)	I	Batholithic Rocks of Coast Mountains
	Jurassic(?)	J	Denain formation
Palaeozoic	Devono-Carboniferous	C	Bridge River series

Symbols

- Geological boundary (observed)
- Geological boundary (approximate)
- Roads
- Trails
- Glaciers

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French Bar Creek
5.1.2
A Geol.

1859

The first published information on the geology of this part of the province is contained in Dawson's report on the Kamloops map-area.[1] His work extended only a short distance west of the Fraser. In 1912, A. M. Bateman made an exploration between Lillooet and Chilko lake[2] and his report described the country and geology but is not accompanied by a map. In 1915 an area of 600 square miles was geologically mapped on a scale of 1 inch to 2 miles by the late C. W. Drysdale[3] who published a very brief report to accompany his preliminary map. The rocks along Seton and Anderson lakes, on the line of the Pacific Great Eastern railway have been studied and described by Camsell.[4]

The object of the reconnaissance made by the writer was to ascertain the areal distribution of the major groupings of the formations of the region, to study their general relations, and to correlate the results of previous investigators. This object has not been wholly attained, because of an unlooked for complexity of geologic relations, and the shortness of the time available for their study due to weather conditions. Because of these adverse factors some of the important general relations are not definitely known, and more questions have been raised than have been decided. The recognition, defining, and localizing of these problems are of value nevertheless; and many facts have been gathered which, useful in themselves, will form a basis for later, and more complete investigations. Particular attention is directed to the map (No. 1859) accompanying this report; it gives the first authentic information regarding the drainage and trails of the large area it covers. The various formations of the region have been correlated almost wholly by lithologic criteria, as fossil evidence is very scarce. Where formations can be traced by means of continual and frequent outcrops these criteria may be safely used; but where formations supposed to be the same are separated by areas of other rocks these means of correlation are unsatisfactory. The map may be considered, therefore, as substantially correct lithologically but of doubtful accuracy with respect to the age and formation relations of the rocks.

Certain parts of the region were studied in some detail, but others were necessarily examined hurriedly. An area of 40 square miles in Taseko valley, about 12 miles above the lake, was studied carefully (see pages 42-70), and is described, and another area of about 50 square miles in the vicinity of Gun, Eldorado, and upper Tyaughton creeks was studied by Mr. Robinson, who assisted the writer until September. Besides these detailed areas the valley of Gun creek was examined throughout its length, and certain side trips were made from it. During September a reconnaissance was carried out from the vicinity of Gun and Eldorado creeks up Tyaughton creek to near its head, where a pass with an elevation of 7,600 feet was crossed into Relay creek. This is a large stream which eventually flows into Tyaughton creek; and from its valley a low divide was crossed which led into Dash creek, a tributary of Churn creek. Dash Creek valley was in turn left and a somewhat devious route followed in a general easterly direction across the rough, high country in which Tyaughton creek in part, Churn creek, and Yalakom river head, this route leading into the headwaters of French Bar creek. The valley of this stream was traversed to Fraser river, where the reconnaissance ended. Lillooet was reached by three long days' travel on the rough, hilly trail which follows the west bank of the Fraser.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, and Map No. 556.
[2] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, p. 177.
[3] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 75, and map.
[4] Camsell, C., Geol. Surv., Can., Sum. Rept., 1917, p. 12 B.

Table of Formations

Period	Formation	Lithology
Recent	Stream deposits	Stratified gravel and sand.
	Volcanic ejecta	Pumiceous scoriæ.
Pleistocene	Glacial deposits	Till; erratics.
	Unconformity	
Oligocene (?)	Taseko formation	Basaltic flows and pyroclastics; quartz-diorite porphyrite dykes and sills.
	Unconformity (?)	
	French Bar formation	Coarse, thick-bedded conglomerates.
	Unconformity	
Lower Cretaceous	Eldorado series	Argillitic shales with interbanded fossiliferous sandstones; conglomerates of various types; dense and semi-crystalline limestones; intercalations of volcanic flows and agglomerates. Cut by lamprophyric dykes and sills.
	(*Nature of contact uncertain*)	
Upper Jurassic (or possibly Cretaceous)	Batholithic rocks of the Coast mountains	Quartz diorite, etc.
	Intrusive contact	
Jurassic (?)	Denain formation	Altered volcanic rocks.
	Unconformity	
Devono-Carboniferous	Bridge River series	Highly metamorphosed sediments and intrusives.

A comparison of this table with the one given by Drysdale for the Bridge River district[1] which lies to the south of the region here described will show that the formations of that district, with one notable exception, are represented here. The exception is the Cadwallader series, which the writer has not recognized in the region mapped by him. In the Cadwallader series to which he doubtfully assigned a Jura-Triassic age Drysdale included and mapped an assemblage of sedimentary, metamorphic, and volcanic rocks which, in lithology, structure, and degree of metamorphism largely correspond to the Bridge River series. The separation was at first (in 1915) made on lithologic grounds alone; in 1916 fossils of uncertain age[2] either Lower Cretaceous or upper Jurassic, were discovered by Drysdale in rocks which he had previously mapped as belonging to the Cadwallader series. In 1916 Summary Report Drysdale does not mention the Eldorado series, of Lower Cretaceous age, but in the structure section published by him[3] he indicates that it is conformable on the Cadwallader series. Fossils collected by W. S. McCann in 1920 near the head of Pearson creek, about where Drysdale maps his contact between the Eldorado and the Cadwallader series, are stated by McCann[4] to be of lower Jurassic age. The published evidence is thus confusing, and although a short time was spent in the field trying to solve the difficulty, the true explanation was by no means apparent and can be reached only by more careful and detailed field work, but in the meantime the writer offers certain tentative solutions.

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 78.
[2] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1916, p. 45.
[3] Op. cit., p. 46.
[4] Personal communication.

It is probable, on account of lithologic similarity and the absence of fossil evidence that many of the rocks mapped by Drysdale as Cadwallader series belong to the Bridge River series. Fossil evidence shows that there are, however, rocks referable to the lower Jurassic in the Bridge River map-area, so that the Cadwallader series is in part correct as mapped.

It is probable further, because of structural and lithologic similarities, that the Eldorado series is conformable on the Cadwallader series, and that both are unconformable on the Bridge River series, as the Eldorado conglomerates hold quartzite and chert pebbles which probably were originally rocks of the Bridge River series.[1]

Bridge River Series

Distribution and Lithology. In the vicinity of the headwaters of Churn creek, and forming part of the divide between the waters of that stream and those flowing into Tyaughton creek, a high, plateau-like ridge is formed of serpentine, with which are associated magnesite and chalcedony veins. Quartzites and crumpled argillites are found here as well. This area of metamorphic rocks widens toward the south and in that direction strikes into the region shown on Drysdale's map of the Bridge River district to be underlain by rocks of the Bridge River, Cadwallader, and Eldorado series. The relations of the first two of these have been dealt with above; but a personal communication by W. S. McCann suggests a doubt as to the occurrence of the Eldorado series in that region.

Age and Correlation. Pending more definite knowledge of the constitution and aerial distribution of the Cadwallader series, the area of metamorphic rocks described above is correlated with the Bridge River series on lithologic and structural evidence.

Denain Formation

Distribution. The name Denain formation is applied to an assemblage of volcanic rocks in the valley of Taseko river for some miles above the lake of that name. The formation consists of tuffs, agglomerates, and flows of basaltic composition. They are considerably altered, and have been severely deformed. The Denain formation is more fully described on pages 48-50 and need not be further mentioned here, except to note that the volcanic rocks of Copper mountain, near Trigger lake in Gun valley,[2] may be perhaps correlated with this formation and they have been so indicated on Map 1859 accompanying this report.

Nothing is known of the relation of the Denain formation to the Bridge River series.

Batholithic Rocks of the Coast Mountains

Distribution. The distribution of the rocks of the great batholith of the Coast mountains may be seen on the accompanying map. In general they lie southwest of Gun valley, from the junction of Eldorado creek to near the head of Gun creek where the boundary of the batholith crosses the valley from east to west. Thence a general west-northwest direction to the upper end of Taseko lake is maintained. Southwest of the boundary outlined above, the rocks for several miles at least are dominantly of batholithic origin.

Lithology and Structure. The composition and structure of these batholithic rocks have been described in the writer's report on the limonite deposits in Taseko valley (page 50). They are almost wholly quartz diorites.

Age and Correlation. The relation of the batholithic rocks to the Eldorado series, which carries Lower Cretaceous fossils, is not certainly known. They are in contact in the country southwest of Gun valley, but this relation was not closely studied.

[1] See Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, pp. 52 B, 57 B, 62 B, also Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1912, pp. 133-139.

[2] Camsell, C., Geol. Surv., Can., Sum. Rept., 1918, p. 26 B.

From the attitudes of the rocks of the Eldorado series near the contact, it is apparent that it is an intrusive one, or a fault. Until the nature of the relation is definitely known the age of the batholithic rocks in this region will be in some doubt, but as it is usually considered to be of upper Jurassic age, it is so designated in this report. However, as no plutonic pebbles have been observed in the conglomerates of the Eldorado series, and as the general relations suggest that the batholith may be intrusive into these sediments, the possibility that the Coast batholith in this region is post-Lower Cretaceous must be kept in mind.

In the vicinity of Gun valley west of Trigger lake, and in Taseko valley, the batholithic rocks are unconformably overlain by the volcanic rocks of the Taseko formation.

These batholithic rocks are correlated with the Bendor granodiorite of the Bridge River area.[1]

Eldorado Series

Distribution. The Eldorado series has not been defined by Drysdale, who first used the name, except that he states it to be of Lower Cretaceous age.[2] In the region traversed by the writer there are large areas of sedimentary rocks many of which certainly, and some of which probably, belong to the Eldorado series. The type locality of the Eldorado series may be here defined as the vicinity of Eldorado valley, Gun valley west of Eldorado creek as far as the overlap of volcanic rocks east of Hummingbird lake, and the upper portion of Tyaughton valley. Rocks of the Eldorado series have been continuously traced into Relay valley, and the rocks of Dash creek and vicinity very probably belong to this series as well, though the correlation is not certain here. It is with less confidence that the rocks of upper Churn creek are correlated with the Eldorado series, but it is probable that they belong there.

Stratigraphy and Lithology. In the Eldorado series there are five different formations which if taken separately aggregate more than 10,000 feet of sediments. As the formations, particularly those composed of limestone and conglomerate, are noticeably lenticular, the actual thickness of the series is probably less than this. Though the series is in the main conformable, at least one stage of contemporaneous erosion is indicated by evidence to be described presently. Following is a general section of the series in the type locality.

	Approximate thickness, feet.
Grey and buff sandstones with blackish-grey shale bands, exposed on Relay creek	500+
Coarse conglomerate, the pebbles mostly dense, semi-crystalline, limestone, exposed in the Eldorado Creek and Tyaughton Creek localities; finer, sea-green chert conglomerates of Upper Relay creek	2,000+
Grey, dense, and semi-crystalline fossiliferous lenticular limestone of Tyaughton creek	2,500±
Grey to black, dense, hard shales with sandstone beds of varying thickness up to 50 feet, the latter frequently fossiliferous; some agglomerate beds and perhaps flows included, and also lamprophyric dykes and sills; exposed on Eldorado creek, Gun creek, and in their vicinity	5,000±
Basal conglomerate of the headwaters of Churn creek	0–50+

Fossils have been found in several places, and careful search would without doubt reveal other localities. An easily accessible occurrence is on the trail along the mountain side west of the small lake on the low divide between Gun and Tyaughton creeks, west of Eldorado creek. This is locally known as Spruce lake, and the fossils occur in large sandstone ledges outcropping above the trail about the middle of the west side of, and 200 feet above the lake. At this locality a greenish grey, fine-grained, hard, sandstone bed about 50 feet thick outcrops for about 200 yards along the strike, and is almost wholly composed of casts and internal moulds of *Aucella crassicolis,* in size varying from a hazelnut to a small hen's egg. A few belemnites, ammonites, and

[1] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 79.
[2] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, pp. 79-80.

large pelecypods also occur. Nearly the whole volume of the rock is composed of the fossils which are crowded together as tightly as possible and at all orientations. The enormous volume of shells makes it difficult to believe that all these animals ever existed at one time in this locality, and suggests that they were probably swept into this accumulation by some change of current. A conglomerate layer at the top of the section 5 to 6 feet thick, with pebbles to ½ inch through, hints at such an explanation, as does the unfossiliferous character of the series as a whole. Fossils have also been found in similar sandstone on Tyaughton Creek trail about 3 miles above the mouth of the creek that drains Spruce lake, and they had been observed also in the mountains east of Spruce lake.

The conglomerates containing a large percentage of limestone pebbles are unusual and interesting rocks and are well exposed in the mountains west of Eldorado creek.

In general, the conglomerates consist of well-rounded to sub-rounded limestone pebbles up to 6 inches in diameter, but usually from 2 to 3 inches, with lesser quantities of smaller pebbles of chert, quartzites, and volcanic rocks all embedded in a sandy matrix. The pebbles are often closely packed together and the matrix fills only the interstices, but gradations into pebbly sandstones occur. The conglomerates are thick-bedded and massive, and form beds from 10 to 50 feet or more in thickness.

The peculiar feature of these rocks is the large proportion of limestone pebbles they contain, and especially the size and angularity of some of these included fragments.

The most striking case of this was seen in some large, slidden blocks on the trail leading up Eldorado creek about a fourth of a mile north of the main Gun Creek trail. The conglomerate consists of rounded pebbles of chert, quartzite, dense, feldspathic porphyry, and limestone, in a finer matrix. There are several large, sharply angular fragments of limestone embedded in this pebbly rock, the largest noted being rudely tabular, 3 feet square and 10 inches thick. It is a bluish-grey, dense limestone and contains obscure fossil remains. The most curious feature of the fragment, apart from its great size, is its sharply angular outline. The corners and edges are not rounded in the least, and small cracks in the fragment are filled with the sandy matrix of the conglomerate. Near the surface of the large fragment this matrix contains numerous sharply angular pieces of limestone up to three-fourths of an inch across. In addition to this largest fragment, others equally angular, showing, as it does, re-entrant angles in their outline, may be seen.

The impression gained while studying this unusual rock was that these fragments had been torn from a partly consolidated bed of limestone and buried in a pebbly mass before their angular outlines were lost. This could occur if some sudden change caused a stream carrying pebbles to flow over a recently formed limestone bed so that steep-sided gullies were quickly formed. From such steep sides, angular blocks of partly consolidated limestone might fall and thus be incorporated in a conglomerate. In the neighbourhood of Boston, U.S., where the general relations are similar to those described above, the writer has seen angular blocks of fine-grained shale embedded in a coarse conglomerate.

The limestone pebbles of these conglomerates in general, and the angular fragments in particular, indicate that contemporaneous erosion took place during at least one stage in the accumulation of the Eldorado series.

At the locality shown on the map where the trail crosses Upper Churn creek, bluffs of coarse, greenish grey, arkosic sandstones contain obscure plant remains. These rocks are provisionally included in the Eldorado series.

The lamprophyric dykes and sills which cut the Eldorado series in several places in the type locality are in general of too varied composition, and are too much altered to be considered as feeders of the overlying flows of the Taseko formation. They represent a period of intrusion following the accumulation, and at least the partial con-

solidation, of the sediments in which they are found. These intrusions add another complication to the igneous history of the region, and they may indicate a post-Eldorado age for some of the batholithic rocks, though their relation to the recognized plutonics of the region is not known.

Structure. The Eldorado series is tightly folded in its western part where it abuts against the massive batholith of the Coast mountains. Along Gun creek and in the ridge south of it, east of the overlap of the Tertiary volcanic flows, the shales and sandstones of the Eldorado series are standing at high attitudes, frequently vertical, and they are apparently disposed here in several compressed folds striking nearly north and south. Eastward down Gun creek, and in the high ridges west of Eldorado creek, these closely compressed folds pass into a more open syncline of thick-bedded, coarse, lenticular, conglomerate with limestones pebbles, which overlies the shales as noted above. The general axis of this syncline also strikes north and south. As already mentioned the batholithic rocks of the Coast mountains are in contact with the Eldorado rocks in the valley next south of Gun valley, and for a distance of about 7 miles the contact is a remarkably straight one. The Eldorado rocks have been seen within from a quarter to a half a mile of the batholith throughout this distance, and striking directly at right angles to the plutonic mass. The contact has not been observed in detail because of drift covering and inaccessibility during a rapid reconnaissance, but it is either a fault or an intrusive one. No pebbles of the quartz diorite or of other rocks have been observed in the Eldorado series, so the possibility that the batholith in this region is post-Lower Cretaceous is suggested.

In the valleys of Relay and Dash creeks the Eldorado series is disposed in open folds, with dips usually less than 40 degrees, and northwesterly strikes.

Age. With respect to the fossils collected, F. H. McLearn of the Survey writes:

"The only species of stratigraphic value is *Aucella crassicolis*. It is characteristic of the upper Knoxville formation of the Shasta group in California and of the Petschora beds in Russia. It indicates Lower Cretaceous and Neocomian in the European nomenclature."

These fossils represent only one horizon, the position of which is not definitely known, though it is somewhere in the lowermost 5,000 feet of shales and sandstones. Until further study and collections are made the Eldorado series may be referred to the Lower Cretaceous. Considerations referred to above suggest the possibility that these rocks rest on Jurassic strata without structural discordance, and may pass conformably into them.

Mesozoic stratigraphy presents many problems of far-reaching importance to British Columbia geology, and the well-exposed rocks of the Lillooet district offer a splendid opportunity for stratigraphical and structural research. In addition, many significant features of the internal and external petrographic and structural relations of plutonic rocks are illustrated here, and await only careful and detailed study to enrich the science with their explanation.

French Bar Formation

Distribution. This formation is well exposed on upper French Bar creek, and underlies the country westward across the ridges in which Yalakom river heads as far as upper Churn Creek drainage basin. It may have a considerable extension in the area southeast of that just described.

Lithology. The French Bar formation is made up of very coarse conglomerates, with lenticular sandstone beds in subordinate amounts. The rocks are much less indurated than any of the sediments of those included in the Eldorado series, and the pebbles and boulders easily weather out of their sandy matrix. The formation is characterized by a high percentage of large, well-rounded boulders of the plutonic

rocks of the Coast mountains, which frequently have a diameter of 2 feet, and many beds are formed of boulders averaging a foot or more. The conglomerate beds range from 10 to 100 feet thick, and the formation as a whole gives the impression of being of fluviatile origin.

Structure. Various attitudes have been observed in the strata of this formation, but there seems to be a preponderance of east-west strikes, with dips in both directions usually under 25 degrees, though one dip as high as 60 degrees was noted. About 8 miles from Fraser river a distinct escarpment with a direction about west-northwest crosses French Bar creek, and limits the conglomerates in a northeasterly direction. This escarpment, from the relative attitudes of the rocks on either side, is thought to mark a fault with a downthrow to the north.

The thickness of the French Bar formation as exposed near the creek of that name is approximately 2,000 feet.

Age and Correlation. The pebbles of the plutonic rocks found in the French Bar formation indicate that it is younger than the Coast Mountains batholith. Pebbles of the greenish arkosic sandstones on the trail crossing Churn creek are also found in the conglomerates of this formation. As these sandstones are, though with some doubt, referred to the Eldorado series, the probability is that the French Bar formation is younger than the Lower Cretaceous.

On lithologic and structural grounds, this formation is tentatively correlated with the Coldwater group of Dawson[1], supposedly of Oligocene age.

Taseko Formation

Distribution. The Taseko formation, by which name are designated the volcanic rocks of the region of Tertiary age, has been described in the previous report as occurring in upper Gun valley and in the Taseko valley. These Tertiary volcanic flows and pyroclastics are found also in the high ground between Gun and Tyaughton valleys, this being part of a large area of these rocks extending westward without a break to Taseko valley. They cap the mountain peaks between Tyaughton and Relay valleys; north of Relay valley they also occur in irregular caps on the higher ground, and cover large areas in the drainage basins of the headwaters of the western confluents of Churn creek and Big creek. At one time a much larger area was underlain by this volcanic formation, from which it has been now stripped by erosion, leaving remnants on the higher ridges.

Lithology. The rocks occurring in this formation in Taseko valley have been described in the preceding report as being dominantly basaltic, effusive, and pyroclastic types. In the area covered by this reconnaissance basalt porphyries with a dense fluidal matrix and phenocrysts of olivine and augite, and amygdaloids, are very common.

West of Swan lake (a small, marshy pond about 8 miles from Fraser river, near French Bar creek) a 25-foot bed of light grey and yellowish, red- and yellow-weathering, finely-banded altered tuff is exposed, identical in appearance with the silicified tuffs of Taseko valley. Farther down French Bar creek this bed is overlain by dark grey to black, highly vesicular, volcanic flows and tuffs. These rocks are well exposed in the valley of the creek and in the great canyon on it as far as the lower slopes of the valley of Fraser river, where the outcrops are buried beneath the alluvium of that stream.

Structure. In the neighbourhood of the batholith of the Coast mountains the bedded rocks of the Taseko formation dip northeastward at decreasing angles up to 25 degrees. In the high, rugged mountains between upper Gun and upper Tyaughton creeks the rocks are flat or gently-dipping volcanics. In the mountains between Tyaughton and Relay creeks, and northwest of Dash creek, the formation is nearly flat.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 68 B.

Age and Correlation. The Taseko formation is unconformable on all the other formations of the region with the possible exception of the French Bar formation, and the relation in this case is probably an unconformity as well. No fossils have been found in the formation, but on structural and physiographic evidence it is clearly of Tertiary age. It is correlated with Dawson's Upper Volcanic Group[1] of the Kam-

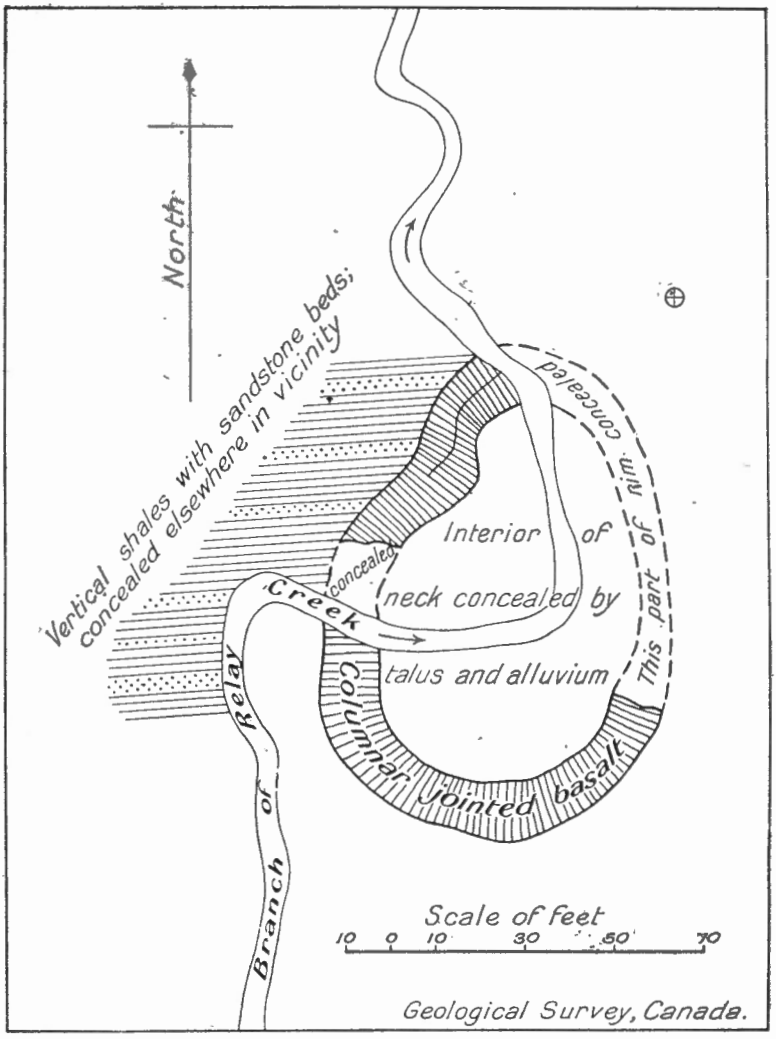

Figure 6. Plan of volcanic neck on branch of Relay creek, Lillooet district, British Columbia.

loops sheet to which he assigned a Miocene age. Palæontologic evidence quoted by Daly[2] indicates that Dawson's Miocene volcanics are better referred to the Oligocene, and they are accordingly so designated here.

Volcanic Neck. Figures 6 and 7 illustrate a most interesting and striking example of a volcanic neck which is exceptionally well preserved and clearly exposed.

[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, pp. 73-76 B, 216 B, etc., and Map No. 556.

[2] Daly, R. A., Geol. Surv., Can., Mem. 68, 1915, p. 126.

The neck is situated near the head of Relay creek, on one of its tributaries, about 100 yards above where it joins the main stream. It lies directly in the path of the stream, which has cut across it as shown in the illustrations. The stream is here flowing in a steep-sided trench about 50 feet deep which cuts through the veneer of drift covering the thin floor of the valley and is incised into the bedrock.

Figure 7. Sketch of volcanic rock looking southwest, Lillooet district, B. C. Point from which sketch was made is indicated by cross in circle, Figure 6. (From a sketch by J. McCann.)

The elevation of the valley where the neck occurs is about 6,500 feet. Another similar but smaller neck is stated on good authority to be in this neighbourhood.

The rocks which the neck intrudes are shales with thin sandstone beds of the Eldorado series, and their attitude is vertical. The valley is here cut into an anticline in the Eldorado series, and overlying the shales are several hundred feet of fine, sea-green chert conglomerates, which are exposed in the valley walls, dipping away from it on both sides.

In the immediate vicinity of the neck the shales are not well exposed, but there is not much distortion of them due to the intrusion in the outcrops that do occur.

The neck is roughly elliptical in outline, with axes of 110 and 80 feet. Weathering and erosion have dissected the neck, and have left its structure clearly exposed. It consists of a rim, and a central portion. Of the rim two segments remain, standing 30 to 40 feet high, in a general appearance like a gigantic ruined chimney. The central portion was evidently less resistant to the weather, and is now eroded away except for some small outcrops in one place near the rim. The rim is regularly jointed, and now consists of horizontal, radially arranged columns averaging 12 inches in diameter and varying in length from 10 to 15 feet, this being the thickness of the walls of the neck. Some of the columns are hexagonal in outline but they are more often quadrilateral, or not of regular shape. The rim is also parted by vertical, concentric joints, so that the columns do not extend across the whole thickness of the wall.

The rock of which the rim is composed is a dark grey to black, very tough, dense trap, probably a basalt, though thin sections have not been examined. The rock forming the central portion of the neck is lighter in colour and softer.

This volcanic neck, where exposed, is vertical, and as the strata which it intrudes are vertical also, it probably maintains that attitude for some depth. No evidence bearing on the mode of emplacement of this extraordinary igneous body could be found. Certainly the result of some unusual combination of geologic forces is here exemplified. It may be pointed out that the longer axis of the intrusion is at right angles to the strike of the enclosing sediments, an orientation that is not what might be expected.

The subject of volcanic necks is fully treated by Daly in his illuminating work on igneous rocks.[1] The fact already mentioned that these rocks are located on or near an anticlinal axis may be significant with respect to their localization and origin. There is no doubt that these necks represent some of the vents from which came the extrusive rocks of the Taseko formation which are found capping the mountains to the south of the plug and over 2,000 feet above it.

Glacial Deposits

Glacial deposits, till and erratics, abound in that portion of the region traversed lying within the Coast mountains, and these evidences of ice occupation can safely be assigned to the presence of glaciers of the alpine type during the Pleistocene, when they were larger than is now the case. Rock scorings, modified valleys, and local disturbance of drainage are other evidences of ice action seen.

In the region immediately west of Fraser river, and especially in the valley of that stream, the case is different. So far as the writer could ascertain there is no positive evidence of ice occupation of Fraser valley to be found from French Bar creek to Lytton, a distance of about 100 miles. In this part of the valley no till, no erratics that could not be explained by stream transportation, and no striæ or rock scorings have come under his observation.

Furthermore, the general shape of the valley, the contours of its walls, and the occurrence of angular, unmodified ledges and buttresses of rocks in positions where they could hardly have escaped strong modification had the valley been occupied by ice to the extent supposed by Dawson[2] is evidence that no large rib of ice occupied the valley during the Pleistocene.

Until more field evidence is collected it is scarcely worth while to debate the subject further, but the evidence given above, though largely negative, is deemed worthy of presentation here.

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[1] Daly, R. A., "Igneous rocks and their origin." McGraw-Hill Book Co., New York, 1914, pp. 126-130, and Chapter XIII, p. 248.

[2] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 257 B, pp. 302 B, et seq. See also Tyrrell, J. B., Jour. Geol., vol. XXVII 1919, p. 55.

Volcanic Ejecta

A surface deposit of fine, white, siliceous pumice is found in Gun valley as far west as 3 miles beyond Eldorado creek, but was not otherwise noted in the region traversed. It has an extensive occurrence in the Bridge River map-area and has been described by Bateman[1] and Drysdale[2] and their description applies equally well to the material seen by the writer.

EUTSUK LAKE DISTRICT

By R. W. Brock

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Figure 8. Diagram showing location of Ootsa, Whitesail, and Eutsuk lakes, Coast district, B.C. ... 82

INTRODUCTION

The field season of 1920 was spent in a geological reconnaissance of the Eutsuk Lake region at the head of the Nechako or north branch of Fraser river. It is best reached from Burns Lake station on the Grand Trunk Pacific. From here a motor road runs to François lake, about 15 miles distant, where a government ferry transfers vehicles and passengers to the south side of the lake. From François lake a wagon road 27 miles long leads to Ootsa Lake post office on the lake of the same name. From Ootsa post office, travel is by small boat or canoe (Figure 8, page 82).

A few days were spent in studying the country around Ootsa. The season for field work in this district is short, and it was thought that the maximum of information could be gained by an examination of the shores of the lakes, supplemented by an occasional traverse inland and a few mountain ascents. The weather during July and August was favourable excepting that the wind was rather heavy for lake work, but after the first week in September the weather broke, becoming wet and stormy. Snow crept down to the lowest valleys in the mountains, and up to the date of leaving, September 21, geological work was practically prohibited. What was accomplished during the season was an examination of Ootsa lake (from 6 miles below Ootsa post office to the head of the lake), Tahtsa river, and Sinclair lake, Whitesail river, Whitesail lake, and Eutsuk lake.

The district is situated southwest of the Grand Trunk Pacific railway about 150 miles west of Prince George and about 120 miles south of Hazelton. Drainage is to the Nechako river, but the district lies almost on the divide between Fraser and Bulkley River waters, and only a few miles east of the Coast range, beyond which short streams lead to salt water at Dean channel and Gardner canal.

In addition to the road from Burns Lake, Ootsa Lake is connected with Wistaria, 12 miles west, by wagon road, whence a road runs to Houston on the Grand Trunk Pacific. A trail was being constructed this summer from the west end of the lake to Sweeney mountain up Tahtsa river. From Ootsa Lake the Bellakula trail runs along the lake.

[1] Bateman, A. M., Geol. Surv., Can., Sum. Rept., 1912, pp. 185 and 193.
[2] Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 78, and 1916, p. 52.

Although the district examined is without trunk trails, access is comparatively easy by means of canoe or small boat. Tahtsa river, to its fork just below Sinclair lake, presents no difficulties, and the main river can be ascended to Tahtsa lake. Whitesail river between Sinclair lake and Whitesail is swift, but, except for a few log jams, calls for little skill on the part of the navigator. A portage, about a mile long, broken

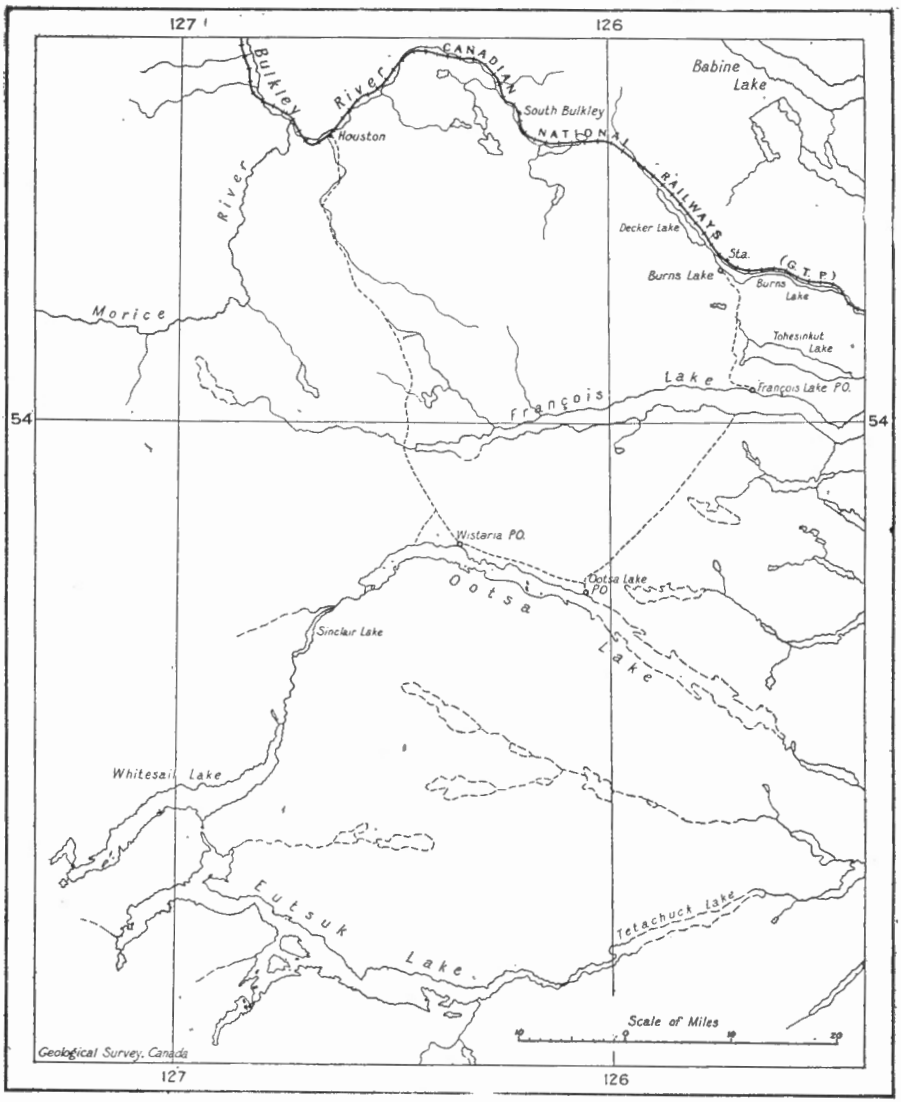

Figure 8. Diagram showing location of Ootsa, Whitesail, and Eutsuk lakes, Coast district, British Columbia.

near the middle by a beaver pond, leads to Eutsuk lake. Eutsuk lake discharges into Tetachuck lake, the connecting river being about a quarter of a mile long. It can be run by good canoemen, but the portage is safer. The river stretch between Tetachuck and Euchu lakes has several rapids, most of them necessitating portages. The northwest arm of Natalkuz lake may be ascended and Intahtah lake and Ootsa river to Ootsa lake. This circular canoe-route of over 200 miles affords a base from which about 10,000 square miles of territory may be conveniently prospected. Experienced boatmen with canoes may be engaged at Ootsa.

Character of the Country

The district lies partly in the Coast range and partly in the Interior Plateau. Whitesail lake east of Portage bay is in the plateau, but west of this bay, lies within the range. The main body of Eutsuk lake lies along the flank of the mountains, but Southwest bay, and Bear bay and Pondosey lake are in the mountains. This depression, flanking the Coast range, and occupied by the main body of Eutsuk lake, continues southeastward, though the lake itself in its lower stretches beyond the Tesla River mouth, departs from it.

The plateau country is a hilly district cut by wide valleys, which are in turn dissected by minor valleys. As a rule the hills are not more than 800 or 1,000 feet above the main valleys, or from 3,500 to 4,000 feet above sea-level. The surface is broken and uneven in detail, but the plateau character is pronounced when viewed from an elevation. The skyline is usually strikingly even. But although the above is the rule, hard, resistant rocks stand up as isolated hills (monadnocks) and may indeed form mountain massifs with an elevation of 6,000 feet above sea, such as Nadina mountain west of François lake, Stoney mountain south of the west end of Ootsa lake, and Quanchus mountains, east of Whitesail and north of Eutsuk. These are mostly flat-topped, dome-shaped masses.

In the country south of Salmon and Blackwater rivers, Dawson mentions volcanic masses rising above the plateau, attaining elevations exceeding 7,000 feet. But these retain their volcanic forms, whereas the hills rising above the plateau that can be seen from the Eutsuk district, are monadnocks or erosion remnants, though some, like the small buttes that rise in line from the low flat bordering the north side of Eutsuk lake (between the "K" of Eutsuk and the "L" of lake on Figure 8) are probably the necks of Tertiary volcanoes. The smaller hills and ridges rising 200 to 1,000 feet above the general elevation, such as Japhat west of Ootsa lake, Bennett hill at Ootsa Lake, Sugarloaf 6 miles east of it, and the ridge 4 miles back from the lake, are also monadnocks. They may be isolated hills like Japhat, or long ridges. Resistant lavas may form low ridges with a steep descent on one side and a gentle slope on the other (cuestas)—such as the ridge north of Ootsa Lake near Wistaria.

The valley systems follow, as a rule, two main directions, though a few take a third course. One direction is parallel to the Coast range or northwest-southeast, the second is at right angles to this, the continuation of the transverse valleys of the mountains out into the plateau or northeast-southwest, the third, more or less exceptional course, is that of François lake, almost east-west. The two first are merely continuing the mountain pattern out into the plateau, in conformity with the general Cordilleran lines. The reason for the east-west lines is not so apparent. In some cases they appear to be due to a local peculiarity in the strike of the rocks, in others it may be glacial erosion, the resultant of the northeastward flowing ice-tongue from the mountain valley meeting the southeastward flowing ice-sheet: but some, like the great easterly prolongation of François valley, along the 54th parallel of latitude, occupied by Fraser lake and Nechako river to Prince George, require a different explanation, which the work of the summer fails to supply. All that may at present be said is that they presumably belong to the Fraser River, north-south, east-west pattern.

Glaciation has had a pronounced effect on the topography. Glacial rounding of projecting rock, and glacial ridges and hogs-backs (roches moutonnées) are to be seen wherever rock is exposed, and glacial deposits are also met with—drumlins, kames, and eskers. But it is in the glacial erosion of valleys and the gouging of lake basins that the ice effects are most apparent. Although some of the lakes may be dammed by glacial detritus, all the larger ones examined occupy rock basins. The large ones are long finger lakes, those in the mountains, fiord-like and deep. Eutsuk lake is over 1,000 feet deep, and those in the plateau, such as Ootsa, are over 200 feet.

From the large lakes there is every gradation to the small muskeg enclosed pond. The small lakes are usually of irregular shape and are often island-studded. They not

only occupy rock basins but fill depressions in the glacial drift. Frequently they are walled from the ice shove piling up boulders along these rivers. It is a lake country like northern Ontario or Quebec and for the same reasons. Indeed, were it not for the greater elevations culminating in mountains, the plateau country would remind one strongly of eastern Canada. Many of the smaller lakes and the plateau lakes, such as Ootsa and Sinclair, have lost considerably in area through silting at the mouths of tributaries, and the encroachment of muskegs. The 3 miles of Whitesail river above Sinclair lake, and Tahtsa river from Sinclair to Ootsa lake, where the rivers wind in a wide valley, characterized by stretches of muskeg, beaver meadows, and sloughs, represent areas recently reclaimed from the lakes.

The plateau is an early Tertiary peneplain, with numerous monadnocks, modified by Tertiary lava flows that tended partly to level off the old erosional inequalities of the surface and partly to introduce new ones, the whole dissected again by late Tertiary and recent erosion, but especially by glacial action. The effect of glaciation has not been wholly erosional, considerable glacial deposits having been laid down on the plateau.

The north side of Ootsa lake is for the most part agricultural land, as is a great deal of the country below Ootsa and Francois lakes though occasional ridges or domes of rock and patches of sand or gravel break its continuity. There are limited areas of land along the south side of Ootsa, and again along the lower half of Eutsuk and along Tetachuck lake. Where unconsolidated materials are found in the lower valleys terraces are characteristic. Along Ootsa lake they range from 60 to 590 feet above the lake level.

The Coast range rises abruptly from the plateau without intervening foothills such as flank the eastern side of the Rocky mountains. It towers above the plateau, not because of the hardness of its rocks—for here it consists of stratified tuffs and volcanic flows that are, in general, less resistant than the rocks of the plateau—but because it has been upraised by the folding and faulting of its beds.

As noted above, the main body of Eutsuk lake lies along the flank of the range, the mountains rising sharply from the water along the upper two-thirds of the lake, but the ridge from Chikoman mountain between Eutsuk and Whitesail lakes has a gradual slope down to the portage. North of Whitesail lake a spur from the range runs northeastward, cutting off the view in that direction, but southeastward Eutsuk valley continues along the base of the mountains as far as the eye can reach. Whitesail lake above the bay from which the portage to Eutsuk lake runs; the southwest arm of Eutsuk lake; Bear bay and Pondosey lake at its head; and Tesla or White river, all lie in transverse valleys within the mountains.

The mountains here have an elevation of from about 6,000 to 7,500 feet, and Eutsuk lake is about 2,800 feet above sea. Chef mountain, an ice-capped peak just south of Tesla valley, must exceed 9,000 feet, and from a mountain top other exceptional peaks are discernible. Tree-line does not exceed 4,700 feet and snowfields and alpine glaciers are abundant, the latter often descending considerably below tree-line. Looking westward into the heart of the Coast range the rocks visible through the snow and ice cannot much exceed 10 per cent of the surface. Near the eastern border, however, large areas above tree-line are grass-covered and park-like.

A striking feature of the mountains is the lack of sharp pyramids and horns; broad-based pyramids, blocky flat-topped peaks, or broad, massive, sometimes dome-shaped, mountains are the prevailing types. The ridges are for the most part flat, or gently sloping. Intricate carving is not far advanced. The mountain slopes are usually steep, many being strongly faceted.

The larger valleys are broad and U-shaped, a few of the smaller only are inclined to be V-shaped. Where hard rocks are encountered in the bottom of the valleys, a rock bench is apt to be found, the softer rocks being more deeply entrenched.

Tributary valleys are frequently hanging, the height of these hanging valleys above the main valleys being exceedingly variable, from one hundred feet, or so, to several thousand.

Whitesail and Eutsuk lakes are near the Pacific watershed, and tributary streams are, therefore, short, but although their basins are only a few miles long they are surprisingly large. The streams, as they descend from hanging valleys, are characterized by falls capable, in the larger streams, of power development. The streams draining Eutsuk and Whitesail lakes are large enough to be termed rivers, as is also the Tahtsa.

Vegetation

Between François and Ootsa lakes, open groves are not uncommon with scattered clumps of poplar (aspen). Scrub pine forms thick woods, especially on the sandy or gravelly patches, alternating with meadows and open land clothed with a great growth of natural grasses, pea, and vetch. Spruce is not uncommon in the woods, and alder, willow, and balsam poplar are found on low ground. White and black birch are also met with. Serviceberries and highbush cranberries are abundant.

Approaching the mountains the vegetation becomes heavier but great areas of the timber have been burned. Within the mountains still heavier vegetation is found and near the heads of the valleys it resembles that of the coast. For instance, 8 miles west of the portage on Whitesail, cedar (*Thuya gigantea*) and Douglas fir also become important and Devil's Club is abundant. Tree-line is about 4,700 feet, above which the mountains are grass-covered where vegetation can grow as on the flat tops of ridges, that are, on the whole, extensive.

Climate

There is, of course, a marked difference between the climate of the mountains and that of the plateau. In the mountains the precipitation is excessive as witnessed by the abundant snow and ice. It is much heavier than the normal for the Coast Range. This is due to the fact that the region is not protected from the moist westerly Pacific winds by a mountainous island barrier, as the rest of the range is by Vancouver island and Queen Charlotte islands, and hence gets all the moisture that elsewhere is divided between the islands and the mountains. The western slope of this portion of the range is consequently almost completely buried in snow and ice and even the eastern flank has a high precipitation and carries a large amount of perennial snow.

The snow and glaciers retard summer and produce cloudy days with further precipitation. The summer consequently is very short and the rest of the year is winter.

At the border of the mountains there is a marked change. Precipitation is very much lighter, and for half the year will take the form of rain where in the mountains it will fall as snow. For instance, according to trappers, a few miles west of Whitesail lake, and not much above it, the winter snow lies 14 feet deep on the level, whereas on Whitesail itself, in the mountain section, it is 7 feet, and on the plateau it cannot be more than 3 or 4.

The presence of snow in the mountains does, however, affect the climate of the plateau near the mountains. Cool winds blow down the valleys, cool nights succeeding hot summer days. The large lakes and moist air tend to prevent early frosts.

Leaving the mountains and proceeding towards Ootsa, the influence of the mountains decreases, spring is earlier, the summer longer, and snow does not come until late in the autumn. It is not, however, a dry-belt like the Interior Plateau to the south. The rainfall is sufficient for agriculture. Even in the scrub pine in the gravel patches, mosses grow, lichens hang from the branches, and the rocks support well-developed cariboo lichen.

GENERAL GEOLOGY

The greater part of the district is underlain by igneous rocks and of these by far the larger part are volcanic in origin and contain fragmental volcanics, agglomerates, conglomerates, tuffs, and ash beds which in amount must almost equal—if indeed

they do not actually exceed—the lava flows. The lavas (mostly basic though a few are acidic) are present in tremendous thicknesses. Granitic dykes form numerous bosses, stocks, and laccoliths. Sedimentary rocks are found in small amount at a few points, but are quantitatively negligible.

The igneous rocks range in age from upper Jurassic or Lower Cretaceous to at least Tertiary. As thin sections have not been received yet, these rocks must in this report be given field names. The sedimentary rocks also belong to different ages; the oldest may be Carboniferous, some are upper Jurassic or Lower Cretaceous, and there are a few patches of Tertiary sediments.

Table of Formations

Era	Period	Series	Rocks	Criteria as to age
Quaternary.....	Post-glacial.....	.....	Alluvium White silts.....	Overlies Cordilleran till.
	Glacial.....	.....	Sands, gravels; clays; boulder clay.	
Tertiary.....	Miocene.....	.....	Basalts, tuffs, etc.	Correlation with neighbouring districts, determined by fossils.
			Sandstones Conglomerates....	Unconformable to Cretaceous and preceding rocks.
	?	Intrusives.....	Pink granite Syenite and dyke rocks.	Cut Cretaceous intrusives, do not furnish boulders to Tertiary conglomerates.
Mesozoic.....	Cretaceous.....	Intrusives.....	Grey granitic rocks, granodiorites, etc. Other plutonic rocks.	Cut Porphyrite series, furnish boulders to Tertiary conglomerates.
	Lower Cretaceous or upper Jurassic.	Porphyrite series.	Lavas, ash and tuffs, argillites, and limestones.	Fossils: correlation with neighbouring districts.
Palæozoic.....	Carboniferous ?...	Cache Creek series.	Cherts, argillites..	Lithological resemblance: cut by old-looking volcanics.

Carboniferous (?)

Selwyn and Dawson in the seventies found Carboniferous rocks about Stuart lake, the lower Nechako, and Telegraph mountains, and Dawson found some exposures south of the Eutsuk district. These rocks, which they called the Lower Cache Creek series, included limestones, quartzites, and argillites. Fossils found in the limestones indicated that the series is Carboniferous in age. The rocks are silicified in places, yielding characteristic cherts. East and north of Ootsa Lake, as for instance between Bennett hill and Skin lake, are cherts and spotted argillites and carbonaceous schistose rocks very similar lithologically to the Cache Creek rocks and possibly belonging to this series. But as neither limestone beds nor fossils were found here, there is no positive evidence on this point. On the other hand Cache Creek rocks are known to occur not very far away and these argillites and schists look like Cache Creek rocks. About 5 miles east of Ootsa Lake these carbonaceous argillites are cut by a rusty, brown-weathering, compact felsite. Inclusions of the argillites are held in the felsite, and the intense folding of these rocks near its contact may be due to its intrusion. This felsite probably belongs to the volcanic rocks to be described next.

Upper Jurassic or Lower Cretaceous

Quantitatively the most important series is that consisting of a great volume of volcanic rocks—lavas (generally porphyritic and rather basic), with associated volcanic fragmental rocks, together with a few true sedimentary beds—limestone, argillite, and sandstone.

Dr. Dawson first encountered similar rocks at about Tatlayoko lake and, later, on Salmon (or Dean) river, and to them he gave the name Porphyrite series.

In this series he placed the corresponding rocks on François lake. Since the Eutsuk District rocks are the same as those of Francois lake, Dawson's name Porphyrite series,[1] a good descriptive one, should properly be applied to these rocks. Leach has given the name Hazelton group to what appears, on lithological and fossil evidence, to be the same series in the Telkwa and Hazelton districts. In the Eutsuk district, this series consists of massive lavas usually containing porphyritic crystals in a dense groundmass, volcanic agglomerates, conglomerates, tuffs and ash beds belonging to many successive eruptions and, at a few points with the tuffs and ash beds, a few limestone and argillite beds.

The lavas vary in composition from quartz porphyries and porphyries to basic porphyrites and basalts, but rocks about andesite in composition form the greater part. The lavas vary in colour from white to black; but green, red, and purple are the dominant and characteristic colours. Generally a single flow is green or red or purple throughout, but occasionally a bed is mottled. Sometimes these rocks are fresh-looking, and difficult or impossible to distinguish from the much younger Tertiary flows, but usually they are somewhat altered, especially to epidote, which forms patches or veinlets giving a mottled appearance. The lavas are occasionally vesicular and the vesicles may be filled with calcite. Felsites showing beautiful flow structure and lithophysae represent altered glassy lavas. The associated agglomerates and conglomerates are mostly made up of fragments of the lavas in a lava base. Often the fragments make up the bulk of the rock with little cementing material. In colour these rocks generally resemble the lavas, though occasionally they are made up of heterogeneous fragments of varying tints. Some of the conglomerates contain fragments that look like Cache Creek material. The tuffs and ash beds made up of finer materials are mostly grey or green. They are as a rule well stratified and some at least have been laid down in water, being interbedded with argillites, etc., and some beds, such as the coarse tuffs in Chikoman mountain, are fossiliferous. The thickness of this series cannot be stated, as neither the top nor the bottom of the series was recognized, and it is folded and faulted and disturbed by intrusives. It is, however, very great. Dawson was unable to get a complete section where he studied the series, but was convinced that the thickness exceeded 10,000 feet. It certainly exceeds this in the Eutsuk district.

These rocks are found in all parts of the district, and form the greater part of its rock framework. They are caught up in the folding of the Coast Range and constitute the main rock of all the mountains of the Coast Range actually observed or the nature of whose rocks was inferred from float or by examination through a field glass.

Sedimentary rocks were occasionally seen. On Whitesail lake near Harrison's cabin about 7 miles west of Portage bay, a crystalline dolomite occurs. Around the point about 2 miles farther west, interbedded with tuffs, are a few seams of argillite and plant remains, and on the east side of the entrance to Little Whitesail lake, near the head of Whitesail lake, are some argillites. On Eutsuk lake impure limestone with a little argillite occurs on Iron point between St. Thomas bay (of which Portage bay is an arm) and the main Eutsuk lake. Argillites also occur near the end of this reach

[1] Geol. Surv., Can., Ann. Rept., 1876-77, p. 58.
Geol. Surv., Can., Sum. Rept., 1910, p. 93.

of Eutsuk lake, on both the north and south shores. Here the rock contains a few imperfectly preserved fossils. Fossiliferous rocks are found on both sides of Beaver point (south shore just south of the east of Eutsuk on Figure 8) within a mile of the point.

The dip of the rocks of this series varies greatly, but the strike is usually northwest, or parallel to, the general structural lines.

In age the rocks of this series are upper Jurassic or Lower Cretaceous. From fossil evidence Dawson concluded that his Porphyrite series bridged the gap which usually separates the upper Jurassic and Cretaceous. The corresponding Hazelton series is upper Jurassic or Lower Cretaceous according to fossil evidence.[1] From Tahtsa river a little below Tahtsa lake, J. D. Galloway reports fossils belonging to the genus *Aucella*, and states that they are diagnostic of Lower Cretaceous age.[2]

As mentioned above, some fossils were obtained from Eutsuk lake. The most promising fossil locality, however, was near the summit of Chikoman mountain on Nickel Plate No. 2 claim where certain tuffs are fossiliferous. It is quite possible that a careful search here would result in the discovery of determinative fossils. Unfortunately bad weather prevented more than a purely chance collection being obtained.

F. H. McLearn makes the following preliminary report on the fossils of the Eutsuk Lake district collected last summer.

"Chikoman mountain
Trigonia cf. *dawsoni*
Perisphinctes ? sp.
Inoceramus sp.
Coal outcrop, Whitesail lake.
Indeterminate plant remains.
S.E., Sta. 58, Eutsuk lake.
Trigonia cf. *dawsoni*
Belemnites sp.

Note on Correlation. The ammonite *Persphinctes* ? sp. and the *Belemnites* sp. are not well enough preserved for determination or comparison. The *Inoceramus* sp. does not indicate any age. The *Trigonia* cf. *dawsoni* belongs to a group of Trigonia found in both Jurassic and Cretaceous. There is a very close form in beds at Iltasyonoco lake, B.C., and in beds east of Zymoetz lake. A little more remote form is found at Alliford bay, but whether in Yakoun or Haida or Honna formations I could not say; Stanton reports a *dawsoni*-like species in the Yakoun (middle Jurassic) form, presumably, Alliford bay."

The fossil evidence from Eutsuk district is not determinative, but does point to upper Jurassic or Lower Cretaceous and increases the probability of the correctness of the correlation with Dawson's Porphyrite series and Leach's Hazelton series.

Cretaceous Intrusives

Intrusive in the Porphyrite series are granitic rocks that disturb and to some extent alter them. The granitic rocks which are probably connected with the Coast Range batholithic intrusions, are generally greyish in colour, medium to fine grained, and they range from granite to gabbro in composition. Granodiorite and diorite appear to be the commonest facies. They occur in bosses, stocks, laccoliths, dykes, and sills. When in small dykes or sills they may be porphyritic and sometimes typically dyke rocks like pegmatites and lamprophyres. Most of the isolated hills, ridges, and dome-like mountain masses that stand up above the general plateau level are composed of these rocks, at least in their central cores. The preservation of the older, softer rocks may be due to the protection afforded by these hard diorites, or to the alteration and silicification produced in them by the contact metamorphism of these intrusives. Thus, Bennett hill, Sugarloaf and associated hills east of Bennett

[1] O'Neill, J. J., Geol. Surv., Can., Mem. 110, p. 4.
Schofield, S. J., Geol. Surv., Can., Sum. Rept., 1920.
[2] Report of Minister of Mines, B.C., 1916, p. 150.

and south of Skin lake, the hills north of Skin lake, and Grassy mountain south and east of the west end of Ootsa lake are all due to these granitic rocks. Numerous exposures of these rocks occur on Whitesail and Eutsuk lakes. In many cases the projecting points of the lakes consist of dykes or little bosses of such rocks, as do many of the benches and knobs that break the symmetry of the characteristic U shapes of the lower slopes and bottoms of the mountain valleys.

In the Coast range the granitic rocks are mostly confined to the lowest valleys, the mountain masses themselves consisting largely of the Porphyrite series with only occasional dykes from the granitic rocks. In other words, in this part of the Coast range it is only in the deeper valleys that the granitic rocks have been uncovered, and these are only stocks, bosses, and dykes that have penetrated into the invaded rocks to higher levels than the general mass of the batholith which is nowhere exposed. Farther west the Coast Range batholith no doubt forms the mountains as it does elsewhere along the coast, but these granite mountains could not be recognized from any point reached this season. The numerous granitic erratic boulders suggest granitic mountains to the northwest. At some points, especially along the coast, the Coast Range granitic rocks have been pretty well established as upper Jurassic in age, but here the intrusions are evidently Cretaceous for they cut the Porphyrite series, and, in the Telkwa district a little to the north, the Skeena series, a definitely Lower Cretaceous formation. They cannot be much younger than Lower Cretaceous, however, for these plutonic rocks cooled a considerable distance below the surface and some of them have been unroofed by erosion and deeply eroded before the Tertiary rocks were laid down. This is shown by the boulders of these granitic rocks contained in a Tertiary conglomerate on islands in the expanse at the foot of Pondosey lake. Furthermore, Dawson observed Tertiary rocks resting on the eroded surface of the granitic rocks a short distance east of Tetachuck lake.

Tertiary ? Intrusives

Cutting the Porphyrite series and the grey granite rocks are red and pink and sometimes white granite rocks, sometimes quartzose but often with no visible quartz. When without quartz they resemble alkali syenite (pulaskite) in appearance. In small dykes they are porphyritic and where quartzose may show quartz phenocrysts. Some fine-grained dykes like rhyolite and trachyte may also belong to these eruptions. They may be seen about the west end of Ootsa lake and cutting the older rocks of Whitesail and Eutsuk lakes. Their light colour makes them conspicuous against the purple, red, and green rocks of the mountains.

Their exact age has not been determined. They are younger than and cut the Cretaceous intrusives. No boulders from them were noticed in the Tertiary conglomerates. They are presumably Tertiary and may be connected with the Tertiary volcanics.

Tertiary Sediments and Volcanics

Unconformably overlying all the preceding rocks with the possible exception of the Tertiary intrusives, is a series of conglomerates, sandstones, ash rocks and lavas (mostly basalts), tuffs, etc. These rocks are exposed on François lake and very extensively in the country to the east and south where Dawson determined their age to be Miocene.

The sedimentary rocks at the base of the series contain plant remains and occasional beds of lignite.

The lavas are usually basic in heavy beds with often perfect basaltic jointing. The upper surface of a flow is often vesicular and the vesicles are usually empty, though in places agate is developed in them.

These Tertiary rocks are developed between Burns lake and François lake and also south of François lake. Some rocks in Ootsa lake, also, appear to belong to this series. Patches are almost certainly to be found in the plateau country, but as much

of this is overlain by glacial drift and recent deposits, they are apt to be concealed. The exposed rocks from the bluff just west of Ootsa Lake to the white cliffs about 6 miles west are considered to belong to this series. The rocks at White cliffs are white ash beds, tuffs with fragments of the older rocks, and a finely-jointed rhyolite, which weathers pink and black from a slight content of manganese. These rocks are assumed to be Tertiary also. South of here, up Wells creek, are some sand rocks with patches of lignite that may also belong to the sedimentary portion of the series.

At the foot of Pondosey lake, a southwest arm from Eutsuk lake, are volcanic conglomerates and lavas of Tertiary age as shown by the granite and vein material boulders of the conglomerate. On the flat north of the widest reach of Eutsuk lake four buttes, in line, rise a few hundred feet above the flat. The most easterly one was found to be of black Tertiary basalt, from the directions of the jointing probably a volcanic plug. The others are probably similar.

Although the Tertiary rocks are usually much fresher in appearance than those of the Porphyrite series; are less disturbed; are generally more basic and as a rule easy to distinguish, yet where the Porphyrite series lavas are fresh it may be difficult or impossible to classify them with certainty. Some lavas west of Portage bay and some from the head of Bear bay through to Pondosey lake may perhaps be Tertiary. As those at the head of Bear bay are closely associated with the Tertiary conglomerates of Pondosey lake this would appear probable, but if so, the Tertiary is involved in the mountain folding. In this connexion it might be mentioned that a piece of fresh obsidian was picked up on Portage bay.

Structure

The rocks in the mountains are folded and faulted, but mostly lie at low angles; a vertical attitude is exceptional and soon gives place to lower dips. The strike is generally parallel to axis of the range but local variations occur. In the plateau country exposures are only occasional, most of them being the more resistant granitic rocks or the older rocks near their contact and hence disturbed by them, but on the whole the same structural lines prevail as in the mountains.

Glacial Geology

The heavy glaciation has given the plateau country somewhat the appearance of northern Ontario or Quebec, and the mountains the characteristic features of the northern Coast range.

Wherever rocks are exposed they show roches moutonnées, furrows, fluting, crescentic gouges, and where the rock is hard and fine grained or protected from weathering, beautiful polishing and striations. Many if not all of the lakes occupy glacial rock basins. The mountain valleys are modified by ice, the spurs truncated, and even the tops of ridges and many summits planed off. Where the peaks are not flat-topped, they are domed or broadly pyramidal. Into the massive, rounded or dome-shaped mountains, torrents are beginning to channel and alpine glaciers to cut cirques, but as a rule they have not yet made much headway.

Erratic boulders are found everywhere, and on the plateau occur boulder clay, kames and eskers, and similar glacial deposits. Sands and gravels and other outwash material are plentiful, and silts, which probably represent such material, are found on Ootsa lake and the lower two-thirds of Eutsuk lake.

The directions of ice movement are indicated by the erratics, fluting, crag and tail, gouging and chatter marks, stoss and lee and striations.

The main direction in the plateau is parallel to Ootsa and Eutsuk lakes, or not quite southeast. Individual readings varied from 120 degrees to 141 degrees. Superimposed upon the major features produced by ice moving as above in places there is minor fluting and striating from 63 degrees to 100 degrees, evidently due to late local ice.

Heavy local ice streams come down the mountain valleys, particularly Whitesail, the southwest arm of Eutsuk lake, Pondosey lake, Bear bay, and Tesla valley. These ice streams were responsible for the gouging of these basins that received ice from several branching valleys at their heads, which coalescing and compressed into one valley gouged it deeply. Whitesail valley steps down, from a hanging valley about 100 feet above the lake, to 400 feet below its surface, reaching 700 feet deep in less than 3 miles and its maximum depth—over 800 feet—within 6 miles. It gradually lessens to about 300 feet at the northerly bend and from that to its rock lip. The southwest arm of Eutsuk lake, within a few hundred yards, drops from about 80 feet above the lake to over 560 feet below it. Receiving ice from the west it rapidly deepens, reaching its maximum depth, over 1,000 feet, within 6 miles of the head. Some of the ice from this arm continued into St. Thomas bay before turning southeast, but the main mass turned down Eutsuk lake. The main lake is much shallower, declining to about 400 feet at the first narrows and 250 feet at Bear bay. The ice from Pondosey lake and Bear bay, however, turned down the lake, increasing its depth at once to over 700 feet, from which it gradually declines to the outlet.

The main southeasterly glaciation is evidently the work of an ice-sheet, the Cordilleran glacier of Dawson. This sheet was at least thick enough on the plateau to override Nadina mountain, Stoney mountain, and other monadnocks, some of which reach about 6,000 feet above sea, for they are beautifully rounded by the ice.

Chikoman mountain, over 7,000 feet high, was the highest point ascended. The ice-sheet overrode this point as shown by the erratics and the southward trend to the fluting on its western slope. The western ridge between it and the next peak is planed off to a park-like area several miles wide. Here the fluting and ice-formed ridges run about 160 degrees toward the main body of Eutsuk lake. The shape of the peaks makes it probable that the ice-sheet went over much higher ones. Chef mountain, just to the south of Tesla, estimated over 9,000 feet, is flat-topped and bears an ice cap several hundred feet thick. Similar high summits, observed at other points, were almost certainly overridden and their existing ice caps may be considered remnants of the ice-sheet. Ice no doubt flowed out of the mountain valleys to the plateau under the southerly and southeasterly flowing ice-sheet, and they continued to send out strong valley glaciers long after the ice-sheet had retreated. Alpine glaciers still reach to within a hundred feet of the lake levels. A valley glacier several miles long is reported at the head of Whitesail lake and is said to descend a long distance through the timber, to an elevation of 400 or 500 feet above Whitesail lake.

The freshness of the glaciation, the lowness of the timber-line, and the remnants of valley glaciers and ice caps, the extent of present snowfields, and above all the rounded summits, planed-off ridges, and limited number and smallness of the cirques, show that an extremely short time, geologically, has elapsed since this district emerged from its last period of glaciation. Post-glacial terraces are so widespread throughout British Columbia as to suggest a common origin. But the disappearance of the ice from this district must have been so much later than from southern British Columbia, that the terraces here are probably much younger, and are, therefore, perhaps due to local causes, such as ice or morainal damming. Work farther east about the outlets of François, Ootsa, and Tetachuck lakes would be necessary to obtain direct evidence as to this.

ECONOMIC GEOLOGY

Apart from limited work, principally by trappers who have staked claims on Chikoman mountain from Whitesail lake to the summit, this district may be said to be unprospected. It was, before the construction of the Grand Trunk Pacific railway, totally inaccessible and even now the distance from the railway and the necessary travel in small boats, serve to deter most prospectors. In the circumstances, the amount of work already done is rather surprising.

A well-known property, the Emerald group, on Sweeney mountain, up Tahtsa river, is a little north of the district examined. A trail was being constructed from Ootsa lake to the property in the summer of 1920.

On the south side of Whitesail lake about 8 miles west of Portage bay, is the Cariboo group of claims with a cabin on the shore. A short distance east of the cabin, an open-cut in the shore discloses a tuff or agglomerate, altered to a talc-like material and somewhat silicified and pyritized. A little purple fluorite forms a thin encrustation on an occasional fracture plane.

A few hundred yards farther east, a green porphyrite and green tuff that weathers to a brown, iron-rich crust, is veined by calcite. Druses in the vein are lined with dog-tooth spar. A little work has been done on an 8-inch vein of carbonates, and quartz carrying some zinc blende.

About one-quarter mile from the cabin, a tunnel has been driven 50 feet in tuff that is somewhat sheared, impregnated with pyrite, and seamed with small veins of calcite and quartz. At the end of the tunnel a crosscut 100 feet long has been run to the east to test parallel sheared zones.

The veinlets carry zinc blende in diminutive shoots a few inches to a foot long and 1 inch to 6 inches wide. The largest veinlet has a maximum width of about 14 inches. With the zinc blende is a little pyrite, chalcopyrite, and galena. Galloway's[1] sample of this vein yielded gold, trace; silver, 1·2 ounce; zinc, 30·5 per cent. About a ton of ore was visible on the dump.

At the head of the little bay about 1½ miles past the cabin, a trail ascends Chikoman mountain to the Silver Tip workings and the Nickel Plate cabin.

The Silver Tip workings are situated about 1,150 feet above the lake, and consist of some surface work in the bed of a stream, and a tunnel about 40 feet long with a 17-foot crosscut at the end. The lead has been exposed at several points in the stream bed and has been followed by the tunnel. Its strike is roughly 170 degrees, dip 75 degrees west. The country rock is porphyrite. The lead is a sheared and fissured zone; some of the fissures are filled with gouge and some are filled with vein matter. The veinlets vary from paper thin to 6 inches in width. They branch and reunite: a 5-inch vein may separate into three or four stringers, of about the same aggregate width.

The ore consists of galena, massive and coarsely crystalline, and some steel galena with zinc blende, pyrite, arsenopyrite, and chalcopyrite. The gangue of the veinlets, small in amount, is quartz carbonates and a talc material.

About 30 tons of ore was said to have been produced in driving the tunnel, but a considerable amount of this has been carried off in the spring freshet.

Galloway,[2] who sampled the dump, states that this ore ran as follows: gold, 0·28 ounce; silver, 32 ounces; lead, 22 per cent; zinc, 20 per cent.

The cabin is at timber-line, 1,850 feet above Whitesail lake. Eight hundred feet above the cabin is a tunnel on the Nickel Plate vein. This is a small but persistent vein that runs to the top of the mountain, 2,500 feet above the cabin, cutting across the porphyrites and tuff. The vein consists of about 15 inches of quartz fairly well mineralized with galena, chalcopyrite, blende, tetrahedrite with possibly a little ruby silver. The quartz is as a rule fine-grained and the sulphides occur in little fractures in the quartz that are sometimes approximately parallel, giving the ore a banded appearance. These bands of sulphides are rarely more than one-half inch wide and are often almost paper thin.

Above the tunnel several open-cuts have been made, and 900 feet higher there is a second tunnel. Some high assays in silver are reported and the ore certainly looks as if it should carry good values, but grab samples taken by the writer yielded only 15 and 24 ounces respectively.

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[1] Ann. Rept., Minister of Mines, B.C., 1916, p. 166.
[2] Ann. Rept., Minister of Mines, B.C., 1919, p. 105.

On a shoulder of Chikoman mountain to the northeast of the cabin, a vein of chalcopyrite is reported to occur and below it, in a canyon, manganese ore, but snow prevented an inspection of these occurrences.

At a number of points along Whitesail lake, small veins up to a foot wide of calcite, siderite, and quartz, slightly mineralized, were seen, and sometimes areas of rock, silicified and impregnated with pyrite.

The tuffs seem to be most susceptible to mineralization, though the porphyrites are also mineral-bearing, and, at one or two places, the granodiorite was slightly mineralized.

Although the discoveries so far made would not justify opening up the country for mining, they are of distinct value as an encouragement to prospecting. Not only are the general geological conditions favourable but there is definite evidence that there has been, in places, important mineralization. The geology is very similar to that of the mineralized areas of Salmon river and Hazelton to the north—tremendous thicknesses of lavas and tuffs, with subordinate amounts of argillite and limestone, have been invaded by later intrusions.

The main Coast Range batholith lies an unknown distance to the west of the area under discussion and it may be that mineralization is more extensive nearer the larger intrusion. Copper ores in particular are more likely to be in closer proximity to its contact with the Porphyrite series.

It is possible that the granodiorite exposed at the lower levels, such as the shores of Whitesail and Eutsuk lakes, may represent protuberances from a main batholithic body not yet unroofed, but this is regarded as unlikely on account of the general freshness, altitudes, and lack of metamorphism of the rocks of the Porphyrite series, and the character of the veins which typify deposits formed under conditions of only moderate heat.

But prospecting need not be confined to the mountains. In the plateau are numerous intrusions near which ore deposits might occur. So far as could be learned, these have not been prospected. The outcrops of such intrusions are usually found easily by reason of their resistance to erosion, which causes them to stand up above the surrounding country. Judging by the size of some of these outstanding masses, the intrusives must be of considerable extent. From the prospector's viewpoint, there is the great advantage that such ground is much more accessible from the railway.

It is true that no important mineralization was observed about the intrusives near Ootsa Lake, but here the invaded rocks may belong to the Cache Creek series, in which case they were cherty and, therefore, unkindly before the intrusion. In some cases the easily replaceable tuffs of the Porphyrite series will certainly be found near the contacts of the intrusives and are there likely to be mineralized. Northeast of the railway, toward Babine lake, promising deposits have been found, and from what was seen of the geological conditions in the country to the southwest of it it is reasonable to expect this experience may be repeated. A possible difficulty, in the way of prospecting, may be to find sufficient outcrops away from the intrusive itself.

Other Economic Materials. A trifling amount of vegetable remains and coaly material was found in argillites associated with tuffs of the Porphyrite series on Whitesail lake about 2 miles west of the Silver Tip trail; and a little impure lignite up Wells creek, south of Ootsa lake. In a large partly petrified root at the latter locality fossil resin occurs, some clear yellow and some a clouded yellowish white. The largest piece was ⅜ inch wide and about 3 inches long. The pieces examined were too brittle for use as amber.

There is a possibility that lignite beds of local importance may be found in Tertiary sandstone underlying the Tertiary volcanics. Dawson[1] reports a 4-foot seam of good quality on Nechako river below the mouth of the Cheslatta.

The rhyolite and associated tuffs on Ootsa lake, and white rhyolite dykes in the Porphyrite rocks might be suitable for stoneware or porcelain.

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[1] Geol. Surv., Can., Ann. Rept., 1876-77, p. 82.

The numerous falls and rapids furnish sources of power that will prove valuable in the case of mining or other development.

Other Economic Possibilities. The district also possesses possibilities in stock raising, dairying, bee-keeping, and as a hunting, fishing, and tourist resort.

Where soil occurs it is exceedingly rich and productive as attested by the luxuriant growth of native grasses, vetch, and wild pea. In addition to the open spaces much of the timbered land about Ootsa lake is sufficiently open for pasturing, and the hills and mountains above timber-line would afford much summer pasture. The abundance of fireweed (*Epilobium angustifolium*) and other honey-affording plants furnishes a plentiful field for bees, and the winter ensures that they would rest without requiring much food. It should, therefore, prove an excellent district for the bee-keeper.

It should prove an attractive spot for tourists, combining plateau, mountain, and lake country, fishing, duck and goose shooting, and big game hunting. For scenery it cannot be excelled. Not only is there the contrast between the mountain with its snowfields and glaciers and the lake and plain in one view, but there are colour effects due to the red, purple, green, and white rocks of the mountains that are seldom seen outside the desert. These desert colours combine with the characteristic tints of the snow-capped mountains and the blues of the distant hills across the plains and down the lakes, to make a picture of surpassing beauty.

LARDEAU MAP-AREA, BRITISH COLUMBIA

By M. F. Bancroft

The Lardeau map-area, which lies between west longitude 116°49′ and 118°20′ and between north latitude 50°05′ and 51°06′, is about 68 miles in longitude by 72 miles in latitude and about 4,870 square miles in area. It lies mostly within Kootenay district, but includes along the western edge of the area a narrow strip of territory belonging to the adjoining land districts of Kamloops and Osoyoos. Eight mining divisions are included within its limits. The Trout Lake mining division is centrally situated in the area and parts of the Ainsworth, Slocan, Lardeau, Golden, Revelstoke, Arrow Lakes, and Vernon mining divisions fill out the remainder.

Approximately one-half of the map-area has been topographically surveyed on a scale of 4 miles to 1 inch with contour intervals of 500 feet. The mapped area covers those parts of the Lardeau district that were most actively prospected in the early days, from the head of Kootenay lake at the southeast corner of the map to the crossing of the main line, Canadian Pacific railway, in the northwest corner of the sheet. This area thus embraces part of the Illecillewaet river west of Albert canyon, the Columbia river from Revelstoke to Arrowhead, the Incomappleux river north to Boyd creek, the Trout Lake-Lardeau River valley and the Duncan River-Duncan Lake valley to Hall creek. The watershed of the upper Duncan and its main branch the Westfall (previously known as the West Fork of Duncan), crosses the northeast part of the area from the head of Boyd creek. Another watershed extending from the head of Davis creek northward forms the divide between Lardeau River-Trout Lake valley and the drainage areas of Slocan and Upper Arrow lakes and bounds the area on the southwest.

The Lardeau district is readily reached from Revelstoke on the main line of the Canadian Pacific and from points south by steamer service on Arrow lake. A daily passenger and mail service is maintained between Arrowhead, Beaton, Camborne, Trout Lake, and Ferguson.

FIELD WORK AND ACKNOWLEDGMENTS

Geological mapping of this area was undertaken by the Survey in 1917 and continued in 1918, carrying the geological boundaries northward from the Sandon map-

sheet to the vicinity of Trout lake and during the season of 1920 the work was resumed about Trout lake, Ferguson, and Camborne. Field work was greatly hampered by a cold, backward spring and effective work could not be carried on above timber-line until after the middle of July. Many forest fires, started during the latter part of July by lightning low on the mountain sides, continued to burn throughout August, the smoke completely obscuring the mountains. This condition prevailed up to September, when prolonged rain made field work impossible.

The writer was ably assisted by M. E. Hurst and two first-year student-assistants, H. Downer and G. A. Good. Thanks are due to prospectors and mining men for kind assistance rendered both at Ferguson and Camborne.

HISTORY

Previous to the Yukon "gold rush," the Lardeau district was being actively prospected. The Lardo-Duncan Improvement Association, operating from Kaslo, published in 1898 a mineral claim map, showing many scattered groups of claims east and west of Duncan and Lardeau rivers. At that time much ground had been staked in the summit portion of the Duncan range up from Westfall river and across Ferguson (previously North Fork of Lardeau) creek to near Ferguson.

A mineral claim map of the northeast section was compiled and published by Cory Menhinick showing the claims located south and east from McDougal creek in the territory adjacent to Camborne and the valley of Incomappleux river.

In 1901 S. Shannon and A. P. Cummins of Ferguson published a map showing the continuity of mineral belts in a northwest direction across Ainsworth, Trout lake, and Lardeau mining divisions. These local maps gave considerable publicity to the district at that time and they now serve to call attention to the limited progress of mining development there in the past twenty years.

PHYSIOGRAPHY

The Lardeau district lies entirely within the Columbia system of the central belt of the western Cordilleras of Canada. The Columbia system as defined by the Geographic Board of Canada in 1918 embraces from east to west, the Selkirk mountains, Monashee mountains, and, northward, the Cariboo mountains.

Parts of two of the chief members of the system lie within the Lardeau map-area, where the Columbia-Arrow Lake valley forms the dividing line between the Selkirks on the east and Monashee mountains formerly referred to as the Gold range on the west.

The valley of the south-flowing Columbia river and its expansion, Arrow lake, is regionally known as the Selkirk valley or Selkirk trench. Its northward extremity is near the 52nd parallel, where it joins the Rocky Mountain trench. The southern end of the trench is about 60 miles south of the 49th parallel, where the Columbia enters the great basalt plateau of Washington. This major trench separates the Selkirk mountains from the Monashee mountains in Canada.

Two other longitudinal valleys effecting the drainage of the Lardeau map-area within the Selkirk mountains are of regional importance. The mountains of the Purcell range are separated from the rest of the Selkirk mountains by the northward trending valley of Kootenay lake and Duncan river. This natural boundary has been called the Purcell trench, embracing the valley of Beaver river to its junction with the Rocky Mountain trench. The second trench referred to above is that separating the Slocan group of mountains from the Valhalla group; it is occupied by Slocan lake and Slocan river.

The chief valley of the Lardeau district is the trough extending southeastward through a low pass, from the Northeast arm of Arrow lake and occupied by Trout lake and Lardeau river. This major valley, with the valley of Kootenay lake, forms a north to northwest trending intermontane trench, since as a topographical unit its trend reflects the general structural trend of the region.

Parallel Trenches. Kootenay Lake-Lardeau River trench has a counterpart to the west where a small valley crosses the Arrow Lake watershed southeastward from Nakusp to the head of Slocan lake. The parallel relation of this major trench on the east to the minor trench on the west is a most striking physical feature in the map-area. Furthermore, it is clear that in the Kootenay district there is an exceptional development of intermontane valley trenches, which form both local and regional natural boundaries between different members of the Columbia system. The valley of Columbia river, northward from Columbia lake in the Rocky Mountain trench, where it forms the boundary between the Beaverfoot range of the Rockies on the east and the Purcell range on the west, approximately parallels the Lardeau River valley. The parallel linear arrangement of three intermontane troughs in such close proximity is clearly one of the outstanding features of the drainage system of this region.

There are also striking parallels in respect to tributary valleys, both those conforming to the underlying structures and those valleys which cut across the trend of the upturned formations. For instance the Columbia valley, averaging more than a mile in width from Revelstoke to the head of Arrow lake, parallels in direction the northwest and southeast portion of Lake Creek valley on the east side of the Lardeau map-area, in general conformity to the regional trend of the underlying structures. Parallel tributary valleys excavated across the structural trend of the formations are a common feature in the drainage systems of Lardeau and Duncan rivers. The same feature shows on a larger scale locally in the valleys of the Illecillewaet and Incomappleux rivers. Incomappleux river southwest from Boyd creek and the Northeast arm of Arrow lake form a parallel with the Illecillewaet back from their junction with the Selkirk trench. The pronounced parallels in the drainage system of this region have many parallels in the underlying structures, and other geological features east to west in both the Rockies and Columbia systems.

GEOLOGY

The physiography of the Rockies and Selkirks is to a considerable degree related to certain broad geological structures common to the southeastern section of the western Cordillera in Canada. The parallel trough-like valleys, which constitute so marked a feature of the Kootenay district, are separated by and have been developed between similarly folded zones of strata. Formational units of widespread character are included in the folded structures of both the Rockies and Selkirks; trending northward from the International Boundary the oldest rocks found in the Rockies are continuous westward into the Purcell range and are there similarly folded.

Collectively the older rocks of the Cordillera have been classified into a number of rock series, which form parts of the Belt terranes of southeastern British Columbia, Montana, and Idaho. At least the relation[1] of the Galton series, of the Galton range of the Rocky Mountain system, to the Purcell series of the Purcell range, has been worked out in the neighbourhood of the Rocky Mountain trench and near Elko, on the Crowsnest branch of the Canadian Pacific railway. One section examined in 1913 showed the uppermost formation of the Galton series stratigraphically beneath the Burton formation, in which fossils were found of Lower-Middle Cambrian age.

The Cambrian rocks and later Palæozoic formations developed in the Rocky Mountain system are persistent for miles northward from the area occupied by the Belt terranes. Their correlation across the trend of the region has proved a difficult matter owing to the scarcity of well-preserved fossils in the Palæozoic rocks of the Selkirks. One fauna, obtained in 1920, from the limestone beds of the Lardeau area, seems to represent at least one of the faunas which characterize the lower half of the Carboniferous in the Banff section of the Rockies.

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[1] Schofield, S. J., Mus. Bull. No. 2, pp. 79-91, 1914.

Near the close of the Palæozoic and possibly up into the Mesozoic the Selkirk and Rocky Mountain regions were alike subject to transgressions of the sea, with prolonged periods of sedimentation. In both the Slocan and Lardeau areas a considerable development of limestone beds yields fossils of Pennsylvanian age.[1] The fossils obtained in 1920 from the Lardeau area are considered to belong to a Mississippian fauna and it remains uncertain what Palæozoic horizons earlier or later than the Carboniferous may yet be discovered in this section of the Selkirks. Infolded rocks of possibly Jurassic[2] age were found by the writer in 1919 in the Sandon map-area. No definitely Cretaceous sediments have been discovered in the Selkirks.

The regularity of the geological boundaries between the upturned sedimentary formations of various areas is a notable feature in different areas of the Rockies and Selkirks. These areas furnish a key to the general parallel arrangement of zones of folding and, moreover, indicate buckling of these folded structures. Where changes in the general trend occur, concentric structural arcs of minor and major rank are outlined by parallel bends in the geological boundaries. In spite of minor irregularities in folding prominent formational units follow the regional trend with great continuity and persistence and their repetition laterally in the different zones of folding shows that they were once widespread.

The regularity of the geological boundaries in the Lardeau is comparable to that shown in the geological mapping on the Banff map-sheet in the Rockies[3] and in the mapping of the foothill region in southern Alberta[4] where the formations occur in similar well pronounced structural arcs.

Areas with less regular geological boundaries are also common to both the Rockies and Columbia systems. Comparable massive structural features are depicted in the Field map-area (Map 142A, 1915) and the Cranbrook map-sheet (Map 147A, 1915).

In respect to detail structures, corresponding zones of folding occur in both the Rockies and Selkirks. Sharply folded structures, overturned to the west, with the strata dipping generally to the northeast, are characteristic of certain folded zones both east and west of the Rocky Mountain trench; for instance, in the Beaverfoot[5] range of the Rockies and in the Duncan range of the Lardeau, the folded structures are of this character. It is worthy of note, in view of the proximity of these ranges, that the Rocky Mountain trench, where it forms the west boundary of the Beaverfoot range, is parallel to the Lardeau River-Trout Lake valley, which forms the western boundary of the Duncan range.

A major flexure of the strata and folded structures between latitudes 50 degrees and 51 degrees has become evident through topographical and geological mapping of the formations in the Selkirks and Rockies. A series of structural arcs or curves has been produced by a bowing of the strata eastward at this latitude.

The geological boundaries of the folded formations on the west side of Kootenay lake have been traced north of the 50th parallel into the Lardeau map-area. At Ainsworth the formations strike northward in parallel bands which continue into the Sandon map-area. North of Kaslo these formations begin to swing to the northwest and the curvature of the geological boundaries is pronounced about the head of Schroeder creek along the watershed of the Blue ridge.

On the east side of Kootenay lake no field work has yet been done in the area where a similar bending may be expected to occur.

The formations northeast of Lardeau river have a general northwest to southeast strike and when followed to the southeast it is found that this strike is maintained across lower Duncan river into the Purcell range.

The feature of lateral regularity in the formational boundaries is prominent in

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1 Bancroft, M.F., Geol. Surv., Can., Sum. Rept., 1917, pt. B, pp. 36-37 B.
2 Bancroft, M. F., Geol. Surv., Can., Sum. Rept., 1919, pt. B, p. 43.
3 Inter. Geol. Cong. Guide Book No. 8, pt. II, p. 188, 1913.
4 Geol. Surv., Can. Mem. 112. Outline map, Pub. No. 1712.
5 Allan, J. A., Geol. Surv., Can., Guide Book No. 8, pt. II, 1913.

the Lardeau and a similar parallel arrangement of formational bands characterizes the folded strata on the west slopes of the Purcell range south of the 50th parallel. In the vicinity of Crawford bay the general strike of the formations is from north to north 15 degrees east. Followed southward their geological boundaries cut across the main valley of Kootenay lake, the general trend of the sedimenatry formations being to the southwest.

From a regional standpoint the northwest-southeast trend of the rocks of the Lardeau together with the regular north to northeast trend of the formations in the area east of Kootenay lake, suggests that the axis of a major structural curve is also outlined in Selkirk mountains by the general trend of formations on the west slope of the Purcell range.

Geological mapping west of the Purcell trench and northward from the International Boundary shows that the sedimentary formations over a wide area at latitude 49 degrees are equally regular, the formations occurring as roughly parallel bands of great continuity, trending north to northeast. These formations are no doubt the southward extension of the formations found on the west slope of the Purcell range east of Kootenay lake.

Passing from the Selkirks eastward between latitudes 50 degrees and 51 degrees a consistent bowing of the structures is evident in the general configuration of Cordilleran region. Departures from the general strike of the folded formations give rise to structural arcs of great magnitude, and in corresponding degree the physiographical features depict this structural change from west to east.

A major flexure of the strata and structures occurs in the Rockies near the north end of High Rock range on the continental divide, which there forms the Interprovincial Boundary between British Columbia and Alberta. A corresponding bending of the structures to the northwest is evident in the Front range of the Rockies in the vicinity of Highwood river and again in the foothill region where Highwood river debouches eastward across the regularly folded structures. A pronounced topographical feature is the change of direction of the parallel strike ridges from north to a northwest direction and this change of strike is noticeable even in the tiny hogsback ridges out on the prairie.

The critical area of bending in the structures of the Rocky mountains north of the 50th parallel is covered to some extent by the Upper Elk and Upper Highwood Rivers map, No. 1754, published by the Survey. In that area the bending to the northwest in the general regional strike of the rocks gives rise to an entirely different kind of topography, quite in contrast with the regularity of feature presented by the frontal range of the Rockies south of Highwood river. In 1885 G. M. Dawson[1] noted a marked development of comb-like spurs, nearly at right angles to the range and to the general strike of the formations in the foothills bordering the Highwood range. It seems certain that erosion has taken advantage of structural lines of weakness across the strike of the formations to produce this type of topography, which is distinctly characteristic of the area of maximum bowing of the structures eastward.

It is certain that in the Rocky mountains the flexure of the structures is consistently portrayed in the physiography. The valley of Kootenay river, on the east side of the Brisco range, parallels the Rocky Mountain trench on the west side of this range, both striking to the northwest. The trend of these two parallel valleys is in contrast to the north and south trend of two other parallel valleys, those of Bull and Elk rivers south of latitude 50 degrees. And in so far as these smaller parallel valleys have proved a valid key to the structure, it seems reasonable to consider that the three parallel troughs, namely the Rocky Mountains trench, the Kootenay Lake-Lardeau River valley, and Nakusp-Slocan Lake valley, furnish a key to the unity of structure throughout the whole southeast section of the western Cordillera in Canada.

Passing from west to east the set of parallel intermontane trenches noted above show parallel curvature of trend and an increase in magnitude, characteristics which

[1] The Rocky mountains, Geol. Surv., Can., Ann. Rept., 1885, pt. B., p. 95 B.

seem to reflect the dominant structural lines of the region in the vicinity of the 50th parallel. Also, the points of departure in the trend of these major valleys line up in a general northeast direction, corresponding to the direction of the zone of maximum flexure eastward in the folded structures at this latitude.

Drainage of the Lardeau Area in Relation to Structure

The parallel linear arrangement of even certain parts of major and minor valleys in the Lardeau district seems significant, since erosion is initiated along lines of least resistance, through softer formations following the regional trend or along other lines of weakness established through crustal adjustments, when the formations were upturned, flexed, and folded. Certainly the chief topographical lines of the Lardeau area are due to the structural features of folding and flexure of the formations with jointing consistently occurring at right angles to the formational trend.

The provisional table of formations contained in the writer's report for 1917 is brought up to date in the following table.

Table of Formations

Quaternary	Recent and Pleistocene		Stream deposits. Glacial deposits.
	Great unconformity		
Late Mesozoic or Post-Mesozoic	Basic dykes Aplite dykes Nelson granodiorite		
	Intrusive contact		
Mesozoic	Gabbro and intermediate types Lardeau schists—Kaslo schists		
	Intrusive contact		
	Jurassic	Milford series	
	Disconformity		
Palæozoic	Carboniferous	Pennsylvanian, Mississippian, and pre-Mississippian	Formations represented in the Slocan and Ainsworth series.
	Disconformity		
	Probably Palæozoic Possibly Precambrian		Duncan series.

The sedimentary formations and the set of igneous rocks included in this table of formations form a large part of the bedrock structures in the Selkirk mountains. The valley of Kootenay lake north from the West Arm of the lake has been excavated in sedimentary formations of the Ainsworth series. The area drained by Lardeau and Duncan rivers is chiefly underlain by rocks of the Slocan, Ainsworth, and Duncan series and the formations of these series and their equivalents occupy a wide area,

trending northwestward across the Incomappleux valley to the valley of the Illecillewaet. In fact the area which has been topographically mapped in the Lardeau is for the most part underlain by steeply upturned, folded, and flexed formations of Palæozoic age.

The territory underlain by stratified rocks, from the head of Kootenay lake northwest to Revelstoke, is almost surrounded by granite to the extent that both igneous and sedimentary rocks occupy equally large areas within the limits of the Lardeau map-sheet.

The sedimentary formations[1] are composed of slates, quartzites, grits, and limestones.

The limestone beds over a considerable area have proved fossiliferous, establishing the fact that an immense thickness of Palæozoic rocks have to be considered in the stratigraphy of the Lardeau. During the season of 1920 fossils were found in a narrow band of limestone on the southwest slope of Silver Cup mountain close to the north end of Trout lake. These are reported on by E. M. Kindle as follows:

"The collection of corals transmitted by M. F. Bancroft from the Trout Lake valley in the Lardeau district, B.C., is of considerable interest since it represents a new locality in a region which has yielded very few fossils.

The corals though numerous are poorly preserved and considerably altered by silicification, making any specific and generic determinations difficult, if not impossible. The general character of the fauna, however, indicates pretty closely a Carboniferous horizon. I believe it to represent one of the faunas which characterize the lower half of the Carboniferous in the Banff section. Provisionally at least it may be considered a Mississippian fauna."

Structural Relations

The Lardeau formations are remarkably regular in trending northwest and southeast across the region. They are steeply upturned so that the geological boundaries reflect the general strike of the formations on the map. The quartzites of the Duncan series form a good horizon marker, showing very little change in character. The contact of the Duncan series with the slates of the "limedyke" belt marks the boundary northeast of which no fossils have been found in the Lardeau. The fossil-bearing formations rest conformably above the quartzites of the Duncan series, which in the vicinity of Boyd creek and southeastward form a strong anticlinal fold. Along the southwest limb of this anticline, the formations younger than the Duncan series are sharply upturned, folded, and flexed, the structures being overturned to the west so that the prevailing dips are to the northeast. Similar overturned structures are a feature of the Beaverfoot range and other folded belts in the Rocky mountains.

A marked flexure occurs in the strata along the western watershed of Duncan river, crossing Hall Creek basin, where the regional strike of the formations northward swerves sharply to the northwest.

The Selkirk structures in the Lardeau map-area have been apparently very little disturbed since the folding was completed. The distance between the principal granite contacts across the trend of the folded formations varies from 20 to 30 miles in the area southeastward from Columbia river.

In respect to the intrusive contacts, there is a great variety of structural relations. The greenstone intrusives which are prominent among the upturned formations of the Lardeau seem to be only a repetition through this section of gabbros and intermediate types, such as were intruded in the Slocan area on a considerable scale at the time of the intrusion of the Kaslo schists. These intrusives occur in bands of varying width in certain belts, suggesting in part parallel linear arrange-

[1] Bancroft, M. F., Geol. Surv., Can., Sum. Rept., 1917, pt. B, pp. 35-36 B; Sum. Rept., 1919, pt. B, pp. 40-46 B.

ment of dykes, closely following the strike and dip of the folded formations. These dykes are composed chiefly of dark, compact, green schists which like the Kaslo schists resist weathering and in the present topography form the crest lines of many ridges and peaks.

Only a narrow belt of stratified rocks, composed of the Slocan and Ainsworth series, intervenes in the vicinity of the 50th parallel to separate the large intrusive areas in the Lardeau from the main Nelson batholithic area. Field evidence, in the form of minor intrusions within the Slocan series together with the metamorphosed condition of the Ainsworth series bordering the west shore of Kootenay lake, indicates that the narrow belt of stratified rocks in question forms but a roof remnant beneath which the Nelson granodiorite is probably continuous, emerging in two main branches northward.

Fry River Granite Area. The Fry River granite area on the east side of Kootenay lake forms a wide belt eastward into the heart of the Purcell range, passing northward along the watershed of the range and southward to the headwaters of the West Fork of St. Mary river. It is in regional alignment with the Midge Creek and Sanco granite area which crosses the south end of Kootenay lake.

Following the regional trend northward from the summit of the Purcell range the Fry River belt seems to be continuous northwestward across the Lardeau map-area, probably linking up with the granite area which occurs in the Illecillewaet valley in the section east from Revelstoke.

The intrusive contacts of the northeast granite belt in the Lardeau have not yet been mapped nor has the continuity of the belt been determined. This intrusive mass bears an important genetic relation to some of the Lardeau mineral deposits and to mineralization such as occurs in the Windermere and other sections of this region to the east and southeast of the Lardeau map-area.

Slocan-Lardeau Granite Area. The Slocan-Lardeau granite area is bounded on the east and northeast by the same belt of Slocan series which occurs along the eastern boundary of the Nelson batholith; in fact the two boundaries in question are in alignment. Westward near the head of Slocan lake, the belt of Slocan series separating the two granite areas is not more than 3 miles in width.

The eastern boundary of the Slocan-Lardeau granite area has been mapped in the field from the headwaters of Cooper creek northwest across Upper Arrow lake in the vicinity of Cranberry creek. It is between this contact and the granite area on the northeast that the majority of mineral discoveries have been made in the Lardeau.

ECONOMIC GEOLOGY

Considering the limited mining operations that have been carried on in the Lardeau it is almost impossible to size up its merits as a mineral district.[1] It is certain that the different silver-lead and zinc ores, such as are mined in the region between Kootenay and Slocan lakes, also occur in the Lardeau mineral district. Silver-lead and zinc ores carrying a small gold value and gold quartz ores carrying very small quantities of the sulphides are two classes of ores obtained from this region, generally where the stratified rocks contain igneous intrusives of Mesozoic or post-Mesozoic age.

Mode of Occurrence

The ore-shoots of the Lardeau have been formed in fissure veins, cross-fissures, stockworks, chimneys, and through the replacement of limestones cut by the ore-bearing fissures.

Productive mineral areas in the Slocan occur in zones of marked fissuring and the extent of ore deposition along these fissures can be determined only through underground development.

[1] Brock, R. W., Geol. Surv., Can., Sum. Rept., 1903, pp. 56 A-81 A.

SUMMARY

The Cordillera in southeastern British Columbia embraces in the Selkirks and Rockies a wide area characterized by parallel geological and physiographical features. Between latitudes 50 degrees and 51 degrees the folded structures in the Selkirks and Rockies have been bowed eastward, so that there is a general change in the strike of the formations from north to a northwest direction. Major and minor flexures are characteristic of the folded areas in this mountainous region.

The regional curvature of the underlying structures seems to be portrayed in the parallel linear arrangement of the intermontane troughs north of latitude 50 degrees. Three of the main valleys in Kootenay district parallel the general configuration of the Rocky Mountain system in departing from a north to a northwesterly direction; these are the Rocky Mountain trench, the Kootenay Lake-Lardeau River trench, and the Slocan Lake-Nakusp trench.

This general parallelism of the broader features of relief and structures seems to favour an interpretation of the physiographical history of the Rockies and Selkirks in terms of structure as well as of erosion. Schofield[1] has treated the subject so far as the Selkirks are concerned from the standpoint that the present main valleys of the Selkirk range bear no relation to structure. But in certain sections along the Duncan and Lardeau River valleys a close conformity of valley trend and formational trend exists.

If the Laramide revolution can be held responsible for not only uplift of the Selkirk region but in a measure for the completion of the folding and other crustal readjustments in the Rockies and Selkirks, it seems reasonable to suppose that considerable areas in Kootenay district are underlain by igneous rocks of early Tertiary age.

Important ore deposits occur genetically associated with early Tertiary batholithic intrusives south of the 49th parallel within the Cordilleran region. But in British Columbia the igneous rocks associated with the gold-copper, silver, lead, and zinc deposits have generally been correlated with the Coast Range batholith and emphasis has been laid on a Mesozoic[2] period of mineralization.

[1] Schofield, S. J., Geol. Surv., Can., Mem. 117, 1920, pp. 60-65.
[2] Schofield, S. J., Trans. Can. Min. Inst., vol. XXI, pp. 422-427.

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