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WILLIAM MCINNES, DIRECTING GEOLOGIST.

Summary Report, 1917, Part B

CONTENTS

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SUMMARY REPORT, 1917, PART B.

EXPLORATIONS IN YUKON TERRITORY.

By William E. Cockfield.

CONTENTS.

INTRODUCTION.

The field season of 1917 was spent in exploring portions of Sixtymile and Ladue River valleys. This area, comprising over 1,000 square miles, was mapped as to geology and drainage, and special attention was paid to an investigation of the mineral resources.

During the performance of this work the writer and the various members of his party were assisted to the utmost by the men encountered in the district. For the various courtesies and favours received the writer wishes to express his sincere thanks. Particular thanks are due to Mr. Pat Owens, of Miller creek, who in the course of the season stored the surplus outfits belonging to the party, looked after the mail, and in many other ways rendered valuable assistance.

Throughout the season the writer was ably assisted by Clive E. Cairnes and Henry G. Boulton, who performed all the work of mapping the drainage and trails, and in addition were able to assist in the mapping of the areal geology. Owing to the death of D. D. Cairnes the writer was forced to carry on the work without his valuable advice and direction.

Placer gold has been mined on some of the tributaries of Sixtymile river since 1893, Miller and Glacier creeks being the most important of the producers. Beyond a rapid reconnaissance survey made by McConnell and Keele in 1901, no geological work has been done in this area, and it was thought advisable to map the Klondike rocks along their strike, both for the purpose of correlation and with the hope of obtaining some further light upon their origin. Furthermore, tungsten had been reported from the gravels of Sixtymile river, and as the use of tungsten in the manufacture of munitions has led to an urgent demand for that metal, it was decided to investigate the report in order to determine whether or not the metal was present. The work was started with the object of ultimately mapping the area lying between Yukon and White rivers and the International Boundary.

The topographic maps of the Boundary Commission were of great service, particularly in fixing the geographical position of the areas adjacent to the Boundary. The base-line maps of the Topographic Survey were used as base maps, and were supplemented by numerous traverses between points whose geographic positions were known. These traverses were made by the plane-table and stadia method. In addition to these, many shorter traverses were made in which pacing was employed in conjunction with the Batson sketch case. In this way the main features of the geology and drainage were secured.

Location and Accessibility.

The area mapped is bounded on the north by the divide between the Sixtymile and the Fortymile drainage, and the wagon road from West Dawson to Glacier creek; on the west, by the International Boundary; on the south, by Matson creek; and on the east, by portions of Sixtymile river and Fish creek.

During the open season for navigation passenger and freight steamers ply regularly between Whitehorse and Dawson. From West Dawson an excellent wagon road connects with Glacier, Miller, and Big Gold creeks. Trails from Glacier and Miller connect with the Boundary pack trail. This latter affords easy access to all points in Ladue valley. The southern portion of the district may be reached in poling boats, which can ascend Sixtymile river as far as the mouth of Matson creek. It is probable also that poling boats could reach points in Ladue valley by means of White and Ladue rivers. In winter all points in the district are readily reached with sleds. In summer the valleys are swampy and frequently covered with niggerheads, making travel difficult. In many places, however, the ridges are open and afford good means of communication.

TOPOGRAPHY.

The Sixtymile and Ladue River valleys lie well within the physiographic province known as the Yukon plateau, which extends from northern British Columbia, through Yukon and Alaska to Bering sea. This terrane has been described by a number of geologists, among whom there is a consensus of opinion that it represents a region which was extensively eroded during a long period of crustal stability and reduced to a low-lying, undulated plain. This period of stability was followed by an uplift or upwarp, elevating this featureless plain into an upland tract. The uplift gave renewed cutting power to the streams and these commenced to incise their channels into the upland surface. The topography thus formed consists of a series of long, branching ridges occupying the space between intersecting streams. The interstream areas, well back from the valley walls are prevailingly flat-topped and stand at an average elevation of 4,000 to 4,800 feet. Occasional peaks rise above the general level of the plateau, but they are to be regarded as residual masses which were unreduced at the time of planation. The maximum relief of the district is about 4,000 feet.

The region studied during the past summer is drained by Sixtymile and Ladue rivers. The Sixtymile has its source in Alaska and crosses the International Boundary at about latitude 63° 55′ north. From the Boundary the valley trends northeast for a distance of 12 or 13 miles, then bends sharply to the east and then south, continuing to run south and southeast until it joins the Yukon at Ogilvie. The most important tributaries, in point of size, are Big Gold, California, Boucher, Fish, Fiftymile (Middle fork), and Matson creeks (south fork). Both main forks of Ladue river rise in Alaska, the north fork crossing the Boundary about 9 miles south of the Sixtymile crossing, and flowing almost due south to the junction with the main stream, a distance of 40 miles. The main stream crosses the Boundary at latitude 63° 15′, flowing due east. Three miles beyond the Boundary it receives the north fork, and turns abruptly to the southeast and continues in a southeasterly direction to White river. The main tributaries to the north fork are McElfish and Bakke creeks; and to the main stream, Rice creek; the latter joins the main stream almost immediately below its junction with the north fork. Both the Sixtymile and Ladue are small, being less than 200 feet wide.

The main topographic feature of the district is the divide between the Ladue and the Sixtymile drainage. This divide swings in the form of a rough semicircle from near White river around the head of the north fork, a distance of over 100 miles

measured along the divide. From this main divide, ridges extend along the tributary streams to both master valleys, becoming progressively lower as the master valleys are approached.

The district shows no signs of having been glaciated. The smaller valleys are distinctly V-shaped with beautiful examples of interlocking spurs. The master valleys are broad-floored, but the valley walls show none of the rounding and scouring so characteristic of glaciated areas. Climate has had a marked effect in the modelling of the land forms. This is due to the perpetually frozen state of the superficial materials, so that erosion is more active on those slopes most exposed to the action of the sun's rays, where alternate freezing and thawing takes place.

The streams as a rule have clear water, indicative of the fact that they are not transporting material at present. This is also due to the frozen state of the valley accumulations, material reaching the valleys tending to become frozen before it can be carried off, and as a result, accumulating there. This mantle of superficial materials supports a growth of moss, trees, and shrubbery. The drainage of the valley flats is poor, and the small tributaries discharging on to them are drained off by means of a slow seepage, making the valleys always swampy.

GENERAL GEOLOGY.

The geological formations of the area include sedimentary, igneous, and metamorphic rocks. Of these the latter are the most widespread forming a series to which the name Yukon group[1] has been applied. These are all probably Pre-Cambrian in age. In point of areal distribution, the next most important series of rocks comprise volcanics and sediments, ranging from Tertiary to Recent in age. Volcanics which are referred to the Mesozoic and small stocks of granitic rocks, also of Mesozoic age, comprise the rest of the consolidated rocks of the district.

Table of Formations.

Era	Period	Formation		Lithological Characters
Quaternary....	Recent and Pleistocene.			Gravel, sand, silt, clay, soil, muck, volcanic ash, and ground-ice.
Tertiary.....				Quartz and granite porphyries, rhyolite.
		Newer volcanics (?)...		Andesite and related volcanics with tuffs and breccias, some sandstones, shales, conglomerates, lignites, and gravels.
Mesozoic.....	Jurassic to Cretaceous.	Coast range batholith (?).		Granitic rocks.
		Older volcanics.....		Andesite and related volcanics.
Pre-Cambrian.		Yukon Group.	Pelly gneiss.....	Granite gneiss.
			Moosehide diabase (?)	Hornblende schists, serpentine, etc.
			Klondike series(?)	Sericite and chlorite schists.
			Nasina series.....	Mica schist, quartz mica schist, gneissoid quartzites, sheared conglomerates, graphite schist, and crystalline limestone.

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

The oldest rocks exposed are members of the Yukon group which are thought to belong entirely to the Pre-Cambrian. These rocks are dominantly gneissoid or schistose. On the basis of lithological characters and of origin this group has been split up into a number of formations. The oldest rocks of the Yukon group are a series of mica schists, gneissoid quartzites, quartz mica schists, sheared and mashed conglomerates, graphitic schists, and crystalline limestone. These rocks are thought to be dominantly sedimentary in origin and correspond so closely with the Nasina series of McConnell[1] that they are correlated with them.

A second subdivision of the Yukon group is to be found in a series of sericitic schists with which are associated some chloritic schists. These rocks differ from the rocks of the Nasina series in that they appear to be chiefly, if not entirely, of igneous origin. The sericitic schists predominate and are typically light in colour, but they are frequently interbanded with the dark green chloritic schists. These rocks cut and contain inclusions of the clastic rocks described above. On the basis of lithological similarity, they are provisionally correlated with the Klondike series[2] of McConnell.

A third subdivision of the rocks of the Yukon group is to be found in a series of hornblende schists, which appear to have been derived from andesites, diabases, basalts, and allied types of rocks. These rocks are usually sheared, but have suffered less in this respect than the sericitic and chloritic schists and in some places appear quite massive. They are extensively altered to serpentine and actinolite.

The remaining part of the Yukon group is made up of gneisses which, while varying widely in composition, belong to a single period of igneous intrusion. The most widespread of these is an augen gneiss, a coarse-textured rock which macroscopically shows quartz, feldspar, and mica or hornblende. As a rule the rock is well foliated, the crystals of feldspar being granulated and extended in the direction of foliation. The quartz frequently shows signs of crushing. The mica is as a rule biotite, but in certain cases, muscovite also occurs and in extreme cases is the only member of the ferromagnesian minerals present.

The members of the Yukon group are not only metamorphosed, but disturbed, folded, crumpled, and faulted. Notwithstanding this high degree of disturbance which they have undergone, the dips as a rule are low, seldom exceeding 30 degrees.

More recent than the members of the Yukon group are certain massive igneous rocks which are cut by the Newer volcanics, and also by some small stocks of granitic rocks. These are tentatively referred to the Mesozoic, although it is quite possible that there are some Palæozoic members present. They are of volcanic origin and consist mainly of andesites, which are dark-coloured, greyish or greenish in colour, usually aphanitic in texture, and massive in character. In places they are altered to serpentine. These are thought to correspond in age to the older volcanics[3] of the upper White River district, which are dominantly of early Mesozoic age. Their areal extent in the Sixtymile district is small.

Small granitic stocks occur at scattered localities. These vary somewhat in composition and texture, but are dominantly granitic with associated porphyritic phases. Similar occurrences are by no means rare throughout the Yukon plateau, and wherever definite proof of their age has been found they are referred to the same general age as the Coast Range batholith, which extends from the Jurassic well into the Cretaceous.

A further series of volcanics with associated sediments is found both in the northern and southern extremities of the district. These are provisionally correlated with the Newer volcanics[4] of the Upper White River district. They are everywhere

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

[2] McConnell, R. G., "Report on the Klondike gold fields," Geol. Surv., Can., Ann. Rept., vol. xiv, 1901, pp. 15-22 B.

[3] Cairnes, D. D., "Upper White River district," Geol. Surv., Can.. Mem. 50, 1915, pp. 87-93.

[4] Cairnes, D. D., "Upper White River district," Geol. Surv., Can., Mem. 50, pp. 97-101.

massive and fresh in appearance. They consist of andesites and related rocks, with associated tuffs and breccias. The sediments which accompany them are loosely-consolidated sandstones, shales, and conglomerates, with thin seams of lignite, overlaid by unconsolidated gravels. These have been referred to the Tertiary.

The youngest consolidated rocks to be found are dykes and flows of quartz porphyry, granite porphyry, and rhyolite. The quartz porphyry and granite porphyry are pale yellow compact rocks with phenocrysts of dull quartz and yellowish decomposed feldspar, with some mica or hornblende. The rhyolites are dull yellowish rocks with a felsitic texture. These rocks cut the Newer volcanics and their age is thought to be late Tertiary.

Overlying all the consolidated rock formations of the district is a mantle of Pleistocene and recent accumulations which includes gravels, sand, silt, clay, soil, muck, volcanic ash, and ground-ice. These accumulations cover the floors of the valleys to varying depths and extend over portions of the valley walls and upland.

MINERAL RESOURCES.

Placer Deposits.

Placer gold is the only mineral of economic value at present being produced in the Sixtymile district. Its distribution in the gravels of Sixtymile river and its tributaries is exceedingly widespread, but thus far only a few creeks have been found rich enough to work. Much prospecting remains to be done, however, before it can be concluded that all the deposits of economic value have been discovered.

Coarse gold was discovered on Miller creek in 1893 and an unknown amount of work was done prior to the discovery of the Klondike fields in 1896. McConnell[1] gives the total production up to 1901 as only $500,000. After the discovery of the Klondike gold fields the district was deserted for a time, but about the year 1900 men began to return. In 1901 there were about fifty men engaged in mining operations in the district and about forty-five men are engaged at the present time.

Sixtymile River. The only portion of Sixtymile river on which active mining operations are being carried out is the stretch from the mouth of Miller creek to a point a short distance below the mouth of Big Gold creek. In this stretch, the Sixtymile is a small, rapid stream, somewhat less than 50 feet in width. The valley is less than a mile in width and at either side are well-defined rock cut benches supporting beds of gravel. The valley is flat-bottomed and swampy.

The rock formations exposed along the Sixtymile at this point belong to the Yukon group and to the Newer volcanics. The rocks of the Yukon group extend along the right limit, and the Newer volcanics are confined to the left limit, crossing the valley at one point only, a short distance above the mouth of Big Gold creek.

In the past, the main workings have been confined to the bench gravels, but at present the creek gravels are receiving more attention. The bench gravels are in every way analogous to the present day creek gravels and bear no relation to the White Channel gravels of the Klondike district. They represent simply a stage in the development of the Sixtymile valley when the river stood at a higher elevation than now. The old channel has a lower and more uniform grade than the present channel, and consequently, represents a relatively longer period of concentration. As a result, it would be expected that the distribution of gold would be more uniform in it than in the creek gravels and this appears to be the case. Though not necessarily leaner than the bench gravels, the gold in the creek gravels appears to be more pockety in its distribution. Insufficient data are at hand at the present time as to the tenor of the creek gravels to permit of any general conclusions, but it would appear likely that

[1]McConnell, R. G., Geol. Surv., Can., Ann. Rept., vol. xiv, 1901, p. 34 A.

the relatively richer concentrations of gold are to be found opposite and immediately below those points where the benches have been broken through and destroyed by tributary streams. The facts gathered in the field appear to substantiate this conclusion.

Large portions of the bench gravels remain, and at the present time the creek gravels are practically untouched. There are many points at which it is known that these can be worked at a profit, so that for some years a small production is to be looked for.

Miller Creek. Miller creek heads near the International Boundary and empties into Sixtymile river about 8 miles below the point where the latter crosses the Boundary. It is a small stream, less than 5 miles in length and 2 or 3 yards in width. The rock formations underlying Miller creek consist of clastic schists of the Yukon group with minor intrusions of the sericitic and chloritic schists covered and invaded, in the lower portion of the valley, by the Newer volcanics.

Prior to the discovery of the Klondike fields, Miller creek was considered a very rich creek, but, so far as the creek gravels are concerned, it is nearly exhausted. The lower portion of the creek has been dredged as far as Discovery, and the ten claims above Discovery have been worked to a considerable extent. Portions of claims which had been imperfectly or only partly worked in the early days still yield gold and the miners working them claim to be making wages or slightly better. The benches on Miller creek are now being opened up and the existence of an old channel, carrying gold in considerable amounts, seems to be very definitely proved. This deposit is being worked from claim No. 8 "above," down to Discovery and the averages given to the writer agree somewhat closely, pointing to a uniform distribution of the gold. The pay-streak varies from 25 to 200 feet in width and in many places carries values of 75 cents or more to the square foot[1] of bedrock.

The depth to bedrock varies, being 4 to 5 feet at the rim and deepening considerably towards the hillside. As large portions of the benches remain untouched, Miller creek should continue to produce at the present rate for some time.

Glacier Creek. Glacier creek is a tributary to Big Gold creek, joining the latter about a mile above its junction with Sixtymile river. It is a small stream, about 7 miles in length and slightly larger than Miller creek, with a valley typical of the district. It rises near the International Boundary to the north of Miller creek in a steep-sided, narrow gulch, but on descending the valley opens out, until at the mouth it is about 200 yards in width. The geological conditions are the same as stated for Miller creek.

Some thirteen men are working on Glacier creek, of whom more than half are working the creek gravels, the remainder the bench gravels. Much of the creek was worked over in the early days, but claims imperfectly worked or left as being too poor to work at that time now yield wages or better to the men working them. As on Miller creek, the benches have received some attention and the existence of an old channel on the bench of the left limit seems definitely proved, and important amounts of gold have been recovered from it. It would appear that a channel, or portions of a channel, exist on the bench on the right limit, standing at an intermediate elevation between the bench on the left limit and the present creek channel. The position and extent of this remain unknown, save for a few old workings in which good values are claimed. Large volumes of the bench gravels remain to be worked so that for some time to come a steady production may be looked for.

Little Gold Creek. Little Gold creek is a tributary to Big Gold creek. It is somewhat longer and larger than Glacier creek, rising at the International Boundary

[1]It is the custom of the miners in the Yukon to give values per square foot of bedrock, or to the box length (144 square feet), rather than in terms of cubic yards. This custom has been followed in this report.

a few miles to the north of Glacier creek and joining Big Gold less than a mile above the confluence of Glacier and Big Gold. Three men are engaged in mining operations on Little Gold creek, the creek gravels only being worked. The pay-streak is about 100 feet or more wide and nowhere very rich, the values running as a rule between 5 and 9 cents a square foot. The depth to bedrock varies from 5 to 10 feet, bedrock pitching slightly toward the left limit. Very little work has been done on the benches and this, from the information supplied to the writer, with discouraging results. On account of the heavy wash the grade of the creek, which is about 70 feet to the mile, is about the minimum with which ground sluicing can be carried out successfully.

Big Gold Creek. The only portion of Big Gold creek on which any work is being done extends from the confluence of Glacier creek to Sixtymile river, a distance of slightly over a mile. Five men are working on this stretch, three on the bench gravels, and two on the creek gravels. The depth to bedrock in the valley flats averages from 20 to 25 feet. On the benches the gravels vary in thickness, from the rim back towards the hillside. No definite pay-streak appears on the creek claims which are now being worked, the distribution of values being pockety. On the benches some good spots have been found. On the bench lying between Glacier and Big Gold creeks, a short distance above their confluence, the owner states that he recovered $500 from a patch of ground measuring 80 square feet.

Bedrock Creek. Bedrock creek is a small stream heading in Alaska and joining the Sixtymile about 2 miles above the mouth of Miller creek. Some prospecting work has been done and gold in paying quantities has been discovered at a few points along the creek. The depth to bedrock varies greatly, the rock at places being exposed in the creek bottom and at others buried under 20 feet of gravel and muck. The bench on the left limit is being opened up on claims No. 25 and 26 "above" and encouraging prospects are reported.

Bedrock creek lies, for the greater portion of its length, on the contact between the clastic schists of the Yukon group and the igneous sericitic schists of the same group. Minor intrusions of later rock also occur in the vicinity. From the general geological conditions and the prospecting which has been performed, it would appear likely that some portions of the creek at least can be worked at a profit.

Matson Creek. Matson creek forms what is known as the south fork of Sixtymile river, and has a watershed comparable to that of Sixtymile river itself above the forks. Matson creek heads towards White river and the north fork of Ladue river and flows in a general northeasterly direction to Sixtymile river. The full length of the creek was not explored during the course of the summer's work, lack of time preventing the traverses being carried as far down as the mouth, but the greater part of the creek has been mapped. The creek is over 30 miles in length. It was discovered and staked in 1911. Until quite recently six men have been employed on the upper portion of the creek near Discovery claim. When this locality was visited by the writer, however, only two men were found to be working their claim. This claim, "Discovery," lies well toward the head of the creek, at the foot of Weide gulch. The upper portion of Matson creek is underlaid by rocks of the Yukon group, chiefly sericitic and chloritic schists and granite gneiss. Below the junction with Angus (Marion) creek, Tertiary volcanics and sediments appear, and follow the valley as far as explorations were carried.

The depth to bedrock on Discovery claim is about 20 feet, on the bench about 5 to 6 feet. The bench gravels are being profitably worked, although they are somewhat pockety, the values found ranging from 18 cents to $1 per square foot. On account of the light overburden even the ground containing 18 cents can be worked at a good profit. The gold in the creek gravels is unevenly distributed and little mining work has been done upon them.

Other Creeks. Certain portions of Walkers fork, Davis creek, and Poker creek lie within the area mapped, but the areas at present producing lie wholly within Alaska. Rice and Deep creeks, tributaries to Ladue river, have been prospected, but so far with discouraging results.

Summary and Conclusions. It will be seen from the outline given above, that much ground remains to be worked on the creeks which have already been discovered and are known to contain gold, and that a small, but steady, production is expected for some years to come. The estimated production for 1917 is $50,000. This estimate was very kindly furnished me by Mr. William Schofield, Mining Recorder at Glacier creek. On the other hand, it does not seem reasonable to suppose that all the economic deposits of gold have been discovered or that the entire gold belt of the Sixtymile river has been prospected. There is no reason, in view of the geological conditions, why the gold belt should be confined to the creeks mentioned above and that the rest of Sixtymile and Ladue River valleys should be barren. The widespread distribution of the metamorphic rocks of the Yukon group and the fact that they are cut at many places by later granitic, andesitic, and other intrusions, conditions which have elsewhere proved favourable to the production of placer gold, should prove favourable also in Sixtymile and Ladue valleys, particularly as the region has not been glaciated. Float gold is known at several points in Ladue valley and although, at the time of writing, no deposits of economic importance have been discovered, still it must be remembered that very little prospecting has been done there. The ground in the master valleys is deep, and consequently discouraging to the prospector, but equally good pay may be obtained by working the tributary streams, where results are more easily and quickly obtained. Consequently, the writer hopes to see the producing field much enlarged in the future. With regard to the creeks which are already producing, the production must come more and more from the bench gravels, as the creek gravels become exhausted.

Lode Deposits.

Up to the present time, little interest has been taken in lode deposits in the district. This is only natural, as none but the richest ores could pay the high cost of mining and transportation. A further obstacle lies in the difficulty of prospecting the moss-covered slopes, where outcrops are rare. Small deposits of galena and zinc blende are known to occur on Miller creek, scattered through the bedrock, and galena is quite common among the concentrates obtained from washing the gravels. One of these deposits is exposed on the right bank, near the head of the creek, and the writer examined it carefully in order to obtain some idea of the extent and value of deposits of this type. The ore occurs in quartz veins replacing limestone of the Nasina series. This limestone occurs in the form of lenses whose maximum extent is 300 feet in length and 70 feet in thickness, with the lateral extent unknown, but presumed to be of the same order of magnitude. The dimensions are commonly much smaller than those given. Small quartz veins containing little bunches of galena and blende occur, cutting across the limestone. The ore is very low grade, as the assay of a sample taken by the writer across some of the best of these veins indicates.

Gold	Trace
Silver	1.40 oz. per ton.
Lead	3.60 per cent.
Zinc	4.44 "

The assay was made in the Territorial Assay office at Whitehorse. The ore proved to be too low grade to work, but it is by no means certain that the best ore has as yet been discovered.

A prospect reported to contain good values in copper and gold lies at the head of Butler gulch, a tributary to Boucher creek. No opportunity of examining this in detail was presented, as the workings have been abandoned for some time and were filled with water.

The discovery of cinnabar (sulphide of mercury) amongst the gravels of Sixtymile river at the mouth of Miller creek should stimulate the search for this mineral. From the usual association of this mineral with rocks of volcanic origin, it is believed probable that in this case, also, it is to be genetically connected with the Tertiary volcanics which form the bedrock in the vicinity. The area to be prospected is not large, the volcanics extending up Sixtymile river to Bedrock creek and up Miller creek for about a mile, thus forming a triangle less than 2 square miles in area. Within this area efforts should be made to locate this mineral, particularly when bedrock is bared in the course of mining operations.

No deposits of tungsten were found in any of the gravels examined. Careful search was made amongst the concentrates from the sluice boxes, and chemical tests were carried out on a number of samples.

Coal.

Some thin seams of lignite occur in connexion with the sediments associated with the Newer volcanics. No outcrops were found during the season, but the existence of the seams is shown by some of the shafts and trenches constructed during mining operations. These deposits are of no commercial value at the present time, as the cost of transportation to a point where the lignite could be used would be prohibitive, and the deposits do not seem of sufficient extent to warrant the construction of improved facilities for transportation.

ECONOMIC GEOLOGY OF THE HAZELTON DISTRICT, B.C.

By J. J. O'Neill.

CONTENTS.

INTRODUCTION.

A detailed geological investigation of the mineral deposits in the district around Hazelton, B.C., was made in the summer of 1917 with a view to furnishing accurate information to be used in the development of the numerous mining properties in this easily accessible and promising region.

Four and a half months were spent on the field work, and the writer was ably assisted by Victor Dolmage; H. J. James was student assistant and performed his duties in a very capable manner. The services of Mr. Dolmage have been continued in the preparation of the preliminary report on the district.

A topographical map of the district was prepared by F. S. Falconer, concurrently with the geological work, on a scale of one mile to one inch, with 100-foot contour intervals. This map will be used as a base for the geological map.

Location and Area.

Hazelton is situated at the confluence of the Bulkley and Skeena rivers, in the northwest quadrant of the area being mapped and in the southwestern part of the Omineca mining division of British Columbia.

The district investigated covers an area of 225 square miles and includes the mineral claims on Ninemile, Fourmile, Glen, and Rocher Déboulé mountains.

Accessibility.

The Grand Trunk Pacific railway practically bisects the district in making a 90-degree bend around the Rocher Déboulé mountains, and provides good shipping facilities to the different properties. A good system of wagon roads extends to all the main camps, and the individual properties are reached by trails or tram lines.

Drainage.

Besides the two main rivers, the Bulkley and the Skeena, which traverse the district, there are many smaller streams tributary to them which reach all parts of the area. All these streams, especially those radiating from the Rocher Déboulé group, have very steep gradients and are a source of considerable water-power. The Bulkley is a turbulent river, flowing through a deep, narrow canyon for several miles above Hazelton, and could furnish all the power necessary for the whole district.

PHYSIOGRAPHY.

The district lies immediately to the east of the Coast range of mountains and is a northward extension of the Interior Plateau country of southern British Columbia. It presents two types of country in striking contrast to one another in the broad valleys of the Skeena and Bulkley rivers on the one hand and abrupt, rugged topography of the Rocher Déboulé group of mountains on the other.

No indication of the plateau feature extends this far north, but the country presents isolated groups of hills and mountains of various altitudes, some of which are subdued in type, whereas others are extremely rugged; these are separated by broad valleys which contain tumultuous streams, all of which are actively eroding and many of which flow through canyons.

Glaciation.

Valley glaciation has accentuated the topographical contrast by truncating the spurs of ridges, and by filling up minor irregularities with debris; these glaciers were active up to an elevation of over 5,500 feet, and created or accentuated a subdued form of topography up to that height.

Above the limits of the main valley glaciation is found a very rugged and serrated topography produced by recent mountain glaciation; many of the small local glaciers are still in existence though they do not show much activity. In the Rocher Déboulé group this type of topography is exceptionally well developed, since the granodiorite lends itself to the formation of sharp pinnacled arêtes.

Boulder clay is common in the valleys and on the lower slopes of the hills; it has been reworked in places by stream action and the resulting clay is suitable for the making of common bricks and tiles.

GENERAL GEOLOGY.

The bedded rocks of the Hazelton district are all of the Hazelton Series, and collections of fossils show that the series is very probably upper Jurassic in age. Leach found this series extending southward into the Telkwa district, and Malloch traced it northward into the Groundhog district.

Extending across the southern portion of the Rocher Déboulé mountains there are interbedded flows and coarse, ill-assorted tuffs or tuff-breccias. Northward the series becomes more and more evenly bedded, with well-assorted material, distinctly banded, and with slight gradation from one band to the next, but all are tuffaceous in composition.

These rocks are folded with axes approximately northeast-southwest (true) and the folding is well seen in the Bulkley canyon above New Hazelton.

The folding was followed by intrusions of small stocks or batholiths of granodiorite and granodiorite porphyry, which now form the cores of Ninemile, Fourmile, and Rocher Déboulé mountains, and by dykes which traverse both the mountains and the valleys.

Some time after the intrusion of the dykes, veins were formed throughout the district, and in certain parts these are grouped. They are not confined to the main intrusions; for some of the most valuable are situated at considerable distances from any known large intrusive. Mining claims have been located on a number of the veins which contain valuable minerals in sufficient quantity to permit of economic mining.

ECONOMIC GEOLOGY.

The district is divided into two parts by the Bulkley river. The northern part, including Ninemile, Fourmile, and Glen mountains, is characterized by silver-lead-zinc deposits, whereas in the southern or Rocher Déboulé area copper and gold are the chief metals mined. Molybdenite is important in one property and wolframite occurs in appreciable amount in another.

The Silver Standard mine is at present the only large producing mine of the first group, but the American Boy is again opening and will ship this year. Both these properties are fissure veins in tuffaceous sediments and neither of them is near the contact of a large intrusive. They are characterized by galena, sphalerite, and tetrahedrite in a siliceous gangue. The tetrahedrite approaches freibergite in composition for it carries more than 2,000 ounces of silver a ton in some places; it is in sufficient amount to bring up the general silver value of the ore to a noteworthy extent.

The ore in these properties occurs in distinct shoots and the high grade material is associated with so much lower grade, or milling ore, that a custom mill has been erected by the Silver Standard; thus the output can be greatly increased. The treatment in this mill of the ore from the American Boy has enabled that mine to reopen, since the high grade ore is not sufficiently bunched to permit of separate mining.

Near the contacts of the igneous stocks on Ninemile and Fourmile mountains the silver-lead-zinc deposits are characterized by a considerable percentage of jamesonite, in addition to the minerals present in the former two properties. Of the numerous properties in this class there is at present none producing, but some of them could be made to produce by the provision of suitable milling facilities. The properties on Ninemile mountain show much more promise than those on Fourmile mountain; the former have strong veins which can be traced for considerable distances along the surface, and which have very promising showings, containing good silver values. The Shegunia river flows along the northern base of the mountain, about a mile distant from the properties, and offers a good site for a mill and for the development of more water-power than could be used by the mines.

South of Bulkley river the Rocher Déboulé mine is the only large producer at present, but development work is being pushed on the Delta, Hazelton View, Cap, and Golden Wonder properties, from all of which small shipments have been made. There are several other properties on which development work has been done, but work on them was not continued because of lack of capital, or because the ore was of too low grade, on the average, to permit of economical mining without milling facilities.

In all of the above properties, except the Hazelton View, the principal mineral is chalcopyrite, and the ore carries small values in silver and gold. In the Hazelton View property molybdenite and gold are both important and there is practically no chalcopyrite in the main vein. Wolframite occurs in important amount in a prospect on the Black Prince group but has not been reported from any other property in this district.

The ore occurs in distinct shoots in veins of the true-fissure-replacement or shear-zone-replacement types, sometimes one passing into the other along the strike.

A scheme of general co-operation among the various companies whose properties have been proved or have showings sufficient to warrant further development, would be a great boon to the whole district. The lack of power, milling facilities, and good transportation facilities, affects all the properties in the Juniper Creek basin except the Rocher Déboulé, and the expense of installing a separate plant for each would be prohibitive.

In conclusion, it may be said that the district about Hazelton offers an excellent example of mining conditions where a certain amount of government supervision would be of great advantage to the properties concerned and to the country as a whole. If legislation were enacted that would ensure a general co-operation in cases like this, it would tend to more efficient development of the whole district, with a thorough test of all likely properties, at a minimum expense. It would also certainly conserve a large amount of valuable mineral in lower grade properties, which by the present methods will be wasted or rendered unavailable for extraction at a profit, when the more valuable properties are exhausted.

RECONNAISSANCE ALONG THE PACIFIC GREAT EASTERN RAILWAY BETWEEN SQUAMISH AND LILLOOET.

By C. Camsell.

CONTENTS.

Illustrations.

INTRODUCTION.

The Pacific Great Eastern railway was designed to follow a route almost due north from Vancouver through the middle of the province of British Columbia and to give rail connexion between that city and the Grand Trunk Pacific at Prince George. At present the only portion of the line completed is that between Squamish, on Howe sound, and Clinton, a length of 167 miles, and this has been in operation since the autumn of 1915. The portion between Squamish and North Vancouver along the shore of Howe sound is still unfinished, and north of Clinton the grade has been built to Prince George, but no steel laid.

From Howe sound to Fraser river at Lillooet the railway traverses the Coast mountains, following a series of transverse valleys across the ranges. At Fraser river it enters the Interior Plateau region, through which it will run when completed, until it reaches the Grand Trunk Pacific at Prince George.

The principal work of the party was the study of the general geology and the mineral deposits along that portion of the railway between Squamish and Lillooet. The remainder of the line was hurriedly traversed more with a view to finding out what mineral deposits might be tributary to it than to study and report on these deposits.

The party included, besides myself, George Hanson, assistant, and a cook. Owing to my absence in other parts of the province for about a third of the season a considerable amount of the work had necessarily to be carried on by Hanson alone.

We are indebted to the officials of the Pacific Great Eastern railway for many courtesies and particularly to Mr. Luedke, the superintendent, for placing a motor car at our disposal for a short time at the close of the season.

General Character of the District.

The Coast mountains of British Columbia form a broad belt 60 to 80 miles in width extending northward from Fraser river into Alaska and separating the Interior Plateau portion of the province from the Pacific coast. On the west the summits rise abruptly from the sea to heights of 4,000 to 6,000 feet, increase in elevation towards the axis of the mountains to a maximum of about 9,000 feet, and decline gradually on the east to the plateau region with which they appear to merge without any sharp break.

The general trend of the whole system is north-northwesterly, but since it is built up very largely of massive granitic rocks it has not such a well-defined system of ranges separated by longitudinal and transverse valleys as, for instance, has the Rocky mountains. Such a system is, however, rudely developed, one series of valleys trending northeasterly across the axes of the ranges and the other north-northwesterly. The principal longitudinal valley along the line of the Pacific Great Eastern railway is that occupied by Lillooet river and where the river is crossed by the railway the valley is deep, flat-bottomed, and about 2 miles wide. In crossing the Coast mountains the railway follows the transverse valleys of Cheakamus river, Green river, Birkenhead river, Gates river, and Anderson and Seton lakes.

The longitudinal valleys are broad and fairly direct. The transverse valleys are narrower and more irregular in shape and trend, a result of the alternation of rocks of varying hardness.

The slopes of the valleys are steep, frequently broken by bare rock cliffs, and rise upwards to massive, dome-shaped or sharply terminated peaks which are frequently flanked by snow fields or mountain glaciers. A heavy growth of coniferous forest clothes all the slopes up to a line about 6,500 feet above sea-level, but within a zone bordering the Pacific coast where the winter snowfall is very heavy and the slopes very rugged forest growth ceases 1,000 feet or more below that level.

A few small snow fields and mountain glaciers are visible from the railway track on its southeast side, but larger glaciers and snow fields occupy the heads of many of the tributary valleys on both sides, particularly in the mountains west of Lillooet river. East of Lillooet river, although the summits are as high and sometimes higher, glaciers are not as common because of the relatively lighter snowfall in this half of the Coast mountains.

An effect of valley glaciation which will have an influence on the commercial development of the district is the over-deepening of the master valleys compared to the tributary valleys and the development of "hanging valleys" in the latter, where water-powers can be developed. Many of the side streams entering both Lillooet valley and the various valleys occupied by the railway, plunge over falls or through narrow rocky canyons for a depth of sometimes several hundred feet, providing in many cases good sites on which to develop electrical power at comparatively low cost. When mining development is carried to the point of actual production of metals some of these sites will no doubt be used. The following table, compiled largely from the reports of the Water Powers branch of the Department of the Interior, gives the principal localities at which power could be developed.

Principal Localities at Which Electric Power Could Be Developed.

Locality.	Stream.	Approx. minimum volume.	Approx. fall.	Distance in which fall occurs.	Horse-power.
Brandywine falls.....	Brandywine river.	40 sec. ft...	200 feet.....	Direct.....	600
Cheakamus canyon.....	Cheakamus river.	400 sec. ft...	400-500 feet.....	3 miles.....	
Nairn falls.....	Green river.....	230 sec. ft...	170 feet.....	400 yards.....	
McGillivray falls.....	McGillivray creek	Small.....	60 feet.....	Direct.....	
Roaring creek.....	Roaring creek.....	Small.....	Several hundred feet per mile.		
Mission mountain.....	Bridge river.....	500.....	1,200 feet.....	Direct fall by tunnel through Mission mt.	100,000
Three miles above mouth.....	Cayuse creek.....	150.....	90 feet.....	Direct.....	
Half mile from mouth..	Portage creek.....	Small.....	200 feet.....	Two direct falls....	

Because of the ruggedness of the topography, the scenery along the line of railway through the Coast mountains is particularly wild and impressive and from the point of view of the tourist will stand comparison with many of the other widely advertised railway routes in the mountains of the west. This is particularly true at the deep, narrow, granite gorge of Cheakamus river below Watson and at Anderson and Seton lakes, along the shores of which the railway runs for many miles. On leaving tidewater at Squamish the railway follows the valley of Squamish river and that of its tributary, the Cheakamus. The divide between Squamish and Lillooet rivers is crossed at Mons at an elevation of 2,000 feet above the sea, after which the railway descends Green River valley to Pemberton and crosses Lillooet valley at an elevation of 700 feet. East of this it ascends Birkenhead river and at Birken station, 1,650 feet above the sea, crosses the divide between Lillooet and Fraser rivers. Beyond this it descends the valley of Gates river to Anderson lake and for 30 miles follows the high, precipitous shores of this and Seton lakes before entering Fraser valley at Lillooet through a deep narrow notch cut into mountains which rise 6,000 feet or more on either side.

GENERAL GEOLOGY.

The following table of formations summarizes the sequence, age, and general composition of the rock bodies encountered in the section between Lillooet and Squamish along the line of railway:

Era	Period	Lithological characters
Quaternary.....	Recent and Pleistocene.....	Gravels, sands, clays. Basalt flows.
Mesozoic.....	Lower Cretaceous.....	Sandstone, shale, conglomerate.
	Jurassic, in part probably later.	Batholithic rocks, mainly granite and granodiorite.
	Jura-Triassic.....	Conglomerate, quartzite, argillite, limestone, chlorite and talc schists, peridotite, andesite.
Palæozoic.....	Devono-Carboniferous, Cache Creek.	Cherty quartzite, argillite, crystalline limestone, chlorite, sericite and talc schists, volcanic flows.

Devono-Carboniferous. The rocks of this series extend along the line of railway from Lillooet almost to the western end of Anderson lake, a distance of 32 miles. They consist mainly of greyish quartzose rocks in thin beds interstratified with schists, argillites, and some narrow bands of limestone. North of Seton lake they contain a great many sills of granodiorite and on Anderson lake are cut by two bodies of granitic rocks.

The beds are highly metamorphosed and much disturbed, fractured, and faulted. They strike west-northwest and on Seton lake are in the main parallel to the trend of the valley. Dips vary widely but are usually high and to the southwestward.

No fossils were found in these rocks in this section, but they were correlated by Dawson at Lillooet with the lower members of the Cache Creek formation.

Jura-Triassic. Stratified rocks of this age probably at one time covered all of the region between Anderson lake and Howe sound. At present, however, owing to intrusion of the Coast batholith and subsequent erosion, only a few isolated bands remain. The most important of these bands are: the Birken band, extending on the north side of the railway from Anderson lake to Birkenhead river; the Pemberton band, lying between Spetch and Pemberton; and the Mons band, extending from Green lake to Cheakamus river. Other smaller bands are found at Watson, Brew, Rethal, and elsewhere.

The rocks of this formation include conglomerate, quartzite, argillite, bands of limestone, peridotite, and interflows of andesite, some of which have been metamorphosed to various kinds of schists. They have a general northwesterly strike and dip at angles ranging from 45 degrees to vertical.

The Birken band is correlated with Drysdale's Cadwallader series of the Bridge River area in which fossils of a Jura-Triassic age have been found, and the other bands are correlated with this on solely structural and lithological grounds, for no fossils have been found in them.

Jurassic. The rocks classed under this head are the granitic rocks of the Coast batholiths. They cover a little less than half the section between Lillooet and Squamish and are disposed in a number of bands striking northwestward across the line of section and separated from each other by the older stratified rocks. The largest of these bands are those on Cheakamus, Green, and Birkenhead rivers. Besides the smaller bands shown in the structure section there are a great many smaller bodies, in the form of granodiorite dykes and sills, which penetrate the Triassic and Devono-Carboniferous rocks.

They consist mainly of granodiorite with more basic and more acid phases. A peculiar pink miarolitic granite, which may be much later in age than the main mass of granodiorite, occurs near the western end of Anderson lake. All of the batholithic rocks are later in age than the Triassic rocks and are intrusive into them, and the greater part are assigned to the upper Jurassic period following the Jurassic orogenic revolution.

Lower Cretaceous. Rocks of this age are represented by some argilites and sandstones or quartzites in the valley of Fraser river at Lillooet and have been described by Dawson.[1] Some massive, green, tuffaceous sandstones occurring to the south of the railway near the head of Stony creek may probably be Cretaceous in age.

Pleistocene. A considerable area of basalt occupies the valley of Cheakamus river from the mouth of Callaghan creek to Stony creek. Other areas lie to the south of Stony creek about Garibaldi lake. In the latter area, Professor Hodge has obtained evidence of a glacial age for some of the flows, as well as evidence of considerable post-glacial vulcanism. In the valley of Cheakamus river, however, the surfaces of the lava flows are glaciated, though in some cases they appear also to rest on a previously

[1] Geol. Surv., Can., Ann. Rept., vol. VII, 1894, p. 149B.

glaciated surface. They certainly belong to a period later than the Pliocene uplift of the Coast mountains which resulted in the cutting out of the Cheakamus valley. All the evidence points to the region about Garibaldi lake being a centre of comparatively recent volcanic activity, more recent in fact than any other known portion of British Columbia. This centre is the northward extension of the line of volcanic foci which are represented southward in the United States by the volcanic cones of mount Baker, mount Rainier, mount Hood, mount St. Helens, and mount Shasta.

Other glacial and recent deposits along the line of railway consist of glacial sands and clays, river deposits, and talus fans.

Structure. The accompanying geological structure section, which cuts across the Coast mountains from the Pacific to the Interior Plateau region, illustrates graphically the attitude and relationships of the various formations in the Coast mountains along the line of railway. The eastern end of the section shows the anticlinal attitude of the Devono-Carboniferous rocks. The trend of this anticline is west-northwest parallel to the valley of Seton lake which has been deeply incised into its crest. Rocks of the same age occur on Howe sound beyond the western end of the section, and between the two areas a great geosynclinal depression was formed in Triassic times in which the Triassic sediments and volcanics were laid down. After folding and deformation of the Triassic beds the Coast granodiorite batholiths were intruded into them in Jurassic times, destroying or assimilating much of the beds and producing such mineralization as now exists on most of the contacts between the granodiorite and the stratified rocks. Deep erosion has since removed much of the batholith's cover, leaving, however, a few remnants. These remnants occur now as long bands striking northwesterly and having a width varying from a few yards to several miles and separated from each other by the granodiorite.

The Coast mountains, therefore, in their geological history, show the following sequence of events: (1) geosynclinal downwarp; (2) filling of the geosynclinal basin by Jura-Triassic sediments and contemporaneous volcanic flows; (3) deformation of the beds and mountain building; (4) batholithic intrusion in late Jurassic; (5) deep erosion and uncovering of the batholithic rocks; (6) volcanic activity breaking out from several centres in Tertiary times and extending into the Pleistocene, with extrusion of lava flows and wide distribution of volcanic ash.

MINERAL DEPOSITS.

Geological maps of the western part of British Columbia show the Coast mountains to be made up of a great mass of eruptive rock, mainly granodiorite, forming a belt from 60 to 100 miles wide and 1,000 miles or more in length. Investigations of the past season have shown that in the section across the Coast mountains along the Pacific Great Eastern railway such a simple condition does not exist, but instead there are several broad bands of stratified rocks—schists, quartzites, argillites, and limestones—which lie in the granodiorite and have been intruded by it. These bands are remnants of the old cover of the granodiorite batholith, which were not destroyed at the time of intrusion nor removed by later erosion. They all strike parallel with the trend of the range and, consequently, their greatest dimension is in a northwesterly direction and their shortest along the line of railway. The contacts of these bands of stratified rocks with the granodiorite are all more or less mineralized. The lateral contacts are mineralized mainly by copper ores, and on the roof contacts, that is where the batholith plunges northwesterly or southeasterly under a roof of stratified rocks, the mineralization is often by the more precious metals.

The significance of the discovery that large bands of sedimentary and other stratified rocks lie in what was formerly supposed to be nothing but a mass of granodiorite in the Coast mountains is far reaching, and it is only fair to assume that other sections through these mountains northward to the Yukon boundary will reveal the same

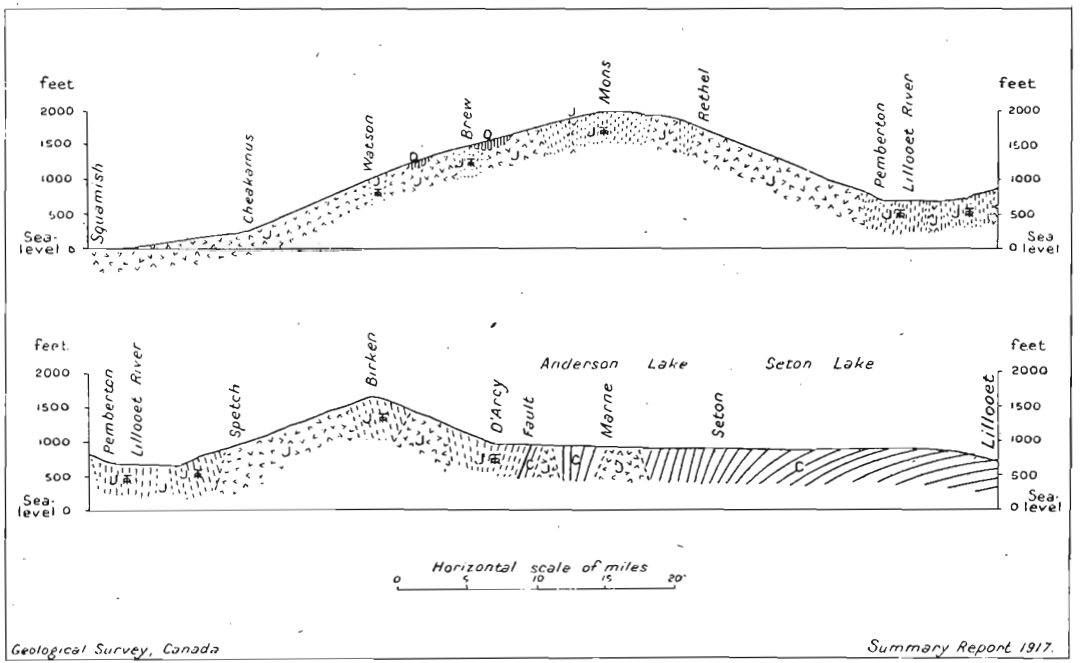

Figure 1. Geological structure section on the profile of the Pacific Great Eastern railway, between Lillooet and Squamish, B.C.

conditions to a greater or less extent. These conditions are most favourable for the occurrence of metallic deposits of copper, lead, zinc, gold, and silver, and the whole interior of the Coast mountains of British Columbia, therefore, becomes an excellent field for prospecting; and not only the eastern and western borders as was formerly believed to be the case. Fortunately the magnificent system of deep fiords that cut deeply into the heart of the ranges makes it possible to prospect for these bands of stratified rocks and to easily develop any ore deposits that may be found in them. Prospectors, therefore, are urged to pay more attention to the possibilities of the Coast mountains than they formerly did.

The mineral resources along the line of the Pacific Great Eastern railway between Lillooet and Squamish include deposits of placer and lode gold, silver, copper, iron ore, talc, and clay. No important developments have as yet taken place, though placer gold has been produced at McGillivray creek and a small shipment of talc made from near the mouth of that stream on Anderson lake. The whole district, however, is new and prospecting was only actively begun about three years ago, at the time of construction of the railway.

Placer Gold.

Mining for placer gold on McGillivray creek was carried on for a short time in the days of the Cariboo gold rush about fifty years ago. Within the last two years mining has again been carried on both above and below the falls near the mouth of the creek. About $700 in gold was taken out in 1916 by two miners, one nugget being valued at $51. The gold has probably been derived from quartz veins in the argillites and schists which outcrop in the valley higher upstream.

Gold, Silver, and Copper Deposits.

Mission Mountain. Near the summit of Mission mountain on the south side of Seton lake some claims have been staked for gold on a massive sulphide deposit near the contact of granodiorite with the rocks of the Cache Creek formation. The deposit was not examined owing to the absence of the owners, so that no statement can be made as to its value or extent, but it is stated to carry fair values in gold and some silver where the development work has been done.

McGillivray Creek. The gold-bearing quartz veins situated 5 miles by trail up McGillivray creek and on the divide between McGillivray and Roaring creeks have been previously described.[1] A number of other locations on gold-bearing quartz leads have recently been made on the west branch of McGillivray creek, but examination of them could not be made owing to the absence of the owners.

Birkenhead River. A large number of claims were staked for copper about twenty years ago in the valley of Birkenhead river near the mouths of Fowl and Tenquille creeks. These have all been abandoned, but in 1917 some more locations were made. The rocks consist of a body of granodiorite cutting through beds of sandstone, argillite, limestone, and lime silicate rocks, the contact running northwesterly diagonally across the valley. The stratified rocks are also traversed by dykes of fine-grained porphyries highly mineralized by pyrite, which on weathering produce a broad, reddish stain of iron oxide on the valley sides. Mineralization, mainly by pyrite, has occurred in places along the contact of the dykes and the granodiorite with the stratified rocks.

Tenquille Creek. Several groups of claims are situated about 25 miles by trail north of Pemberton, on the divide between Wolverine and Tenquille creeks, at elevations of 5,900 to 7,000 feet. These were examined by Mr. Hanson, from whose notes these observations are made. Access to the claims is, at present, by trail up Wolverine creek from Lillooet river, but it is proposed to cut a new trail from Birkenhead river up Tenquille creek which will shorten the distance from the railway to about 15 miles.

[1]Geol. Surv., Can., Sum. Rept., 1912, p. 204.

The rocks of this locality consist of conglomerate, sandstone, slate, limestone, and schists cut by a number of dykes and sills of quartz porphyry and granodiorite porphyry, probably apophyses from an underlying batholith of granodiorite. The deposits are associated with the porphyry dykes and are situated either in them or on their contacts with limestone or schists, and the chief values are in copper with less amounts of gold and silver.

On the Eva group, owned by Phil White, the ore, which is 6 feet wide, occurs as a replacement of siliceous, sericitic schist along the border of a dyke of quartz porphyry, and contains chalcopyrite, pyrite, and some zinc blende and bornite. Surface assays of the ore are said to have yielded as much as 8 per cent of copper.

On the two groups adjoining the Eva group, namely, the Regal and Copperplate, the ore occurs in shear zones 4 or 5 feet wide in quartz porphyry and the mineralization is by chalcopyrite, pyrite, and zinc blende. On these three groups the development work consists of open-cuts and shallow pits.

Situated a few miles south of the Eva group on the ridge between Lillooet valley and Tenquille creek, at about 6,800 feet elevation, are a number of other claims owned by McLeod. The ore here appears to be the indefinite contact metamorphic type in limestone on the borders of a granite porphyry. Mineralization is mainly by magnetite and some chalcopyrite over a zone from 8 to 50 feet in width. Here also the development work consists of open-cuts and shallow pits.

Owl Creek. The group of claims situated on Owl creek above the Dominion Government Fish Hatchery at Spetch post-office and owned by the Copper Queen Mining and Smelting Company has been described in detail by W. Fleet Robertson.[1] The country rock here is a wide granite porphyry dyke which is intrusive into the quartzites and schists of the Jura-Triassic formation. The whole dyke is more or less mineralized by pyrite, but concentrations of both pyrite and chalcopyrite have taken place along a number of parallel shear zones up to 8 feet in width in the porphyry and from these zones Robertson obtained samples which yielded about 5 per cent copper, with traces of gold and silver.

Immediately north of the Owl Creek claims and at an elevation of about 5,000 feet on the mountain between Owl creek and Birkenhead river is the Iron Man group. The country rock of the claims is mainly granodiorite with, however, a roof remnant of limestone about 1,500 feet long and about 400 feet wide, completely surrounded by the granodiorite. The limestone is now highly altered to hornfels and lime-silicate rock by the intrusion of the granodiorite into it. The thickness of the limestone as exposed at the west end is not more than 100 feet. The ore-bodies are the contact metamorphic type and occur in ill-defined bunches throughout the limestone. At the west end of the limestone area a body of ore about 50 feet long and 10 or 15 feet wide is exposed and has been opened up. The ore contains magnetite, pyrite, arsenopyrite, and some chalcopyrite, and in the fracture planes is an appreciable amount of cobalt bloom. Assays of this ore are stated to yield from $7 to $35 in gold. About the middle of the limestone area a shaft 15 feet deep shows magnetite in a gangue of calcite with some arsenopyrite, cobalt bloom, and copper carbonate. The geology of the deposit would indicate that though the surface showings are fair it is unlikely that the ore would go deep enough to make the deposits in the locality worth working.

Lillooet Lake. The band of quartzites, argilites, limestone, and schists which extends along the railway from Spetch station to Pemberton continues southeastward as far as the northwest end of Lillooet lake. It is bounded on the northeast and southwest sides by granodiorite which is intrusive into it. Claims have been staked in the sedimentary rocks on both the north and south sides of the upper end of the lake.

The Margery group is situated at an elevation of 3,500 feet above the sea, about 2 miles northwest of the end of Lillooet lake, and is reached by a very steep trail over which horses could be taken only part way. The rocks are quartzites, argillites, and

[1]Ann. Rept., Min. of Mines, B.C., 1916, p. 270 K.

some limestone which is usually altered to "garnetite." These are cut by dykes of porphyry. The ore is of the indefinite contact metamorphic type without definite walls or boundaries and is, consequently, difficult to outline or to follow. It, however, occurs in the altered limestone or garnetite and contains chalcopyrite, arsenopyrite, pyrite, blende, and magnetite. Free gold, also, has been reported to occur in the outcrop. Assays show both gold and copper, the former in picked samples running up in the hundreds of dollars to the ton, but the distribution of the values is very erratic. Some platinum is also stated to have been found in the assays.

The Eagle group, owned by Keddy and Charlston, is situated about 700 feet above the lake on the southwest side. The country rocks here are quartzites interbedded with limestone and cut by small dykes of hornblende porphyrite and larger dykes of fine-grained quartz porphyry. In a tunnel 110 feet in length an ore-body about 5 feet wide replaces a band of limestone on the borders of a dyke at a point 50 feet from the portal of the tunnel. The ore consists of pyrite, chalcopyrite, magnetite, zinc blende, and pyrrhotite; having its chief values in copper with some gold and silver. About 200 feet northwest from the tunnel is a large deposit of the contact metamorphic type containing magnetite, hematite, and some iron and copper sulphides. The ore-body lies at the contact of a fine-grained acid porphyry with the quartzite and limestone, the ore occurring in the sedimentary rocks. The mineralization is exceptionally heavy and widespread and the zone of mineralization is said to extend a considerable distance to the southeastward along the lake shore.

Fitzsimmons Creek. The Fitzsimmons group of claims is situated about 3 miles south of Green lake on the northeast side of Fitzsimmons creek at an elevation of about 700 feet above the railway, and is connected by an indifferent pack trail with Mons. Nothing has been done on the claims for some years and what development there is consists of stripping the surface and open-cuts. The rocks, as exposed in a number of steep bluffs, consist of limestone altered by the development of garnet and epidote in it and cut by a number of narrow, irregular quartz porphyry and granite porphyry dykes. The ore appears to be the result of the intrusion of the dykes and occurs in the altered limestone in indefinite bunches up to 20 feet in width and of unknown length. The mineralization is by copper and iron sulphides, zinc blende, and some magnetite. At the lower working a dump of about 20 tons of broken ore might average 3 per cent in copper. At the upper workings much blende is associated with pyrite and there is less chalcopyrite. The gold content here, however, is said to run about $20 to the ton.

The Green Lake Mining and Milling Company's claims [1] are situated on the southwest side of Fitzsimmons creek about 7 miles up and at an elevation of about 2,000 feet above the railway. These have not been worked for some years and the tunnels have caved in, so that they could not be examined.

The King Solomon group is situated at the head of Fitzsimmons creek on the divide overlooking Cheakamus lake. A tunnel, 45 feet in length, has been driven to cut a bed of argillaceous limestone, mineralized by pyrite and magnetite, which outcrops on the hillside above and in which an open-cut has been made about 85 feet higher up. The limestone is in contact with sheared granodiorite nearby, which is probably the cause of mineralization. The values are in gold, but are apparently low for that location.

Mons. Several groups of claims are situated on the slope of the valley west of Mons. The rocks of this locality consist of interbedded slates, limestones, and some volcanic rocks cut by numerous dykes of granodiorite. The ore-bodies are all of contact metamorphic origin and are situated in the limestone near its contact with the granodiorite, the limestone having been altered at the time of intrusion and mineralization to a garnet-epidote rock. The following descriptions are from the notes of Mr. Hanson, who examined the various groups.

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[1] Ann. Rept., Min. of Mines, B.C., 1910, p. 149 K.

Archibald and Horstman's claims lie at an elevation of about 3,400 feet above the railway. Here at one point a lens of limestone 100 feet long by 20 feet wide, altered very largely to garnet and epidote and bounded on either side by dykes of granodiorite, has ore for 5 or 6 feet on either wall consisting of magnetite, chalcopyrite, pyrite, and arsenopyrite. At another point a short tunnel cuts across 15 feet of altered limestone impregnated with the same minerals, and other small bunches of ore are present in the neighbourhood. Besides the short tunnel these ore-bodies are developed by open-cuts. Assays give from 2 to 5 per cent of copper with small amounts of gold and silver.

Farther down the slope of the hill are three groups of eight claims, each owned by McGillivray, known as the Summit, Greentree, and Alpha groups. On the Summit group a body of ore 8 or 10 feet wide containing pyrite, chalcopyrite, magnetite, and some bornite occurs on the edge of a band of altered limestone where it is in contact with a dyke of granodiorite. Assays of this are said to show about 2½ per cent in copper and considerable gold. A tunnel is being driven to prove the existence of the ore-body at a depth of 160 feet. About 450 feet below this tunnel, another tunnel 95 feet in length is being driven along a band of mineralized schist to cut an ore-body which is exposed in a cut 50 feet above.

A number of other mineral claims have been staked about Alpha lake and along the railway to the southwest, but little development work has been done and no important bodies of ore have been opened up.

Brew. A band of sedimentary rocks at this point, composed of conglomerate, sandstone, schists, and limestone, is intruded on the west by a sheared granodiorite and on the south and east passes underneath basalt surface flows. A number of mineral claims have been staked in this band, but no important deposits of ore have been proved as yet. On Widow creek a tunnel 40 feet in length has been driven across the strike of the beds showing up some small lenses of quartz mineralized with pyrite, chalcopyrite, zinc blende, and galena. A second tunnel near the railway shows no mineralization in its length of 65 feet.

On the May Queen mineral claim, which lies on the east side of the railway track between mile-posts 26 and 27, a short tunnel has been driven to cut a band of limestone 7 feet wide mineralized by zinc blende, pyrite, galena, and chalcopyrite. The band of limestone can be traced some distance southeastward toward Cheakamus river. No information could be obtained as to the valuable metal content of the deposit.

Daisy Lake. Several mineral locations have been made on the east side of Daisy lake, but the only important deposits seem to be on the Venetian group, the development work on which is 750 feet above the lake. Sandstone, slate, and some limestone, striking north 30 degrees west and dipping at high angles, are traversed by a quartz vein striking north 75 degrees west and dipping to the southward 20 to 35 degrees. The vein is very irregular in size and pinches and swells from a few inches up to 15 feet. The ore minerals are mainly pyrite and chalcopyrite which occur more abundantly near the walls and along fractures in the quartz. The ore contains gold, silver, and copper and about fifteen tons of it have been picked and sacked for shipment. The owners estimate this will average about $90 per ton in these metals. The vein is developed by an incline from the outcrop, 72 feet in length, and a crosscut tunnel 156 feet long which cuts the vein at a vertical depth of 40 feet below the outcrop.

Watson. A narrow band of massive quartzites crosses Cheakamus valley at Watson siding and four or five tunnels, 20 to 100 feet in length, have been driven into small lenses of ore that occur in the quartzites. This work has since been abandoned because of the small and discontinuous character of the lenses.

Iron Ore.

A group of about twenty claims at one time covered an area at the north end of Alta lake, where deposits of bog iron ore occur on the western slopes of the valley. All except four of these claims have now been abandoned. The principal exposure of

the iron ore occurs about half a mile west of the north end of Alta lake. Here on a heavily wooded slope a large number of trenches have been dug to expose the iron ore. These trenches show the deposit to have a maximum thickness of about 10 feet, thinning out, however, on all sides. The area covered by the deposit is about 60,000 square feet, having a length of 450 feet and a greatest width of 250 feet. The top of the deposit is composed of loose earthy material, whereas the bottom is hard and shows stratification. It is estimated that there are about 12,000 tons of ore in this deposit. A partial analysis, by H. A. Leverin of the Mines Branch, of a sample (2) taken from the lower part of the deposits and also of a sample (1) taken by Mr. W. F. Robertson to 1910[1] gave the following results:

Analyses of Iron Ore from Near Alta Lake.

—	1	2
	Per cent	Per cent
Iron, metallic	48·0	40·98
Sulphur	0·2	1·60
Phosphorus	0·1	1·88
Insoluble, silica	2·2	1·24

Other small areas of bog iron ore of similar character occur in the neighbourhood, but their extent is unknown. The iron ore seems to be derived from pyrite-bearing rocks which are exposed on the hillsides above the deposits.

Talc.

Both the Carboniferous and Triassic rocks in the Coast mountains contain bands of talcose rocks associated with the other beds. Samples of a high grade commercial talc have been found in the stream deposits of Cayuse creek, which come no doubt from the Carboniferous rocks higher up on that stream. About two carloads of talc have been shipped from a bed about 3 feet wide that crosses the railway track at Anderson lake, near the mouth of McGillivray creek. Talc occurs again in the form of talc schist just west of Owl creek, but an examination of this by Mr. Keele of the Mines Branch shows that the material is too gritty and dark-coloured to be useful in the paper industry and the rock itself is too impure to be of value as a commercial source of talc.

Clay.

Clays of glacial origin, from which the common red brick could be manufactured, occur in Fraser valley at Lillooet and at the fish hatchery on Birkenhead river. At the latter locality the clay occurs as a bed about 10 feet thick exposed in the bank of the river covering an unknown area. The following report, by Mr. Keele of the Mines Branch, on a small sample submitted to him, gives the character and value of the clay:

"Sample of clay from mouth of Owl creek, Birkenhead river, Lillooet district, B.C.

"This is a light grey coloured clay containing a large amount of silt. It is stratified, stoneless clay of glacial origin. Owing to its silty character it does not work up into a very plastic body when ground and mixed with water, but is short in texture and rather flabby.

"It can be dried quickly after moulding without danger of cracking.

[1] Ann. Rept., Min. of Mines, B.C., 1919, p. 147 K.

"This clay burns to a light red, porous, but strong body at a temperature of 1,800 degrees F. with a total shrinkage of 5 per cent. When burned to 1,900 degrees the brick darkens slightly in colour and becomes more dense in structure.

"The clay will begin to fuse at a temperature of 2,000 degrees F. Common red building brick can be manufactured from this clay by the soft mud process, and as the shrinkage is low it would not be necessary to add sand. It is not suitable for field drain tile on account of its lack of plasticity."

INDIAN RIVER COPPER DEPOSITS, VANCOUVER MINING DIVISION.

By Charles Camsell.

Indian river is a stream about 20 miles in length flowing south into the north arm of Burrard inlet about 25 miles from the city of Vancouver. It occupies a steep-sided, heavily-wooded valley in the Coast mountains which rise in massive peaks 3,000 to 4,000 feet on either side. Claims have been held for a number of years on the upper part of the stream and on the divide separating Indian river from Stamish river. Recently, however, a large number of additional claims have been staked farther down the valley and much interest has been shown in prospecting these claims. A trip of three days was made at the end of August from Squamish to the mouth of Indian river and the more important copper deposits were examined en route.

A wagon road runs up the valley of Indian river from the north arm about 6 miles to an abandoned lumber camp and from that point a trail extends up to the head of the river, across the divide, and down the valley of Stamish river to Squamish. The trail on Stamish river is, however, not in good repair and some work would have to be done on it before pack horses could be taken through.

A band of stratified rocks a mile or more in width, consisting of schists, andesites, argillites, and some limestone, extends more or less continuously in a northwesterly direction along the valleys of Indian and Stamish rivers. It lies a few miles east of the Britannia mineral zone and is separated from that zone by a belt of granodiorite. The rocks are all highly metamorphosed by regional as well as contact igneous action and the limestone shows a pecular silicification whereby kernels of quartz have been abundantly developed in it. Dips and strikes are difficult to determine, though the attitude of the beds is usually highly inclined and their strike conforms in general to the trend of the whole band. They are cut and surrounded on all sides by granodiorite of the Coast batholithic intrusion and are traversed by numerous dykes of aplite, quartz porphyry, granite porphyry, granodiorite porphyry, and other more basic dykes.

The deposits all contain copper as the principal valuable metal and occur either as irregular replacements of the stratified rocks or in the dykes themselves after enrichment by mineralizing solutions. Chalcopyrite is the only copper-bearing mineral noted, but associated with it are much pyrite and some zinc blende. Most of the deposits are of somewhat different character to those of the Britannia mineral zone, though their origin may be attributed to the same general causes and the same period of metallization.

Owing to the abundance of sulphide mineralization in the igneous rocks, and especially some of the dyke forms, and the widespread distribution of these dykes throughout the whole band of stratified rocks the geological conditions are favourable for the occurrence of important bodies of copper ore and it is reasonable to expect that such will be proved to exist when prospecting and development work have been carried farther. The difficulties presented to the active prospecting of this district are great, however, owing to the heavy forest growth and the deep covering of drift. The situation, too, of the mineralized zone, 12 to 15 miles from tidewater and served only by a rough pack trail, will make the progress of development slow.

Belle Group.

The Belle group, consisting of five crown-granted and surveyed claims owned by J. Habrich and P. Herres, is situated on the west slope of Indian River valley about 15 miles up from the north arm of Burrard inlet. The workings are from 500 to 700 feet above the stream bed, at an elevation of 2,300 to 2,500 feet above the sea, and consist of a crosscut tunnel 100 feet in length and considerable surface stripping.

The rocks of this group consist of argillite, greenstone, and limestone that is metamorphosed by the development in it of much quartz and biotite. The ore exposed by the workings lies in a dyke or dykes of granodiorite porphyry mineralized mainly by pyrite and some chalcopyrite, in which a later fracturing has permitted silicification and a second sulphide mineralization. About 107 feet above the tunnel the outcrop of the ore is about 10 feet wide with an apparent dip of about 45 degrees into the mountain. The tunnel was driven to cut this, but has not been carried far enough. Three other exposures of ore have been made diagonally up the slope of the hill to the northwest, at intervals of 150 to 200 feet, the first one showing ore 30 feet in width, the second about 7 feet, and the third 4 feet. It has been assumed that these four exposures are all on the same lead, but it seems quite possible that they may be separate but parallel ore-bodies perhaps in echelon arrangement, for the apparent strike of the beds in the tunnel would bring the outcrop of the ore-body to the northward lower down the hill than where the exposures have been made. Two other outcrops of ore appear in the canyon of Copper creek several hundred feet south of the tunnel. The ore here occurs in quartz porphyry dykes and along their contact with the intruded rocks. Mineralization is mainly by pyrite with less chalcopyrite and some zinc blende, the chalcopyrite occurring usually as a later impregnation along fractures. The dip here seems to be about 65 degrees to the southwest and the strike north 40 degrees west.

Assays of several samples of the ore are said to average about 3 per cent in copper, one ounce in silver, and some gold.

Bulliondale Group.

This group of claims is situated on the same slope of Indian river as the Belle group and about a mile lower down the valley. It is on the same ore zone and the ore occurs under similar geological conditions. A tunnel about 100 feet in length was driven to crosscut the lead at a point about 1,000 feet above the river, but the entrance was covered by a slide and could not be examined. The ore occurs in a fine-grained, acid porphyry dyke, mineralized by pyrite and chalcopyrite, and also in a reddish, knotted, silicified limestone along the contact of the dyke. The owners were not present at the time of our visit so that little information could be obtained regarding assay values.

London Group.

This group is situated on the east side of Indian River valley diagonally opposite the Bulliondale and a little below it. The main work is a tunnel 110 feet long driven into a wide granodiorite dyke outcropping 300 feet above the river. The granodiorite shows a large, iron-stained outcrop, but where cut by the tunnel is massive and breaks on irregular fracture lines. Pyrite is abundantly disseminated through the granodiorite and more sparingly, along with a little chalcopyrite, in small quartz veinlets that traverse the rock, indicating a second period of mineralization. Molybdenite also occurs sparingly in the fracture planes. The ore, however, appears to be very low grade.

Roy Group.

This group also lies on the east side of Indian River valley and adjoins the London group on the south. The workings are situated 850 feet above the river, or about 1,900

feet above sea-level, where a number of good cabins have been built. A good trail connects the workings with the main Indian River trail. The distance from tidewater is about 14 miles.

The country rock is a greenish, medium-grained, slightly porphyritic rock, probably an andesite, which is in places schistose and passes into a chlorite schist with a strike ranging from north 60 degrees west to north 40 degrees west. It is cut at the outcrop of the ore-body by a granodiorite porphyry dyke a few feet in width which strikes south 50 degrees west. The andesite is generally mineralized by disseminated crystals of pyrite.

The ore-body is of the replacement type and occurs in the andesite along a strike of north 40 degrees west, the replacing minerals being chalcopyrite, pyrite, silica, and some zinc blende: Where the ore zone is cut by the porphyry dyke a strong concentration of the copper and iron sulphides has taken place to form a high grade ore-body covering a surface area of about 2,300 square feet. This area of intense mineralization extends along the dyke and on either side of it for about 50 feet and at right angles to it for about 25 feet on one side and 45 feet on the other side. The replacing sulphides are well crystallized and bunches of almost pure chalcopyrite several inches in diameter are common throughout the concentrated zone.

The surface of the ore-body has been completely exposed by stripping. Much stripping and trenching have also been done for several hundred feet around in the attempt to determine the horizontal extension of the ore. Some diamond drilling has been done on the side of the hill farther down to prove the vertical extent of the ore, but the results of this could not be ascertained.

Several other groups of claims have been staked on the slopes of Indian River valley below the Roy group, but since very little development work has been done up to date and the owners of the claims were not present at the time of our visit no examinations of these were made.

NOTE ON THE OCCURRENCE OF DIATOMACEOUS EARTH, CLAY, AND MAGNESITE ALONG THE ROUTE OF THE PACIFIC GREAT EASTERN RAILWAY.

By Charles Camsell.

MAGNESITE.

A discovery of magnesite in what has not yet, however, proved to be commercial quantity, was made during the past summer by Mr. C. E. Cartwright, C.E., in several places along the railway grade on the southwest side of Lac la Hache. The magnesite is a hard, white, fine-grained variety and was first discovered in the form of float in several of the cuts in the railway grade. The discovery was made since our visit to that region and was consequently not examined by us. Mr. Cartwright, however, reports that he was able to trace the float to deposits in place in volcanic rocks of apparently Tertiary age. A section of the rocks in a railway cut in which the magnesite occurs, shows several feet of glacial drift overlying a hard, volcanic rock apparently an olivine basalt, which in turn rests on a yellowish, decomposed material. The decomposed material at the base of the section shows evidence of having been subjected to thorough weathering, as it is quite plastic and easily moulded when wet, but has not been completely leached of its lime contents, since it effervesces in cold dilute acid. Mr. Keele describes it as probably being residual from dolomite and representing the old decomposed surface over which the basalt flowed out.

The magnesite occurs in a number of short, narrow veins, the largest only about 12 inches wide, in the basalt and on the contact between the basalt and the underlying

decomposed material, and though the deposits so far discovered are not of commercial importance it is probable that larger bodies, capable of being profitably worked, exist somewhere in this district. The presence of a number of deposits of hydromagnesite [1] between 108-mile house and 127-mile house supports the idea that such deposits may exist.[2]

Mr. Keele of the Mines Branch, to whom a small sample of the magnesite obtained from Mr. Cartwright was submitted, describes it as follows. The material is white in colour, fine-grained and dense in structure, not crystalline like the Quebec magnesite. A chemical analysis made by M. F. Connor shows it to have the following composition:

	Per cent.
Magnesium carbonate	70
Calcium carbonate	27
Iron	2

The material was submitted to heat treatment up to 1,600 degrees C. without being affected. It has not been subjected to a higher temperature, so that its softening point is unknown at present. The lime content is rather too high for a commercial magnesite. Further prospecting in the vicinity of the above occurrence appears to be necessary in order to determine if a workable deposit of higher grade magnesite exists.

DIATOMACEOUS EARTH AND CLAY.

Rocks of Tertiary age are exposed at intervals in the valley of Fraser river between Alexandria and Quesnel, representing either a single interior lake basin or a series of small disconnected basins. The rocks consist of sandstones, clays, and some coal overlaid by a bed of diatomaceous (infusorial) earth or tripolite lying in a horizontal attitude or dipping at angles of about 20 degrees. They have been described by G. M. Dawson [3], and from collections of fossils made in them, Penhallow [4] concluded that the beds were of Eocene age. The series is overlaid by flows of basalt of considerably later age.

The coal seams exposed in the sections near Quesnel are all thin and are considered by Dawson to be of little commercial value on account of their small size and disconnected character. On Australia creek, however, Mr. J. M. Yorston, M.P.P., is mining and using coal from a seam 6 feet in width which outcrops on the stream a short distance above his house. The coal is fairly clean, holds blebs of amber, and is stated to contain about 35 per cent of fixed carbon. It makes a fairly good domestic fuel. Near Quesnel some of the seams have been burnt out and for some miles along the valley of Fraser river a wide area of landslides has occurred in consequence.

Clays of a grey or yellowish colour are exposed at several places in the valley of the river and at a point on the bank of Quesnel river immediately behind the town of Quesnel they have been used for the manufacture of brick. A small sample collected from the pit at the brick factory was submitted to Mr. Keele, of the Mines Branch, who makes the following report:

"Sample of soft grey clay shale from the Tertiary formation in the vicinity of Quesnel, B.C.

"When ground and mixed with water this material works up into a very plastic, smooth, and rather pasty substance. Its working qualities appear to be good and it will probably flow easily through any shape of clay-working dies.

"Its drying qualities could not be determined, as the sample submitted for examination was too small.

"The shrinkage on drying of small bricklets was 10 per cent, which is rather great.

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[1] Geol. Surv., Can., Ann. Rept., vol. xi, pp. 10-12 R.

[2] More important discoveries of magnesite have since been made near Clinton by Mr. Cartwright.

[3] Geol. Surv., Rept. of Prog., 1871-72, p. 58; 1875-76, pp. 256-260.

[4] "Tertiary Plants of British Columbia," No. 1013, Geol. Surv., Can., pp. 28 and 110.

"It burns to a dense, hard, buff-coloured body at a temperature of 1,000 degrees C., and it vitrifies at 1,250 degrees. The clay fuses at cone 15 about 1,430 degrees C., therefore, it cannot be considered as a refractory material.

"Owing to the high shrinkages of this clay it would require the addition of a certain amount of sand or other non-plastic ingredient.

"Nothing definite can be stated on the uses of the material until a larger sample is tested with the addition of sand."

The diatomaceous earth or tripolite immediately overlies the clay at the brick factory, where it has a thickness, as exposed in the bank of Quesnel river, of 5 feet. It was observed in the sections on the wagon road south of Quesnel river, 2 miles or more distant from the town, and is stated to form the white cliffs that are visible across Fraser river 3 or 4 miles away in a westerly direction, where according to Dawson's section [1] it is overlaid by beds of rusty rounded gravels and basalt flows. The area, therefore, over which the diatomaceous earth was originally laid down must have covered several square miles, and though much of it must since have been carried away through the erosion of Fraser and Quesnel rivers and Baker and other creeks that enter Fraser valley in this locality, a large area still remains.

The material represents a deposit that was laid down in a lake basin, and since the beds are conformable with the clays and sandstones previously described and determined as Eocene in age the diatomaceous material must be ascribed to the same period.

Dawson [2] describes an occurrence of similar material on Blackwater river 25 miles northwest of Quesnel and another 105 miles due west of Quesnel on the south side of Tsacha lake, which, though not actually seen in place, he believed to occupy a position beneath some comparatively recent volcanic rocks. The material resembles "a very fine white clay, but proves to be a diatomaceous earth rich in *Gallionella, Cyclotella,* and other freshwater forms."

Another British Columbia locality is on Vancouver island within 10 miles of Victoria in the valley north of Prospect lake. This has recently been described by C. H. Clapp.[3]

C. W. Drysdale [4] describes a locality 18 miles from Ashcroft and another on Deadman river in the same region.

The Quesnel diatomaceous earth is a white or greyish, very light, porous material which before it absorbs water will float. Examined under the microscope it is seen to consist very largely of the broken fragments of tests of diatoms so small that a very high power of magnification is required to identify them. Mr. Keele of the Mines Branch makes the following report on a sample submitted to him for examination:

"Sample of soft chalky material from vicinity of Quesnel.

"Examined under the microscope this material appears to be made up mostly of diatoms, and although there is a small amount of impurities present it may be called diatomaceous (infusorial) earth.

"A partial analysis shows it to contain:

	Per cent.
Silica (by difference)	76·16
Loss on ignition	10·78
Residue	13·04
	99·98

"The material fuses at cone 16 (1,450 degrees C.) and, therefore, cannot be considered to have refractory qualities.

"The material in the crude state has various uses, and it is possible to float off the finer portions in water for special uses.

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[1] Geol. Surv., Can., Rept. of Prog., 1875-76, p. 256.
[2] Geol. Surv., Can., Rept. of Prog., 1876-77, p. 79.
[3] Geol. Surv., Can., Mem. 36, p. 137.
[4] Geol. Surv., Can., Sum. Rept., 1916, p. 53.

"Insulating brick for conserving heat in furnaces, kilns, etc., can be made by mixing the earth with about 20 per cent of the Quesnel clay and adding sawdust. The mixture is made up into bricks and burned, resulting in a light, porous, non-conducting, structural material."

The analysis indicates a somewhat impure earth compared to the high grade earths of California and New York state which contain as much as 86 per cent of silica.

The effectiveness of diatomaceous earth as a thermal insulator has led to its extensive use in various forms, not only for the conservation of heat in ovens, furnaces, boilers, etc., but for the conservation of low temperatures in cold storage plants, refrigerators, etc. In addition, one of its oldest uses is as a polishing material in the form of dry powder or mixed with hard grease or some cleansing fluid. It also finds a wide application as "a filler for rubber goods, and records for talking machines, a wood filler in paints, for water filters, and beet and sugar solution filters, as an absorbent for artificial fertilizers, for glazing tiles and pottery and in the manufacture of water glass, ultramarine, and various pigments, analine and alizarine colours, paper, sealing wax, fireworks, matches, gutta percha articles, solidified bromine, papier-mache, and many other articles."[1]

The only production of diatomaceous earth in Canada is from Nova Scotia, the amount ranging in the last ten years from 30 to 600 tons annually, and the amount used in Canadian manufactures has been in the neighbourhood of 100 tons annually.

The situation of the Quesnel diatomaceous earth, on the route of the Pacific Great Eastern railway, is excellent for easy and economical handling if any demand for it should arise.

INVESTIGATIONS IN THE SLOCAN DISTRICT, B.C.

By M. F. Bancroft.

CONTENTS.

INTRODUCTION.

Slocan district, including the Ainsworth, Slocan, Slocan City, and Trout Lake mining divisions, embraces the area in British Columbia which annually leads in the silver production of the province. Four months of the field season of 1917 were devoted to a reconnaissance survey of 800 square miles of the northern part of the Slocan district in the Ainsworth and Trout Lake mining divisions. The object of the work was to continue geological mapping north from the Slocan map-area and investigate the geology of ore deposits known to occur in the country drained by the Lardeau and Duncan rivers, north and west from the head of Kootenay lake.

[1] Dept. of Mines, Mines Branch, Mineral production 1914, p. 170.

In addition to areal mapping in the Lardeau, deposits of manganese in the vicinity of Kaslo were examined, also the L. H. gold mine near Silverton.

J. A. McLennan, of the university of Alberta, ably assisted in the field work. The writer wishes to thank mine owners and those interested in the different prospects visited for their whole-hearted co-operation.

REGIONAL GEOLOGY.

The regional geology of the Slocan district presents many factors to be taken into account as governing, in a measure, ore deposition. Three of these have to be consistently regarded, namely, widespread igneous intrusion, the lithological character of the rocks invaded, and the structural relations, particularly where ore deposits requiring detailed investigation occur.

Igneous intrusion on a large scale is exemplified in the Coast Range batholith of the Cordillera. The granite areas of southwest Kootenay are fairly continuous westward to the Coast range and it would seem that the granites in the Slocan district are a part of this great batholithic complex. Different periods of vulcanism and intrusion are recorded in the rocks of the Kootenay district, but it is the intrusive contact and structural relations of the large granite massives that seem to have the greatest economic significance. The most important mineral-bearing fissures bear genetic relationships to the Jurassic mountain-making revolution and the intrusion of the Jurassic and early Cretaceous batholiths. This is recognized as the most important ore-forming period in the history of the Cordillera. Consequent to intrusion there followed widespread mineralization and the heavy sulphide ores of the Slocan district were then introduced under favourable conditions of temperature and pressure.

The groups of rocks invaded by the Jurassic granite in southern British Columbia are composed of older igneous and sedimentary members, which constituted the batholithic roof and were uptilted and folded during the period of mountain-building and intrusion. The sedimentary argillites, quartzites, and limestones belonging to different geological horizons have now been studied in some detail in the mining areas of Sheep creek, Ymir, Nelson, Ainsworth, and Slocan.

SLOCAN MAP-AREA.

Two prominent groups of rocks have been recognized in the Slocan map-area. The most widespread group is the Slocan series, consisting of carbonaceous argillites and fossiliferous limestones. The second group, consisting of igneous material with minor sedimentary members, is known as the Kaslo Volcanics group and underlies the Slocan series.

Both groups are exposed through folding and erosion in the Blue ridge, northwest from the town of Kaslo, where the central part of an anticlinal fold is marked by a belt of Kaslo volcanics trending from north to south and flanked on each side by the Slocan series.

Once this structure was understood, it became evident that the belt of Slocan ast of the Kaslo Volcanics area of the Blue ridge could be traced northward into the Lardeau. It seemed apparent as well that the Pend d'Oreille group of Nelson mining division, which forms the country rock of many of the ore deposits of Ymir, was persistent along the trend of the Selkirk Mountain region, and might be represented in the Slocan district by the Slocan series.

MANGANESE IN THE SLOCAN MAP-AREA.

Both primary and secondary deposits of manganese occur on the northeast side of the valley of Kaslo creek in the Ainsworth mining division.

The primary silicate, rhodonite ($MnSiO_3$=silica 45·9, manganese protoxide 54·1), is now known to occur in three widely separated localities, namely, in the mining divisions of Ainsworth, Yale, and Kamloops. The fact that rhodonite occurs in rocks of any particular region is of two-fold significance in prospecting. Its occurrence warrants a search, especially for the ores of zinc, and suggests in itself a possible source for the superficial oxide ores of manganese.

Silicate ores of manganese are of value if found in close proximity to smelters treating iron ores and manufacturing spiegeleisen. The silicate ores used for that purpose contain 39 to 45 per cent manganese and 20 to 22 per cent silica. A relatively pure rhodonite would give about 40 per cent manganese, but allowing for admixture of oxides through decomposition of the silicate a higher content of manganese is possible.

Primary Manganese Deposit of Rhodonite.

Three claims, the Harp, Collingwood, and Black Diamond, owned by W. J. Murphy, are situated 5 miles from the town of Kaslo at 2,690 feet elevation, on the northeast side of the valley of Kaslo creek. The property is reached by a short trail starting from the junction of the road to Zwickey station. The workings examined were at an elevation of 2,630 feet close to Murphy's cabin, where a quartz vein 3 to 4 feet wide has been explored by open-cut and tunnel for 33 feet. The vein occurs in the Kaslo Volcanics group of rocks. It conforms with the strike of the formation and dips 80 degrees west.

The immediate hanging-wall is a banded, compact, argillaceous, and somewhat graphic schist. The foot-wall is a 2-foot band of chlorite schist, an altered eruptive. Both walls have gouge material and are well-defined.

The rhodonite in the vein is massive, dull grey to deep pink in colour. It occurs along the foot-wall in fairly continuous bunches which were probably at one time joined together in a continuous band of rhodonite varying in width up to 18 inches. The gangue consists of vitreous smoky quartz, carrying pyrrhotite, pyrite, and chalcopyrite. These sulphides impregnate the wall rock and cause the foot-wall in particular to weather to a rusty brown.

The vein has been formed by hydrothermal solutions ascending along a contact fissure. The veins found associated with the sedimentary members, where the fissuring is along a contact or bedding plane, form the prevailing type in the Kaslo volcanics.

Secondary Changes Within the Vein. The secondary changes in the vein are due to oxidation and carbonation. Fractured surfaces of the rhodonite, especially of the pink-coloured ore, scintillate with secondary carbonate. Eugene Poitevin, of the Geological Survey, reports on a specimen submitted to him, as follows: "It consists of calciferous rhodonite, that is, impure rhodonite, due to the presence of calcium and iron carbonate. Some brownish quartz is also observed on one side of the specimen, this colour being due to the manganese hydrates formed from the weathering of the manganese silicate."

The brownish-black quartz is conspicuous in patches over exposed surfaces of the ore in the vein. When this vitreous black coating is broken through it is seen to form an irregular border of penetration into the light-coloured rhodonite. A small amount of manganese oxide in the form of wad is mixed with the rhodonite in the vein.

Secondary Manganese in the Kaslo Creek Valley, B.C.

The secondary deposits of manganese occurring on the valley terraces and slopes flanking the Kaslo Volcanics area of the Blue ridge are the most noteworthy yet discovered in British Columbia.

The ores consist of different forms of wad or bog manganese (variable $H_2Mn_2O_5$). A sample of this material proved it to be a very good grade of wad, containing 48·14 per cent of manganese and 1·65 per cent iron.

Six claims were staked for wad in July, 1917, at a point 2 miles beyond Murphy's property and 7 miles from Kaslo. On three of these claims, owned and prospected by A. J. Curle, of Kaslo, wad was found in segregations or layers associated with calcareous tufa and limonite.

A study of the distribution and character of the wad deposits on the northeast side of Kaslo Creek valley points to the fact that mineral springs and swampy ground with sluggish drainage played an important part at one time on this valley slope. Deposition must have been in progress for a considerable period, since layers of wad attaining a thickness of 3 feet have been encountered in shallow holes and ditch-like excavations. Beds of wad averaging 6 to 10 inches in thickness, separated by tufa or limonite bands, are typical of the occurrence.

In their distribution the different types of wad may be classified as follows:

Unconsolidated wad forming the surface soil, in places covered by a thin layer of wood ash due to forest fires.

Layers of partly consolidated wad associated with other deposits derived by chemical precipitation from mineral-bearing solutions. Waters charged with carbonic acid readily take into solution, manganese, iron, and calcium. These three minerals are deposited more or less separately in the form of wad, limonite, and calcareous tufa, respectively, near the source of the solutions, about mineral springs, and in drainage basin swamps.

Hummock-like deposits, formed near mineral springs, having abrupt lateral limits.

Concentrating or lumpy ore consisting of nodules and concretions of wad in beds of unconsolidated detrital material. The manganese content in the form of nodules is due to admixture consequent upon mechanical disintegration, transportation, and deposition of debris through surface erosion. In this surface waste, manganese oxide, chemically precipitated, acts as a cement, binds together portions of the detrital material, coats pebbles, forms concretions about organic remains, and exhibits all degrees of dissemination.

These four types of wad deposits may all be considered as subaerial segregations of manganese oxide conforming with the contour of the ground on which they have accumulated.

Wad has been deposited on the east side of Kaslo creek, as the mineral-bearing solutions are carried from Blue ridge into Kaslo creek and the Kaslo volcanics are a source from which iron, calcium, and manganese have been obtained to be deposited later as limonite, calcareous tufa, and wad. This is shown[1] by the relation of drainage to bedrock along Kaslo creek. All streams coming in from the east side of the valley have their basins limited to the area of Kaslo volcanics, specifically those which enter the creek north from Zwickey. Furthermore, in the Kaslo volcanics there are quartz veins carrying calciferous rhodonite, such as Murphy's deposit; boulders of manganese-rich gneiss, such as those occurring on Curle's property; and the black oxide of manganese sparsely distributed in and near metalliferous veins mined in different parts of the Slocan district. Mineral springs are at the present time depositing a ferruginous, calcareous, manganiferous tufa, at a place one mile from Curle's property on the same side of the valley below the old tote-road. The hummocky ground produced by the deposition of minerals and the shifting of the various channels is a marked feature of these deposits.

The bog manganese includes varying quantities of organic material such as accumulates in swamps. The swampy conditions have, however, almost disappeared since the removal of the protective covering of forest and vegetation from the terraced valley sides.

The terrace or benches extend intermittently on both sides of the valley and have been carved from the unconsolidated alluvial and boulder clay deposits, accumulated

[1] Geol. Surv., Can., Sum. Rept., 1916, pp. 44-63.

during Glacial and post-Glacial time. Patches of swamp were formed in the irregularities of the ground across these terraces, but the results of exploration thus far have not brought to light any one deep or extensive basin in which wad has accumulated. However, these deposits tend to smooth out the surface contour by filling in the depressions and only systematic prospecting will definitely settle on how large a scale the deposition of wad concentrated in any one place. The layers of wad approximately conform with the contour of the present ground surface.

The swamps are the result of sluggish drainage and stagnant pools. Exposed to evaporation, the carbonic acid gas is driven off and the carbonaceous matter acting as a reducing agent precipitates the carbonates in the form of oxides.

Prospects for Manganese. Local geological relations justify an active search throughout the Slocan for deposits of wad. The lower portions of the valley of Kaslo creek from Zwickey 6 miles northward and beyond Adamant station offer a hopeful field for prospecting within easy reach of transportation.

Detailed Description of A. J. Curle's Property. The ground covered by the six claims owned by A. J. Curle extends from the valley bottom of Kaslo creek over a series of benches on the east side of the valley. The Kaslo-Nakusp branch of the Canadian Pacific railway and the old tote-road to Bear lake, completed in 1892, traverse the property. The long strips of corduroy at intervals along the tote-road show that swampy conditions had to be overcome at the time the road was built across the valley terraces in this locality. However, it was not generally known that bog manganese was being deposited here about the mineral springs and in the patches of swamp.

Wad has thus far been found definitely in place on three of Mr. Curle's claims, Manganese, Manganese No. 1, and Manganese No. 2. The excavations on the average are scarcely 4 feet in depth and one to three bands of wad may be present in a 4-foot vertical section. The layers of wad are separated by surface waste or bands of limonite either cellular or of an early texture.

Manganese claim is crossed by the Canadian Pacific railway at an elevation of 2,338 feet. The ground rises from close to the track at a 30-degree slope to the top of a terrace 150 feet higher. This terrace is approximately 200 feet in width. Then comes a step of 50 feet to the next terrace which is somewhat broader. The third terrace, at 2,718 feet elevation, is much wider and longer than the lower benches. The valley side steepens from this altitude towards the Blue ridge.

The wad deposited on Manganese claim occurs in scattered showings. The first is on the slope up to the lowest terrace, where some very hard and sinter-like wad appears overlying boulder clay and capped by calcareous tufa from 3 to 6 feet in thickness. A block of tufa 10 feet by 6 feet, and 3 feet thick has been lifted into a conspicuous place among the roots of stumps at the railway level. The under half of this block is thoroughly impregnated with the black oxide of manganese.

Other indications of wad were noted in passing up to the highest bench at altitude 2,718 feet. It is on this bench, crossed by the tote-road, that most of the ore areas are to be found. The chief ore area on Manganese claim is 600 feet in length and 200 feet in width. Scattered holes in this ore area show thicknesses of comparatively pure wad from a few inches to 2½ feet. Calcareous tufa forms a 10-foot cover in one place on this claim and though water could be heard flowing through the tufa in an underground channel the presence of wad beneath this tufa was uncertain. Manganese claims No. 1 and No. 2 adjoin Manganese claim on the west side. The only patch of swampy ground noted on the property was below the tote-road on Manganese No. 1 claim. This ore area has a width of 400 feet along the bench. It narrows toward the southwest and branches to the northeast with a maximum length of 1,500 feet.

Hummocks, exhibiting the former work of mineral springs, are found on Manganese claim No. 1. The other classes of wad are here also and the surface soil, judging from its blue-black appearance, is rich in manganese oxides. Vertical sections show a maximum of 3 feet of wad close to the ground surface.

Two lobes of the branching ore area lap over on Manganese claim No. 2 and are separated by higher ground, the wad having been deposited along the natural water-courses on either side. Upturned roots of trees exposing lumps of wad in the soil constitute the upper showings on the property.

Average samples of wad taken by the writer from the different excavations on this property gave the following results on analysis by the Mines Branch:

	Per cent
Manganese in ore dried at 110°C	48.14
Iron in ore dried at 110°	1.65
Moisture at 110°C	12.65
Further loss on ignition	7.30

This analysis shows a fairly high manganese content for the wad and the absence of phosphorus and silica further commends this product.

The aggregate tonnage available of this quality of ore would seem to be a few hundred tons at most. It will only be by systematic blocking out of the ore areas that the merits of this type of deposit will become evident. Facilities for transportation are good and as the present price of manganese is high, conditions for recovering the wad in Kaslo Creek valley may never be better than at present.

GOLD IN THE SLOCAN MAP-AREA.

Gold is found at many points in the Ainsworth and Trout Lake mining divisions and two locations have been held for some years within the Slocan map-area. The gold either occurs free in quartz or is associated with sulphides in fissure veins or contact deposits. Gold, where found in the Selkirk Mountain region, seems to be characteristic of the mineralization of certain zones irrespective of the country rock formations.

The fissure vein gold ores of Sheep creek are enclosed in the Summit series of quartzites and argillites; those of Ymir are contiguous with two later sets of rocks which have been intruded by the granite, the Pend d'Oreille schists and the Rossland group of intrusives. Well-marked fissure veins also occur in the Jurassic granite in the vicinity of Nelson and the ore is essentially gold or gold-copper with a quartz gangue. Gold also plays an important part in the mineralization of the Lardeau district.

Gold values are not important in the silver-lead ores mined between Kootenay and Slocan lakes. However, there are two areas in which gold-bearing veins are found, namely, in the Kaslo Volcanics area of the Blue ridge and on Eightmile creek above Silverton, where a roof remnant mostly of igneous material stands out surrounded by granite.

Phœnix Claim.

The Phœnix is owned by M. J. Mahoney, Zincton, B.C., and is situated at 5,500 feet elevation on the west side of Lyle creek. The property is reached by trail from the Whitewater mine. The country rock is Kaslo volcanics. A sample of gold quartz ore taken from the upper showing at altitude 5,650 feet, assayed by the Mines Branch, gave 2·6 ounces of gold. The sample contained no visible gold, but carried sparkling bright cubes of pyrite. This particular fissure vein strikes north 40 degrees west and dips steeply southwest.

L. H. Mine.

The L. H. mine, situated 5½ miles from Silverton on a wagon road at an elevation of 5,250 feet, was examined by R. G. McConnell[1] in 1895. About 1,700 feet of tunnels and raises driven since that time suffices to demonstrate the character of the deposits in their underground relations. The owners of the property, A. R. Fingland and

[1]Geol. Surv., Can., Ann. Rept., New Ser., vol. viii. 1895, pp. 26A-27A.

Charles Brand, had done considerable development work prior to 1911, when the British Columbia Copper Company took a bond on the property, allowing it to lapse in 1913.

Geology. The roof remnant on the headwaters of Eightmile creek embraces a complex of igneous rocks surrounded by granite. It extends 3 miles northeast-southwest and has a maximum width of one mile. The L. H. is located on the northwest margin of this elliptical-shaped area.

It would have required more time than was at the writer's disposal to establish the sequence of geological events recorded on the L. H. property. However, one thing was clear in point of time. Above the L. H. workings there is a considerable outcropping of breccia composed of angular fragments of granite included in basic igneous rock, such as forms the country rock of the L. H. ore deposits. Granitic, aplitic, and micropegmatite dykes cutting through this basic member represent the acidic differentiation phase segregated and intruded into the roof rocks from the upper surface of the magma reservoir.

The country rock of the L. H. is plainly an early basic differentiate, consolidated, and later sheared through dynamic metamorphism. It is a hard, massive porphyry similar in appearance to a sill-rock found in No. 7 tunnel of the Standard mine. This sill-rock, which is intrusive into the Slocan series, has the composition of a kersantite, with plagioclase feldspar and biotite as the chief minerals. The biotite being abundant and of a yellowish colour gives the rock its reddish to brownish-grey colour. In composition, the feldspar is andesine to labradorite. There is a little quartz present and a lesser amount of orthoclase. Secondary calcite is associated with the biotite and there is a certain amount of pyrite developed in the rock.

The lamprophyre dykes of West Kootenay are considered to be the basic differentiates of the greater granite massives and mineralization is only another phase of this prolonged process of magmatic invasion, beginning with Jurassic. Fractures developed locally by dynamic metamorphism furnished the channels of access for silica and sulphides into these rocks above the invading granite. A pronounced and regular jointing along an east and west line has been developed in the rocks of the L. H. property. Besides this there are crushed zones, the material of which has been mashed in situ. Movements of displacement seem to be slight and the underground workings show little positive evidence of faulting beyond a certain amount of sheared structure.

The sulphides are in a zone, varying from 20 to 40 feet in width, which follows the master jointing. This zone strikes 80 degrees (magnetic) and dips 55 degrees northeast. An abundance of quartz stringers prevails in the ore-bodies and furnishes guides to the same.

The ore-bodies developed by the L. H. workings vary from 8 to 30 feet in length and the boundaries are not well-defined. The jointed rock breaks in a very blocky manner outside the ore-bodies, whereas inside the ore-bodies the tunnel walls are much more even and the jointing has been more or less obliterated through replacement by silica and sulphides. The pitch of the ore-shoots appears to be to the northeast. Surface indications point to other smaller zones paralleling the main one in which the underground development work has been done.

The ore consists of pyrrhotite, pyrite, arsenopyrite, and quartz and the gangue is country rock. It is reported that quartz stringers carrying visible native gold have been found on a nearby property, cutting this set of rocks. Small stringers of native arsenic and calcite occur in the ore-body near the mouth of tunnel No. 1. The native arsenic is tin white on fresh fracture and tarnishes to a dull grey. The gold values obtained in the different ore-bodies are not uniform.

Development Work. Tunnels have been driven at three different levels on the property, involving 1,700 feet of underground development.

No. 1 tunnel is at an altitude of 5,580 feet. The first crosscut shows a width of 16 feet of ore. At the face of the second crosscut is an aplitic dyke 2 feet wide, marking the supposed southern limit of the ore-body on this level.

No. 2 tunnel is 80 feet below No. 1 and follows in on an aplite dyke. Here and there in both No. 1 and No. 2 tunnels considerable ore has been encountered, but the difficulty of picking out ore from country rock can only be overcome by systematic sampling.

No. 3 tunnel is 330 feet below No. 1 and has been run through about 120 feet of talus, 30 feet of porphyry, and lacks only a few feet to break through into the ore zone, provided the shear zone followed in tunnels No. 1 and No. 2 dips at 67 degrees northeast. The present indications in this tunnel are good; quartz stringers and a fair degree of sulphide impregnation in the country rock are already evident.

Mineralization at depth in a contact metamorphism deposit is difficult to judge. The ore-bodies form and are localized where temperature and pressure conditions are favourable for a concentration of the minerals. The L.H. is a low grade gold deposit that will require the outlay of considerable capital to handle the ore in quantity. If workable ore-bodies are found on the level of No. 3 tunnel a fairly large tonnage might be assumed. A mill site has been chosen below the property on one of the branches of Eightmile creek.

SOUTHERN LARDEAU, SLOCAN DISTRICT, B.C.

The southern Lardeau embraces the country northeast from the Slocan mining division in the Slocan mountains and the Duncan range. The area mapped and examined in 1917 includes the country from the head of Kootenay lake northward up Duncan river to the West Fork and southwestward to the boundary of the Slocan mining division. This takes in the area, drained by Lardeau river and its tributaries from Trout lake to Kootenay lake.

HISTORY.

Prior to 1901 numerous mineral claims were located over this section of the Slocan district. The Canadian Pacific and Great Northern railways were then competing to build railways from the head of Kootenay lake. By 1902, 33 miles of railway had been built connecting Kootenay and Trout lakes, from Lardeau to Gerrard. There was some talk at that time of a railway up the Duncan River valley, for both the mineral and timber resources seemed worthy of development.

Development of the properties in the northern section of the Lardeau began and there has been since 1896 approximately 85,000 tons of ore credited to the Trout Lake, Lardeau, and Revelstoke mining divisions in the annual reports of the Provincial Bureau of Mines. The annual production of silver-lead-gold ores has ranged from 26,494 tons in 1904 to 149 tons in 1914. The metals extracted from the ore mined have been silver, lead, and gold. The figures for production prior to 1907 show in addition 6,559 pounds of copper. Lode mining has yielded 15,825 ounces gold and about 3,800 ounces placer, giving an aggregate of 19,625 ounces for the three mining divisions.

GENERAL GEOLOGY.

The following provisional table is submitted for the southern Lardeau:

Recent	Stream deposits.
Pleistocene	Glacial deposits.
Unconformity	
Jurassic	Nelson granite.
Post-Carboniferous?	Lardeau diabase schists.
Carboniferous	Slocan series (fossiliferous).
Carboniferous or pre-Carboniferous	Kaslo volcanics.
Pre-Carboniferous	Duncan series.

The alluvial and glacial deposits of the Lardeau are widely scattered owing to the youthful and rugged character of the topography. The meadow land at the head of Kootenay lake has been developed on the delta deposits of the Lardeau and lower Duncan rivers. Box canyons are characteristic of the tributaries of the Lardeau river before their junction with the main valley. Evidences of Cordilleran glaciation are widespread. The alpine glaciers and snowfields are numerous, but the area occupied by these has appreciably diminished in the past ten years.

Sedimentary rocks are present in great volume, but eruptive rocks are also well represented.

Duncan Series.

This is a well stratified group of rocks embracing quartzites, limestones, argillites, and grey schists. It is lithologically similar to the Summit series of the 49th parallel and the Cougar quartzites of the main line, Canadian Pacific railway.

Kaslo Volcanics.

This group is made up of a complex of igneous rocks intercalated with minor bands of limestone and argillite. This group weathers a light grey to dark green and stands out in sharp contrast to the black argillites of the overlying Slocan series. Both the Kaslo volcanics and Slocan series have been traced northward from the Slocan map-area into the Lardeau.

Slocan Series.

The synclinal belt of Slocan series to the east of the Kaslo Volcanics area widens northward and there is a marked increase in thickness of the limestone and argillite members of this group in the Lardeau. The limestones in the lower part of the series hold fossils of Carboniferous (probably Pennsylvanian) age. Conformably above the fossiliferous horizon is a thick series of argillites which may be considered as part of the Slocan series.

Lardeau Diabase Schists.

These consist of a series of grey to greenish weathering igneous rocks containing minor bands of sedimentary strata, and this series overlies the argillites of the Slocan series.

The areal distribution of these different sets of rocks is similar to the folding and uplift in the terranes of the Selkirk mountains to the south. The Slocan series occupies a broad synclinal belt trending northwest across the central part of the area; the older rocks appearing on the southwest and northeast limits of this belt. The valley of Duncan river is underlain by the oldest series, whereas Lardeau river and its tributaries drain the area underlain by a broad syncline of the Slocan series and Lardeau diabase schists.

The table of classification given is based on structural and fossil evidence. The finding of fossils in the lower limestone members of the Slocan series in August, 1916, placed this series definitely above the Pre-Cambrian and called for readjustments in geological mapping. More diagnostic fossils were found in the summer of 1917 in the limestones on both sides of the Lardeau Valley syncline, which have been reported on by E. M. Kindle, as follows:

"Four lots of fossils from the Kootenay district, B.C., which include three lots collected by M. F. Bancroft and one lot (5564) collected by L. D. Burling and M. F. Bancroft.

"Lot 5563 (No. 2) from the north fork of Cooper creek, Lardeau, West Kootenay, contains numerous crinoid stems but no determinable fossils.

"Lot 5564 (No. 1) from ridge, east of Cooper mountain, Lardeau, West Kootenay, includes, besides some undeterminable fragments, *Athyris* sp. undt. and *Spirifer* cf *marionensis.*

"Lot 5565 (No. 3) from head of Cascade creek, Lardeau, West Kootenay, shows numerous crinoid stems, three or more undetermined species of bryozoa, *Lithostrotion?* sp. and *Athyris* sp. undt.

"The lithology, fossils, and opinion of the collectors appear to concur in indicating that these three lots of fossils belong to about the same geological horizon. The presence in the fauna of a *Spirifer* which is either identical with or closely related to *Sp. Cameratus* seems to place this horizon in the Pennsylvanian. It has heretofore been placed in the Slocan series and assigned to a much earlier horizon.

"Fossils (from Bannockburn basin on the headwaters of Hall creek, a tributary of the Duncan flowing east from the Duncan range) were found in the lower beds of the "lime-dyke" anticline. Owing to the highly schistose character of the rock the recognizable fossils are confined to some sections of crinoid stems and sections of what may be *Syringoporoid* corals."

The first three lots of fossils are from limestones which continue far to the northwest beyond the area explored in 1917. R. W. Brock, in 1903, found crinoid fragments in these rocks on the Beaton-Trout Lake wagon road and in one other locality near the head of Murray creek, a tributary of Salmon creek on the Arrow Lakes watershed.

The fourth lot of fossils are from the "lime-dyke" anticline, which is also a conspicuous feature for miles through the Ainsworth, Trout Lake, and Lardeau mining divisions. C. W. Drysdale found fossils in June 1917 in the Laurie formation, which would indicate the persistence of these Palæozoic rocks north to and beyond the main line of the Canadian Pacific railway.

STRUCTURAL GEOLOGY.

The regional structure across the Lardeau River drainage basin is that of a broad syncline with minor folds. The lower beds include numerous limestone strata of greater thickness than has been noted in the Slocan series or the Pend d'Oreille series to the south. These limestones appear on both sides of the Lardeau River drainage basin. On the west side they dip away from an area of granite to reappear on the east in a conspicuous anticline locally known as the "lime-dyke." A fringe of Kaslo volcanics is found along the margin of the granite area on the southwest, and east of the "lime-dyke" the Duncan quartzites appear in full strength as a geological horizon. The southwest side of the syncline is broken through by masses of granite tongues and cupolas from the head of Davis creek northward. The central portion of the syncline is occupied by diabase schists with minor sedimentary members. The diabase schists mark the central mineral belt of the Lardeau and the two limbs of the syncline have been aptly called the "southwest" and "lime-dyke" mineral belts.

The "lime-dyke" exhibits the best example of minor folding across this broad syncline. It comes up as a sharp anticline overturned to the west, so that both limbs dip steeply to the east. This structure is the reverse of that found in the Blue ridge to the south, where the structures are overturned to the east and the prevailing dips are to the west.

ECONOMIC GEOLOGY.

The results of the geological work carried on by R. W. Brock between Kootenay lake and Revelstoke, at different times during the field seasons 1903, 1904, and 1907, furnish valuable data regarding the mining properties of the Lardeau and their general distribution along certain mineral belts.

Ore deposits occur in all four groups of rocks; in the Central mineral belt, the Southwest, and "lime-dyke" mineral belts, and the Duncan River mineral belt. Scattered groups of mineral claims have been staked on the strength of surface showing over the area as a whole, but in the Central and the "lime-dyke" mineral belts ground has been taken up for miles along the regional trend of certain formations.

Types of Ore Deposits.

The ore deposits examined in 1917 are of two types, namely, contact metamorphic deposits formed close to or in the granite through pneumatolytic processes and the circulation of high temperature solutions, and vein deposits formed in more or less well-defined fissures by aqueous solutions at intermediately high temperatures.

Knowledge of the types of ore deposits found in the Kootenay district is fundamental in considering the Lardeau as a mineral district. The ores resemble those of the Slocan and Ainsworth in variety of mineral content, associated country rock, and the general modes in which the ore-shoots have become localized. Argentiferous galena, galena, tetrahedrite, zinc blende, chalcopyrite, stibnite, arsenopyrite, pyrrhotite, pyrite, bornite, molybdenite, and barite are minerals which may be looked for in ores of the Lardeau. The central mineral belt has yielded some spectacular specimens of native gold. Native silver occurs as thin films in fractures through the silver-lead ores and wall rocks in a number of the mines in the Slocan district. The silver is a product of secondary enrichment; a feature most pronounced in the deposits where the country rock is limestone.

Contact Metamorphic Deposits. Contact metamorphic deposits are of minor importance in the Slocan district. Their occurrence in close association with igneous rocks suggests that mineralization is a phase of the intrusion and it is reasonable to assume that fissure veins adjacent to the contact will contain ore-shoots. The Blinke group of claims, at an altitude of 4,000 feet on Poplar creek, illustrates this genetic relation, where granite and limestone are in contact, and galena, zinc blende, pyrite, and chalcopyrite are sparsely scattered through the granite for 50 feet or more back from the limestone. In vertical section the granite contact goes down abruptly and a few hundred feet northeast from it a quartz vein outcrops exposing a small ore-body of the minerals noted in the granite.

Fissure Vein Deposits. The fissure vein deposits are the important type from an economic standpoint. The ore occurs in shoots in the veins or as replacements in the country rock traversed by the fissures. These fissures either cut the formations obliquely or follow planes of bedding or other lines of weakness.

The bedded variety of fissure vein is very common in the folded structures of the Lardeau. Such veins are prominent on the western slope of the Purcell range up from the Duncan river and in some cases are persistent in outcrop for thousands of feet. The metalliferous vein on the International property, up from McGuire's landing, is of this sort and displays excellent galena ore in quartz.

Replacement Deposits. The probability of good replacement ore-bodies being found, where fissure veins follow formational contacts of limestone or cut across limestone members, is manifest in the Lardeau. The mines of Ainsworth, Riondel, and the Slocan furnish examples of such ore-bodies. The ore-bodies of the Red Elephant, and those in Bannockburn basin at the head of Hall creek on Duncan river are in bedded fissure veins associated with limestones, in part replaced by galena and zinc blende. The claims at the head of Hall creek in the "lime-dyke" mineral belt furnish no doubt some of the best surface exposures of silver-lead-zinc ores, still undeveloped, in the province.

Metals of the Lardeau.

Gold, silver, lead, zinc, copper, and antimony are the metals thus far obtained from the ores of the Lardeau.

Gold. Gold (both lode and placer) mining has been recognized as a feature of this district, especially along the central mineral belt from Camborne, Ferguson, and south beyond Poplar in the Lardeau River valley.

The surface indications in the Lardeau valley and through the whole central mineral belt are good and merit more intelligent investigation for gold. There are numerous quartz veins in this belt with persistent outcrop. In the vicinity of Poplar these veins carry pyrrhotite, arsenopyrite, and pyrite; and sparsely scattered through the quartz are galena, sphalerite, bornite, chalcopyrite, and siderite, the last occurring abundantly as the gangue mineral in some of the veins. It appears in the Poplar deposits that there is always a possibility of striking rich pockets of gold, either free in the quartz or associated with the heavy sulphides.

Quartz-gold Ore. The quartz in the veins is smoky, watery, or milky in shade. The smoky quartz bears the coarsest gold and the watery is generally richer than the milky quartz. The larger veins, as a rule, are much less heavily mineralized, whereas the adjoining stringers may give high gold values.

The mineralization here compares very favourably with that of the fissure veins of Sheep creek, Ymir, Nelson, and Bridge river. Cross stringers from the veins in Sheep creek carry important values and in places considerable portions of the quartzite wall rocks are stoped and milled. In Ymir if the gold values are in pyrites they are highest where the gangue is blue quartz. Limonite is present in the oxidized portions of the veins in which visible free gold may occasionally be seen. Galena always indicates high gold values in veins found on the properties about Nelson and vicinity. Throughout the Ymir district, C. W. Drysdale[1] notes that "the iron pyrites is auriferous and the presence of galena is invariably a sign of good gold values. Zinc blende is of rare occurrence, but where found is generally accompanied by good gold values." The gold fissures veins of the different districts are known to carry rich pockets. The heavy sulphide ores of Lardeau district are auriferous; the development of arsenopyrite and pyrrhotite is very marked in the deposits of the southern part of the Central mineral belt. Auriferous pyrite is found in quantity in "honeycombed" quartz on the Red Elephant property on Hall creek, Duncan river.

Country-rock-gold Ore. The diabase schists and phyllites extending for miles along the Central mineral belt in the Lardeau River valley, "[2] besides being full of quartz stringers, are impregnated more or less with pyrite and arsenopyrite, which weather to yellow or red oxides of iron respectively, giving the country rock a spotted appearance. Where these crystals were large and are now weathered, wire, sponge, and flake gold may sometimes be detected. Evidently the arsenopyrite is the heaviest gold carrier. The country rock, therefore, when spotted with iron oxide, carried gold values, especially near the stringers and veins of quartz, where the sulphides are apt to have been present in greatest quantity."

Search should be made for the areas of schist where the soil and generally spotted character of the rock point clearly to such impregnation. The cost of mining this rock should be low. It is easily worked and although fresh and massive when taken out, weathers rapidly, so that after a few months' exposure it may be crumbled in the hand. While at Poplar the writer tested some of this decomposed schist by panning material from the Lucky Jack. A fairly rich assay was also obtained from a sample of similar material submitted to the Mines Branch.

Placer Gold. Placer gold is to be found in diggings on the Duncan and Lardeau rivers and on some of their tributaries. An experiment in placer mining near Gold hill on the Lardeau river was unsuccessful; the machinery employed proved inadequate to handle the large boulders in the river bed.

Silver-lead-zinc. Silver-bearing lead-zinc ores form the most conspicuous and characteristic deposits of the Slocan and Lardeau districts. The "lime-dyke" mineral belt is well mineralized, but on account of the altitude and distance from transportation, the ore-bodies have remained undeveloped. The Wagner, Bannockburn, Superior, and Red Elephant all show considerable ore.

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[1]Geol. Surv., Can., Mem. 94, 1917, p. 81.
[2]Geol. Surv., Can., Sum. Rept., 1904, p. 89A.

On the western slope of the Purcell range up from the Duncan river are other prospects, of which the International group of mineral claims is representative.

In the Central mineral belt of the southern Lardeau the Mother-lode, owned by A. G. Johnston, shows excellent ore, which is in part a replacement of limestone. The Rio Tinto, owned by Hansen and Garvey and situated on the northwest side of Poplar creek, is another prospect on which considerable work has been done.

In the southwest mineral belt there are silver-lead-zinc properties at the heads of Cascade, Poplar, Tenderfoot, and Mobbs creeks. This belt, again owing to altitude and lack of transportation facilities, has remained undeveloped, in spite of some good surface showings.

Copper. Some of the ores of the Lardeau carry chalcopyrite, tetrahedrite, bornite, and other copper-bearing minerals. Mineral claims for copper have been located on Cooper creek, where the country rock is Kaslo volcanics. The Copper Cliff group on the south fork of Cooper creek and the Copper King on the main fork show ore-bodies composed of pyrrhotite, chalcopyrite, and zinc blende occurring as lenses and impregnations in the country rock.

Antimony. Stibnite (Sb_2S_3=sulphur 28·6, antimony 71·4) occurs in fissure veins in the Kaslo volcanics and Slocan series. A fairly large shoot of solid stibnite was mined on the Alps and Alturas claims in the vicinity of Dolly Varden mountain during 1915 and 1916. Fine specimens of stibnite are to be obtained on the headwaters of Cascade creek at Blue lake.

Molybdenite. Two mineral claims have been taken up for molybdenite, on the east side of the Duncan river opposite Stevens creek, by Andrew Garvey and Osten Foss of Poplar. The mineral occurs in a series of quartz veins which crosscut grey mica schists.

Other Minerals. Manganese, tin, platinum, and nickel ores are to be regarded as of possible importance in the mineralization of the Lardeau district. Primary and secondary deposits of manganese occur near Kaslo. The tin ore, cassiterite, occurs in a few scattered crystals in pegmatite dykes in the drainage basin of McDougall creek, a tributary of Incomappleux river, Lardeau mining division. Areas of black sand should be tested in this region for platinum, as it occurs in small quantity near Ferguson. The ores of the Lardeau might well be tested for nickel also, since pyrrhotite ore from the Queen Victoria mine at Beasley, west of Nelson, showed on analysis 0·41 per cent nickel.

Non-Metallic Minerals.

Chromite and asbestos occur in small quantity in the serpentine and basic intrusives of the Lardeau River drainage basin.

Massive barite is the gangue mineral on the Reno group of claims, owned by Earl Stevens, on the west side of the Duncan river up from Duck lake.

A very good grade of marble can be obtained from the limestones at different geological horizons in the rocks of the southern Lardeau. At present only a small quantity has been quarried at a point on the Lardeau-Gerrard, Canadian Pacific railway, 8 miles from Lardeau.

Mining Activity in the District.

On the western slope of the Purcell range, development work was being done on the St. Patrick, Lavina hill, International, and Silver Gable groups of claims and on the east side of the Duncan range, the Red Elephant, the Superior, and Wagner groups of claims were receiving attention.

In the Lardeau valley assessment work was done on several groups of claims. A creditable amount of prospecting was accomplished on the Champagne group on Rapid creek.

In the Southwest mineral belt, the Blue Lake group at the head of Cascade creek was under development by W. J. Milne.

Status of the Southern Lardeau.

Mineral production from the Lardeau and Duncan River valleys has been almost negligible when compared with other portions of the Slocan district. It is difficult to understand why more systematic prospecting and testing of the properties has not been attempted, for the Central mineral belt in the Lardeau valley constitutes a fairly well-defined area from Cascade creek north beyond Tenderfoot, in which the essential mineral to be looked for is gold.

It appears that with very little outlay some of the silver-lead-zinc deposits could be brought up to a shipping basis. There are many small ore-bodies of good quality distributed throughout the Lardeau district, as well as much low grade material requiring concentrating and milling in order to be of commercial value.

INDEX

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

V

W

Y

Z