CANADA
DEPARTMENT OF MINES
HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1929, Part A

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OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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THE MINING INDUSTRY OF YUKON, 1929

By W. E. Cockfield

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INTRODUCTION

About six weeks of the regular field season of 1929 was devoted to a general survey of the mining industry of Yukon. The industry enjoyed a rather satisfactory year in 1929. Although no new camps of importance were discovered and several development schemes in some of the older camps proved to be disappointing, yet production from the established camps was maintained at a high level, and in the case of lode mining in the Mayo camp, was even slightly increased.

PLACER OPERATIONS

KLONDIKE DISTRICT

In Klondike district production of placer gold was maintained at a high level. Four dredges were at work for the greater part of the summer, and the company operating these, Yukon Consolidated Gold Company, was actively engaged in refitting a fifth, which it hoped to place in operation before the end of the summer. Two of the dredges operating were on the flats of Klondike river, between the mouths of Bonanza and Hunker creeks. These are dredges of large capacity having a daily capacity of 10,000 cubic yards, and are electrically driven. The other two dredges operated on Dominion creek, one at Cariboo and the other at Granville. These are boats of smaller capacity, having a yardage of about 3,500 cubic yards apiece daily. The Yukon Consolidated Gold Company also operated hydraulic plants at Jackson gulch on the Klondike, and on Lovett gulch on Bonanza creek. In addition to this work, the company, to secure adequate power for extending its operations in the future, undertook the digging of a ditch to bring the water of the Klondike to the power plant now using the water from the North fork of the Klondike.

Gold production was augmented to some extent by a number of individuals, working chiefly on Bonanza and Hunker creeks. The gold production from this source probably will not exceed 5 per cent of the total. Figures for the production of the Klondike are not available, but it is estimated from reliable sources that for 1929 they will probably prove to be slightly in excess of $600,000.

The amount of ground still available for dredging in the Klondike is difficult to estimate. Lowering of costs may in the future increase the available ground, as has been the case in the past. The method of thawing with cold water in the place of steam has on the whole considerably cheapened the cost of thawing and made available ground which could not be considered before. Whether there will be other advances in dredging practice that will prolong the life of the camp is impossible to predict. It seems certain, however, that there is still available to the company very considerable ground, particularly on the Dominion slope, that can be dredged profitably under present conditions.

OTHER DISTRICTS

There has not been a great deal of activity in placer mining in other districts. On Sixtymile river, a dredge which had lain idle for about 12 years was refitted, and started operating late in the summer, between Glacier and Miller creeks. The ground ahead of this dredge has been only partly prospected as it was intended to prospect with the dredge itself. The early results of dredging were reported to be quite satisfactory. This dredge is a steam-operated boat of the smaller type.

On Thistle creek, Manley and Logan did a certain amount of work, largely stripping, as a preliminary to sluicing; but no washing for gold took place.

On Squaw creek, in Dezadeash Lake section, there was not a great deal of activity. Most of the ground is still held by Indians, who were the original locators and are unlikely to accomplish much in the way of mining.

LODE MINING

KLONDIKE DISTRICT

In Klondike district the only development in lode mining was the attempt to reopen, by means of local capital, the Lone Star. This property was operated a number of years ago, and for a period of four months milling of the ore showed recoveries running from $3.69 to $3.90 a ton. These values are considerably in excess of those shown by the sampling of the property by T. A. McLean[1], and it was claimed that the values contained in the sulphides were not recovered as the mill was equipped to recover only the free gold.

The property is situated on the eastern slope of Victoria gulch, a tributary of Bonanza creek, and may be reached by road from Dawson, the distance being about 25 miles. The road is normally in fair condition, and an automobile can be taken right to the property.

[1]McLean, T. A.: "Lode Mining in Yukon"; Mines Branch, Dept. of Mines, Ottawa, 1914, pp. 20-31.

The deposit is not a definite vein or lode. It consists of a crushed zone in the schists of the Klondike series, with veins, bunches, and masses of quartz developed along the zone. These are very plentiful, and McLean estimated that they make up about 20 to 25 per cent of the mass of the country rock in this vicinity. Accompanying these bodies of quartz are feldspar, pyrite, and galena, with occasional specks of chalcopyrite, and small amounts of free gold in particles large enough to be visible to the naked eye. From the work already done, and from samples taken, it appears that the values are not confined to the quartz, but extend into the schists on either side of the quartz bodies. There are no definite walls to the deposit. Mining has been carried on for widths ranging from 15 to 35 feet, and it has not been established that the values are confined even to these widths.

The main workings have been divided into two groups, those driven before 1911 and those made since that date. Prior to 1911 there was a main tunnel about 300 feet long which cut a rather persistent quartz vein known as the Carthy ledge at 225 feet with a drift to the north into the main zone. This encountered a clay zone which was explored by several crosscuts. From a point about 150 feet from the portal in the main tunnel there is a crosscut to the south to the Carthy vein which drifts to the north and south along this vein; the northern drift being connected to a shaft from the surface and the southern drift being terminated by a 42-foot winze. Several shallow shafts to the northwest of these workings complete the work done prior to 1911, all of which are now inaccessible as they are partly caved and partly filled with water.

The workings driven since 1911 consist of an open-cut about 350 feet long, 12 to 14 feet wide, and 30 feet deep, from which the ore that was milled was taken. There is also a drift now caved, from the open-cut into the foot-wall side of the mineral zone, and a shaft 22 feet deep with a drift 65 feet long at the bottom. These latter workings are filled with water. It was in these that the company secured some rather high, but erratically distributed, values, as a result of sampling during the driving of these workings.

At the present time the company is driving an adit to hit the mineral zone, and intends to drift along it to the north until under the workings mentioned above, to which a raise will be driven to drain them. At the time of the writer's visit, this adit had encountered the Carthy lode, thus proving its continuity to the south, but had not entered the main mineral zone beyond.

As pointed out before, sampling did not demonstrate commercial ore on the property; but mill run recovered values far in excess of that indicated by sampling. This, however, can hardly be cited as an argument against sampling, and in spite of past results, the writer is of the opinion that careful, systematic sampling is the only method to test properly this deposit, but the samples should be cut at very small intervals, owing to the occurrence of free gold. The problem is to determine if commercial ore exists over reasonable mining widths. If it be established that this zone contains commercial ore-bodies, there is no doubt whatever that other similar zones exist in the neighbourhood, for the amount of quartz in the schists is very high. Quartz bodies have been found in a number of open-cuts on the property, and there is a good deal of quartz float generally on the hill.

MAYO DISTRICT

Mayo district had on the whole a very satisfactory year. No new areas of importance were discovered, but developments in the better established camps were encouraging, and production was slightly increased, amounting to about 8,300 tons of ore and concentrates. Although exact figures as to the metal content are not available at the time of writing, it is believed that they will constitute a record for the camp. In 1924, when Keno Hill, Limited, withdrew from the camp, and Treadwell-Yukon Company, Limited, began milling its ores, there was a falling off in tonnage of shipments, but since then the tonnage has been increasing year by year until last year the tonnage shipped about equalled the combined tonnage of the two companies in 1923. The metal content, however, is much higher, as a very considerable part of the shipments are now composed of concentrates running higher in silver than the crude ore which was formerly shipped.

The producing area for the year centred about Keno hill. The major mining operations are being carried on by Treadwell-Yukon, Limited. This company owns the Ladue mine situated on the western slope of Keno hill at an elevation of about 4,000 feet, and is also operating under lease from Keno Hill, Limited, the adjoining property known as the Sadie mine. The two are being worked as one mine. Treadwell-Yukon Company, Limited, has also pursued a campaign of developing likely looking prospects in the vicinity, and this policy has been meeting with marked success. Four properties have been acquired either by purchase or under option, and good progress has been made in developing them. These properties are the Lucky Queen, Silver King, Arctic, and Elsa groups. All these, with the exception of the Lucky Queen, are situated on Galena hill.

For a general description of the geology and ore deposits the reader is referred to previous work by Stockwell[1] and Cockfield[2].

On the Sadie and Ladue groups work has been very much extended since the properties were last described. A drainage tunnel over 3,000 feet in length has been driven to tap the vein, and about 900 feet of drifting done on the 600-level where the tunnel entered the vein. A raise to connect with No. 2 shaft has been made, and the 400-level driven about 750 feet north of the shaft, and south into the Sadie workings, a distance of about 2,500 feet. The 200-level has also been extended into the Sadie. In all this work very little ore was encountered that extended below the 400-foot level. The vein has a maximum thickness of 70 feet, but the average thickness is probably about 7 to 8 feet. The mineralization is

[1]Stockwell, C. H.: "Galena Hill, Mayo District, Yukon"; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 1-15.

[2]Cockfield, W. E.: "Silver Lead Deposits of the Keno Hill Area, Mayo, Yukon"; Geol. Surv., Canada, Sum. Rept. 1920, pt. A, pp. 1-6.

"Geology and Ore Deposits of Keno Hill, Mayo District, Yukon"; Geol. Surv., Canada, Sum. Rept. 1923, pt. A, pp. 1-22.

a siderite gangue, with galena, freibergite, and zinc blende as the important ore minerals. Small amounts of native silver and pyrargyrite also occur, as well as quartz, arsenopyrite, pyrite, and chalcopyrite. The vein is one of the main longitudinal fractures of the area. Beyond the workings to the north it appears to become lost in a clay zone, probably as the result of the brecciation of the schist, and it has not been traced to the south beyond the limits of the Sadie claim.

On the Ladue group there are two main ore-shoots, one in the vicinity of each shaft. These shoots have lengths of about 150 and 500 feet, but practically terminate at the 400-level, very little ore having been found below that level. On the Sadie and Friendship group there are three shoots of ore. The smallest is 125 feet long, and the other two are 175 to 200 feet in length. As on the Ladue, very little ore has been encountered below the 400-level. The vein is cut by a fault which weaves along its length and is accompanied by numerous cross fractures and small slips, and by one large cross fault on the Sadie claim. These faults have the effect of cutting the ore into a series of fault blocks, which adds considerably to the amount of development work necessary to expose the ore. These faults are much in evidence in the vicinity of the ore-shoots, and it is not known whether they had some influence on the deposition of the ore and continued as zones of weakness along which movement took place after ore deposition ceased, or whether the ore-bodies happened to be the weakest parts through which adjustments took place long after deposition ceased, thus causing a somewhat accidental relationship between the location of the ore-shoots and the post-mineral faults.

The vein continues as a strong fracture below the 400-level on these groups. It is mineralized with siderite, but is practically without ore minerals in that stretch in which development work has been carried out. There is, so far as is known, no adequate reason that can be assigned why mineralization should not continue to greater depths, nor has the existence of an unfavourable horizon for ore deposition been recognized. Possibly work elsewhere in the district will furnish the key to this problem, but in the meantime it may be stated that the known ore reserves of these two properties are approaching exhaustion and for the present at least their place will have to be taken by the other properties which the company is now developing to the stage of production.

The *Lucky Queen* property is situated on the western slope of Keno hill, somewhat less than a mile east of the Ladue. It is connected with the Ladue mill by an aerial tram, and there is also a road to the property from the main camp. The property consists of the Lucky Queen, Mud, Uncle Sam, and Mayo claims, the Too Good Fraction, and a lease on the Maythole claim.

There are in addition to the older workings described in earlier reports, two shafts, one to the 100-foot level, and the other to the 200-foot. These shafts are approximately 260 feet apart. From the main shaft levels have been driven southerly at 50, 100, and 200 feet, and work was in progress sinking the main shaft to the 300-level preparatory to drifting on that level. The 100-foot level has been driven approximately 1,300 feet in a southerly direction from the shaft. The 50-foot level terminates in an ore-shoot which has been removed from the 100-foot level to near the surface. This shoot was 80 feet long and varied from 6 to 10 feet in width; it included nearly all ore of shipping grade.

The vein follows a shear zone in quartzite and has a general strike of south 45 degrees west, astronomic, and a dip of 55 degrees to the southeast. It varies considerably in width, from seams to 10 feet, and in places the width is considerably increased by the presence of mineral in the joints and seams of the country rock. On the 100-level the ore zone is somewhat over 300 feet long, with some mineralization continuing beyond for a considerable distance to the south. On the 200-level, the ore zone had not been fully explored at the time of the writer's visit. On this level the mineralization in the seams and joints of the quartzites includes very considerable amounts of native and ruby silver, the former occurring as a coating on the galena.

It is to be expected, as development of this property proceeds, that other ore-shoots similar to the one already found will be discovered. Such ore-shoots rarely occur singly, and considerable further development is justified by the results already obtained.

Elsa Group. One of the holdings of the Treadwell-Yukon Company on Galena hill is the Elsa group, consisting of the Elsa, Porcupine, Jean, Lucky Strike, Minerva, Minerva Jr., Keno, Mohawk, Punch, and Weston claims. This property lies on the northwestern slope of Galena hill, and is situated below timber-line in the vicinity of Porcupine gulch. The country rock in the vicinity is quartzite, with some graphite schist, and the mineralization occurs in a vein striking north 45 degrees east, and dipping about 55 to 60 degrees to the southeast. The vein varies considerably in thickness, ranging from a stringer to 6 or 7 feet. The ore minerals are galena and freibergite with some pyrite and chalcopyrite in a gangue of siderite and oxidation products. On the 200-level, the vein consists largely of oxidation products with small nodules of galena and freibergite. Judging by the silver content of this oxidized material, it is doubtful if there has been much movement of the silver by leaching. The thoroughness of the oxidation in this vein is probably accounted for by the fact that it contains considerable pyrite as contrasted with some of the other veins of the district.

Besides the original prospect workings there are three crosscut adits to the vein, either driven or in progress. The lower of these had not reached the vein at the time of the writer's visit, but was at that time about 800 feet long. The second level is 165 feet above the lowest level, and is 380 feet long to the point where it taps the vein, and from this point a drift has been driven to the south upwards of 500 feet with a raise to the surface, and a drift to the north is 240 feet long with a raise to the surface. At 140 feet in this drift the vein is cut off by a fault, and its northern continuation has not yet been located. The upper workings were filled with ice at the time of the writer's visit; they consist of a crosscut 200 feet long to the vein.

Arctic and Mastiff Property. This group was described at some length in Stockwell's report referred to above. Some of the earlier work was done by the original owners, and was continued by lessees. After this earlier work ceased the workings filled with water, and have only recently been drained by the new shaft put down by Treadwell-Yukon Company, Limited. This shaft is being sunk in the country rock on the foot-wall side of the vein, to a depth of 200 feet, from which point a crosscut is to be driven to the vein. As at the time of visit sinking the shaft had not been completed, no new data regarding the property was obtainable from these workings. The older workings consist of a shaft about 85 feet deep, following the dip of the vein, with levels at 38, 70, and 80 feet. The workings on the south side of the shaft encountered a body of ore lying above the 70-foot level, and varying from 2 to 6 feet in width. This body has been stoped out to within 20 feet of the surface. On and below the 70-foot level the vein widens considerably, and shows disseminated ore minerals over a total width of about 70 feet. To the north of the shaft, the vein does not appear to be heavily mineralized.

The extension of the vein to the southwest has been stepped to the northwest by a fault, and has been traced on the surface by means of prospect shafts. The horizontal movement amounts to about 400 feet.

The minerals in the vein are galena, freibergite, and siderite, with some pyrite and quartz, and oxidation products such as cerussite, limonite, and manganese oxide. Taken as a whole the values are probably not as high as those obtaining on some of the other properties of the district; fairly massive galena assaying from 125 to 135 ounces of silver.

Silver King Group. This group is one of the most recent acquisitions of Treadwell-Yukon Company, Limited. It is situated on Galena creek, to the west of Galena hill proper. This property was the first producer of silver-lead ore in Mayo district and its history dates back to about 1906, although it was not until 1912 or 1913 that it came into prominence. In 1914 it was acquired by T. Aitken and H. Munroe, who worked the property until 1916. In 1915 the property was reported on by Cairnes[1] who urged further prospecting on the extension of the vein. This, however, proved to be quite a difficult undertaking as in that direction the drift cover was thick, in some places attaining 70 feet, and after the property was closed down twelve years passed without any new discoveries being made. Last spring, however, the northern extension of the Silver King vein was picked up and an ore-shoot about 800 feet long, of which about half is reported to consist of shipping ore, was discovered on the Silver King and adjoining Webfoot claims.

The property was purchased last summer by Treadwell-Yukon Company, Limited, and preliminary work, such as road building, erecting a camp, and shaft sinking, was started. As the original workings and the more recent prospecting shafts and cuts were inaccessible, being either sloughed or filled with water, an examination of the property was not made. It is expected, however, that this property will very soon enter once more into the list of producers.

[1]Cairnes, D.D.: Geol. Surv., Canada, Sum. Rept. 1915, pp. 27-29.

The ore-shoots of the original properties worked by Treadwell-Yukon Company, Limited, are approaching exhaustion after 7 years of continuous shipments, but the new properties now being brought in are fully capable of taking the place of the Sadie and Ladue groups, so that even if no further ore should be found on the older properties this does not mean that the company's operations in Mayo district will be discontinued, and should mining progress not be retarded by the unduly low prices obtaining for the metals produced, it might even be expected that the company's operations would produce a larger annual output than is the case at present.

As many as possible of the claims held by individuals were visited, but time did not permit of seeing even all those claims that have mineral showings on them, many of which have had considerable work done on them since the writer last visited the district. Claims were visited as opportunity occurred, but no ground lying to the east of Monument hill was included in the work of the past summer.

Shamrock Group. This group has been one of the most consistent producers of the claims held by individuals in the area. It lies near the head of Erickson gulch, adjoining the original holdings of Keno Hill, Limited, on the west, and is being worked under lease from the owners, by McIvor, McKay, and Formo. To date it has shipped 1,900 tons of sorted ore, of which amount 565 tons were shipped during the season of 1928-29.

The workings lie on what is believed to be one of the major veins, sometimes called the Gambler vein, which crosses Faro gulch and swings southwest across the broad flat at the summit above this gulch and consist of a shaft 120 feet deep and inclined at 60 degrees. This shaft has levels driven from it at depths of approximately 65 and 110 feet. The upper level is approximately 580 feet long, and drifts along the vein for about 250 feet to the south of the shaft to form an adit tunnel, and continues 330 feet to the north of the shaft. The lower level follows the vein for about 240 feet north from the shaft, and about 90 feet south. A number of streaks of ore have been encountered and stoped in these workings. As a general rule these have not been large, seldom exceeding 4 feet in width. Although the ore-shoots discovered to date have not been large, it is interesting to note that this property is one that has paid for its development by the ore extracted, and the chances seem very favourable that as development work goes on, other shoots of ore will be discovered.

Properties of Keno Hill, Limited. Very little work has been done on the original group of this company since the property was closed in the autumn of 1923. For several years after that the property was worked by lessees, and some ore, chiefly some that had been developed before, was extracted. The main workings were on the vein known as No. 9, with some prospecting on a number of other veins crossing the property. Lately the company has secured options on some of the adjoining claims, notably the Nabob, Toledo Fraction, Venus Fraction, Gold Hill, Orphan, and Ladue Fraction. On some of this ground one of the main veins has been traced in places by a number of open-cuts, and promising showings have been obtained at some points. Although many of the cuts have now sloughed, the dumps show galena mineralization.

Two of the other main veins, known as, respectively, the Kinman and No. 6 veins, cross the southern part of this company's property and have lately been receiving some attention. On the Kinman vein, representation work being done on the Porcupine claim near the head of Hope gulch encountered a shoot of ore 4 feet wide, which where exposed in the open-cut consisted of massive galena. Data with regard to the length of this shoot have not yet been obtained. The extension of this vein has also been discovered on the Teresa claim near the head of Charity gulch. This property is owned by Smith, Corp, and Ryan, and is leased to a group of individuals. The workings here consist of a shallow shaft, which at the time of the writer's visit had not quite reached bedrock, but which was yielding the float of the vein, making it apparent that the outcrop was not far off. This float was mineralized with quartz and arsenopyrite but contained none of the ore minerals.

Bunny Highlander and Cub Group. This group, owned by O. Letourneau and D. Mercure, adjoins the Lucky Queen on the northeast side. Six open-cuts have been excavated in which ore has been obtained, but in most of these, owing to sloughing, very little information with regard to the deposits could be obtained. To the northeast of these is a shaft 26 feet deep terminating in a drift 48 feet long. These workings were filled with water, and, therefore, were inaccessible. It is reported that 51 tons of ore was obtained from these workings, and that the ore-body on the floor of the drift showed 2 feet of massive galena. From the material on the dump it is evident that the ore-body consisted of a shear zone in quartzite, with siderite, pyrite, galena, freibergite, and zinc blende. Much more work is necessary on this property before the exact relations of the various showings can be determined. It is possible that the mineral showings represent the faulted, northward extension of the Lucky Queen mineralization, but until more work is done, it is impossible to prove this is the case.

Stone Group. This property is owned largely by M. Butyer who owns outright the Stone and Ray claims, and has a half interest in the Scott claim, the other half interest being owned by Mrs. W. C. Sime. The property is situated northeast of the ground last described, and extends across Faro gulch. The main workings are on the slope on the western side of Faro gulch, and consist of two adits. A third was, at the time of the writer's visit, being driven lower down towards the creek, but had not yet penetrated the overburden. The lower of the two completed adits is about 475 feet long, with a crosscut, 16 feet long, to the east at 230 feet, a crosscut 70 feet long to the west at 430 feet, and several small stopes at intervals in the adit. At the face there is a fault with a highly polished hanging-wall with 18 inches of siderite and freibergite. The balance of the face shows shattered greenstone with siderite. About 15 feet back from the face there is about 1 foot of siderite heavily impregnated with grey copper, in which a small stope about 12 feet high and about the same length has been excavated. The 70-foot crosscut to the west is in schist which has been shattered and filled with siderite, and carries some values throughout. This terminates against a greenstone body, into which the main adit penetrates about half-way between the crosscut and the face. The shorter crosscut shows the ore-body to be about 12 feet wide.

The upper adit is 135 feet long, and is now partly caved near the entrance. It encounters the vein about 30 feet from the portal, and continues along the vein for the balance of its length.

A shipment of 6 tons from this property assayed 161 ounces of silver to the ton, and a small shipment, less than a ton, of hand-sorted ore showed 586 ounces of silver to the ton.

Apex Claim. This property is on the southern slope of Keno hill, on the southwest side of Charity gulch, and is owned by T. McKay, and worked under option by F. Hoffman and J. Grenier.

The development work includes an open-cut terminating in an adit with a winze sunk near the face. The general course of the vein is north 45 degrees east, and it is composed mainly of manganese oxide and siderite. Most of the workings do not permit of obtaining an idea of the mineralization owing to the timbering that was necessary in the adit. At 35 feet the adit encountered a slip striking north 77 degrees east, and dipping to the northwest on which a winze was sunk 18 feet. This slip was mineralized with calcite and zinc blende. The workings to date have not encountered any ore-shoots of value.

Vanguard Claim. This claim adjoins the Apex on the south and is being worked by D. Ferguson and associates. A considerable amount of heavy galena float was picked up on and near the surface and a good deal of prospecting work has been done in an endeavour to locate the vein from which the float came. From the nature of the float it is deemed impossible for it to have travelled any great distance, and although the present workings have not yet picked up the vein, further prospecting in the vicinity is justified.

Bunker Hill. Only one property was visited on Bunker hill, namely the Homestake group, which consists of six claims owned by J. Walsh and associates, and leased by J. Carpenter, J. McLean, and G. Lee.

The work done consists of two open-cuts, and a shaft 43 feet deep with a drift 15 feet long in a southerly direction from the bottom of the shaft. The shaft at the time of the writer's visit was filled with water to within 6 feet of the surface, so that very little of the vein could be seen. The strike of the vein is approximately north 30 degrees east astronomic, and the dip 70 degrees to the southeast It is reported that at the bottom of the shaft the vein had a width of 7 feet; composed of a little over 3 feet of siderite, and somewhat over 2 feet of shattered quartzite with siderite, followed by 1 foot of siderite with streaks of the ore minerals through it. South in the drift the vein narrowed to 5 feet, and was about half siderite and half country rock; towards the end of the drift the siderite appeared to pinch out. The siderite is coarsely crystalline with blebs and streaks of galena and grey copper in it. To the north of the shaft a width of 4 feet of siderite was encountered in an open-cut, and still farther to the north a second open-cut, which had not reached bedrock, showed heavy siderite float. Further surface prospecting is desirable on this property, before underground work is undertaken, but prospecting is difficult, as the overburden is about 12 feet thick.

Sourdough Hill

A number of promising showings have been located on Sourdough hill, which lies immediately to the south of Keno hill, and a considerable amount of work has been done on these in the past few years. Unfortunately, however, the ownership of this ground has been the subject of litigation, and in the meantime the work has not been proceeded with. Such workings as exist are full of water and, therefore, inaccessible.

Galena Hill

A number of mineral showings have been found on the northern and eastern slopes of Galena hill. Time did not permit of visiting all of these, and on many of those visited earlier work had sloughed so that little could be learned. Many of the properties are described in Stockwell's report referred to before.

Hector and Darling Claims

This property is owned by C. Sinyard and M. S. McCown, and is situated just west of the summit of the hill. A vein striking from north to north 20 degrees east and dipping from 45 degrees east to vertical has been prospected by means of a number of pits, and several prospect shafts. The main shaft is 57 feet deep with a drift 82 feet in all at the bottom and extending both to the north and south from the bottom of the shaft. The vein in the shaft shows about 5 feet of oxidized material with nodules of galena. To the north of the shaft in the drift, the vein is about 8 feet wide, with bunches of galena and carbonates throughout. It is reported that this material will assay from 60 to 70 ounces across the width of the vein, and that samples of the clean galena yield very high assay values. Two other prospect shafts, one about 50 feet north of the main shaft, and the other about the same distance south, have picked up the vein. On the Darling claim to the south, a number of open-cuts and prospecting ditches have been put in, but these have not yet been successful in picking up the extension of the vein.

Eagle Group. This group is owned by A. McLeod, M. S. McCown, D. Matheson, and Miss J. Stewart, and is situated near timber-line on the easterly slope of Galena hill. A vein which strikes north 40 to 50 degrees east and dips about 67 degrees to the southeast has been located by means of a number of open-cuts and by sluicing. The vein was not very well exposed at the time of the writer's visit, but is apparently about 18 inches wide, and mineralized chiefly with quartz and arsenopyrite, with seams of galena. From the float visible on the dumps it is apparent that siderite, pyrite, limonite, and sphalerite also occur.

Rio Claim. On the Rio claim, owned by Mrs. W. C. Sime, a vein is exposed by an incline driven down the strike of the vein. The incline is about 30 feet deep, and follows a stringer of galena which widens to 3 feet. The vein strikes north 37 degrees east and dips at 63 degrees to the southeast. Immediately below the large showing the incline is filled with water. Some 65 feet lower in elevation an adit was started with the intention of striking the vein, in which all told 140 feet of drifting and crosscutting was done, but the workings were not driven sufficiently far to intersect the vein.

Bluebird Claim. This claim is owned by O'Sullivan and Nicholson. On it a vein striking north 27 degrees east and dipping 62 degrees southeast was exposed by means of open-cuts. The vein is mineralized with galena, sphalerite, and pyrite, in a gangue of ankerite, calcite, quartz, limonite, and manganese oxide. Two shafts have been sunk, the lower of which is 40 feet deep, and hit the vein at 22 feet. The upper shaft is 23 feet deep. Both shafts were filled with water at the time of the writer's visit.

Tin Can Claim. This claim is owned by A. McLeod, H. Rohr, and S. Turpin, and is situated on the eastern slope of Galena hill. Most of the workings were full of water or ice, so that very little information could be obtained with respect to the mineralization. One shallow pit, the highest of the group of workings, showed, in greenstone, a small vein striking north 40 degrees east and dipping 82 degrees to the southeast. The maximum width of mineralization exposed in this pit is about 12 inches. The vein is heavily oxidized and carries abundant zinc.

Formo Group. A group of seven claims on the northern slope of Galena hill, near the mouth of Christal creek, is owned by H. C. Formo. The workings consist of a shaft about 30 feet deep. It was partly filled with water. The vein strikes nearly north and south, and for the first 16 feet in the shaft is nearly vertical; below it flattens out to an angle of 45 degrees, and towards the bottom of the shaft is reported to be straightening up again. The vein is about 3 feet wide. On the foot-wall side there is a seam of calcite 4 inches wide, followed by slightly over 2½ feet of galena, with zinc blende and pyrite. The wall-rock is greenstone. It is reported that fairly pure galena carries about 120 to 135 ounces of silver to the ton, a somewhat lower silver value than obtains in most of the surrounding properties.

Beaver River Area

Time did not permit of making a trip to Beaver River area. The Consolidated Mining and Smelting Company, Limited, has for several years been developing a prospect on McKay hill in this area, and surface work resulted in a very good showing of ore. During the summer of 1929 the property was diamond drilled, and it reported that the results were very disappointing, as it was found that the deposit did not extend to any reasonable depth. It is reported that the option held by this company has been abandoned.

Windy Arm District

Last year a group of claims known as the Dail and Fleming group situated along the west side of Windy Arm near the boundary between Yukon and British Columbia, attracted some attention. A company known as Yukon Gold Mines, Limited, incorporated under the laws of British Columbia, was formed to take over these claims, and to develop them. Early last spring a start was made on the development of the property.

The company owns the Humper, Red Deer, Peggy, Bull Moose, Venus Extension, and Ray claims, and has options on the Humper No. 2, Nipper No. 2, Hobo, Lakeshore, Bum, Ruby Silver, and Maybell Fraction. This property and the adjoining property, the Venus, have been described at length by Cairnes[1] and that description has been summarized by the writer[2], so that only a brief description need be given in this connexion.

Unfortunately for the enterprise, operations were started before sufficient money was in the treasury to carry the project through to a successful conclusion. Difficulties of financing arose after development work had started, and the operations had to be abandoned without thoroughly testing the ground.

The rocks of the area are Mesozoic andesites with their accompanying tuffs. The claims are at no great distance from the main contact of the Coast Range batholith, and some intrusives, apparently related to the batholith, also occur in the area between Windy Arm and lake Bennett. The veins are fissures filled mainly with quartz, arsenopyrite, and galena, with some zinc blende. A number of other minerals are present, but are by no means abundant. These include a number of silver minerals such as argentite, pyrargyrite, stephanite, and some native silver; also jamesonite, yukonite, chalcopyrite, and chalcocite, and the arsenic minerals orpiment and realgar, together with oxidation products of copper and lead. The ores are valuable chiefly for their gold and silver content.

There are three main veins. Some other showings occur, but the work done on them is not sufficient to enable a true idea of their importance being obtained. The vein to which attention has been mainly directed is known as the Venus vein. This is apparently continuous across the Venus property, and extends into the property of Yukon Gold Mines, Limited, on the Venus Extension claim. It has not been traced across the Venus Extension claim. Certain workings on Nipper No. 2 have exposed a vein in a gulch to the south of the Venus Extension. This vein may possibly be the continuation of the Venus vein, but more work is necessary in order to prove this. The Venus vein strikes approximately north 10 degrees east astronomic, and varies considerably in its dip, ranging from nearly flat to 60 degrees. In most places, however, the dip is about 30 degrees. The thickness of the vein ranges from a few inches to 6 or 7 feet, but is generally from 2½ to 3 feet on the Venus claim and from 1½ to 2½ feet on the Venus Extension. The workings include an incline shaft reported to be 140 feet deep, but which at the time of the writer's visit was filled with water below 115 feet. Near the bottom of the incline

[1]Cairnes, D. D.: Geol. Surv., Canada, Sum. Rept. 1916, pp. 39-44.
[2]Cockfield, W. E., and Bell, A. H.: "Whitehorse District"; Geol. Surv., Canada, Mem. 150, pp. 40-41 (1926).

drifts run north and south along the vein; higher in the incline, an intermediate drift runs north. About 800 feet southerly from the incline, and about 75 feet below it in elevation, is an adit which drifts along the vein for 560 feet, and which has several raises one of which extends to the surface. Near the southern boundary of the Venus Extension, another adit, known as the Dail tunnel, drifts along a small vein for about 26 feet.

On Nipper No. 2 there are two crosscut tunnels, the lower 170 feet long, with a drift to the south in a fault zone, and the upper 90 feet long. Both were, apparently, driven to explore a vein showing in the gulch higher up, but neither is long enough to reach its objective. The vein on the surface is partly exposed by a number of open-cuts. It has a strike of north 30 degrees east, and a dip of 30 degrees into the hill. The mineralization is very like that of the Venus and Venus Extension vein. The thickness of the vein where exposed in the gulch is about 12 inches. As pointed out before, there is a possibility that this represents the southerly extension of the Venus vein, but more work is necessary in order to prove this.

On the Red Deer claim a vein is exposed in three small open-cuts. Where exposed the vein has a thickness of about 2½ feet, and is mineralized with quartz, pyrite, and galena. The mineralization at these points is somewhat scanty, but it appears fairly well-established that the best of the ore at these points was removed when making the open-cuts. The vein strikes north 30 degrees east astronomic, and dips to the northwest at about 50 degrees. At these localities Cairnes specifically mentions a number of high-grade silver minerals, but none is now visible.

On the Humper claim, the Humper vein is exposed by a shallow shaft and a number of open-cuts. The same vein is exposed in another shaft on Humper No. 2. The strike of the vein varies from north 60 degrees east to nearly east astronomic, and the dip ranges from 35 to 65 degrees to the north. The entrances to the shafts are caved so that nothing can now be learned from these workings. The gangue of the vein is quartz, with galena and pyrite as the chief ore minerals present. High-grade silver minerals were also reported by Cairnes from these workings, but none was identified by the writer.

There are a few other points on the Yukon Gold Mines property where mineral showings have been found, but on these not sufficient work has been done to give a true idea of their relations and importance, though some of them are probably deserving of further work.

The Venus property is not part of the holdings of Yukon Gold Mines, Limited. No work has been done on it for a number of years, and as the later winzes are nearly filled with water, there is nothing to be added to the earlier reports on this property, to which the reader is referred for full details.

The Venus vein which crosses the Venus and part of the holdings of Yukon Gold Mines, Limited, has been established to be continuous. It crosses Venus No. 1 and No. 2, and part of Extension claim, thus giving it a length as traced on the surface, of between 3,500 and 4,000 feet. The vein averages perhaps 2½ to 3 feet in width, and the metal values are not high. The vein on the Venus has been proved to a depth of about 630 feet below the surface, but of its characters in the lower workings there is not a great deal of information available. It is difficult, without a systematic sampling of the properties, to estimate the average content of the ores, as the values appear to be somewhat erratic. Some high assays have been obtained from the veins in this section, but Cairnes concluded, from a survey of different samplings made from the properties, and from smelter returns, that the ore in general would run under $25 in gold, and from 5 to 10 ounces in silver to the ton, and that the average content might possibly be about $15 a ton, based on normal prices for silver. Much of the vein is, of course, very low grade, and will not go over $10 a ton. It is difficult at the present time to secure representative samples from the Venus workings, as the best of the ore has undoubtedly been extracted from the workings open to inspection. The writer took a number of samples which are intended not as a systematic sampling of the property but rather to afford a general idea of the mineral content. The assay results of these samples are listed below.

No.	Location	Gold	Silver	Lead	Zinc
		Ozs. per ton		Per cent	
1	Extension adit	0·41	0·73	none	none
2	"	0·41	1·54	0·50	none
3	"	0·25	4·01	1·37	none
4	"	0·17	1·82	0·65	none
5	"	0·30	9·45	3·54	none
6	"	0·19	3·97	0·66	none
7	"	0·05	25·36	0·51	none
8	Raise from adit	0·29	0·82	0·09	none
9	Extension shaft	1·64	8·11	2·67	none
10	"	0·29	3·04	0·79	none
11	"	0·44	3·01	0·73	none
12	"	0·76	40·35	7·34	0·61
13	Dail tunnel	0·06	0·46	0·14	none
14	Nipper	0·05	6·07	1·87	none
15	"	0·02	1·57	0·33	none
16	Venus N. adit	0·14	22·61	7·34	0·61
17	"	0·06	2·71	0·56	0·59
18	"	0·06	6·34	1·77	5·12
19	"	0·02	2·09	0·72	0·40

There is no ore blocked out on the properties, but a considerable tonnage of ore is indicated by the present workings. The Humper and Red Deer veins are worthy of investigation to test their continuity and mineral content. Although the tenor of the ores is undoubtedly low, it seems probable that with careful, systematic sampling, ore-shoots of economic size and value could be outlined, and there seems a chance that with economical management the properties might develop into a small mine.

TAKU RIVER DISTRICT, BRITISH COLUMBIA

By F. A. Kerr

CONTENTS

INTRODUCTION

Late in October, 1929, a few days were spent in Taku River district and short visits were paid to the two most important mining developments in the area. Taku River district, since it lies within the eastern contact zone of the Coast Range batholith, has long been considered a favourable area for the occurrence of mineralization, but other than prospecting that was more or less the outcome of the early gold rushes in northern British Columbia relatively little attention seems to have been paid to this section until the summer of 1929 when there was a considerable influx. Since the close of the war, however, and even before that there were probably few years when some prospecting was not done; this work resulted in the discovery of the showings on the present Tulsequah Chief property. The history of these according to some of those most familiar with the territory dates back to the period before the war and it seems probable that they had been observed long before that, since many men seeking a route to the Klondike must have passed this place and could hardly have failed to note the well-displayed, large, rusty showings on the lower claims. Possibly owing to difficulty in recording claims, it was many years after the first reported discovery that they were duly registered and the present good standing of the claims is said to date from but a few years ago. During 1929 the promising developments on the upper claims of this property, the discovery, sale, and development of the Manville showing, and the discovery of other promising showings in various sections of the area, mainly in the vicinity of the major developments, have attracted widespread interest to the district.

Since little new geological data about the area was collected during the writer's brief visit, this report, other than to give general information about the section, is largely for the purpose of indicating what information about nearby districts is available. There are a number of maps and publications which might be of value to prospectors going into the district. The Atlin sheet, on a scale of 8 miles to 1 inch, recently published by the Geological Survey, affords a good map of a large region of which Taku River district is a part, and shows the geology of the nearby sections. Sheet No. 8 of the

International Boundary series, embracing the area from cape Muzon to mount St. Elias, is the most detailed topographical map of the lower Taku river available. This can be obtained from the International Boundary Commission, Ottawa. Memoir No. 37, " Portions of Atlin District, British Columbia," by D. D. Cairnes (Geological Survey, Canada), gives much information about the district immediately north of the Taku. The description of the geology and mineral deposits, some of which lie in the Taku drainage basin, ought to be of considerable value to prospectors working along Taku river. An earlier publication, " Atlin Mining District, British Columbia," by J. C. Gwillim, volume XII, 1899, Geological Survey, Canada, contains a topographical and geological map which extends well into the Taku drainage basin and gives some details of routes and other features not repeated in the later report. " Explorations Between Atlin and Telegraph Creek," by W. E. Cockfield (Summary Report 1925, part A), includes geological maps and descriptions of the greater part of the upper drainage basin of the Taku. This report, together with Memoir No. 37 and the two maps first described, ought to be of value to all prospectors going into Taku district.

The general characteristics, climate, river conditions, vegetation, game, fish, and some features of the general geology of the area, are believed to be similar to those of Stikine and Iskut River areas farther south and which have been described in Summary Reports for 1926 and 1928, part A, and elsewhere in this volume.

The Annual Reports of the Minister of Mines for British Columbia from 1923 to 1929 contain considerable valuable information, as does also a special publication by J. D. Mandy on Taku river (Bulletin No. 1, 1930). Other publications containing information about the district, or that may be of value to prospectors, include:

Cockfield, W. E.: "Silver-lead Deposits in Atlin District, B.C."; Geol. Surv., Canada, Sum. Rept. 1925, part A.

Buddington, A. F., and Chapin, Theodore: "Geology and Mineral Deposits of Southeastern Alaska"; Bull. 800, U.S. Geol. Surv.

Kerr, F. A.: "Dease Lake Area, Cassiar Dist., B.C."; Geol. Surv., Canada, Sum. Rept. 1925, part A.

"Recent Developments in Northern British Columbia"; British Columbia Miner, Nov., 1929.

"River Navigation and the Prospector"; Can. Min. Jour., Feb. 7, 1930.

"The Significance of Recent Discoveries in Northwestern British Columbia"; Can. Min. Jour., March 7, 1930.

"Prospecting in Northwestern British Columbia"; Can. Min. Jour., April 11, 1930.

LOCATION AND MEANS OF TRAVEL

Taku river in northwestern British Columbia and Alaska is about 40 miles long, being formed by the confluence of Nakina and Inklin rivers. With Taku inlet, which is about 25 miles long, it occupies a large, fairly straight valley which trends northeast directly across the Coast range. About 36 miles of this valley, including about 11 miles of the river, lies in Alaska and the remainder in British Columbia. The area of most concern at the present time consists of relatively narrow strips of accessible country along the Taku from the International Boundary to the head of the river, along the various tributaries that join the Taku in this stretch, a small area east of the confluence of the Nakina and Inklin, and, possibly, a fairly extensive area stretching northwest of this toward Atlin lake and also southeast.

Access to Taku River district can be gained by three or more different routes. Practically all Canadian and American coastal steamers plying from Vancouver and Seattle to southeastern Alaska call at Juneau and even the largest of these can proceed from there nearly to the head of Taku inlet. During the summer most of the boats carrying tourists visit this point and it is probable that if traffic warranted, and facilities were provided, disembarkation could take place here instead of at Juneau as at present. Taku river, at least as far as the Talsekwe[1], is easily navigated by fairly large river boats from about the middle of May to the middle of October. Power boats are reported to have reached the head of the Taku and beyond for 10 miles up the Nakina. The Talsekwe, which is about 15 miles long, is navigable for 10 miles or more, and other tributaries will probably serve at least for manhandling boats. In this way the district is well served by one main transportation route with several branches.

During the summer of 1929, the United Transportation Company maintained a through boat service from Juneau, Alaska, to Eaton (Tulsequah) just above the Talsekwe. The same company planned for 1930 to operate at least one fairly large boat as far as Eaton, and with smaller boats equipped with outboard motors to maintain other services up Talsekwe and upper Taku rivers.

A second route to the district commences at Atlin, whence a road leads south for 20 miles, and is continued by a pack trail for 10 miles to Kuthai lake at the head of the Silver Salmon, a tributary of the Nakina. An alternative route to the same point, somewhat shorter though probably not as good, follows the telegraph line from near the mouth of Pike river on Atlin lake. From Kuthai lake two routes may be followed. The Telegraph trail proceeds southeast and crosses the Nakina at about 45 miles from Atlin. Whether it is possible to proceed down the Nakina is not known, but it is reported to be feasible to travel the country to the south and thereby reach the Inklin and eventually the Taku. Again, from Kuthai lake an old trail follows down the Silver Salmon to its mouth and on down the Nakina to a point to which boats have ascended. This trail was described many years ago as being "rough and mountainous." A trail forming part of the old Indian route from Taku river east to Teslin lake leaves Silver Salmon river 3 to 4 miles above its mouth, and 10 miles to the northeast crosses the Telegraph trail. Whether this is a better route to the mouth of the Silver Salmon than the more direct one is not known. Possibly another route from Atlin to Nakina river is by way of Sloko river. Travel from Atlin lake to Sloko lake at the head of Sloko river is easy and it is reported that the valley of Sloko river has been followed to the Nakina.

A third route to Taku area is by good pack trail from Telegraph Creek, reaching eventually the same points as from Atlin. Both of these routes

[1]Talsekwe is the spelling authorized by the Geographic Board of Canada for the name of this river; the name s also spelt Tulsequah or Tallsaykway.

(from Atlin and Telegraph Creek) are much longer and more costly for reaching most parts of the district than that up the Taku. However, it is probable that for a considerable area in the upper drainage basin away from the main river they would be the more suitable, since the transportation of large quantities of supplies by way of the upper reaches of the river system by boat and by back packing from the limits of navigation is probably much more difficult than by pack horses along and even beyond the trails.

Except in the eastern part of the area and along a few valleys travel on foot for long distances away from the main valleys is practically impossible because of the rugged character of the country. Progress on foot is slow and arduous and it is seldom possible to travel more than a few miles in a day. Except for limited facilities near the mining operations, transportation away from the navigable rivers in the central part of the Coast range must be entirely by back packing. Horses or dogs cannot be used effectively here in the absence of trails. In the eastern part of the Coast range, which is less rugged, dogs could probably be used to advantage for packing and over a limited area west of the Telegraph trail horses can be used.

Airplanes have been used effectively in making the trip from Juneau to the mouth of the Talsekwe and at least two companies have been considering maintaining services in this section during the summer of 1930. The lower Taku river offers many stretches satisfactory for landing and though the upper part of this river is swifter it may also afford some favourable sites. Beyond or just within the eastern borders of the Coast range there are numerous large lakes which could be utilized in reaching the eastern part of the area. Airplanes have been used to a considerable extent farther north.

The lower Taku, though considerably smaller, resembles the lower Stikine, and from information gathered it would appear that the upper part of the river is more like the Iskut. The ice usually goes out in the latter part of April and the navigation season opens some time after the first of May. High water is reached early in the summer. For about two months thereafter conditions for navigation are best. By the middle of September the river is usually low but with autumn rains it again rises for a short period. With the setting in of cold weather the river falls rapidly and slush or frazil ice may run anytime after October, generally fairly late in November.

Talsekwe River valley is a wide gravel flat over which the river is continually changing its course. The river is fed largely by a great glacier at its head and exhibits the vagaries common to glacial streams, showing marked and rapid changes in level due to daily variations in temperature or weather changes. It is subjected to flood conditions. The first large tributary valley above the end of the glacier on the west side is only partly occupied by glaciers and is dammed across its lower end by the main Talsekwe glacier, thus giving rise to a lake into which ice and water are discharged by a distributary of the main glacier and by two small glaciers at the valley head. The space where the lake forms is over 2 miles long, nearly ½ mile wide, and at the eastern end may be several hundred feet deep. With accumulation during the summer a stage may be reached when either the ice dam breaks or the water overflows and rapidly cuts a channel or an under-ice passageway is forced open. Once a channel is established it seems likely that it would be maintained until winter comes, though it is conceivable that the movement of the distributary glacier and the falling of masses of ice at its face could close an under-ice outlet. Close observation of this lake may make it possible to predict when it is likely to break forth and also might reveal whether it could be used for power development. The drainage basin is only about 100 square miles, but it is an area of heavy snow and ice accumulation, and abundant rainfall in summer.

GENERAL CHARACTER

Practically all of the area under consideration lies within the Coast range, which, trending northwest, occupies the mainland of Alaska and a strip of western British Columbia 30 miles or more in width. The International Boundary line follows approximately the axis of the range which in the vicinity of Taku river is marked by peaks mostly from 7,000 to 8,000 feet in height, reaching a maximum of over 8,500 feet and showing a general decrease in elevation immediately adjacent to the river valley. Except where great valleys cut across it the axis is flanked on either side by extensive permanent ice fields from which glaciers extend down to the lowest levels. The range throughout is characterized by extreme ruggedness; slopes of 45 degrees and more are common and great relief is to be found in most sections. Eastward from the axis there is a falling off in the general height of the peaks, and with increase in elevation of the valleys the relief decreases, as does also the ruggedness and the extent of permanent ice and snow fields.

Taku valley cuts directly through the range and shows a general increase in size from east to west. From above the Talsekwe to the mouth of Taku inlet it maintains a width at its base of over 2 miles. About 5 miles above the International Boundary the Talsekwe, one of the largest tributaries, enters the main river from a large valley extending about 20 miles northwest parallel to the axis of the range. On the south side directly opposite is another fairly large valley with about the same general trend. This direction appears to be characteristic of most of the tributary valleys in the mountains.

The climate on the Taku is believed to be similar to that on Stikine and Iskut rivers. The wet belt probably extends 20 to 25 miles up river above the International Boundary. Beyond this within the mountains is a somewhat narrower zone of less intense precipitation and to the east is the interior plateau with a relatively dry climate.

Vegetation in Taku area appears to be similar to that of Stikine and Iskut rivers. Game of the same sort and of about the same abundance as on the Stikine is reported to occur, though moose appeared to be much more abundant along the lower part of the river than is usual in corresponding sections of the rivers to the south. The river is reported to be a good salmon stream and has been frequented by Indians for fishing purposes since before the white men came to the country.

GENERAL GEOLOGY

No detailed geological work has been done on lower Taku river in Canadian territory, but the coastal areas in Alaska have been surveyed as have also those areas in British Columbia immediately to the north, including part of the Taku drainage basin, and those to the east including the headwaters of this system. Work has been done 100 miles to the south along Stikine and Iskut rivers in a position corresponding structurally to that of the lower Taku. From reports on all these sections it is possible to obtain an idea of the formations and relationships likely to be found on Taku river.

The main geological feature in this district is the Coast Range batholith which here as elsewhere occupies the core of the Coast range. On Taku river the eastern contact of this mass crosses near the International Boundary, probably in Alaska. The contact is likely to pursue a very irregular course and to the east satellites occur even as far away as along the Telegraph trail.

The non-intrusive rocks of the areas already mapped (to the north, east, and southeast) show so many similarities that it is reasonable to expect that much the same type of material will be found in Taku River district. The little information that it was possible to gain in a short visit supports this belief. The oldest group of rocks in the mapped areas is a series of Palæozoic and possibly Precambrian age mainly of highly altered sediments, quartzites, slates, schists, and gneisses, with some limestone and possibly some highly altered volcanics. In places near the batholith intensely altered schists and gneisses are found. The next oldest series consists of limestone which in Stikine and Dease Lake areas is a very light grey, is usually crystalline, and in places is metamorphosed to lime silicates such as wollastonite, epidote, and garnet. As a rule it occurs in more or less discontinuous masses, usually of rather limited size, though in some places there are remarkable displays. Both in Dease Lake and Stikine River areas fossils have definitely fixed the age of this series as Permian. Fusulina found by Dawson[1] in limestone occurring in southern Yukon has led to the assignment of the limestone of the northern districts to the Carboniferous, but since Fusulina also occurs in the Permian limestone it is not unlikely that the Fusulina-bearing limestones of the northern districts are also Permian. There are, also, still younger Mesozoic limestones in various other sections.

Another group of series in the areas already surveyed, mainly of Mesozoic age, is largely volcanics. Tuffs predominate, with smaller quantities of other pyroclastics and flows. The tuffs as a rule are bedded, though it is frequently difficult to discern the individual beds. Generally they present a dense, massive appearance. Green is the predominating colour. Greys are abundant and a great variety of shades of red, purple, and yellow are also to be found. Interbedded with the volcanics in most localities are minor quantities of sediments and in some places considerable conglomerate, sandstone, shale, and argillite are present. As a rule

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[1]Dawson, G. M.: "Report on an Exploration in Yukon District, N.W.T."; Geol. Surv., Canada, 1887, p. 170.

these Mesozoic sediments are not as greatly metamorphosed as those of Palæozoic age, but in places they cannot be definitely differentiated from them. In Stikine River area only small quantities of Mesozoic sediments are found near the batholith. This relationship does not hold as well in Atlin district, but it is probable that in the lower Taku the sediments encountered will be mainly Palæozoics.

The three main groups indicated (the older Palæozoic sediments, Permo-Carboniferous limestone, and Mesozoic volcanics) probably include all of the non-intrusive rocks that are likely to be encountered in the area adjacent to Taku river. Throughout Stikine and Iskut River areas these rocks have been found to be intensely folded and faulted, and considerably metamorphosed. Observations by Cockfield and Gwillim to the north and east indicate that the rocks there are much disturbed. The few dips and strikes noted along the Taku showed the strata to be either vertical or intensely distorted and it would seem likely that structure in this district would prove to be similar to that on Stikine and Iskut rivers. If such is the case the formations will be greatly mixed: small masses of younger limestone and volcanic series may be expected anywhere in the older non-calcareous sedimentary series and vice versa. The importance of this condition if it holds is apparent in the case of replacement deposits such as some of the important discoveries already made, for such deposits are probably confined to one type of rock and an individual ore-body, as a rule, ends with the termination of the mass of favourable country rock regardless of any further extension of the fracture or shear zone which gave rise to the ore-body.

The rocks exposed along the east side of the Talsekwe, at and between the Tulsequah Chief and Manville properties, appear to be mainly Mesozoic volcanics. The general appearance of the mountains nearby suggests that this material predominates in the vicinity. There is some evidence that points to the occurrence of the older sediments on the peak north and east of where the International Boundary crosses the Taku and J. D. Mandy notes[1] that slates and argillites have been reported from farther north on the Talsekwe. No extensive body of limestone was observed in the section visited, but at some distance up the Taku a light-coloured mountain on the south side suggests the presence of this material.

All these older rocks are cut by intrusives of various types. Some, and possibly most of them, are related to the batholith. However, in Atlin Lake country intrusives have been described as being older than the batholith. There are, probably, throughout the area many intrusive stocks and dykes associated with the vulcanism of the Mesozoic.

ECONOMIC GEOLOGY

The Taku section of the contact zone of the Coast Range batholith, like many others in northern British Columbia, has been little touched by the prospector despite its recognized potentialities. In 1929, however, promising developments on the Tulsequah Chief and Manville groups and reports of several other discoveries of merit, attracted considerable attention. Not a

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[1]B.C. Bureau of Mines, Bull. 1 (1930).

great deal is as yet known regarding the types of ore deposits to be found in Taku area. Mandy has visited a number of the new discoveries and has classified them into two groups:

"(1) Copper, zinc, lead, and iron sulphides carrying appreciable gold and silver values in a barite-calcite-quartz gangue. (2) Antimony and iron sulphides, with very minor quantities of copper, lead, and zinc, but carrying decided gold values, and practically negligible silver contents, in a quartz gangue."

However, in the more highly developed district immediately to the north and including part of the Taku drainage basin, Cairnes has made the following more detailed classification which might very well be applied at least tentatively to the whole section: "(*a*) Gold-tellurium quartz veins. (*b*) Gold-silver quartz veins. (*c*) Cupriferous silver gold veins. (*d*) Silver-lead veins. (*e*) Copper veins. (*f*) Antimony veins. (*g*) Contact-metamorphic deposits." Besides the metallic deposits coal has been found mainly in the area around Sloko lake and is reported from other sections of the Taku drainage basin.

The two deposits visited in 1929, the Tulsequah Chief and the Manville, are of the copper, lead, zinc, and iron sulphide type. They occur as replacements in a series of volcanics believed to be early Mesozoic age. Many of the characteristics exhibited by the volcanic series in other districts were observed in the vicinity of the mineral showings. Bedding was noted in several places, but in only one was it well defined. A fragmental character is clearly exhibited at the Tulsequah Chief in a few places on both sides of the main mineralized zone and also near the Manville showing. In part this fragmental character is probably due to shearing, but some of it represents the original clastic nature of the material. In the main the rocks are dense to fine grained and are dominantly green and dark grey, with some black, light grey, red, and purple. The colour is generally due to some secondary mineral which masks the true character of the rock and makes it practically impossible to gain any accurate idea of its composition without microscopic study. However, field evidence is sufficient to show that adjacent to both mineralized zones there is a series which includes tuffs, fine-grained breccias, and probably flows and tuffaceous argillites, slates, and quartzites. Though the nature of the materials probably varies considerably the original composition appears to have been fairly uniform, that is, within the limits of the areas examined immediately adjacent to the main showings. The dark grey and green material on either side of the mineralized zones, which is usually designated as andesite, was found, in all cases noted, to be very acidic, being largely quartz and albite-oligoclase feldspar or alteration products of these. No orthoclase was definitely recognized in any specimens examined.

The few places observed that afforded a clue to the structure of the volcanics indicated vertically or steeply dipping beds and one outcrop suggested the crest of an isoclinal anticline. Though this is hardly sufficient data upon which to base an interpretation of the structure it supports the belief already advanced that it is complex. This complex folding is not likely to have as profound an influence on replacement deposits as might be expected, since the volcanics show a fairly uniform composition and characteristically exhibit poorly developed bedding. Further, more important factors unrelated to the folding appear largely to have controlled the distribution of mineralization. However, with a change in composition of the volcanics or their termination the structure would become an all-important factor, as has already been pointed out, since an individual replacement deposit is usually confined to rocks of about the same composition.

The Manville showing occurs in a fairly well-defined shear zone with a general northwest trend. On either side just beyond the limit of well-defined shearing is the dark green or grey quartz-albite rock (quartz keratophyre or alkali rhyolite), a porphyry, tuff, or breccia. This grades to or sharply abuts considerably sheared rock of about the same appearance and composition. Albite-oligoclase fragments of fair size are present in this and represent remnants of badly broken phenocrysts or fragments in the original rock and though still fairly fresh most of them show an irregular edge due to alteration. They occur in a fine-grained groundmass of badly sheared material like that of the rock beyond the zone, except in the more sheared structure and a slight increase of secondary minerals. This groundmass appears to be made up mainly of white mica (probably paragonite rather than sericite), albite, and quartz. The first of these is secondary and the other two may also be in part secondary. The dark constituents such as chlorite are somewhat less abundant than in the unsheared rock. Small quantities of sulphides are also present in some places. The dark, sheared rock grades to a light grey to white rock which constitutes the gangue. In some places the line between the two is sharp enough to suggest a change in the character of the original material, but in most places the gradation is fairly apparent—especially so on the other property, the Tulsequah Chief, where there are offshoots from the main mass into the green material. The central part of the zone then is occupied, other than by the sulphides, by a generally well-sheared, light grey material which usually weathers slightly rusty and yellow. This rock is almost entirely white mica (paragonite) and quartz with possibly in places considerable albite-oligoclase and rare carbonates. In some specimens examined the position of the large fragments of albite-oligoclase is still apparent, but the areas are almost completely occupied by secondary minerals. The rock across the whole zone and on either side appears to have been originally the same type of material and any differences which now exist are the result of varying degrees of alteration.

The mineralization at the upper showing of the Tulsequah Chief appears to exhibit in general the same relationships as that at the Manville. The main difference of the sections already opened up appears to be that the shearing and other factors controlling the distribution of mineralization here were not restricted to as well defined a zone. This feature, however, may be more apparent than real due to more extensive exposures and development. The zone has a general trend slightly east of north. In places the altered light grey zone has offshoots into the adjacent dark grey rock and elsewhere there are masses within the zone which appear to be unsheared sections and still retain the dense texture and dark colour of the unaffected, or slightly affected, bordering rock.

At both properties mineralization appears to have taken place by replacement of the series of volcanics. The controlling factors were shear zones which are believed to be a later development than the main folding of the volcanics and, therefore, are to a large extent independent of the older structure. The trend of such zones appears generally to be northerly or northwesterly, parallel to the Coast range.

For the prospector and operator it is important to note that the light grey rock of the type found here and in many other places is generally an indication of channels along which mineralizing solutions circulated and as such is of the very greatest value in locating mineral deposits of this nature. In some places on Stikine and Iskut River areas the altered rock is almost entirely carbonate or quartz, but light grey is still the characteristic colour. Deposits of this type are confined to Mesozoic volcanics or similar rocks.

TULSEQUAH CHIEF

The general geology of this property has already been discussed and much information is given in Mandy's report. Remarks here will, therefore, be confined to the more salient features. The Tulsequah Chief property is located on the east side of Talsekwe river 6 to 8 miles from its confluence with the Taku. The claims extend from the river up the steep slope of the valley wall, to an elevation of probably over 3,000 feet. Surface mineralization consisting mainly of pyrite occurs, judging by scattered exposures, over a considerable area from river-level to 2,000 feet or more. The chief developments, on the best known shoot or shoots of mixed sulphides, consist of two adits, at approximately 1,500 and 1,700 feet, open-cuts from just below the latter to about 1,850 feet, and a number of diamond drill holes at lower levels. The adits, which in the main follow the mixed sulphide zone, are both approximately 600 feet long and are supplied with numerous cross-cuts. The zone (or zones) though rarely less than 10 feet wide, varies from less than 2 feet in width in a few places, to over 60 feet exclusive of the dyke which is contained in this section. The similarity of shape of the body at both levels is a fair indication that it maintains this size in between, that is, for a depth of 200 feet. Above the upper adit the zone is well exposed by open-cuts for another 150 feet. The dip as shown by these workings is somewhat irregularly steep westerly. Diamond drill cores indicate similar concentrations of sulphides at some distance below the lower adit, but results are as yet insufficient to show whether these are parts of the same mass or to give any very definite idea of their extent.

Mineralization, as previously stated, is by replacement in a shear zone. The more important minerals are chalcopyrite, pyrite, and sphalerite with lesser quantities of galena in a gangue mainly of quartz and white mica. No detailed studies have as yet been made of the sulphide, so that not a great deal is known about less abundant minerals, or relationships. Pyrite is much more widespread than the other sulphides. The altered zone shows all variations in mineral content from that which is almost barren to massive sulphide. The proportion of these minerals from place to place shows considerable differences. Massive mineralization of each of the sulphides, as well as various interbandings and intermixtures, is to be found.

As a rule a fine-grained texture is exhibited by the sulphides. No fair interpretation of values can be gained without very extensive channel sampling. From fifteen samples of from 4 to 8 feet in length, taken from other than very lean sections of the workings, the following results were obtained: gold in ounces per ton, from 0·02 (only four below 0·10) to 0·03; silver in ounces per ton from 1·60 to about 15·0; zinc (in per cent) from about 2·0 to about 10; copper (in per cent) seven samples below 1·0, five from 1·0 to 2·6, two from this to 6·0 and one of 14·0; and lead, a trace in all except four which showed 0·5 to 0·8 per cent. This affords at best only a very rough idea of the values likely to be obtained. How much of the zone will maintain these values was not ascertained; where it is exceptionally wide there appears to be considerable lower grade material but in many places the values are maintained practically across the whole width so that they would appear to persist in the greater part of the zone. It has been stated that the gold appears to accompany the copper, but the assay results obtained from these samples do not support this: the highest gold value, which goes with a very high silver value, was obtained from a specimen with the highest zinc, relatively high lead, and very low copper content; the highest copper content was found with relatively low gold and silver values; and high zinc content was generally accompanied by high silver value. The gold values appear to be indiscriminate, whereas the silver values show a tendency to be relative to the zinc content.

The deposit is divided into two sections or zones by a light cherty or chalky grey dyke 8 to 18 feet wide. This dyke much resembles in composition the intruded unaltered rock, being mainly albite-oligoclase and quartz (quartz keratophyre-porphyry), but has a different texture, and in the main is much less altered than even the least altered phases of the volcanics on either side of the mineralized zone. In places it is banded due to shearing. On the surface this dyke cuts obliquely across the altered section of the volcanics and by its intrusions appears to have cut the mineralized zone into two sections. In the upper adit it does much the same sort of thing, since in the southern part of the workings it lies to the east beyond the mineralized zone in the dark-coloured rock, in the central part it is in the mineralized zone for about 150 feet, and then passes out of it on the west side again into the dark, unmineralized rock. On the lower level the dyke lies within the mineralized zone for about 200 feet and passes out of it to the east at both ends of this stretch. These features strongly suggest that the dyke was intruded later than the development of the shear zone and probably also than the mineralization and the following observations appear to support this belief. (1) the dyke, though somewhat altered and sheared, is very much less affected in these ways than are the volcanics and, further, it is generally compact and very little fractured. Though it is fairly crooked and in some places broken it does not appear to be at all sufficiently disturbed to have been present during the development of the zone. (2) There was little evidence noted either in the field or in the assay returns to show any change in mineralization toward the dyke. Bands of the various sulphides appeared to be cut off abruptly by the dyke as if their development had been earlier. Three channel samples taken along crosscuts on each side of the dyke in the upper adit exhibited about the same mineral content. Similar results were also obtained from surface sampling. This evidence tends to show that, though the dyke seems to have been practically impervious to the circulation of mineralizing solutions, there is no excessive concentration along either contact nor evidence of the dyke's having exercised a very definite controlling influence, as might normally be expected if it had been intruded first. (3) The similarity in composition of the dyke and intruded rocks would, if the former were pre-mineralization, normally lead to the expectation that it would be similarly affected by the mineralization, at least along its borders. Though there is some evidence of this it is relatively very slight compared with that in the volcanics. There is on the other hand some evidence of the dyke having been injected before mineralization, but after the shear zone had been mainly developed. Where the dyke is included the zone is by far the widest. This may be a coincidence, but it does suggest that the dyke exercised an influence over the distribution. In places it is partly sheared and somewhat altered in a manner similar to the volcanics and it shows some impregnations of pyrite and tiny stringers of chalcopyrite along its edges. No mineralization was noted more than a few inches within the dyke, and the stringers in places cut banded mineralization in the adjacent rock in such a way as to suggest a later origin for them. From the foregoing observations it is concluded that the dyke was intruded after most of the shearing and mineralization had taken place, but that there was some later movement of the rocks and some circulation of mineralizing solutions. Previous observers have considered the dyke to be pre-mineralization. In some cases the idea that a mineralized zone would be found on either side of the dyke has been a working basis. This has, however, proved to be incorrect in several places where the dyke was crosscut. That such is the case does not necessarily indicate that the dyke was later, since mineralization would be confined to the shear zone and beyond this the dyke would be in barren ground regardless of its age. The general trend of the dyke appears to be oblique at a slight angle to the mineralized zone. That it should lie within or at the edge of the zone for some distance merely indicates that both the mineralizing solutions and the dyke sought out the same line of weakness. There is some suggestion in the composition and character of the dyke that it is closely related to the mineralization and it is of the greatest importance to establish definitely the exact relationship, since if the dyke were present before penetration by the mineralizing solutions it would be expected to exert a very great influence on their distribution, but if it is later it is of no great consequence except so far as its presence detracts from the general worth of the zone and increases mining difficulties.

Since mineralization is by replacement in a not too well-defined shear zone it is probable that the shoot will have an irregular shape as has been more or less demonstrated by development work in the adits. A depth of from 200 to over 350 feet, according to the position on the hill slope, has already been indicated by this work. Drill holes have shown two or more important mineralized zones at some depth below the lower adit and showings of altered rock occur widely scattered in a considerable area on the mountain side, especially between the upper adit and the Talsekwe river. It may be that all the light grey, altered rock constitutes part of one large mass, at least it seems likely that all the separate masses are in some way connected though possibly at considerable depth. The exposures clearly indicate that there are offshoots of at least a minor nature. Within this zone of altered rock there occur concentrations of sulphides. That all these concentrations are connected by similarly rich material seems unlikely. Conversely, so long as the altered zone persists, even though very narrow, the termination of one shoot does not mean that no more concentrations are likely to be found beyond.

MANVILLE

The Manville showing is located on the north side of Taku valley about 3½ miles above the confluence with the Talsekwe. The property extends from the valley flat for well over a mile up the slope of the mountain. There is a marked similarity between the mineralization here and that at the Tulsequah Chief. The nature of the shear zone here has already been described. The altered portion of the zone can be traced intermittently for over 1,500 feet and has a width that appears to be over 30 feet. Within this, richer concentrations of sulphides similar to those of the Tulsequah Chief are exposed by open-cuts, pits, and in a stream bed, for a distance of about 900 feet and a width said to average something under 20 feet. The values found are of about the same magnitude as those of the other property, though lead appears to be somewhat more persistent. The development, besides the surface workings, consisted in October, 1929, of a short adit and a crosscut which penetrated the zone at a short distance below the surface.

Shearing and consequently mineralization at the showing are fairly well confined, though more extensive distribution of altered rock near the base of the mountain suggests that this confinement may not continue. Within this altered zone, as at the Tulsequah Chief, concentrations of sulphides are likely to occur more or less discontinuously. The impressiveness of the present showing should normally be expected to be a fair criterion of what may be expected at depth.

CONCLUSIONS

The occurrence of mineralization of importance in Taku area has already been proved, even though the economic worth of the properties has not yet been fully demonstrated. The possibilities of some of these developing into valuable producers is already apparent, as is also the splendid opportunity for fruitful prospecting. The area that can be profitably productive is probably relatively small, but even at that there is much room for prospecting.

It seems reasonable to expect that a variety of types of deposits will be found. High-grade mineralization similar to that found just a short distance to the north may occur as well as the relatively low grade deposits. An absence of placer gold concentrations here similar to those at Atlin does not necessarily indicate an absence of gold lode deposits, since glaciation has probably been of such a nature as to destroy any concentrations that may have existed. There is little as yet that can be taken to indicate the most favourable rocks for mineralization. For replacement deposits limestone is as a rule the most favoured. In Taku district, as well as in many other sections along the Coast Range batholith, the volcanics also seem to be very susceptible to replacement—more so than the older non-calcareous sediments. However, all these materials, as well as certain phases of the Coast Range intrusives, are known to be mineralized in places, and in a prospecting campaign no formation should be ignored. All of these rocks have been in a position favourable to receive mineralizing solutions, and these solutions must precipitate their valuable mineral content in the rocks where they find themselves confined regardless of whether it may be the most desirable medium or not. In the Coast range only the central uniform portion of the batholith can now be designated as probably unfavourable prospecting ground.

The zone favourable for mineralization more or less parallels the International Boundary and is not likely to be over 40 miles wide. Within this it is not yet possible to designate any sections as having relatively greater merit than others. Beyond the designated zone to the east is an area much less favourable for prospecting. It is probably not barren and it may yet be possible to indicate certain sections as being equally as promising as those of the Coast Range zone, but until this can be done, and in view of the great extent of definitely potential ground still untouched, it would seem inadvisable for the prospector to go beyond the limits of known promising ground.

PRELIMINARY REPORT ON ISKUT RIVER AREA, BRITISH COLUMBIA

By F. A. Kerr

CONTENTS

Illustration

INTRODUCTION

This report constitutes the third of a series of preliminary reports based on the work that has been done during the last four years in Stikine and Iskut River areas. The purpose of these reports has been to make available as quickly as possible any information that would be of immediate assistance to prospectors and others interested in the development of the country. Since the field work has now been completed this represents the last report of this nature.

The mineral potentialities of the areas adjacent to the eastern contact of the Coast Range batholith in northwestern British Columbia have been recognized for a long time and it was partly with the idea of securing definite information about these in Stikine and Iskut River areas that work was undertaken there. This section was chosen in preference to any of the other undeveloped sections such as Taku and Unuk River districts because it is by far the largest and the most accessible, and, therefore, seemed to offer the greatest possibilities of developing into an important mineral producer. As the work has been carried forward the mineral potentialities of the district have become more evident and last summer, with the advent of a genuine prospecting campaign, the number of new discoveries resulting from this first relatively modest effort have gone far toward demonstrating the important possibilities of the section.

This report deals essentially with the section covered during the summer of 1929, which is only the southernmost part of the total area encompassed in the work of the last four summers. Owing to the fact that snow conditions prevented the commencement of satisfactory geological work before the first of July, the field season was necessarily confined to three months. During this period, owing to exceptionally bad weather, less than half of the time was suitable for carrying on efficiently, so that results are necessarily very sketchy in nature. C. F. Hillary, S. S. Holland, E. D. Kindle, and E. G. N. Player rendered able assistance in the field. The Barrington Transportation Company, W. R. Overend, customs officer, John Choquette, and Jack Fowler, by their co-operation and assistance, did much to further the progress of the work.

Practically no geological work has previously been done in this area. Both Dawson and Buddington visited the section and made mention of a few of the geological features. The Annual Reports of the Minister of Mines for British Columbia give some descriptions of the country and of the prospecting and development work carried on there.

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GENERAL FEATURES OF THE DISTRICT

The area with which this report deals includes practically all the territory lying east of the International Boundary between latitudes 57° 30′ and 57° 50′ and extending eastward to longitude 131°. It includes narrow strips along either side of a section of Stikine and of Iskut rivers, Craig river (south fork of Iskut), and Kahtate river. The navigable rivers represent the axes along which all operations were carried on. With the decrease in accessibility away from these main axes there is a corresponding decrease in data obtained and a lessening of the accuracy of the geological information recorded.

Within the area herein described there are no permanent inhabitants, the nearest permanent habitation is to the north on the Stikine at the Great Glacier. The custom house on the Stikine is open during the navigation season. The customs officer is a sub-mining recorder and represents both the provincial and federal governments in other capacities. In 1929 other than the through traffic up and down Stikine river and a little desultory prospecting near the custom house only one party of three prospectors was in the field, and these only for a period of about one month.

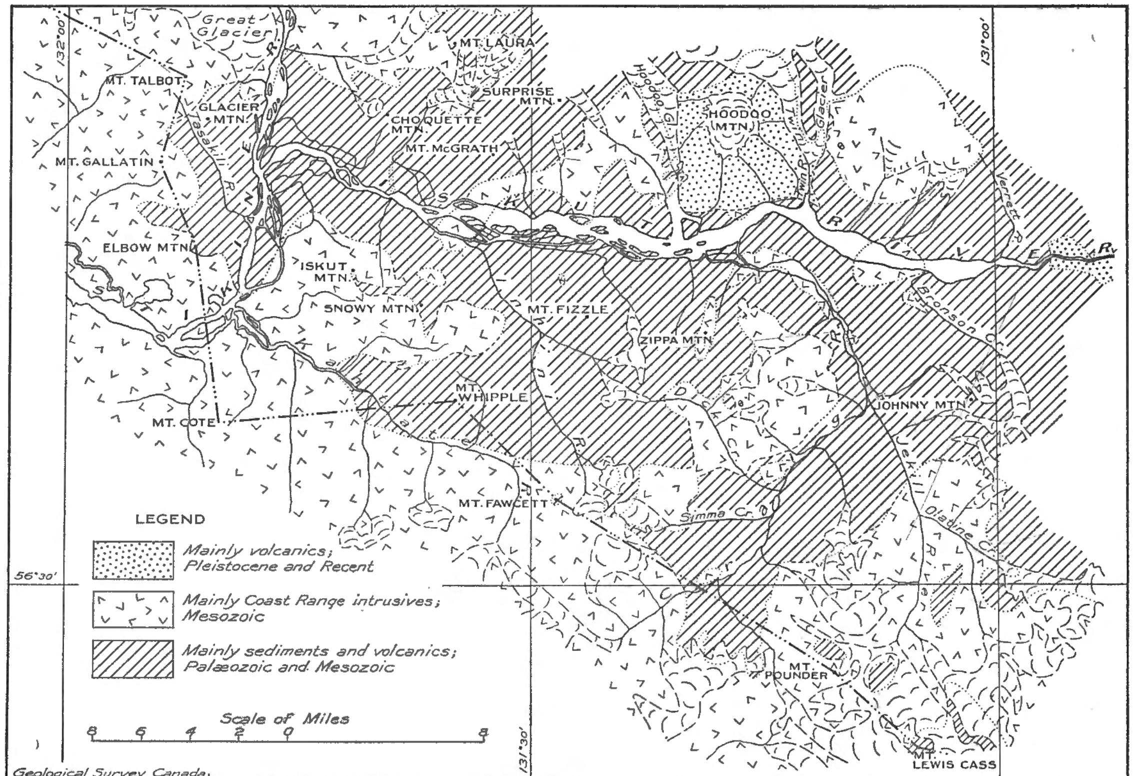

Figure 1. Iskut River area, Cassiar district, B.C.

In winter of late years there has been only one trapper in the whole of Iskut River section. There are about six habitable cabins in the district belonging in the main to the one trapper.

CLIMATE

The Coast range of northern British Columbia is a zone of extremely heavy precipitation. The prevailing winds from the coast sweep in over the mountains heavily laden with moisture and as they strike the areas of increased elevation the atmosphere is cooled and precipitation takes place. During the summer, except occasionally in the higher altitudes, this takes the form of rain. During the winter west of the axis both rain and snow fall, the former exceeding the latter at lower levels and vice versa at higher levels. East of the axis, however, precipitation during this period only rarely assumes the form of rain. In general there is a decrease in the quantity of precipitation from the axis northeastward to the interior plateau. For the first 20 miles of this distance, however, the falling off is not sufficient to make any appreciable improvement. This strip of territory is truly a wet belt and the map-area lies almost entirely within it. Snowfall in winter is very heavy. By the first of July the slopes to timber-line are for the most part free of snow, but above this the bare ground hardly exceeds 25 per cent of the total, even in areas beyond the extensive permanent ice fields and glaciers. During July, however, the snow disappears rapidly. Fresh snow begins to accumulate again shortly after the first of October and slowly the snow line works its way down from the high peaks to the lower levels.

May, June, July, and August weather conditions are as a rule the most favourable. September is usually an uncertain month and once the weather breaks, which may be any time after the first week, the sky is more or less continuously cloudy and rain falls intermittently. However, although this may be considered normal, variations from it are common. In 1929, during the latter half of June and throughout July and August, on Iskut river there were but eight clear days; of the rest, nineteen were cloudy days of which seven might be described as threatening, with as a rule some rainfall, and forty-eight were days when important quantities of rain fell, about half being marked by an overcast sky and frequent showers, whereas the remainder were truly rainy days. Snow fell above 4,000 feet on several occasions in sufficient quantity to entirely whiten the peaks and the rains for the most part were cold. September was a splendid month; rain fell on but few days and many were clear, bright, and warm though the nights were cold. Undoubtedly the summer season of 1929 was unusually severe, but the weather is always extremely uncertain and at best much bad weather must be expected. Little can be accomplished unless work is carried on almost regardless of the weather.

The prospecting period is very limited. Some work can be done during May on very limited parts of favoured southern slopes. During June it can be extended to most of the area below timber-line. By July it is possible to accomplish considerable higher up, but it is not until August that large areas of snow-free, unwooded ground are available for inspection. Through August and September these conditions improve, but towards the end of September the very cold nights and low altitude of the sun prevent appreciable thawing even though days are clear. By the middle of October conditions as a rule reach a state where little prospecting work can be carried on.

During 1929 the unusual summer developed abnormal snow conditions. The abundant rains, rather than merely cloudy weather, during the early part of the summer, washed away most of the snow of the previous winter. The following warm September wrought havoc on what remained, as well as on the accumulations from previous years. Glaciers and ice-fields crumbled away in a most remarkable manner, following a period of years during which recession of most glaciers had become increasingly rapid. The autumn set in unusually warm and wet—rain fell instead of snow. Early winter saw little precipitation. A continuation of this during the winter with a following summer of something near normal conditions would result in greater recession of the glaciers and more snow-free ground throughout the wet belt than has been witnessed since the white man first visited these parts.

In the extreme northeastern part of the map-area the vegetation, and the extent of glaciers and snow accumulation indicate the beginning of a zone with different climatic conditions. This zone might be considered as belonging to an intermediate belt between the dry belt of the interior and the wet belt just described. Precipitation on the whole is much less, partly because of a general decrease in elevation of the mountains and partly because the higher peaks to the westward have caused the removal of most of the moisture from the atmosphere passing over this section. Working conditions in the intermediate belt are much more favourable. Snow disappears from the various altitudes a month or more earlier than in the wet belt, rainfall during the summer is very considerably less, and snow accumulation in the autumn begins somewhat later, so that a much longer and better prospecting season can be gained.

VEGETATION

The river flats which are not subjected to the occasional wash of the river or its tributaries are a veritable jungle: large cottonwood trees and occasional evergreens stand out above a tangled mass of willows, cranberry bushes, devil's clubs, and other shrubs. The lower slopes wherever conditions are favourable are heavily clothed with a mature forest of spruce, hemlock, and fir. Travel through this is as a rule easy. Where the trees are sparse there is generally a thick tangle of alders, huckleberry bushes, and devil's clubs, and over many of the slopes which are steep and subjected to snow slides the growth is almost always of this nature and extremely difficult to traverse. In many places, however, the slopes are so steep as to support but very little vegetation, and present much bare rock. Gullies and protected spots where the snow accumulates and lingers are generally fairly free of vegetation. Timber-line throughout the wet belt is low, averaging about 3,500 feet, though in localities favourable to growth it extends to 4,500 feet. Though most of the deep valleys are well timbered on their lower slopes some, notably those lying northwest and southeast of mount Whipple, are devoid of appreciable timber, alder being the chief growth.

In the northeastern section of the map-area there is a change in the vegetation. The valley flats are slightly more open than in the lower part of the river. The lava flats through which the canyon is cut are clothed with evergreens of which a large percentage are jackpine. Probably where these trees are mature there is little underbrush and travel is easy. The southerly slopes carry a much scantier growth; the northerly are not greatly different from those in the wet belt. Pines, birches, and poplars are present and in places are the most abundant types.

Along the principal valleys there is a band of timber 2 to 5 miles wide. In most places the growth is mature and in the wet belt has been almost untouched by fire. Many of the spruce trees attain a diameter of 5 to 6 feet and the hemlocks of 2 to 3 feet. Western hemlock spruce is probably the most numerous species. Sitka spruce in many places occurs almost as abundantly. Mountain hemlock spruce is found in the higher reaches and sometimes as low as 1,000 feet above sea-level. Alpine fir was noted, though it is relatively rare compared with the other species. In one locality only, very spindly cedars were observed. Near the canyon and above, jack or lodgepole pines are to be found. Cottonwoods, which reach greater dimensions than any other trees, are abundant along the river flats and show a remarkable rate of growth despite the northern climate. Most of the others mature very slowly and trees one hundred and fifty years old are less than 2 feet in diameter.

GAME AND FISH

The map-area is not as favourably endowed with game as most other sections of northwestern British Columbia. On practically all the mountains some goats are to be found, but in much smaller numbers than is characteristic of the mountains beyond the wet belt. No sheep occur in this section. Moose frequent all the main river valleys but are not abundant except toward the eastern limit of the map-area. Coast deer are known to have penetrated as far up the Stikine as its confluence with the Iskut, but even in the western part of the area they are rare. Black, brown, and grizzly bears are fairly abundant throughout the area, especially up the Kahtate. Porcupine occur in all sections, but are rare. Geese and ducks nest in the sloughs along the rivers in fair numbers and these are augmented by others late in the summer, so that in September they are fairly abundant. Grouse and ptarmigan are sparsely scattered in all sections.

Fur-bearing animals appear to be fairly abundant, especially beaver, which in unmolested sections have extensively dammed most of the suitable tributary streams and sloughs. There are many miles of favourable trapping ground along the main rivers and the larger tributaries.

Salmon do not seem to be as abundant in the waters of the Iskut system as in the Stikine, though they do ascend most of the suitable rivers and streams. Fishing in the Iskut itself for trout and dolly varden is not very fruitful, but in some of the clear sloughs and streams frequented by salmon and in small lakes an abundance of fish easily caught is to be found.

WATERPOWER

Iskut river in its canyon section and above with a drop of over 600 feet in 25 miles ought to afford a number of splendid sites for developing waterpower. The lava poured into the old valley has built up a magnificent dam through which only a very narrow rock-bound channel has been cut. Within the map-area this river would not seem to afford any favourable sites. The rivers from the north pour through canyons which could easily be blocked to afford a small head, but storage facilities are lacking and though the flow in summer is very considerable, in winter it is probably negligible. The rivers to the south and Tasakili river to the west appear to afford much more favourable sites. Many of these have canyon sections with steep gradients to afford good head, and storage facilities are provided by the wide, glaciated valleys with low gradients.

PHYSICAL FEATURES

Iskut river flowing west cuts across the northwest-southeast trend of the Coast range. It occupies a great trough which increases in size from east to west regardless of the topography of the area through which it passes.

Iskut river heads in what would normally have been a part of the Interior plateau had not Tertiary vulcanism imposed upon it a great, flat, mountain mass with elevations reaching above 9,000 feet. Capped by a tremendous permanent ice and snow field this mass forms the divide between the waters flowing directly to the Stikine and those of the Iskut. Other high and large volcanic mountains flanking the head of the drainage basin contribute a liberal supply of water, so that before the river enters the Coast range it has already attained considerable size. For about 40 miles it flows approximately south parallel to the Stikine. Then it receives from the northwest More creek, which is one of the largest of the tributaries, if not the largest. This creek drains part of a vast mountainous area between Iskut and Stikine rivers. On the opposite side not far below More creek Ningunsaw river enters the Iskut. Though this river occupies a large valley entering the main valley at right angles its contribution is relatively small as compared with what might be expected in a normal drainage system, since a low divide not far to the south marks the height of land between this basin and that of Nass river.

From the Ningunsaw junction the river flows southwest for 20 miles and then west for 45 to join the Stikine. To the south the drainage area is relatively narrow, averaging less than 15 miles, though in Craig and Snippaker rivers there are at least two large tributaries on this side. Peculiarly the valleys on this side are cut very deep and despite the fact that some come from the very axis of the Coast range they are occupied mainly by streams, glaciers being found only on the steeper slopes at their heads. On the north side there is a more extensive drainage area. Within the map-area there are four large streams in this section. In marked contrast with the south side the rivers are short and glaciers occupy the valleys for the greater part of their length. Hoodoo and Twin glaciers, respectively below and above Craig river, represent abnormal conditions due to the presence of a Tertiary volcano, but even without this the conditions here would have been similar to the other valleys. Beyond the map limit on the north side there are probably one or more large tributaries which have never been mapped.

From above the junction of the Ningunsaw, Iskut river can probably be considered to be within the Coast Range physiographic province. The limit of the range in this section is poorly defined because to the east it merges with the Klappan range and other mountain groups. The map-area lies well within the Coast range, in fact is situated along its axis. The topography, however, is not normal for an area so located.

To the north of Iskut river is a high area largely covered with permanent ice and snow fields from which glaciers extend far down the valleys. Between these the mountains rise abruptly from the main valley so that only a relatively small area is free of ice, and this is very rugged.

South of Iskut river the physical features are markedly different. This section is so intimately cut up by deep valleys that there are no extensive upland areas and as a consequence no extensive ice fields or glaciers. Though the predominant trend is northward the valleys are not systematically arranged. Those of the Stikine, the Iskut, Craig river, and the Kahtate form an ellipsoidal pattern and more or less isolate a fairly large section of mountain masses. These are of irregular shape and size and are separated from one another by fairly low passes. As the peaks attain a height of 6,000 feet or more from valleys little above sea-level considerable relief and ruggedness are maintained everywhere.

South and east of Craig river the mountains attain somewhat greater height; they rise abruptly from the main stream valleys, and their upper parts are largely covered with ice which is somewhat more extensive than in the section immediately to the northwest. Numerous glaciers extend down the slopes to feed the many streams that descend in relatively small valleys to the few main drainage channels. The relief and ruggedness here are even greater than to the northwest.

Beyond the map-area to the east there is a falling off in ruggedness and relief. The mountains are rounded, not so high, and carry much less ice and snow, and in general in this way show the normal tendency common to the Coast range.

MEANS OF TRAVEL AND ACCESSIBILITY OF VARIOUS SECTIONS

Stikine River section is readily accessible during the open season. From Wrangell, Alaska, river boats can make their way to the mouth of the Iskut without any great difficulty or danger. The current of the river on the lower section is relatively slow and can easily be conquered by a boat travelling at moderate speed. Bars and snags, however, exist and because of the slack water it is somewhat more difficult to observe them here than farther upstream. From about the middle of May until the middle of October, the Barrington Transportation Company of Wrangell, Alaska, maintains fairly regular weekly service on Stikine river. It is probable that a service as far as the mouth of Iskut river could, if required, start one month earlier and last at least one month later.

Stikine river, from the mouth of the Iskut to the Great Glacier, is on the whole similar to the stretch below but is slightly swifter. It is easily navigated with the exception of a short section opposite the southern part of the face of the glacier. Here during high water there is a riffle which causes some difficulties. At low water in the autumn for about a mile below this point fairly swift water and gravel bars are somewhat of a menace.

Iskut river has frequently been navigated by the smaller boats of the Barrington Transportation Company as far as the mouth of the first large creek (Bronson) on the south side above Craig river, and under normal conditions they can reach the canyon at the mouth of Snippaker river without much greater difficulty. The period favourable for such navigation is probably at least one month shorter than the present navigation season on the Stikine.

Iskut river for about 7 miles above its mouth to Johnson bar presents a character somewhat similar to that of the lower Stikine. It is confined more or less to one well-defined channel, but the water flows swifter than on the nearby Stikine and snags are much more numerous, especially for the lower quarter mile. From Johnson bar to the canyon the river presents a much different character. The valley bottom maintains a width of from 1 to 2 miles with a general tendency to narrow upstream to the lower dimension. This flat, of gravel, constitutes a base over which the river is continually shifting. A small part of it is clothed with mature vegetation, but even these sections are being continually attacked by the river. Other sections more recently deserted by the waters have vegetation in various stages of advancement, but the greater part, in some places the entire valley flat, is practically barren gravel bars. Nothing is stable; with the lodgment of an obstruction the entire river may in a short time change its course. The gradient of the valley is considerably steeper than that of the lower Stikine. As a consequence of these factors the river generally is very much split up, in some places into hundreds of channels, it flows swiftly with practically no stretches of slack water, and obstructions in the form of snags (floating or fixed) and bars are numerous. Because of these conditions this section of the river is always difficult and dangerous to navigate. During high stages it is continually changing its course and partly because of this carries much drift. Later in the summer it settles fairly well into a lesser number of channels from which a route may be picked that can be more or less maintained in use for the rest of the season, but is invariably subjected to some changes which must always be carefully watched for. As a rule one channel exists that carries enough water for navigation by the larger boats, but there may arise occasions when even small boats would have to be manhandled to overcome obstacles. One of the chief difficulties, of course, is finding the most suitable channel. As a rule it is best to follow that carrying the largest volume of water but not infrequently this leads to difficulties.

Beyond Snippaker river at about 40 miles from its mouth the Iskut flows in a canyon said to be about 12 miles long. The lower 5 miles of this exhibits abrupt turns every few hundred feet. The width in the main varies about 100 to 200 feet and is such that at low stages of water there is usually a bar on one side or the other. Even at high water there are probably many stretches of exposed bar as some have a well-sustained growth of timber. The height of the walls probably averages somewhat less than 100 feet, though since the channel follows along the base of the mountain on the north side in places a relatively steep slope extends from the canyon to a much greater height. The south wall is almost entirely horizontal lava flows with only occasional masses of intrusive. For the most part it is vertical and cannot be scaled. However, there are trees at certain places which could be felled against the cliff and thus constitute ladders. It is believed, also, that there is at least one point where it would be possible to climb out without the aid of a tree. The north wall is made up mostly of intrusive with occasional masses of the horizontal lava flows. It is not as consistently vertical as the other side and would seem to offer many routes for ascent, but since it is part of the steep slope of the mountain there is little likelihood that many will desire to set out from here.

In September, 1929, with a low water stage and employing a 24-foot river boat with a 14-horsepower outboard motor, it was possible to ascend the canyon for about 5 miles. The route was somewhat dangerous and the riffles became increasingly difficult to overcome; the last because of large combers and swift water taxed the boat to its limit. To this point all the riffles were flanked with bars and a boat might even have ascended by hand-power. It would not seem to be advisable, however, to attempt the journey even with power except at low water in the autumn and then caution should be exercised, for it is probable that a rain storm or other causes would raise the water-level very rapidly. No one is known to have gone farther up the canyon. Everyone questioned, who had travelled in the vicinity of the upper part of the canyon, was convinced that it was absolutely impassable for boats, though no informant had actually seen the obstacles. From various sources of information it was learned that at the head of the canyon the water plunges through a narrow crevice which has been easily bridged with logs. At this place drift periodically accumulates and backs up the water to a considerable extent until with a sudden change of current the water breaks loose and rushes forth. If this is correct a craft caught in the canyon in such a deluge would have little chance of reaching safety. The difficult nature of this stretch of the river is further evidenced by the fact that no one is known to have been able to go through the canyon on the ice. The elevation at the farthest point reached in the canyon, about 5 miles above its mouth, is about 500 feet, whereas about 25 miles higher up at the junction of the Ningunsaw with the Iskut, it is 1,100 feet. From the Ningunsaw to the canyon the river is reported to have a fairly even and not excessively steep gradient and, therefore, it would seem that a great part of the drop of 600 feet takes place in the upper part of the canyon.

Craig river, the south fork of the Iskut, from its junction with the main river for between 15 and 16 miles to the mouth of Dick creek, was navigated without serious difficulty by power in a 24-foot boat, in September, 1929. Except for a few miles below the junction of the main tributary, Jekill river, the water is fairly well confined to one channel. The river is for the most part very swift and even in late summer attains in stretches a speed of 10 miles or more an hour. There are many sharp, narrow turns which are difficult to navigate, and snags and cobble bars are numerous. Though travel by boat on rivers of this size is invariably difficult and dangerous, Craig river was found to be considerably better than might normally be expected. During high water, however, in the early part of the summer it is probably a rushing torrent that might at times be very unsuitable for navigation. In stretches the river is subjected to changes that occasionally may be of such a nature as to make travel beyond the first 5 miles very difficult. Also, parts of the upper 5 miles may well be in an unfavourable state the greater part of the time. However, with capable management and some man-handling it is probable that boats can ascend to Dick creek at almost all times during the open season.

Above Dick creek, the limit to which boats were used in 1929, the river was greatly split up for about one mile. Opposite the mouth of the creek (Simma) above Dick the river is constricted into what is called the "gorge", on the south side of which is a rock wall and on the north a boulder bar. The water is fairly well confined to one channel through which it rushes over a bouldery surface at a speed which in places exceeded 15 miles an hour at the time of visit, during a fairly low stage. International Boundary survey parties working at the head of this river portaged canoes around this section. No boat is known to have attempted to go through it, but at favourable stages late in the summer it might be navigated if the boat were sufficiently powered and a tow line run out for safety, as tracking along the north side is not unduly difficult. At highwater stages in the early summer the ascent might not be possible and portaging would then become necessary. Above the gorge there are several miles of navigable water.

The chief tributary (Jekill river) of Craig river does not appear to be navigable wth power, but at low stages a boat could be tracked up it with difficulty because of the swiftness of the current, for several miles. A short canyon just over one-half mile above its mouth might be a bar to tracking during high water.

The only other navigable waterway in the area is Kahtate river which enters the Stikine just above the International Boundary. For about 4 miles, the greater part of which is in Stikine valley, the river is sluggish and follows a meandering though well-defined course and is very easily navigated. To the junction of its main south fork, though the current is somewhat swifter, no serious difficulties are encountered. From here to a point about one mile below the International Boundary power can be used only intermittently even at a fairly high stage of water and for not much more than half the distance. A boat can be tracked without serious difficulty to the boundary and probably beyond this to the beginning of a canyon about 4 miles above. Then follows about 1½ miles of canyon which, as seen from a distance, does not appear to be suitable for boating and above this a stretch of several miles may be favourable for tracking. The south fork, because of an abundance of log jams near its mouth, is not of much value as a transportation route.

The navigable waterways form the only means of ingress to the various sections of Iskut River area. There is no established service on Iskut river, but the Barrington Transportation Company has in the past made a few special trips every summer and is generally prepared to send a boat whenever need for such arises. Practically all travel has been confined to small open river boats powered with outboard motors. The most common and probably most practical type for average use is about 24 feet long, flat-bottomed, and shovel-nosed, with considerable beam. The engine should be capable of driving the boat at speeds up to 15 miles an hour. Motors now designated as 12 to 14 horsepower generally can accomplish this with a light load. Successful navigation of the rivers in the area requires skill and experience and should not be attempted by a novice. A fairly complete discussion of the whole subject of river navigation appears in an article entitled " River-Navigation and the Prospector."[1] Airplanes have not been used in this section other than to pass through the western part of the area on their way up and down Stikine river. It would seem that their use would be feasible to some extent and their employment might be given consideration. The lower Stikine has presented no serious difficulties in the way of affording good landing sites and numerous coves or bays where the water is slack make it easy to find a convenient mooring place. For starting there is no dearth of long and wide, straight stretches. The river valley itself averages well over 2 miles in width so that gaining height is not difficult. The chief danger lies in the occurrence of snags and bars in the river, but most of these should be easily discernible from the air. Besides the main river there are numerous sloughs and lakes which might very well be used for landing providing they offer suitable places for disembarkation and in this connexion it must be remembered that travel on the river flats is for the most part extremely difficult and in some places is impossible. The lakes in front of the Great Glacier contain numerous jagged blocks of rock which because of the very muddy character of the water and lack of current are not readily discernible. On the north end of the mountain southeast of the confluence of Stikine and Iskut rivers at an elevation between 2,500 and 3,000 feet and amid beautiful, park-like surroundings, are two or three fairly large lakes which might afford landing sites.

The lower 7 miles of Iskut river has many stretches that could be used as landing sites, though the water is fairly swift. In the next 6 miles the sloughs on the south side of the river, if not too narrow, afford the best landing sites. The main section of the river here and beyond to the canyon is very swift and dangerous, though there are places of sufficient width, length, and depth. Hoodoo and Twin River bars at 14 and 20 miles by direct route from the mouth of the river probably form about the most satisfactory points for disembarkation. There are no large lakes in this whole section. Opposite Twin River bar and about 1 mile south of the Iskut is a lake estimated to be about a mile long which would seem to offer the best landing site in this vicinity. There is, of course, no trail to the lake. Other small lakes occur in the general area between Iskut river

[1]Kerr, Forrest, A.: Can. Min. Jour., Feb. 7, 1930.

and Craig river, also on the south side, above Bronson creek, which is situated about 6 miles above Twin river and again 2 or 3 miles farther up river on the same side. All of these, however, because of high trees or abrupt slopes surrounding them, may not afford practicable landing sites.

Craig river for the most part is narrow and swift, but small planes possibly could land and take off with some difficulty and danger, from the better reaches. Small ponds exist in this valley, but none observed was thought to afford favourable landing sites. Kahtate river in its lower reaches is very crooked and higher up is narrow and swift with few unobstructed straight stretches of appreciable length. It seems doubtful that this valley affords any satisfactory landing places.

On the whole, except for the western edge, the area is not at all well adapted for the use of airplanes in summer. In winter, probably many snow-covered gravel flats could be used. The ice of the river, besides being unsafe, in many places may be very rough.

Within the area there are no roads and except for trapper's blazed lines, only one short mediocre trail. The country for the most part is extremely difficult to travel on foot. In general beyond the navigable rivers it is best to follow the valleys if they are wide and glaciated to their base, and do not receive too many large tributaries. If these do not serve the purpose then it is best to go direct to timber-line, following ridges clothed with mature timber so far as possible, and then travel the open spaces above. To attempt to move along the slopes below timber-line in most places involves a tremendous loss of time. The valley flats at Stikine and lower Iskut rivers because of dense, jungle-like vegetation, swamps, and numerous sloughs are almost impassable. It is always advisable to reach the valley wall by boat if possible, even though this may involve a somewhat longer trip. Above the junction of Craig river, extensive, bare, and sparsely vegetated bars, extending to the valley walls, make travel much easier in the autumn. During high-water stages, however, these are largely flooded. The lower 8 miles on Craig river present conditions somewhat analogous to those along the Stikine and lower Iskut, but the upper part of this valley has extensive, bare gravel bars and flats not densely timbered which are not exceptionally difficult to travel. Below Craig river, Kahtate valley has the characteristics of the Stikine. In all these valleys travel as a rule is best just at the foot of the steep walls, where good bear trails are generally to be found.

The valley of Tasakili river cannot be traversed from its mouth and is difficult to reach because the western slope of Glacier mountain, to the north and east, is in places precipitous. The southern part of this mountain can be ascended best from the mouth of a small creek opposite and above Iskut river. It is impossible to traverse the ridge to the high point, but ascent of this can be made fairly easily by proceeding up the slough at the base of the mountain to the most northerly stream which feeds it, thence by following this stream. The headwaters of Tasakili river can be reached best by passing directly over the ridge by this route. Elbow mountain can be ascended easily from the upper side of the bay above the Custom House. From here a course is pursued westward and then northward between a spur and the main mountain until a rock slide is reached up which ascent is easy.

The base of Choquette mountain just northeast of the confluence of Iskut and Stikine rivers can be reached by boat through the slough at the north limit of the mouth of the Iskut. This waterway, which is clear in its upper reaches, can be navigated easily by power during fairly high water. From a point not far above an old cabin, where the channel strikes the base of the hill, a good route can be found which ultimately leads to the basin directly above. The ridge of this mountain cannot be travelled beyond the peak. The northwest side beyond this, and mount Laura can be reached from the valley to the north. The southern end of Johnson valley to the east of Choquette mountain can be reached by a clear bar from the Iskut. The river occupying this valley is too large and swift to cross, though higher up there may be logs across the canyon. For the most part the river is confined in a canyon with vertical walls 50 to 100 feet high. Above these the slopes are very steep and since they are frequently swept with snow slides are clothed almost entirely in alders. Travel is exceedingly difficult and to reach the glacier is nearly a day's journey. The east side is probably the best to travel, but with the river in its present position this is very difficult of access. The base of mount McGrath, east of this river, can be reached through sloughs at several points, and fairly easy ascent can be made. The southwestern spur of mount Surprise, still farther east, is reached most easily from Hoodoo valley which lies to the east, and the best route is along the north side of the ridge near the top. The bar of Hoodoo river is clear from the Iskut to the mouth of the canyon. This is another big river that cannot be crossed. About 500 feet west of the mouth of the canyon that extends about 1,000 feet beyond the face of the glacier is a small stream that makes an easy route to the valley above the canyon. Beyond this travel along the west side of the glacier is very good. Ascent of the ridge to the west can be made with little difficulty at any point above where it has reached a height of 3,000 feet. Beyond this the ridge also is easily travelled. The glacier can be crossed within 500 feet of its terminus and again above the ice cascade.

Iskut mountain southeast of the mouth of Iskut river can be ascended from many points on the north face, as also can Snowy mountain, which lies to the southeast. The crossing between these two can be effected either at the summit of the divide or considerably lower down. The journey from the western part of Snowy mountain to the central part is difficult and must be accomplished either at the summit of the divide, or near the face of the glacier, which may be very dangerous. Travel southward toward mount Whipple on top is possible, but there is no vegetation other than alders and no very desirable camp-sites either on top or in the valleys north and east of mount Whipple. Inhini river east of Snowy mountain occupies a canyon for about 2 miles above its entrance to Iskut valley and again about one-half mile above the large tributary from the east. The valley walls here are steep with but a slight discontinuous bench above the canyon, are subjected to numerous snow slides, and are clothed mainly with alders. Travel along this section of the valley is probably extremely difficult, and trail and road construction would be a very serious problem. Above the second canyon the valley bottom is wide and gravel filled with numerous bare or sparsely wooded bars. Alternative routes reaching the headwaters of this valley are from the Kahtate over the low ridge south of mount Whipple, through the low pass from Craig river, or by the ridge west of the valley from Snowy mountain. For a hurried trip the route by the Kahtate is probably the best with the ridge as the alternative. The former would be best for heavy loads, also, unless time was available for exploring and cutting a trail along the valley of the Inhini itself. Fizzle mountain to the east of this valley can be ascended best from a point near the small creek on the northwest spur. The ridge can be traversed easily for at least some distance beyond the first high point.

Zippa mountain directly south of the confluence of Craig river with the Iskut presents a precipitous but quick route for ascent on its north face, starting at the rock slide directly south of the gravel hill which protrudes prominently into the river valley. By an easy route along the ridge and through a low divide to the east, at the head of Raven creek, the headwaters of Dick creek, to the south, can be reached easily in one day. A more suitable route for carrying heavy loads may be found up Raven valley.

Twin river, the first large tributary above Craig river, cannot be crossed below the glacier. With the river flowing mainly west of the bare bar as it was in 1929 the best route up this valley is on the east side. Almost opposite the head of the bar a tree ladder extends to the top of the lava flow which because of its vertical face cannot be scaled farther upstream. From this point the valley is thickly wooded, first with a mature growth of evergreens, then thickly matted new growth which is gradually encroaching on alders. Travel is difficult to within a short distance of the glacier; thence along either side of this or along the base of the nunatak in the centre there is good going. The glacier can be crossed near its face. Verrett valley, the next large one to the north, can probably be reached best from a point just south of the confluence of its river with the Iskut.

Bronson creek, the first large stream above Craig river on the same side, is served by the only trail in the area. This starts from the cabin, which is situated between the two channels of the creek, and crossing the more easterly of these trends along the hill-slope. This trail though poorly defined offers a fairly good route to the head of the valley. A branch leaving it at the stream about one-half mile above the bridge affords a poor, but the best, route to the spur of the mountain (Johnny). Once on this, travel to the south as far as the glacier beyond this mountain is easy. Snippaker mountain east of Bronson creek can be ascended easily from the lake on the trail. The valley of Snippaker river to the east can probably be travelled along its base. This is a large river and cannot be crossed, though it flows through a lava canyon near its mouth across which it may be possible to fell trees.

South of Iskut canyon, which begins just above Snippaker river, is an extensive lava flat occupying the greater part of Iskut valley. It is clothed with a fairly open growth, mainly of evergreens, and is said to be traversed by a trail. It seems that this would be the best route for penetrating eastward beyond the western end of the canyon. It should be possible to transport horses to this point and their use beyond would seem to be feasible. In fact, with a little trail cutting up Snippaker valley and in other directions their use might greatly facilitate the opening up of this section.

The upper Iskut at present can be reached by a good trail from Telegraph Creek and in time probably a better route will be afforded from Stewart by way of Meziadin lake and Bell-Irving River valley. Further, some of the numerous small lakes at the confluence of Ningunsaw and Iskut rivers probably afford good landing sites for airplanes. Other lakes west of the Ningunsaw are reported which may also be suitable. Possibly boats could be used on sections of the Iskut between the Ningunsaw and the canyon. Travel on foot below the Ningunsaw is said to be obstructed by tributary streams that are difficult to cross. One fairly large stream is reported to enter the canyon from the south approximately at its centre. Another large one may occur higher up, but for a long stretch south of the Ningunsaw the streams are small. If these streams can be crossed and horses used, penetration, other than by plane, from below the canyon would be by far the quickest and probably much cheaper under present conditions. This, of course, would involve trail cutting.

Either by way of Snippaker valley or one not far to the east there is said to be a fairly low "unwooded" and "gravelled" pass to the headwaters of Unuk river. This was used by the Indians and is reported to be easy to travel.

Jekill river, the large tributary of Craig river, cannot be crossed by ordinary means. As previously stated a boat can, probably, be tracked up it for some distance. Travel on foot is best along the east side, though no serious difficulties are to be encountered on either side, at least as far as the main canyon which is about 3 miles above the junction and continues to a point one-half to a mile above the mouth of the large tributary (Olatine creek) from the east. Travel along this section can probably be accomplished with difficulty on either side at some distance above the base, though there are some small streams that are probably confined in steep-walled valleys. Beyond the junction on the west side the valley of Jekill creek should be easy to travel. Olatine creek occupies a canyon in its lower reaches and probably cannot be crossed. Travel up this valley as well as that of its large tributary is probably difficult. All the passes to the Unuk in this drainage basin exceed 4,000 feet and are covered by extensive glaciers, so that to reach the other side would be extremely difficult.

Of the tributaries of Craig river (the south fork of the Iskut in its upper reaches), all except three can be crossed fairly easily: Dick creek, the first large one on the north side, may be waded at its mouth only during very low water stages and when it is considerably split up—on the whole very exceptional circumstances; the creek (Simma) above this on the same side can be forded at low water stages, in the autumn; Pounder creek, the large one at the International Boundary on the south side, may cause some trouble. Otherwise travel along either side of the river to its head is fairly good. Dick creek, for about half a mile above its entrance to the valley of Craig river, occupies a canyon. Except for this short stretch, which can be covered best on the west side, the valley is wide and glaciated to its base and affords a good route for reaching a large area. Simma creek, west of this, flows partly in a canyon, but it is probable that this difficulty can be overcome. The upper part with a relatively wide base offers a splendid means of reaching a low pass to the headwaters of Inhini river. A low pass at the head of Craig river affords access to Bradfield river.

About twenty years ago a splendid trail existed along the east side of Kahtate river. This has been kept open in places by the bears and can be travelled to the International Boundary line and beyond. The canyon of the Kahtate, together with that of Whipple creek from south of the mountain of the same name, may be a bar to progress along the base of the valley. If not, the headwaters of the valley could be reached fairly easily in this way. Above timber-line Whipple creek can be crossed without difficulty on snow bridges. In this way the ridge south of mount Whipple may be attained and the headwaters of both Kahtate and Inhini rivers are made accessible.

In early summer, and in some places much later in the season, snow bridges afford a means of crossing many streams. They, of course, must be carefully examined and tested before being used, as invariably they are dangerous. They are to be found most abundantly where the valley walls rise steeply from the stream and, therefore, are subjected to snowslides. It is this unusual accumulation of snow that is as a rule responsible for these natural bridges.

Conditions for railway facilities in Iskut River valley are very favourable. From the canyon to tidewater is about 70 miles, of which about 40 are in Canadian territory and can be considered to be a potential mineral-bearing section. The valley is wide, with a flat, gravel-filled base, and in this distance has a gradient that would average less than 7 feet to the mile. Other than bridges no serious engineering difficulties are apparent. On the south side the two largest rivers, Craig and Kahtate, are confined to definite, well-established channels near their entrance to the main rivers and, therefore, should afford no unusual difficulties. The danger of snowslides resulting from the heavy accumulation of snow would not be serious, since in very few places would it be necessary to approach steep slopes subjected to such conditions. The valleys of Craig and Kahtate rivers, as well as several smaller streams, also offer favourable sites for roads or railways.

WATER CONDITIONS ON ISKUT RIVER

Water conditions on the Stikine[1] and in general on Coast Range streams have already been described. The Iskut differs from the Stikine mainly in having a more limited and less varied drainage basin, drawing all its water supply essentially from one continuous mountain belt rather than from three distinct physiographic provinces.

During the winter Iskut river shrinks very appreciably because a large part of its water supply is derived from glaciers. It is, however, subject to

[1] Geol. Surv., Canada, Sum. Rept. 1928, pt. A.

fluctuations, particularly in the late autumn and early spring, due to rain falling at the head of some of the tributaries which rise well to the west and are influenced by the coastal climatic conditions. Because of this and its swiftness the ice may go out somewhat earlier than it does on the Stikine. Navigation season probably opens about the middle of May, though in some years it might be possible to use small boats a month or more earlier. During May and June the river shows a general tendency to rise, but with great and sometimes very rapid fluctuations. High water on the Iskut is believed to come late in June or early July, probably somewhat later than on the Stikine. During the subsidence period daily fluctuations are notable. Rain and hot weather rapidly influence practically all tributaries. In September, cold clear weather causes marked daily fluctuations but sustains a moderate level; cold, cloudy weather causes a very rapid shrinkage, whereas rain storms are responsible for short but not well maintained increases in water supply. The river is liable to run slush ice any time after the first of November, but complete freeze-up is probably much later because of the many stretches of swift water.

North of Iskut river all the large tributary streams are fed mainly by great glaciers and are subject to the usual fluctuations of such streams. Kahtate river is fed largely by the runoff from melting snow and rainfall and to a smaller extent by melting ice. It probably has a relatively rapid rise in the spring, reaching high water late in June, followed by a general fall with rapid fluctuation due either to hot weather or rain storms. Somewhat similar conditions probably apply to Inhini river and to Craig River system. The latter, however, derives from Jekill river and some other tributaries a relatively larger supply of water from melting ice. Mild rains toward the coast during snowfall farther east have a marked effect on the Craig and the Kahtate. Practically all the streams on the south side depend on glaciers for water supply to an extent sufficient to show considerable daily fluctuations, especially in hot weather. They reach the lowest stage early in the morning and rise during the day to the maximum stage at about sunset, a factor of importance to travellers since many streams which are easily forded in the morning are impassable in the evening. Similarly on navigable streams the rapid fluctuations due to weather or daily temperature changes are sufficient to warrant careful observation.

GENERAL GEOLOGY

The geology of Iskut River area is very similar to that of Stikine River area and the general description of formations and relationships as previously given[1] applies sufficiently well, so that much data given there will not be further discussed here.

The rocks of Iskut River area are divided for descriptive purposes into two main groups, the intrusives and non-intrusives. The latter group includes a smaller number of formations than are present on the Stikine: a Pre-Permian series mainly of non-calcareous metamorphosed sediments, Permian limestone, Mesozoic, probably entirely Triassic, volcanics, and Pleistocene to Recent flows. The Coast Range batholith here presents much the same heterogeneity of character as it does on the Stikine.

[1]Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1928, pt. A.

The batholith assumed a very irregular shape, so that throughout the area there is a considerable intermingling of intrusives and non-intrusives. At no place in areas of the latter are the former thought to be far below the surface and in many places, especially near the bases of the deeper valleys, there are numerous small masses of the intrusive. The structure is extremely complex; intense unsystematic folding and faulting are present everywhere so that the boundaries between formations are not well defined and can be indicated only in a very general way. Intense metamorphism in most sections has further complicated the geology and made the differentiation of the formations more difficult.

NON-INTRUSIVES

Pre-Permian

The Pre-Permian rocks of Iskut river are in general like those of the Stikine, being mainly well-bedded quartzites, slates, argillites, and schists. In the vicinity of the Stikine-Iskut Rivers junction, limestone or altered limestone and calcareous beds were noted at a number of horizons, but toward the southeast the quantity appears to decrease considerably. These rocks occur through the map-area, generally in small, irregularly shaped masses. They are most abundant near the contact of the batholith and are here dominant among the non-intrusives. Northeastward there is a general decrease in these Pre-Permian sediments, but in the lower parts of the deep valleys, which are mainly cut in non-intrusives, they retain their dominance for some distance farther east. Around the mouth of Iskut river and extending for some distance up its south side is one of the most extensive sections within the map-area. The valley of Craig river above the junction of Jekill river occupies another large area of these rocks. Between these two masses at the head of Inhini river there is believed to be still another fairly large area, but owing to the difficulty of reaching this part its boundaries have not been very well defined. In the valley of Jekill river, Craig river, and northward to Twin glacier, there is another extensive though very irregularly shaped mass of these materials. Smaller areas occur scattered throughout in no systematic manner. Owing to the complexity of structure they may be found as long, narrow bands or small, irregular masses anywhere in areas of later rocks in such attitudes that individual occurrences might very well be interpreted as lying within the younger series. In some places due to the erosion of recumbent folds or faulting they may occur definitely on top of and completely surrounded by younger materials. No extensive section of the Mesozoic volcanics can be considered to be entirely free of these older rocks without the most detailed investigation; likewise the reverse is true, that small masses of infolded or infaulted younger rocks may be expected almost anywhere in areas of Pre-Permian sediments. Consequently it has rarely been possible to assign large areas, and in many cases even small areas, with complete assurance of no admixture of formations, to one series. Further, it is equally impossible in many cases to determine whether small masses of volcanics or limestone occur interbedded with or infolded into the series.

All the Pre-Permian materials are intensely altered. Originally largely marine sediments, which were dominantly shale and sandstone of fine texture, they are now altered at least to slates, argillites, and quartzites. Imposed on this is more intense alteration which has produced a variety of changes, and of degrees of change. The most intense metamorphism is as a rule found in small masses included in some of the darker intrusive phases or lying along their edges. In these positions complete gradations from altered but unmistakable sediments to typical igneous rocks can be observed. Less intense but more widespread metamorphism occurs throughout a large part of the area near the junction of the Iskut with the Stikine, on upper Craig river, and, less extensively, in many other places from Johnny mountain (northeast of the junction of Craig and Jekill rivers) to Choquette mountain (northeast of the mouth of Iskut river). In some places the altered sediments are in direct contact with intrusives and in others no intrusive body is known to be nearby. These highly metamorphosed rocks include a great variety of schists and gneisses mostly of varying shades of grey. Dark brown to black mica and quartz are the dominant minerals. White mica occurs in a few localities. Garnet, staurolite, and other minerals of this type occur in the schists and slates. The gneisses, which are on the whole rare compared with the schists, contain quartz, feldspar, and mica in varying proportions. Chlorite schists occur, some of which undoubtedly belong to the series, but rarely is it possible to ascertain whether they do, or whether they are altered dykes, sills, or other extraneous material. The calcareous beds are, in many places, entirely silicified or altered to wollastonite, epidote, garnet, and similar minerals. Other types of contact and hydrothermal metamorphism are present, making on the whole a great variety of materials.

No fossils have been found in these rocks and because of their highly altered condition it is unlikely that they hold any. They are overlain by a white limestone which carries fossils determined to be either Carboniferous or Permian. Both the limestone formation and the underlying metamorphosed assemblage have been correlated on lithological and structural evidence with formations farther north where the limestone has been definitely fixed as of Permian age and the upper part of the underlying series as Carboniferous. No lower age limit has been fixed for these Pre-Permian sediments since no fossils have yet been found in the older sections.

The structure, as previously stated, is very complex. In many places the strike and dip have been found to be fairly uniform over small areas, but from evidence gathered it seems logical to conclude that in practically all such places the strata are isoclinally folded or at least lie in a series of many small, close folds. The most common structural trend is northwest, with dips northeasterly, but there is every possible variation from this. Notably the trends throughout the upper Craig River Valley section are northeast, parallel to the river—with most of the dips northwest. The structures are in some places so complex that even with a white limestone member between dark overlying and underlying rocks, and almost complete mountain sections, no reasonable interpretation could be conceived. Great recumbent folds with an overturn of several miles are believed to occur and many such of less size have been observed. These are not simple and in places are represented by tongue-like protrusions of one formation down or up into another. Faults, of course, are numerous, but because of the nature of the folding it is rarely possible to distinguish between major and minor breaks.

Permian

Since the Permian limestone is the top of the Palæozoic rocks, which are separated from the Mesozoic by a pronounced unconformity, it is in many localities cut down to a relatively narrow band or is entirely absent. In other places where its maximum thickness is attained, because of isoclinal folding and conformity of the slope to the attitude of the formation a very impressive showing is made.

The Permian formation occurs throughout the map-area. Along the south side of Iskut river below the junction of Craig river there is a very extensive display of this material, marred only by a few small outliers of the overlying Mesozoic volcanics. The exposures extend from the base of the valley to peaks nearly 6,000 feet above. Down the slopes course streams and glaciers which have cut several hundred feet into the mountain mass, creating the impression that the whole might very well be limestone. Such, however, is a very false impression. At the western limit the thickness of the limestone is as low as 20 feet and at the eastern limit it pinches out entirely. Though the thickness undoubtedly is greatly increased between these two points, possibly to as much as 1,000 feet, the effect is largely the result of the fact that the slope corresponds to the south limb of a syncline made up of a continuous series of close, minor folds. Other than this the limestone is confined to narrow bands 1,000 to 5,000 feet in width and to relatively small, irregular masses. These occur in all sections of the map-area and tiny masses, in areas of other rocks, may be expected to occur almost anywhere except well within the batholith.

The Permian limestone is easily recognized in most localities by its white or light grey colour, though in a few places it assumes a somewhat darker grey colour. In most cases it is well bedded, though extensive exposures of massive material have been observed. It is usually crystalline, in places coarsely so; elsewhere it assumes a marble texture. White, cherty material is abundant and in some places the whole series is silicified but still retains much the same general appearance. Other alteration products have been observed but are not extensive. Mineralization in this formation was noted at a number of localities.

The structure of the Permian is similar to that of the underlying sediments and because of its easy observability the distribution of the limestone has formed the most accurate basis for an interpretation of structure. Because of structural complexity many masses of the Permian limestone are peculiarly isolated in either the overlying or underlying formation and their identity is never without some doubt.

The age of this limestone has not been very accurately fixed by the fossil collections made. These have been sufficient only to place it in the

Carboniferous or Permian, but its exact similarity to the limestones found farther north, from which fairly good collections of fossils were obtained, fixes the age fairly definitely as Permian.

Triassic

In the previous reports the rocks of this group were designated Triassic, Jurassic, and Lower Cretaceous. It is believed that most of the rocks of this group within the map-area belong to the Triassic, though some may very well be younger. In general they resemble the rocks of the same age found farther north.

Throughout the greater part of the area south of Iskut river and west of Craig-Jekill valley, they occur mainly in relatively small masses infolded into the older formations or perched on top of them. Many of the peaks in the non-intrusive areas are capped by small masses of these materials. In the northern and eastern parts of the map-area they are much more abundant and form a nearly continuous fringe which is part of what appears to be an extensive area extending some distance north and east. There is, as already noted, a complex intermingling of the older formations with this and in addition there are present intrusives which so closely resemble the extrusive members of this series that the two groups could not be differentiated.

The Triassic rocks maintain a dominant green colour with some grey and rarely other shades and are essentially volcanics. The base of the series in many sections is an explosive breccia containing much angular material from the underlying formations as well as volcanic fragments. Elsewhere the base is marked by a series of bedded calcareous tuffs which seem more or less to grade into the limestone below. Most of the materials of the formation appear to be massive and dense, though under favourable weathering conditions much shows definite bedding and in some places is very well bedded. In the main the rocks appear to be tuffs and fine-grained breccias with minor quantities of flows. Interbedded sediments in most sections seem to be rare, though it is not always possible to determine that closely associated sediments definitely belong to the older series, as they generally appear to do. There are, as is the case farther north, many odd phases of breccias, agglomerates, and conglomerates.

Metamorphism of the volcanics is, in general, probably not as intense as that of the Palæozoic sediments, but all the strata are altered. The development of chlorite and similar minerals practically everywhere, which is chiefly responsible for the green colour, is by far the most evident feature of this change. In some places the volcanics have been altered to chlorite schists and it is believed that mica-quartz schists of the general type produced by the alteration of the Pre-Permian sediments have also resulted from the alteration of the volcanics, but because such schists occur in areas where Triassic and Pre-Permian are intricately intermixed, it has not been possible to establish definitely the age of the schists in question. A type of alteration which is very common in some sections is an apparently direct change from a rock of ordinary dense extrusive texture to one which has a medium-grained, granitic texture. The change in some cases seems to be the result of direct assimilation by an intrusive body or of assimilation of materials furnished by a nearby intrusive, but in other cases there is no evidence of any intruding mass in the immediate vicinity, though in all cases an intrusive is not very far distant. It is possible that the coarse texture may have been an original character produced in the rock as in a thick flow or sill, but in general the field relationships do not support this explanation as in some cases the rock so affected clearly is a bedded tuff. This type of alteration makes the classification of the affected rocks extremely difficult. Another type of alteration of the volcanics which is fairly extensive and of considerable importance will be discussed under economic geology, since it is the result of the action of mineralizing solutions. As a result of this mode of alteration the volcanics in many places are altered to a light grey material which has the aspect of altered limestone.

This volcanic series is correlated with a similar series farther north from which fossils of Triassic age have been collected. At the base of the series in one locality in the map-area fossils were observed, but were too badly distorted to allow of definite determination, though there was one specimen which might represent a species of Upper Triassic age. As previously stated, it is possible that rocks of younger age are included in this group, but nothing has been noted to support this contention and some evidence is forthcoming that tends to controvert it.

Though a pronounced unconformity occurs at the base of the Triassic, and the underlying series has undoubtedly undergone more deformation, both series have been so greatly deformed that the differences exhibited by them are insignificant. Everywhere the rocks of the Triassic are intensely folded and faulted in the same manner as the already described older series.

Pleistocene and Recent Lavas

North of the confluence of Craig and Iskut rivers there rises one of the most magnificant and interesting mountains in northern British Columbia: a volcano which probably began erupting in the late Pleistocene and which has continued intermittently to such recent times that it seems reasonable to expect that the volcano may still be active and capable of further eruptions. This mountain does not possess the extreme ruggedness of its neighbours, but retains the characteristic shape of volcanoes, rising for the greater part of its circumference with a gentle slope of 10 to 20 degrees to a relatively flat top of over 6,500 feet elevation. Except for minor digressions due to excessive erosion in certain sections the mountain in horizontal cross-section is practically a circle. Its slopes are characterized by a base of brilliant spruce and hemlock green with here and there bright yellow spots where slides or cliffs expose the underlying rock. Above this the east side rises with a gradual talus and flow slope, exhibiting variegated browns and yellows. The south side is marked across its middle by two great vertical cliffs, each several hundred feet in height and over which streams drop in magnificent falls. Above this is another fringe of green from which long, bright yellow and brown talus slopes rise toward the top. The west side has been subjected to abnormal erosion and presents an irregular series of vertical cliffs, of which the lowest are as much as 700 feet in height. Here and there above these cliffs are strips of green or long, bright yellow or brown talus slopes. Occasional needle-like pyramids up to 500 feet in height stand out, and higher up and on all sides other similar monuments and many odd forms—hoodoos from which the mountain gains its name—give it a weird appearance. The old crater is filled with ice and from this blue-white top irregular tongues protrude on all sides to supply a multitude of streams which on the west, by a series of beautiful vertical falls and cascades, reach the glacier below. Erupted in the centre of an old valley, mount Hoodoo has dammed the two main tributaries of the old drainage system and created two ice lakes from which magnificent glaciers extend and circle its base.

The mountain is made up largely of lava flows. On the west side, where the exposures are best, it is found that the basal part consists of several very thick flows of dark grey, to green, to black, dense material which exhibits considerable uniformity. The flows emanating from above 3,500 feet are much thinner and differ from the older series in the presence of phenocrysts up to one inch long of glassy feldspar. Breccia is associated with some of them: much of it is undoubtedly flow breccia but some may be the result of the consolidation of interflow talus. The most recent flows, which were limited to the top, are of somewhat different type. They contain the phenocrysts and may still be of much the same composition, but, probably because of greater vesicularity and an *aa* character, are now mainly loosely consolidated and badly weathered broken fragments which contribute to the great talus slopes. The needle-like monuments are stocks or dykes of the same material as the flows, but are more resistant to weathering. They are for the most part fine grained and light grey. Other monumental forms are the result of irregular weathering of lavas, especially the *aa* material. Dykes extend beyond the mountain and were observed most abundantly in the valley to the west.

Interbedded with the lava flows exposed in the valley to the west, which are the oldest, and with those in the valley to the east, which are among the youngest, are consolidated drift, delta deposits, pisolitic mud, and possibly other ejectamenta. For the most part these are not of great extent or thickness, but in the valley to the west the delta deposits, together with drift, show up in a bank about 200 feet high and extend up the valley in places to an elevation of 1,200 feet in considerable thickness.

The age of these lavas is not definitely known. There is considerable evidence to support the belief that the first eruptions took place when the area was well covered with ice, possibly during late Pleistocene. What is thought to be the last eruption appears to occupy in part a well-developed gully on the side of the mountain. This would tend to suggest that the period between the development of the second to last and the last flow (during which the gully was developed) was greater than that since the last (during which the flow occupying the gully was not removed by erosion). Many thin flows on the east side are very slightly cut into by the streams that flow from the glacier on top. It would seem that much evidence bespeaks a very recent age for the youngest eruptions.

In the western part of the map-area a considerable extent of Iskut valley is covered with lava flows similar in appearance to those on Hoodoo mountain which bear the phenocrysts of glassy feldspar. They constitute the western limit of a series that has blocked Iskut valley and is now cut into by the canyon. Interbedded with the flows are river gravels and pisolitic mud. The lithologic similarity of all these materials to those at Hoodoo mountain suggests contemporaneity.

Intrusives

Intrusives are continuous along the west and south side of the map-area, representing the eastern limit of the Coast Range batholith. From this continuous strip long, narrow protusions extend northeast practically across the area, and throughout the section of non-intrusives there are many small satellites.

The batholith and its associates here assume much the same aspects as they do farther north along the Stikine, except that some of the phases present there were not observed and one phase was noted in this section for the first time. This phase, which is a porphyry occurring in a number of small masses, was observed in the area between upper Craig river and the Iskut, and for 6 miles to the east. Most of these masses are believed to be closely related, though they show marked difference in appearance. They are generally to be recognized by the presence of phenocrysts of feldspar of various sizes from a length of ½ inch to 2 inches. These vary in colour from a fairly light grey to pink, purple, and green, probably depending on extent and nature of alteration. In some localities they occur in parallel layers and appear to constitute most of the rock; in others they are scattered through in varying quantities from very abundant to extremely rare, and probably in places are entirely absent. The matrix of the rock likewise varies greatly from a coarse-grained granitic to a dense green texture. To add to these difficulties of identification, in most places the porphyry is considerably intermixed with the intruded material, which it has greatly altered. Generally the porphyry and the associated intruded rock are considerably impregnated with and cut by stringers of pyrite, and in some cases other sulphides.

The previous description[1] of the batholith south of Patmore creek applies fairly well for the rest of the intrusives here: the fairly uniform phase found there in the central part of the mass continues south in much the same relative position and to the east of this is the discontinuous fringe of heterogeneous materials. The satellites here show the diversity of character that was noted farther north.

ECONOMIC GEOLOGY

The general information relative to the eastern contact zone of the Coast Range batholith as given for Stikine River area applies to the section dealt with in this report. It had always been considered probable that in the area south of Iskut river the eastern contact of the batholith passed at

[1]Op. cit.

some distance to the east of the International Boundary. However, it has been found that the contact is farther west and except for the irregular protusions to the northeast it follows the International Boundary very closely. So far as the mineral potentialities of British Columbia are concerned it could not have been much more favourably located. The valleys, notably of Iskut and Craig rivers (in both cases from the International Boundary east), which are the most accessible parts of the area, are located almost entirely in non-intrusive materials, whereas the more inaccessible mountainous sections, on either side of these, are cut by long protrusions or satellites of the batholith. There is practically no part of the extensive areas of non-intrusive materials that is more than a few miles from a contact and further it seems logical to conclude that all of these areas are underlain by the batholith at no very great depth. It follows then that all the non-intrusive rocks of the area have been in a position favourable to receive mineral deposits.

Since certain Coast Range intrusions have been greater mineralizing agents than others it is of importance to consider the evidences of mineralization associated with the phases here represented. Extensive rock alteration and impregnation by pyrite and other sulphides are found abundantly throughout the area. Other than the showings in the vicinity of Bronson creek, and near the Custom house, and a few other reported discoveries, no definite data were previously available to indicate much about mineral deposits. However, during the summer of 1929, much definite evidence of their presence was observed in a large number of localities. Stringers, largely of tetrahedrite, and some chalcopyrite mineralization, were noted on Kahtate river. On the lower Iskut there were observed a zone of tetrahedrite, chalcopyrite, galena, and sphalerite carrying fair silver values, and, on the opposite side of the river several miles away, a chalcopyrite quartz vein which also showed a small silver content. On Elbow mountain a deposit of magnetite was prospected last summer and a pyrite impregnated zone was opened up and sampled. The assay return of the latter is reported to show insignificant gold values. Twin Glacier moraines showed considerable float of chalcopyrite, galena, and pyrite and several miles to the southwest further float of a similar nature was observed, probably from a different source. In the last locality small veins completely altered to gossan were also found. On Craig river massive, coarsely crystalline galena, and galena and chalcopyrite replacing limestone, were noted. The glacier at the head of Bronson creek carries considerable quantities of float containing pyrite, sphalerite, and galena. Chalcopyrite-calcite veins cut the mountain west of this. The deposits covered by the staked ground on Bronson creek, and north of the river at a point about 2 miles farther west, will be described later. In this general vicinity other similar deposits were observed and a few miles up river chalcopyrite stringers occur with much the same associated materials. In many localities malachite stain was noted. Practically all bodies of porphyry are highly impregnated with and cut by stringers of pyrite. In one mass nearly all casually broken specimens showed malachite stain which is thought to be due to the weathering mainly of chalcopyrite, though some may come from tetrahedrite; other sulphides are also present in smaller amounts. The porphyry seems to have been associated with more mineralization than any other phase. It was not apparent that any of the exposures observed indicate deposits of economic value, though most of them are at least as good as the average staked showing in other districts. The indications of mineralization are widespread and in practically every section a mineral deposit of some sort was noted. Such results obtained in a hasty reconnaissance geological survey would seem to indicate extensive mineralization, and it is reasonable to suppose that in some places there are deposits of economic value.

Only one group of claims, on Bronson creek, is known to have been in good standing at the beginning of 1929 and except in the vicinity of these and near the Custom house no evidence of prospecting was observed, though a few other discoveries have been reported and other groups staked.[1] The total prospecting done during the summer of 1929 was very little. One party of three spent about one month in the vicinity of Bronson creek and a little prospecting was done on Elbow and Glacier mountains. During 1928 there was only slightly more activity than in 1929, and so far as could be learned not a great deal of prospecting was ever done in this section. Annually since about 1907 the Iskut Mining Company or its predecessors have done work on their property on Bronson creek, which seems to have constituted the chief activity within the map-area.

The property of the Iskut Mining Company on Bronson (Quartz) creek has already been described by George A. Clothier[2] and brief mention of it has been made in several previous reports. Unfortunately at the time of visit there was no one acquainted with the property available to act as guide, and as most of the trails either followed streams or were largely grown over it was not possible to locate all the prospect pits, though much time was spent in trying to do so. However, a large number of prospects were observed and sufficient information was gained to obtain a general idea of the nature of the deposits. It is believed that interest in the showings here began in 1906 or even earlier. In 1909 a ton of ore (picked?) was sent to the smelter, which has been reported[3] to have yielded $44.11. Clothier reports[4] that a ton of chalcopyrite ore was sorted from one cut and yielded $1.20 in gold, 44·2 ounces silver, and 12·45 per cent in copper. It is not known whether or not these were separate shipments. Nothing that was observed seemed comparable with this, though small quantities were noted that might very well show as high values. It is possible that the cut or cuts from which the shipment (or shipments) came was not found.

During 1929 a large number of claims were staked on behalf of the Consolidated Mining and Smelting Company in a belt practically surrounding those of the Iskut Mining Company. Since many of the claim posts and claim lines could not be established it was impossible to determine the limits of the property held by the individual companies. The area will, therefore, be treated as a whole.

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[1]*See* Ann. Repts., Minister of Mines, B.C., 1907-28.
[2]Ann. Rept., Minister of Mines, B.C., 1917 and 1919.
[3]Ann. Rept., Minister of Mines, B.C., 1911.
[4]Ann. Rept., Minister of Mines, B.C., 1919.

The surface of the spur of Johnny mountain between Craig river and Bronson creek represents approximately the contact between the Mesozoic volcanics and Palæozoic sediments, including the Permian limestone. The valley of Bronson creek lies in a syncline and the spur of Johnny mountain in an anticline. Owing to rather complicated structure minor folds are abundant and the formations are, therefore, rather badly mixed. The high peak of Johnny mountain is essentially of Mesozoic volcanics, as are also the cap of the spur, part of its west side, and the lower part of its east side. The underlying sediments are mainly the older pre-Permian argillites, slates, quartzites, and schists, but there may be occasional small masses between these and the volcanics which are discontinuous remnants of highly altered Permian limestone. On the east side of the forepart of the spur there outcrops a small intrusion of feldspar porphyry. Extensive alteration of all these materials, together with the introduction of new materials by mineralizing solutions, has created an unusual heterogeneity. Mineralization occurs in two different loci: on or near the top of the spur are many small mineralized masses lying between the volcanics and the non-calcareous sediments; the whole eastern slope of the spur for a length of over 2 miles and a width averaging about 2,000 feet is more or less mineralized. The materials involved are mainly the volcanics and porphyry, though some limestone and non-calcareous sediments may also be included.

On the crest of the ridge at practically every point where the contact between the volcanics and sediments was observed mineralization was noted. It would seem that this was the path for the circulation of the mineralizing solutions. The mineral deposits occurring in this locus were found to vary greatly in thickness. The maximum noted probably did not exceed 10 feet and in many places was much less. The nature of the deposits suggests that they are replacing either a thin bed of limestone which was probably of variable thickness and not continuous or varying thicknesses of the base of the volcanics.

A large number of pits and open-cuts have been made. They exhibit a peculiar variety of mineral content; in places arsenopyrite, or pyrite or pyrrhotite, predominates, with almost complete absence of the other two sulphides. Other sulphides, including chalcopyrite, sphalerite, and galena, occur in most places, but with a few exceptions noted are not abundant. Gold and silver values for the most part are believed to be low. The mineralization appears to be confined to the spur of Johnny mountain and so far as this group of deposits is concerned seems to become less intense toward the south. None was observed at the contact at the base of the peak a short distance farther south. Probably the whole area of volcanics on top of the spur is underlain by a fairly flat-lying mineral deposit of which the exposures in cuts and pits are representative. Prospecting could be carried out easily by tracing the contact between the volcanics and the sediments. So far nothing of prospective economic value seems to be indicated. It would seem possible that erosion of the crests of minor anticlines on either side of the volcanic masses still remaining may have carried away the best part of this deposit.

The large mineralized area on the east side of the spur of Johnny mountain does not exhibit the same systematic stratigraphic limitation as is evident on top. The mineralizing solutions appear to have affected all the rocks present with the possible exception of the older non-calcareous sediments. This difference may have been due to greater proximity to the source of the solutions and consequently their greater abundance, or to a somewhat different character of solutions.

The slope of the spur is largely volcanics for several hundred feet above the base. Higher up for some distance non-intrusive rock consists of a shell and infolded masses of volcanics, possibly some limestone, and Pre-Permian sediments which, though probably extensive not far below the surface, are displayed only in limited exposures. Into these rocks is intruded the small mass of porphyry and it is in the vicinity of this and in this general zone that the mineralization occurs. Approximately between 2,500 and 3,000 feet in elevation is a band of Pre-Permian sediments, which separates the mineralized area of the top of the spur previously described from that on the slope. At the time of mineralization volcanics were undoubtedly continuous from the top to the bottom of the slope, but, since this band of sediments represents the position of a minor anticline, the overlying volcanics, together with the part of the mineralized zone that originally occurred here, were removed by erosion. The large slope deposit represents the central part of the original deposit, whereas that on top of the spur was toward the outer limits. This difference in position probably influenced the circulation of the mineralizing solutions and may have been the sole cause of the general differences to be observed between the two deposits or groups of deposits.

In the slope mineralized area, chiefly the upper part, there is a considerable extent of light grey sheared material, mainly carbonates, quartz, and white mica (sericite), impregnated with pyrite and other sulphides, which weathers rusty brown and yellow. For the most part this is believed to be highly altered volcanics, though it has more the appearance of altered limestone and some may be remnants of the Permian limestone. At a number of points the gradation from the green volcanics, unaltered by the mineralizing solutions, to the completely altered material could be observed. This, however, is not sufficient to establish definitely that the new product was originally volcanic material, since here it is in all cases the basal part of this series that was altered and this in many localities has been observed to grade in a somewhat similar manner to limestone. However, from other observations it has been definitely established that at least a large part of the altered rock was originally volcanics. How much, if any, was limestone it would be extremely difficult to determine.

Associated with the light grey material and below most of it on the slope is the porphyry mass. The part exposed appears to approximate the original roof. It exhibits a great variety of materials, from that which has large purple and grey phenocrysts of feldspar in a medium-grained granitic ground mass to a dense green material with few phenocrysts, to that which has none and greatly resembles the volcanics; in fact, it is doubtful that the two can be distinguished in the field on lithological evidence alone. There are many dykes and small masses of this last type of material, which may in part be later than the main porphyry intrusion. Within the area of the intrusive there are numerous inclusions of the different non-intrusive materials found here, which are variously altered. Impregnations of pyrite and other sulphides are found in most of the rocks of the intrusive area. Along a creek section of over 500 feet practically every sample broken showed malachite stain believed to be the result of the weathering of chalcopyrite and possibly tetrahedrite.

Near the intrusive in many places are masses of material which are essentially quartz, and stringers of this mineral are in many places very abundant. Whether the quartz rock was the result mainly of the presence of veins or of silicification was not definitely established. Much of this quartz, which is mainly glassy in appearance, is barren.

In general, mineralization occurs throughout the exposed part of the intrusive mass and the adjacent rocks, being confined here largely to the altered zone at the base of the series of volcanics which may include some limestone. Mineralization is in the main in the form of disseminated sulphides, with pyrite by far the most abundant and including arsenopyrite, pyrrhotite, chalcopyrite, galena, sphalerite, tetrahedrite, molybdenite, with possibly others, and some oxides such as hematite and magnetite. In the altered volcanics massive pyrite occurs locally in parallel streaks. In general, the most highly mineralized rock shows a similar banding which is believed to parallel the shearing. Mineralization is mainly by replacement. Many open-cuts have been made in this general area, but the values are on the whole said to be fairly low. The mineralized area, however, is extensive and there may be a large body of this low-grade material. So far as is known no attempt has yet been made to test the zone as a whole. Under present conditions this aspect does not offer very much encouragement.

Besides the general widespread mineralization there are local concentrations of the various sulphides. Operators in the past have had encouragement in the location of such concentrations and probably the relatively rich ore shipped out came from one of these. The enriched sections appear to be in part replacement deposits and in part fracture filling. So far as present work reveals these zones appear as small, discontinuous pockets of iregular shape. Nothing of a very definite nature has been observed which would suggest possible controlling factors, except as already indicated that the contact of the volcanics probably exerted considerable influence. A more detailed study of these materials than it has as yet been possible to make may throw some light on this subject, but it would seem that more careful prospecting in conjunction with the known geological data will be necessary. There is no doubt that a large part of the original mineralized zone has been carried away by erosion and it seems very probable that a part at least of the most valuable concentrations was included in this. However, there are still some remnants and though these conditions may prevail in the immediate vicinity of the intrusive there is ample evidence that the mineralization extends beyond and other concentrations not deeply eroded may well occur.

On the slope of the hill below the mineralized zone, especially in stream gullies, there is much breccia or conglomerate. This consists of materials from the slope above cemented by limonite, iron oxide, into a coherent material which in places resembles the underlying bedrock. As a rule it is not more than a few feet thick. It is very significant of the tremendous amount of iron dissolved from the mineralized rock higher up the slope.

On the east side of the peak of Johnny mountain beyond the staked areas, and north of Iskut river about 2 miles west of Bronson creek, are extensive areas of light grey, highly mineralized materials, probably altered volcanics, very similar to those that constitute the upper part of the slope-zone on the spur of Johnny mountain. So far as was observed the mineralization was mainly pyrite and the material was likely to have a value too low to be of any economic importance. The Johnny Mountain mass may have been prospected, but that to the north probably has been studied little, though it was partly staked in 1929 for the Consolidated Mining and Smelting Company. These and other similar zones in this section, as well as throughout the area, may carry richer concentrations within their limits or closely associated, as is the case on the property of the Iskut Mining Company. They are at least valuable indicators of the loci of extensive mineralization and warrant very careful prospecting.

CONCLUSIONS

The map-area is ideally situated so far as mineral potentialities are concerned; in fact it would be difficult to picture a more suitable distribution of intrusive and non-intrusive materials. Geological conditions are favourable for the occurrence of mineralization and there is ample evidence in practically every section of the area of mineralization capable of developing deposits of economic value. Although much of this has been dissipated in small, scattered masses it seems reasonable to expect that in some places concentration has been such as to develop deposits of sufficient size to be of economic worth.

Conditions for study of the rocks of the area are very favourable, though so far very little prospecting has been done. Records seem to indicate that what little work was accomplished was confined largely to the area embraced by the Iskut Mining Company's claims, and the immediate vicinity. The discovery of mineral showings at least sufficient to afford a working basis for further prospecting does not appear to be difficult.

Immediately beyond the map-area to the north, except in the most easterly part and in Stikine River map-area, there is little favourable ground for prospecting, since most of this section constitutes part of a great permanent ice-field. Just to the east, however, there are many hundreds of square miles of very favourable territory which is practically untouched except for a little placer mining. Under present conditions this area is not readily accessible, but the construction of trails or roads from the lower end of the canyon on the Iskut would probably not be difficult and the use of pack horses on these would place an additional extensive area within two or three days travel of Wrangell. The eastern part of this favourable area can be reached by the telegraph trail (from Telegraph Creek, Stewart, or Hazelton) by pack train, but the time involved is many times greater. With the location of adequate landing sites in this area the eastern part would probably be reached readily and with fair safety, both as to flying conditions and emergency landing places, from Stewart. This whole section certainly warrants being opened up and prospected.

To the southeast of the map-area lies Unuk River district which has already proved itself to be favourable for prospecting in that a number of discoveries, some of which yielded high values, have been reported from there. This section is accessible most readily from the coast by Unuk river. Little work has been done there in recent years, but the area undoubtedly warrants more attention than it has received.

OWEN LAKE MINING CAMP, BRITISH COLUMBIA

By A. H. Lang

CONTENTS

Illustrations

INTRODUCTION

Owen Lake mine, situated south of Bulkley River valley in central British Columbia, is a silver-copper property. It lies in a transitional zone between the Coast range and the Nechako plateau, within the general mineral province constituting the eastern contact zone of the Coast Range batholith; but the mineralization is associated with small stocks instead of with the batholith itself. The camp has been active since 1928, particular interest being aroused in 1929 when Noah A. Timmins optioned the control of the Owen Lake Mining and Development Company. This option was dropped in the spring of 1930, but Mr. Timmins still retains a one-fifth interest in the company. To date there has been no production, with the exception of two cars of ore shipped in 1915; recent operations consisting entirely of development work. Since silver is the camp's most important metal, its price must have a direct bearing on the future of the district.

Owen Lake map-area includes about 100 square miles of semi-mountainous country, situated 28 miles south of Houston, a village on the CanadianNational railway, 270 miles east of Prince Rupert and 40 miles east of Smithers. The location of the area is shown on the accompanying index map (Figure 2), the camp is reached from Houston by means of an excellent road up Morice river and Owen creek, a distance of 34 miles. In 1928 and 1929 freight was carried on a scow up François lake to Nadina River post office, or in winter by tractor and sleighs on a sleigh road constructed for the purpose from Houston to the mine. Trucks are now used on the Morice River route.

This report is based on field work done during the summer of 1929. In 1928 Mr. F. C. Swannell completed a triangulation of the Morice River watershed for the British Columbia Department of Lands. Mount Nadina was his only station within Owen Lake map-area. The writer made an independent triangulation with a tie to mount Nadina for latitude, longitude, and elevation; and mapped an area of approximately 8 by 12 miles.

It is a pleasure to take this opportunity of thanking the officials of the Owen Lake Mining and Development Company, and the residents of the district for their ready co-operation, and for many courtesies extended to the party in the field. Prof. J. M. Turnbull, Consulting Engineer, kindly furnished information on development work after the close of the field season.

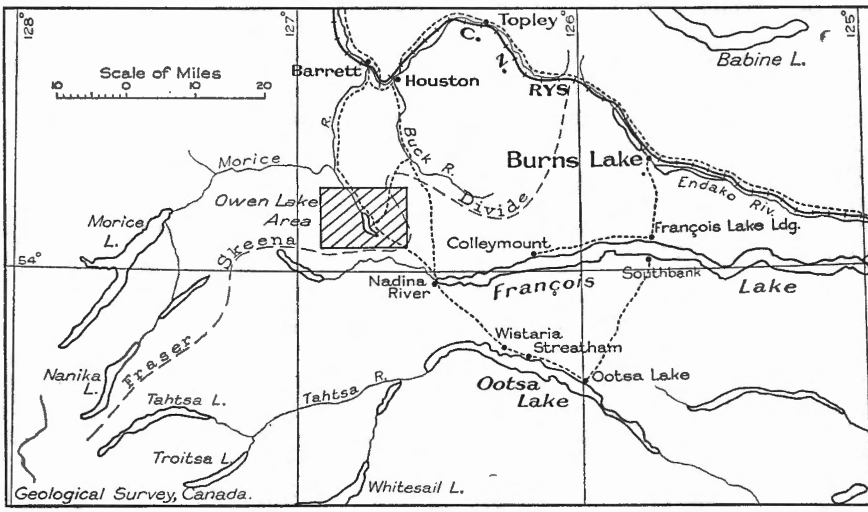

Figure 2. Index map showing location of Owen Lake area, Coast district, B.C.

The faculty of geology at Princeton University have been most generous in supplying assistance and laboratory facilities. The writer is under the deepest obligation to Professors Edward Sampson, A. F. Buddington, A. H. Phillips, and Paul MacClintock, who have given freely of their time and advice. He wishes to express his appreciation to Dr. M. N. Short, of Washington, D.C., who identified the mineral alaskaite; and to Mr. J. E. Umbach, Surveyor General for British Columbia, who furnished the geographical position of mount Nadina.

The field work was done under the supervision of Mr. George Hanson, to whom the writer is indebted for assistance and advice. Mr. W. A. Bell identified the fossil plants.

W. K. Dobson and R. P. Mason acted as field assistants, rendering efficient service at all times.

PREVIOUS WORK

In 1876 Dr. G. M. Dawson made a geological reconnaissance in the vicinity of Nechako river and François lake. He ascended Nadina river for about 3 miles, being thus very close to the southern boundary of the present map-area. Dawson commented on the striking appearance of mount Nadina, which he called "Na-di-na."[1]

[1]Geol. Surv., Canada, Rept. of Prog. 1876-77, p. 49.

In 1916 J. D. Galloway made a reconnaissance from Houston via Eutsuk lake to the Chilcotin country, with a side trip to Owen lake. His observations on the geology of the camp, which at that time had just begun to attract the attention of prospectors, are recorded in the Annual Report of the Minister of Mines for 1916.

LOCAL TOPOGRAPHY

The transitional belt between Nechako plateau and the Coast Range includes Owen Lake area. It is characterized by lateral ranges of inferior elevation to the main Coast range, extending eastward into the plateau.

Owen Lake area is divisible into three main topographic sections: Owen valley which traverses the centre of the area, and two semi-mountainous regions on either side of this valley. Each of these higher sections includes a prominent topographic feature; the western section contains mount Nadina, and the eastern one contains Te-kai-zi-yis ridge. Mount Nadina, the highest point in the area, has an elevation of 7,065 feet; the lowest point is about 2,300 feet in elevation, giving a maximum relief of approximately 4,750 feet.

Owen Valley

This valley trends northwesterly and forms a pass connecting the master valleys of Morice river to the north and Nadina river and François lake to the south. It represents a late Tertiary valley, subsequently glaciated and partly filled with fluvioglacial material. Owen Lake area includes about 10 miles of this valley which is here about $1\frac{1}{2}$ miles wide, with its bottom varying from about 2,500 feet above sea-level at the southern end of the area, to 2,300 feet at the northern end.

The highest point of the valley, at an elevation of approximately 2,600 feet, is just south of the area, so that the part of the valley under discussion drains northward to Morice river. From this watershed to the head of Owen lake the valley slopes gently to the north for 2 miles, being occupied by As-lik-kwa creek and a great deal of muskeg. On either side of this creek are low, rounded hills, composed of drift.

Owen lake is $4\frac{1}{2}$ miles long, averages $\frac{1}{3}$ mile in width, and is roughly crescent-shaped. Its elevation is 2,489 feet above sea-level; in the centre its depth varies from 100 to 120 feet. Most of the creeks entering the lake have formed small deltas. On the western side Taylor ridge slopes gradually to the lake, but on the eastern side there is a large terrace of imperfectly stratified fluvioglacial material, upon which the mine camp is situated. The surface of this terrace, averaging 2,650 feet in elevation, is slightly undulating, with a steep slope toward the lake. Its widest portion, opposite the bend in Owen lake, is two-thirds of a mile broad. On the hill between the two arms at the southern end of the lake there is a small terrace at the same elevation as the main one.

From the exit of Owen lake the valley extends northwestward for 8 miles to Morice River valley. It is occupied by Owen creek, which has an approximate fall of 50 feet a mile.

Numerous lateral valleys join the main one, the largest being those of Redick and Puport creeks.

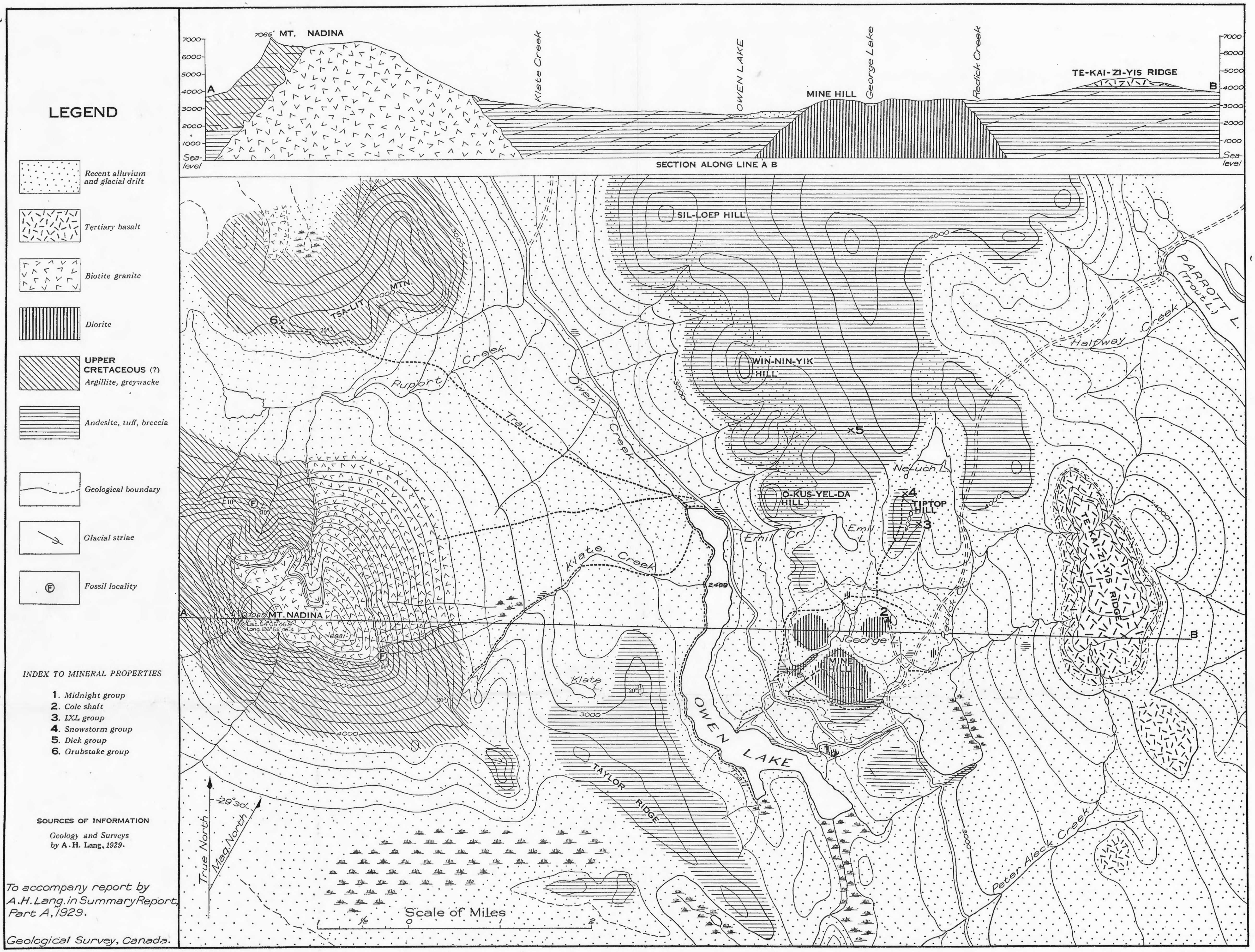

Figure 3. Owen Lake area, range 5, Coast district, B.C.

Western Section

Mount Nadina (*See* Plate I A), is one of the most prominent landmarks in the whole district, being visible from great distances. It is only 7,065 feet in elevation, but is isolated and well above the level of the surrounding country, from which it rises as a monadnock. It owes its position to the fact that it has a core of granite which has indurated the sedimentary rocks forming the remainder of the mountain. It is, therefore, an example of differential erosion on a large scale. The flanks of the mountain are steep or even precipitous, being in marked topographic unconformity with the flat, glaciated top. Two cirques have been cut into the northern flank by more recent alpine glaciation.

A ridge 4,000 feet in height extends for about a mile from the south-eastern corner of mount Nadina. A depression separates this ridge from Taylor ridge, which flanks the western shore of Owen lake. Taylor ridge averages 3,200 feet in elevation, with a slope toward Owen lake of 800 feet a mile.

Tsa-lit mountain, situated in the northwestern corner of the area, is a bold mountain with an elevation of 4,300 feet. Its eastern flank, facing Owen valley, is very precipitous, but the northwestern side slopes gently to a swampy upland about 3,600 feet in height.

Between mount Nadina and Tsa-lit mountain a hanging valley one mile wide is occupied by Tsa-lit-pn lake and the upper reaches of Puport creek. This is an old cirque about 1,200 feet above the present bottom of Owen valley. The presence of the lake may be due in part to a rock basin at the bottom of the cirque, but is more largely due to damming by morainal material from the two more recent cirques on the north side of mount Nadina. Puport creek has cut a canyon about 50 feet deep through this material.

Eastern Section

This section is less rugged than the western half of the area, being characterized by rounded hills and lava-capped buttes. The main upland of this section forms part of a dissected, lava-capped ridge some 4,500 feet in elevation, as shown in Plate I B. This ridge extends along the northern shore of François lake, separates Owen valley from that of Parrott lake, and continues northward, rising in elvation, to form Morice mountain, lying just outside the area.

The eastern tributaries of Owen lake and Owen creek have dissected this upland into a series of rounded hills. These flank the eastern side of Owen valley, and are from 3,300 to 4,000 feet in elevation. In the northern part of the section these hills slope steeply toward Owen creek, with an average relief of 1,500 feet, but their eastern slopes drop only 200 or 300 feet before reaching the general upland surface. In the vicinity of the camp, Mine hill rises some 500 feet above the level of the terrace, its eastern and southern slopes descending gently to a rolling, grass-covered upland about 3,000 feet above sea-level. East of Redick creek this surface rises more steeply to the base of the lava-capped butte which surmounts Te-kai-zi-yis ridge. This butte is nearly 2 miles long, from $\frac{1}{4}$ to $\frac{1}{2}$

mile wide, and its flat top is 4,600 feet in elevation. Its walls are steep, the last few hundred feet being practically vertical and embayed by small cirques. The eastern side of the ridge slopes fairly steeply to the valley of Parrott (Trout) lake, which is 2,700 feet above sea-level.

DRAINAGE

The region occupied by the transitional belt and Nechako plateau has been aptly called " the lake district of British Columbia." It includes such large lakes as Takla, Babine, Stuart, François, Ootsa, Whitesail, and Eutsuk, together with innumerable smaller ones. The writer verified Galloway's[1] statement that seventy-two lakes are visible from the summit of mount Nadina. These lakes range in size from mere ponds to François lake, which is about 70 miles long. All of the larger lakes are narrow, occupying old stream valleys. Their presence is attributed to the effect of glaciation in disorganizing the drainage of a region of heavy precipitation.

The drainage of Nechako plateau is tributary to Fraser river. West of the main divide at Bulkley lake, about 50 miles east of Houston, the country is drained by the tributaries of Bulkley river which flows into the Skeena. This Fraser-Skeena divide extends southwesterly from Bulkley lake and diagonally across the southeastern part of Owen Lake map-area. It is evident, therefore, that only a small, eastern part of the area is tributary to the Fraser, most of the drainage flowing by way of Owen creek to Morice river which joins the Bulkley near Houston.

The creeks in the northeastern corner of the area have steep gradients and flow into Parrott lake which is really a chain of lakes draining by way of Parrott creek into François lake. Peter Aleck creek rises in a series of small ponds at the southern end of Te-kai-zi-yis ridge. It flows southward with a steep but gradually decreasing gradient until it reaches the southern part of Owen valley which it then follows (south of the map-area) until it joins Nadina river about 5 miles above the debouchure of the latter into François lake.

Most of the tributaries of Owen creek have very steep gradients near their sources, flowing more gently on approaching the main valley. This is particularly true of the streams rising on mount Nadina, their head-waters being a series of cataracts. Numerous watercourses on the sides of this mountain contain streams only when the snow is melting.

RELATIONSHIP OF TOPOGRAPHY TO GEOLOGY

The marked relationship between topography and geology existing in the cases of mount Nadina and Te-kai-zi-yis ridge can readily be seen on the geological map. Mount Nadina consists of a granite stock flanked by indurated argillite and greywacke. These relatively resistant rocks have withstood erosion, causing the mountain to stand as a monadnock well above the general level of the surrounding country. The top of Te-kai-zi-yis ridge is a remnant of a Tertiary lava flow, sculptured into a flat-topped butte with almost perpendicular sides.

[1]Galloway, J. D.: Ann. Rept., Minister of Mines, B.C., 1916.

Mine hill is underlain by a stock of microdiorite, but it is not a prominent topographic feature like mount Nadina. This is probably due to the fact that, being near the main valley, it has been subjected to intense erosion both by the stream that cut Owen valley, and by valley glaciation. This stock is traversed by numerous shear zones, some of which have surface expression in the form of canyons and gullies. Wrinch canyon is thought to be due to one of these shear zones.

GLACIATION

Three types of glaciation have been active within the area: the main Cordilleran ice-sheet; large valley glaciers; and late Pleistocene to Recent alpine glaciers.

The effect of the Cordilleran ice-sheet is best shown by the flatly rounded summit of mount Nadina, and by the numerous rounded hills already mentioned. The summit of mount Nadina is covered with angular joint-blocks, so that the direction of ice movement cannot be determined. The upland surface of the area in general shows the effects of the ice-sheet in rounded hills, a general deposit of ground moraine, and disorganized drainage typified by numerous small lakes and muskegs.

Alpine glaciation was active until very recently, but at the present time there are no glaciers within the area. Tsa-lit-pn lake occupies a large cirque which was probably formed by a glacier contemporaneous with, and joining, the valley glacier that occupied Owen valley.

The sides of mount Nadina have been sculptured by small alpine glaciers. This is particularly well illustrated by the two cirques on the northern flank of the mountain. The northeastern cirque, which is the more perfect of the two, extends into the flat summit a distance of about 4,000 feet. The vertical headwall is about 400 feet high, and the bottom slopes gradually toward the side of the mountain, thus forming a hanging valley 1,200 feet above the valley of Puport creek. Near the base of mount Nadina, below this cirque, there is a small terminal moraine and a series of recessional moraines. These cirques do not contain glaciers at present; but their fresh appearance, higher elevation, and the fact that their moraines have not been removed, suggest that they are much younger than the cirque occupied by the headwaters of Puport creek.

Origin of Owen Valley and Owen Lake

Redick creek flows southward from Né-uch lakes, through a muskeg flat at the base of Te-kai-zi-yis ridge. It then makes two right-angled bends, and flows into the head of Owen lake. These bends suggest that the stream once flowed southward as a tributary of Nadina river, but that subsequent damming of the valley by alluvium has caused stream piracy so that the creek is now a tributary of the Skeena system. From this evidence, and from the fact that Owen valley is a continuation of the François Lake trench, it is thought that at least a portion of that part of the valley now draining northward to Morice river, drained southward during late Tertiary time.

From its U-shaped cross-section it is evident that Owen valley was occupied by a valley glacier, and from the above evidence of the Tertiary drainage direction, it is concluded that this glacier moved southward and joined a larger valley glacier occupying the valley of Nadina river and François lake. These glaciers probably formed previous to the Cordilleran ice-sheet. After these had retreated, the valleys were filled with an unknown thickness of fluvioglacial material. This is the material forming the terrace at Owen lake.

The present divide in Owen valley consists of rounded hills of drift, situated near the southern border of the map-area. This damming of the valley is thought to be due to alluvium brought down from the hills on either side of the valley, resulting in a post-Glacial diversion of the drainage and in the capture of Redick creek.

Two theories for the origin of Owen lake and its terrace are advanced.

(1) After the valley was filled with the fluvioglacial deposit, at least to the height of the terrace, a post-glacial stream, probably flowing northward, cut through this material at the present site of Owen lake and Owen creek. The ridge near O-kus-yel-da hill forms a natural constriction of the valley near the end of the lake, and alluvium from this ridge may have been deposited so as to dam the valley at this point, thus forming the lake.

(2) Lakes such as the one under discussion have been considered to be due to an ice block remaining insulated after the main glacier retreated, thus preventing the site of the lake from being filled with drift at the time that such material was being deposited elsewhere. When the ice block melts it leaves a depression which fills with water to form the lake. It is considered quite possible that Owen lake occupies such a depression.

Conclusive evidence regarding the origin of Owen lake is lacking. If the site of the lake had been cut by a stream, as required by the first hypothesis, the stream, probably, but not necessarily, would have cut a series of terraces at different elevations, whereas only the one terrace exists. The presence of undrained depressions on this terrace suggests that it represents the top of a valley-fill; in other words, that it is a constructional rather than an erosional terrace. The evidence is thought, therefore, to be slightly more favourable toward the second hypothesis.

Resting upon the surface of the above-mentioned terrace are several large granite erratics, which evidently came from mount Nadina. The following theories are advanced to explain their position: (1) they may have been deposited by an alpine glacier descending from mount Nadina, after the deposition of the fluvioglacial debris; (2) they may have been deposited on Mine hill by a glacier descending from mount Nadina at any time and have reached their present position by avalanching; (3) possibly they were transported by a second advance of the valley glacier; (4) they may have been deposited by snow-avalanching directly from mount Nadina. The distance is about 4 miles and the relief over 4,000 feet.

No evidence was found favouring one of these theories more than another. They are listed merely to show that the presence of the erratics does not necessarily indicate that the fluvioglacial deposits are of interglacial age.

GENERAL GEOLOGY

Owen Lake area lies some 30 miles east of the Coast Range batholith. The area is underlain principally by volcanic rocks consisting of andesite porphyrites and associated tuffs and breccias. Overlying the Volcanic series in the northwestern part of the area is a group consisting chiefly of argillites and greywackes and of Upper Cretaceous or later age as indicated by palæobotanical evidence.

A stock of biotite granite intrudes the sediments on mount Nadina, the intruded rocks suffering extreme induration. A stock of microdiorite intrudes the Volcanic series in the vicinity of Mine hill, the more important mineral deposits of the area occurring in shear zones within this stock. The relationship of this intrusion to the sediments and to the granite is not known.

Horizontal flows of Tertiary basalt overlie the Volcanic series unconformably on Te-kai-zi-yis ridge.

The entire area has been glaciated, resulting in the deposition of a thick mantle of morainal and fluvioglacial debris over the lower portions. For this reason outcrops are practically restricted to the mountains and the tops of hills and ridges, a fact that renders the interpretation of structure and the measurement of sections rather indefinite.

Table of Formations

Period		Estimated thickness (Feet)
Recent	Alluvium	....
Pleistocene	Morainal and fluvioglacial debris	....
Tertiary	Volcanics: vesicular and amygdaloidal basalt	600
Tertiary	Hornblende granite stock	....
Probably post-Cretaceous	Microdiorite stock	....
Upper Cretaceous(?)	Indurated argillite and greywacke, conglomerate. Carbonaceous material.	5,000
Jurassic	Volcanic: andesite porphyrite, with associated tuffs and breccias	8,000

VOLCANIC SERIES

Approximately 75 per cent of Owen Lake area is underlain by effusive and pyroclastic rocks which constitute the oldest formation exposed in the area. The members of this series strike in a general northwesterly direction, with an average dip of 15 to 20 degrees to the southwest. The following generalized section may be given, although the scarcity of outcrops and the absence of key beds render impossible a detailed interpretation of the structure or the measurement of an accurate section.

Partial Section of the Volcanic Series

	Feet
Erosion surface	
Chiefly andesite porphyrite	5,000
Chiefly andesite porphyrite breccia	2,000
Chiefly light-coloured, fine-grained tuffs	1,000
Base concealed	
	8,000

A fairly well-defined band of light coloured tuffs occurs at the summit of the road to Weiden's ranch, and can be traced in a northwesterly direction as far as the winter road to Houston. These tuffs are succeeded to the westward by an imperfectly exposed belt of breccias in the vicinity of Tiptop hill and the Dick group of mineral claims.

The scattered outcrops of the Volcanic series near the mine are chiefly of andesite porphyrite, similar rocks being found on O-kus-yel-da, Win-nin-yik and Sil-loep hills. Four outcrops of andesite porphyrite occur at the shore of Owen lake. West of the lake, outcrops of andesite porphyrite are fairly common on Taylor ridge, and isolated exposures are found on the top of hills. The tuffs are fine grained, massive, and highly altered; grey, cream, and buff being the predominant colours. Under the microscope these rocks are seen to consist of small, angular fragments of altered feldspar in a fine-grained, indeterminate groundmass.

The breccias consist of angular fragments of andesite composition; grey, buff, and purplish red in colour; and ranging in size from 2 inches to very small fragments blending into the fine-grained, tuffaceous matrix. These rocks present a mottled assembly of the colours listed above, but the general colour and that of the matrix in particular, is preponderately purplish red, generally weathering yellowish due to the formation of limonite. All the breccias observed are of tuffaceous character. They are distinguished from the tuffs by their uneven texture and the size of their fragments. Both the tuffs and the breccias are massive, without definite sign of bedding.

Andesite porphyrites are the most common rocks in the area. They are generally dark greenish grey, rusty weathering, only slightly porphyritic in the hand specimen, massive, or with obscure flow-structure. The flows are seldom vesicular, but in a few instances are amygdaloidal. This is particularly true of the andesite outcropping in Wrinch canyon, where amygdules of cream coloured calcite occur up to one inch in diameter. Microscopically these rocks exhibit a rather fine-grained, porphyritic texture, with scattered to well-defined trachytic structure. The phenocrysts are stout, lath-shaped crystals of plagioclase averaging one-quarter of an inch in length and having the composition of andesine to labradorite. Some phenocrysts of idiomorphic hornblende, generally of the basaltic variety exhibiting well-defined prismatic cleavage, also occur. The groundmass consists chiefly of fine grains of plagioclase having the same composition as the phenocrysts, with interstitial quartz grains. Pyrite is the chief accessory mineral. A few inclusions of apatite were noted in the larger quartz grains.

The highest outcrop of andesite in the section, near the base of mount Nadina, consists of augite andesite. It is a greenish black, massive rock, darker than the other andesites, containing small phenocrysts of labradorite and augite.

The andesites are much altered to chlorite and epidote, thus imparting a greenish colour to the rocks. There is also some alteration of the ferromagnesian minerals to biotite, and possibly to uralite. The weathering of pyrite generally stains the surface and fractures with limonite. The above-described rocks are correlated, on the basis of lithology, with rocks near François lake, which were examined by Dawson, who included them in his Porphyrite group. The Volcanic series is believed to be a correlative of the Hazelton series of Jurassic age, but as no fossils were found in the Volcanic series at Owen lake, their age is not definitely known.

UPPER CRETACEOUS (?) SEDIMENTARY SERIES

Overlying the Volcanic series is a series of carbonaceous argillites, and greywackes. Being intruded by granite stocks, these sediments have suffered varying degrees of induration, but there is a remarkable absence of contact metamorphism of an intensity usual in such cases.

The series is restricted to the highest parts of the area, occurring only on mount Nadina and Tsa-lit mountain, where the rocks are considered to be remnants of a once more extensive formation which have resisted erosion because of their indurated character.

The general structure is that of a homocline with a northerly strike and dipping about 20 degrees to the west. Minor anomalous structures are found near the contact of the main intrusive stock on mount Nadina.

The lower portion of the series consists of interbedded argillite, often carbonaceous, and greywacke; with some thin beds of quartzite and conglomerate. The thickness of the beds varies from ⅛ inch to 10 feet. Owing to the precipitous nature of the slopes of mount Nadina, where the best exposures occur, the measurement of a section would have required more time than circumstances warranted. The upper part of the formation, near the summit of mount Nadina, consists of massive, fine-grained, tuffaceous greywacke of greenish colour.

The rocks exposed on Tsa-lit mountain are chiefly fine-grained argillites, with some greywackes, quartzites, and conglomerates. One outcrop of highly calcitized andesite was noted, but this rock is so altered that it could not be determined whether it is a flow or a sill associated with the dykes occurring on the mountain.

The thickness of the Nadina formation is estimated at 4,000 feet, an unknown additional thickness having been removed by erosion.

The argillites are very fine-grained, massive, and black, weathering to greenish grey, with some alteration to chlorite. They vary from medium hard types to indurated hornstones of great hardness and marked conchoidal fracture. Numerous carbonized plant fragments occur at some horizons. Near the granite contact on mount Nadina a few well-defined slickensides were found in the argillites, with some development of chlorite, the more highly deformed examples resembling a chlorite schist. These rocks are so fine grained that little can be determined by a microscopic study. They consist of a minor amount of sub-rounded quartz grains averaging 0·1 mm. in diameter, in a groundmass of very fine argillaceous material.

Hard, massive, cherty quartzites occur in a few thin beds. This rock is steel grey, well jointed, and rusty weathering along the joint-planes.

The typical greywacke of the series is fairly fine-grained, massive, dark grey, weathering to a somewhat lighter grey. It is generally indurated. Microscopically these rocks are seen to consist of about 40 per cent rounded andesite grains and 40 per cent rounded quartz grains, with subordinate amounts of tuff, chert, feldspar, pyrite, and magnetite. The average size of the grains is 0·5 mm. On the other hand, the beds exposed near the summit of mount Nadina consist of massive, fine-grained, tuffaceous greywacke, containing numerous angular fragments. These rocks are light greenish grey, weathering to a dark, rusty brown. They contain small, subangular quartz grains and some plagioclase with abundant fine-grained sericite and chlorite. These rocks are close to the contact of the granite stock, so that the development of sericite and chlorite is considered to be the result of hydrothermal alteration.

On the north side of mount Nadina one transitional zone between a bed of greywacke and one of argillite, consists of conglomerate. This rock consists of angular fragments of argillite up to 2 inches in length embedded in a matrix of typical andesitic greywacke. A few beds were seen of conglomerate with rounded pebbles of tuff and limestone. The source of the limestone pebbles is unknown.

Although most of the carbonaceous material in the sedimentary series was unidentifiable, a small collection of fossil leaves was made. These were submitted to W. A. Bell of the Geological Survey, who reported as follows:

"For the most part the material is in the form of coalized broken stems and obscure impressions that are unidentifiable. Specimen 64-29, however, shows a doubtful *Aspidiophyllum* and parts of two foliage branches of a species of *Myrica* hitherto undescribed, whilst specimen 134-29 shows the upper part of a lobed dicotyledonous leaf that suggests, although not without doubt, *Aspidiophyllum platanifolium* Lesquereux from the Dakota group. The material at hand, whilst suggesting somewhat a basal Upper Cretaceous age, is quite insufficient to justify positive conclusions otherwise than post-Lower Cretaceous."

Specimen 64-29 was obtained on the east side of mount Nadina, near the summit, and specimen 134-29 was found on the north side of the same mountain, at a lower elevation than the former. On the above evidence the age of the series is referred tentatively to the Upper Cretaceous. No Upper Cretaceous sediments have been previously described from this part of the province, the nearest occurrence being that mentioned by F. A. Kerr from Stikine district.[1]

If fossils had not been found, the sedimentary series would, on lithological grounds, have been correlated tentatively with the Skeena formation believed to be of Kootenay age.[2] With the above fossil evidence indicating definite post-Lower Cretaceous age, it is considered probable that a shallow basin of sedimentation existed here during part of the Upper Cretaceous.

[1]Geol. Surv., Canada, Sum. Rept. 1928, pt. A, p. 21.
[2]Malloch, G. S.: Geol. Surv., Canada, Sum. Rept. 1912, p. 86.

The base of the series must be near the foot of mount Nadina and Tsa-lit mountain, but is everywhere mantled by talus and drift, so that the contact with the underlying Volcanic series could not be studied. However, as the Volcanic series is probably Jurassic, it is probable that an unconformity exists. Since these two formations exhibit a reasonable concordance of dip, such an unconformity would be a disconformity rather than a nonconformity.

POST-CRETACEOUS INTRUSIVES

Microdiorite Stock

A stock of microdiorite, with which the most important mineral deposits are associated, intrudes the Volcanic series in the vicinity of the Owen Lake mine. The part of the area where this stock occurs is heavily drift-covered, so that only scattered outcrops are to be found, but their distribution tends to show the presence of a single stock, with some apophyses, and numerous inclusions of the Volcanic rocks.

Outcrops of microdiorite occur chiefly in Wrinch canyon, on the tops of the hills on either side of this canyon, immediately east of Thomas George's cabin, and between George lake and Cole lake. Hydrothermally altered microdiorite is the principal rock penetrated by the main adit of the Owen Lake mine; and is also found at the collar of the main Cole shaft. It occurs at the shafts on the Midnight group, where it appears to represent an apophysis, since volcanics occur between this point and the main microdiorite outcrops on Mine hill.

The outcrops are so scattered that the boundary of the stock cannot be determined with any accuracy. The stock appears to be elliptical in shape, its north-south dimension being about $1\frac{1}{4}$ miles, and its east-west dimension approximately $1\frac{3}{4}$ miles. With two exceptions, all of the outcrops of this rock lie within the boundary of the claims controlled by the Owen Lake Mining and Development Company. The two extraneous outcrops are near the June claim. No evidence was found to suggest that another body of microdiorite is present within the area, but outcrops of any kind are lacking in much of the territory.

The outcrops in Wrinch canyon are interpreted as indicating several irregular apophyses of microdiorite intruding andesites of the Volcanic series. Outcrops of volcanics near the McLean vein are thought to represent a flat-lying remnant of the roof. From the above evidence, and from the low-temperature type of associated mineral deposits, it is considered that the exposed microdiorite represents the top of a small stock barely unroofed.

The stock consists of fine-grained, massive, dark greenish black rock of dioritic composition, weathering rusty or dark grey. Numerous pyrite grains may be seen microscopically. The texture is often fine-grained porphyritic, thereby imparting to the hand specimen a somewhat coarser appearance than is suggested by the prefix "micro."

Upon microscopic examination the micro-porphyritic texture is evident, with abundant lath-shaped phenocrysts of plagioclase averaging 1 to 2 mm. in length. The composition of the plagioclase is labradorite or intermediate between andesine and labradorite. The groundmass consists of fine-grained, anhedral plagioclase and some interstitial quartz. Accessory hornblende and biotite occur sparingly. Grains of pyrite are very abundant, but since these occur also in the hydrothermally altered phase of the microdiorite, they are considered to be the result of propylitization.

A partial analysis of this rock, given below, kindly made by Professor A. H. Phillips, compares closely with published analyses of microdiorite, and also with the closely related rock "malchite."

Part Analyses of Microdiorite

	Per cent
SiO_2	57·59
Al_2O_3	18·83
Fe_2O_3 / FeO	6·67
MgO	1·98
CaO	5·03

The age of this intrusive could not be determined definitely. It intrudes the Volcanic series, and may, therefore, with reasonable assurance be regarded as post-Lower Jurassic.

GRANITE STOCKS

A stock of biotite granite, about 1½ miles in diameter, intrudes the sedimentary series on mount Nadina, being exposed on the summit and on the northern and eastern slopes. The contact is rather irregular. The stock contains small inclusions of the sediments, and dykes and apophyses cut the sediments.

A smaller body of similar rock occurs to the north of Tsa-lit mountain. It is, therefore, probable that the granite underlies the sediments occurring on the latter mountain. Prospectors state that a larger body of granite is found on the mountain to the north of Tsa-lit, near the junction of Owen creek and Morice river.

The granite is rather fine grained, slightly porphyritic, light pinkish grey, and weathers cream to grey. Orthoclase is the principal constituent, sometimes occurring in small phenocrysts, and is often clouded due to alteration to white mica or kaolin. Microperthitic intergrowths are sometimes found. The plagioclase is albite-oligoclase. The quartz grains are anhedral, occasionally containing inclusions of plagioclase. Stout plates of biotite are fairly common, and hornblende is found in minor quantities. As accessory minerals, titanite and magnetite are relatively abundant. The quartz grains contain a few inclusions of apatite, zircon, and tourmaline.

The following average of three mineralogical analyses made by the Rosiwal method, shows the rock to be a normal biotite granite.

	Per cent
Orthoclase	61·3
Plagioclase	12·9
Quartz	19·6
Biotite	5·2
Accessories	1·4
Total	100·4

The granite intrudes the sedimentary formation, whose age as determined from fossil evidence is probably Upper Cretaceous. The intrusive is, therefore, considered to be of early Tertiary age.

There is no direct evidence regarding the relative ages of the microdiorite and granite stocks. However, trachyte dykes which may be related to the granite, cut the microdiorite. It is considered possible, therefore, that although both probably belong to the same general period of intrusion, the granite may be slightly younger.

TERTIARY BASALT

Horizontal flows of Tertiary basalt overlie rocks of the Volcanic series with angular unconformity. Within the area, these flows are found only on Te-kai-zi-yis ridge, where they form a capping about 2 miles long and from $\frac{1}{2}$ to $\frac{3}{4}$ mile wide. The thickness of the basalt is estimated at 600 feet, the base being unexposed. Similar rock is abundant to the south and east of the area, occurring in the form of isolated buttes. These buttes are erosional remnants of a more extensive formation which once covered a large part of the plateau country.

The basalts are fine grained, black, weathering dark brown to purple, and exhibit imperfectly developed columnar jointing. In the lower flows vesicles and amygdules are practically absent, whereas the upper ones are highly vesicular and filled with chalcedonic amygdules. The larger vesicles show horizontal elongation, averaging 1 inch in length; and contain an inner lining of drusy, cream coloured calcite surrounded by a thin, drusy layer of chalcedony.

Upon microscopic examination, the basalts are seen to possess a fine-grained, porphyritic texture, with phenocrysts of bytownite, locally showing zoning. The groundmass consists chiefly of small, felted laths of plagioclase, of the composition labradorite-bytownite, sometimes exhibiting trachytic structure; with minor amounts of augite, biotite, magnetite, and glass. Hematite and limonite occur as products of weathering, but the basalts are very fresh compared with the andesites of the Volcanic series.

Neither fossils nor sedimentary rocks were found associated with these volcanics, so the age cannot be determined accurately. However, they are structurally and lithologically very similar to the Tertiary volcanics so common in the interior of the province, which have been variously classed as of Oligocene or Miocene age on the basis of palæobotanical evidence. Therefore, although the basalts under discussion are undoubtedly Tertiary, they can merely be tentatively referred to the Oligocene or Miocene.

DYKE ROCKS

The dykes of the area may be divided into three main groups, as follows:

(1) Diabase porphyry dykes cutting the microdiorite stock, but believed to be differentiates of the same magma as the microdiorite.

(2) Diaschistic dykes of rhyolite and diorite associated with the granite; and post-mineral soda trachyte dykes intruding the microdiorite

and neighbouring andesite, possibly genetically associated with the granite.

(3) A single, large, fresh, fine-grained diabase dyke intruding the microdiorite and neighbouring andesite, possibly genetically associated with the Tertiary basalt.

The older diabase dykes occur on Mine hill; and at one locality in the main adit, where the dyke is about 10 feet wide. The relationship of the surface outcrops is obscure, but there appear to be at least two dykes striking across the stock in a northwesterly direction, one of which evidently widens to form the underground exposure. The rock consists of stout labradorite phenocrysts averaging one-half inch in length, in a fine-grained, black groundmass which often penetrates along cleavage cracks in the phenocrysts. The ophitic groundmass consists of fine laths of labradorite, with minor quantities of interstitial quartz, pyroxene altering to calcite, and a few crystals of apatite. The rock is of approximately similar composition to the microdiorite, differing chiefly in texture.

Rhyolite dykes occur on the west side of mount Nadina, near the granite contact, and similar dykes are found on Tsa-lit mountain. These dykes intrude the sediments. They are light grey, rusty weathering, and consist essentially of orthoclase and quartz. The contact of one of these dykes with argillite, examined microscopically, shows flow structure parallel to the contact, a narrow border facies of strained glass, and alteration of the biotite in the argillite to chlorite. The diorite porphyry dykes have the same field relations as the rhyolites, the two not being observed cutting one another. These dykes consist of stout labradorite phenocrysts in a fine-grained, dioritic groundmass of laths of labradorite and some interstitial quartz. These are considered to be the melanocratic relatives of the rhyolites.

A soda-trachyte dyke cuts the main Wrinch vein. The rock is fine grained, light grey, and possesses micro-porphyritic texture and trachytic structure. The rock is altered, consisting of feldspar phenocrysts altered to the pale variety of chlorite, pennine, and a carbonate which is probably ankerite. Similar dykes are found in the main adit of the Owen Lake mine, but none was found at the surface. The original composition of these dykes would be much like that of the granite, with a diminution of quartz; therefore, they are correlated tentatively with the granitic intrusives.

A single vertical dyke, 8 feet wide, is exposed on both sides of Wrinch canyon, where it intrudes both microdiorite and andesite. The rock is fine grained, black, and very fresh in appearance. Microscopically it is seen to be slightly porphyritic, with small phenocrysts of labradorite and pyroxene, in a fine-grained, ophitic groundmass consisting of labradorite with minor amounts of pyroxene and magnetite. This dyke is probably related to the Tertiary basalt, which it resembles in lithology and lack of alteration.

PLEISTOCENE AND RECENT DEPOSITS

The glacial deposits of the area consist of a general mantle of ground moraine, together with the roughly stratified fluvioglacial gravels filling the bottom of Owen valley, and the moraines of alpine glaciers in the vicinity of mount Nadina.

The Recent deposits consist of sand, gravel, and alluvium in the stream beds. At the falls on Redick creek the stream flows over a small body of partly consolidated conglomerate which is believed to be a Recent stream gravel, or a portion of the fluvioglacial material, partly cemented by the action of percolating waters.

ECONOMIC GEOLOGY

CLASSIFICATION OF MINERAL DEPOSITS

The mineral deposits of Owen Lake area are the result of sulphide mineralization by solutions emanating as the later phase of the intrusion of igneous rocks. Evidence to be presented below is considered conclusive that the mineralization is of Lindgren's[1] epithermal class, i.e. deposits formed relatively near the surface, at temperatures varying from 200 to 50 degrees C., and under pressure scarcely exceeding 100 atmospheres.

The deposits constituting the Owen Lake mine are veins filling shear zones and fractures in the microdiorite and in included blocks of andesite. Prospects situated within 1½ miles of microdiorite show scattered replacement deposits in the matrices of tuffs and breccias. From the fact that the most important deposits occur within the stock itself, with replacements in the neighbouring pyroclastics, it is assumed that the microdiorite magma was the source of the mineralizing solutions, as well as of the host rock of most of the veins.

A single vein, and replacement deposits in the matrix of conglomerate, are exposed on a prospect on Tsa-lit mountain. Because of its proximity to the granite stock on mount Nadina, this mineralization is believed to be associated with the granitic intrusion.

OWEN LAKE MINE

General Account of Mineralization

The mineralization at the Owen Lake mine takes the form of a series of roughly parallel veins filling shear zones and fissures within the microdiorite stock. These veins vary in width from mere stringers to somewhat irregularly mineralized shear zones 5 to 6 feet wide. There are two general types of mineralization: chalcopyrite-sphalerite and sphalerite-galena, but gradations between the two types occur, and as yet no zonary arrangement is exhibited.

The chalcopyrite-sphalerite veins contain the following metallic minerals, in order of abundance: chalcopyrite, sphalerite, pyrite, tetrahedrite, and alaskaite ($PbS, Ag_2S \cdot Bi_2S_3$), the latter two generally occurring in microscopic grains in intimate association with the chalcopyrite. These veins have a high silver content and a moderate gold content. The logical association of the silver is with the tetrahedrite and alaskaite; a minor quantity may be present in sphalerite. It is likely that most of the gold is contained in the chalcopyrite and pyrite. The gangue minerals in order of abundance are: rhodochrosite, quartz, chalcedony, and barite.

[1]Lindgren, W.: "Mineral Deposits," 3rd edition, p. 236.

The sphalerite-galena veins contain the following metallic minerals, in order of abundance: sphalerite, pyrite, and galena. Only an occasional grain of chalcopyrite is found. These veins contain moderate silver values and a low gold content. No silver minerals were observed, so the silver is apparently in solid solution with the galena, and possibly with the sphalerite. It is possible that some argentite might be found. The gold may be contained by any of the sulphides, but it is likely that most of it is contained by the pyrite. The gangue minerals in order of abundance are: rhodochrosite, quartz, chalcedony, and barite. Adularia was not found in any of the five thin-sections of gangue matter, but this mineral might well be expected to occur.

The veins generally exhibit marked banding and crustification, different bands varying from microscopic size to 4 inches. Pyrite is the only mineral showing any tendency to penetrate the wall-rock. A few of the veins are of the " true fissure " type, but the majority fill shear zones. In some cases a shear zone contains a single, clearly defined, persistent vein, separated from the walls by gouge and sheared rock. In other cases, although the mineralization as a whole is persistent and of fairly constant total width, the shear zone is filled with a series of parallel, more or less lenticular, ore-shoots separated by waste. Such ore-shoots vary from definitely banded types to those in which the sulphides are disseminated through the gangue, both as a result of normal crystallization, and as a result of brecciated fragments of the earlier-formed sulphides being included in the gangue.

As already indicated, banding is the most common structural characteristic of the veins. In the chalcopyrite-sphalerite type the chalcopyrite is generally nearest the walls, whereas in the sphalerite-galena veins, sphalerite forms the outer bands. Excellent examples of the more or less concentric deposition of minerals around brecciated fragments in a vein are found in some of the chalcopyrite-sphalerite veins at the Owen Lake mine.

Quartz is the first formed mineral in the veins, being followed by a small quantity of an early generation of pyrite, which is replaced by chalcopyrite. Chalcopyrite and sphalerite are practically contemporaneous, showing mutual boundaries in some cases, whereas sphalerite replaces chalcopyrite in others. The sphalerite mineralization evidently lasted longer than the chalcopyrite stage. Native gold is seldom seen under the microscope, but the gold is probably nearly contemporaneous with the chalcopyrite. Galena is associated with, and replaces, sphalerite. Tetrahedrite veins sphalerite and replaces chalcopyrite. Tetrahedrite and alaskaite are nearly contemporaneous, but the former is found replacing alaskaite. Alaskaite is found in "gashes" in chalcopyrite.

The main stage of gangue mineralization is late. In the well-banded specimens the metallic minerals line the walls, with intervening rhodochrosite containing brecciated fragments of sphalerite and chalcopyrite. Rhodrochrosite in many cases contains euhedral crystals of barite, but these crystals follow fractures in the rhodochrosite. A late generation of quartz commonly forms colloform bands with rhodochrosite. Chalcedony is the latest gangue mineral, veining the others, but this mineral also forms colloform bands with rhodochrosite. The deposition of rhodochrosite, quartz, and chalcedony is in many cases rhythmical.

The last primary mineral to form is a late generation of pyrite.

The wall-rock in the vicinity of the shear zones has been greatly altered by the action of hydrothermal solutions accompanying the mineralization. In the extreme phase of alteration both microdiorite and andesite are altered to a light greenish grey rock in which the original minerals are almost completely replaced by ankerite, penninite (the pale variety of chlorite), chalcedony, and pyrite. The accompanying analyses kindly made by Professor A. H. Phillips show that the alteration involves an increase in the percentage of iron and magnesia, with a decrease in percentage of silica, alumina, and lime. This type of alteration is known as *propylitization,* a common associate of epithermal mineralization.

Chemical Analyses of Propylitized Rocks

—	1	2
SiO_2	57·59	45·55
Al_2O_3	18·83	16·92
Fe_2O_3 } FeO	6·67	16·92
MgO	1·98	6·71
CaO	5·03	1·74
Na_2O	....	....
BaO	....	....
K_2O	....	....
H_2O plus	....	....
H_2O minus	....	....
TiO_2	....	....
P_2O_5	....	....
CO_2	....	....
Total	90·10	87·84

1. Comparatively fresh microdiorite from surface. Owen Lake mine. Partial analysis by Prof. A. H. Phillips.
2. Propylitized microdiorite, Owen Lake mine. Partial analysis by Prof. A. H. Phillips.

Three degrees of propylitization were observed in the underground exposures of microdiorite at the Owen Lake mine. Where shearing and mineralization have been most intense, the wall-rock has been completely altered to a light grey rock. Upon microscopic examination it is just possible to distinguish the outlines of the altered feldspar crystals. In an intermediate grade of alteration the product is a fairly dark, greenish grey, rock in which the original grains can be distinguished and the degree of alteration is estimated at 50 per cent. Where the microdiorite is massive and the veins are more nearly of the "true fissure" type, the wall-rock is dark greenish black, resembling the surface exposures, but microscopic examination shows an alteration of perhaps 5 per cent. These three grades of propylitization merge into one another, and correspond quite definitely to the degree of shearing and mineralization. The andesite in Wrinch canyon undergoes the same type of alteration. The wall-rock alteration on the other properties in the area resembles the above, but microscopic studies have not been made.

An analysis of mine water from the main adit, where strong flows of water are encountered in fractures, yielded the following result:

SO_4	279·6	parts per million
CO_3	177·5	
Cl	14·0	
SiO_2	4·0	
Ca	103·6	
Mg	22·9	
Na	86·1	
K	6·6	
Al	5·3	
Cu	nil	
Fe	0·7	
Ni	nil	
Mn	1·0	

Br and I not sought—insufficient sample.
E. A. Thompson, analyst, Mines Branch, Division of Chemistry.

Since the adit is within a few hundred feet of the surface, this water must be regarded as normal meteoric water, changed slightly by leaching of the abundant pyrite in the wall-rock. The analysis shows that the principal constituents are calcium sulphate, sodium sulphate, and calcium magnesium carbonate.

The vein outcrops have been highly oxidized and somewhat carbonated by the action of surface waters. Oxidation extends to a depth of about 40 feet along fissures, but neither oxidation nor secondary enrichment occur in the underground workings. The outcrops consist of a "honeycomb" pattern of quartz and barite, with abundant manganese oxide and limonite. Microscopic examination shows that the manganese takes the form of minute colloform deposits of pyrolusite and psilomelane. Smithsonite occurs sparingly, forming thin, botryoidal encrustations in cavities. A little copper stain is found in the form of malachite, but this mineral is rare on account of its solubility. Chalcopyrite which has been exposed on the dump acquires a faint tarnish of covellite, bornite, and cuprite.

The veins are roughly parallel, with a northwesterly strike and, in general, with steep dips. They occur at various intervals, and there is no definite arrangement of the two types. The most westerly vein (Chisholm) is of the sphalerite-galena type, then follows a group of chalcopyrite-sphalerite veins, then a group of the first-mentioned type, then at least one chalcopyrite-sphalerite vein (Wrinch), and finally a group of sphalerite-galena veins.

The veins fill pre-mineral shear zones and fractures having a fairly uniform parallel strike. The veins are displaced by a complex system of post-mineral faults, that may be divided into two general groups, striking northwest and northeast.

The following evidence is presented in support of the writer's opinion that the veins are of epithermal origin. (1) Propylitization is a typical alteration accompanying epithermal deposits. (2) Chalcedony is a characteristic gangue mineral of epithermal veins. (3) The following structures found in the veins at Owen lake are typical of epithermal veins; cockade structure; colloform structure; banding and crustification; feather structure; zonal lines in quartz crystals. (4) All of the metallic minerals occurring in the veins are found in other epithermal deposits. (5) All of the gangue minerals (rhodochrosite, quartz, barite, and chalcedony) are typical of epithermal veins.

Perhaps no one of these criteria, alone, could be regarded as diagnostic of epithermal conditions; but the aggregate, together with the absence of diagnostic minerals of the hypothermal and mesothermal veins, are considered conclusive evidence.

The veins show definite structural control, being located in zones of pre-mineral faulting, shearing, and fracturing. Evidence of intermineralization movement is shown by the brecciated fragments included in the cockade structure; brecciated fragments of metallic minerals cemented by later gangue; veinlets of later minerals following fractures in earlier-formed minerals; and evidence of brecciation and cementing by later minerals is observed in thin sections of vein material. The complex system of post-mineral faults shows that these movements continued long after the period of mineralization.

Sixty-seven full claims and fractions, all surveyed and Crown granted, are under option to the Owen Lake Mining and Development Company, F. H. Taylor, President; H. N. Monk, Secretary; Registered office 736 Granville street, Vancouver, B.C.

HISTORY OF MINING DEVELOPMENT AT OWEN LAKE

The original discovery was made in 1912 at Wrinch canyon, by Jim Holland, a member of a land-survey party. This was staked as the *Silver Queen* group, which became the property of Dr. H. C. Wrinch of Hazelton, B.C.

Prospectors were attracted to the district and a number of claims were staked, many being allowed to lapse. The *Chisholm* group was staked soon after the original discovery; two small shafts were sunk and two cars of ore were shipped in 1915. This property was re-staked as the *McLean* group and was again re-located in 1928 as the *Midnight* group, owned by Alex. and Angus Chisholm.

In 1915 J. P. Cole of Houston staked the *Diamond Belle* group to the northeast of the *Silver Queen.* He retained a half-interest and his partners, O. W. James and Frank Brown, each received a quarter interest. James and Brown sold their interests to F. L. Mosher, whose widow now owns the half-interest.

In 1923 the Federal Mining and Smelting Company secured an option on the *Silver Queen* and did about 500 feet of drifting on the veins in Wrinch canyon, under the direction of Henry Lee. The option was relinquished in 1924.

F. H. Taylor organized the Owen Lake Mining and Development Company in 1928 and bonded the *Silver Queen, Diamond Belle,* and *Midnight* groups. This company began an extensive development campaign, including the road building already mentioned and the establishment of a well-equipped camp. The Cole shaft was sunk on the main *Diamond Belle* vein, and a long crosscut adit was begun to intersect the *Silver Queen* veins. This adit encountered a number of unexpected veins, before striking the main *Silver Queen* vein during the winter of 1929-30.

This development work aroused a great deal of interest, and during the spring of 1929 the property was examined by representatives of several large mining companies. In July, 1929, Noah A. Timmins optioned the control of the Owen Lake Mining and Development Company for $1,000,000, making an initial payment of $150,000. This option was dropped in the spring of 1930, but Mr. Timmins retains an interest of approximately one-fifth of the shares of the company. At the time of writing this company is engaged in diamond drilling.

Surface work has been done on several other properties staked in 1928 and 1929.

The only published reports on this property are those found in the Annual Reports of the Minister of Mines for the years 1916, 1923, 1924, 1925, 1927, 1928; and Bulletins 1 and 2, 1929, of the British Columbia Department of Mines.

Early development work consisted of surface trenching on the veins of the Silver Queen and Diamond Belle groups, together with the sinking of small prospect shafts on the Midnight group and on one of the Cole veins.

The work of the Federal Mining and Smelting Company consisted of about 500 feet of drifting on the Silver Queen veins.

The Owen Lake Mining and Development, in 1928, first sunk an 80-foot shaft on the principal Cole vein, doing 123 feet of drifting on the 75-foot level. After establishing the width and continuity of this vein, they allowed the shaft to fill with water, and began a long adit to crosscut the Wrinch veins at depth. This adit encountered several unexpected veins, upon which considerable drifting was done. On September 1, 1929, the adit had a length of 1,736 feet, and about 1,020 feet of drifting had been done on the veins. The adit was continued during the winter of 1929-30, the main Silver Queen vein being encountered. At about 2,800 feet from the portal, tunnelling was discontinued, and a 300-foot diamond drill hole was projected from the face. At the time of writing the company is engaged in diamond drilling.

The surface is generally covered with a thick mantle of drift, outcrops being practically restricted to the tops of the hills and to Wrinch canyon. The oldest formation underlying the claims consists of andesite porphyrite. This is intruded by the microdiorite stock described in an earlier chapter. The mineral deposits occur as veins filling shear-zones, generally in the microdiorite, but occasionally in the andesite. In the vicinity of the veins these rocks are highly propylitized. Pre-mineral dykes of diabase porphyry and post-mineral dykes of diabase and soda trachyte occur. The veins are commonly displaced by post-mineral faulting and shearing.

The veins are roughly parallel, with a northwesterly strike and, in general, steep dips. Veins of both the chalcopyrite-sphalerite and sphalerite-galena types occur, the former carrying high silver values with some gold, whereas the precious metals content of the sphalerite-galena veins is considerably lower. The number of veins exposed at the time of examination is estimated at from 17 to 22. The reason that only an estimate can be given at present is due to the fact that there is some evidence of repetition of veins by faulting. There is reasonable possibility of encountering additional veins in the section not yet crosscut by development work.

The veins are divided into the following groups, from west to east:

(1) Chisholm or Midnight vein
(2) McLean vein
(3) Veins exposed in main crosscut adit.
(4) Wrinch or Silver Queen veins
(5) McKay vein
(6) Cole or Diamond Belle veins.

Chisholm Vein

The Chisholm vein on the Midnight claim is about 400 yards northeast of Owen lake, on the alluvial terrace at an elevation of 2,650 feet. The vein is exposed by means of two shallow inclined shafts 70 feet apart, no further extension being proved. These shafts were sunk in 1914 or 1915, no more recent work being done. There are no surface exposures or rock outcrops, and as the shafts were nearly filled with water, the writer's examination was practically confined to a study of the dump.

The mineralization is in the form of an irregular banded filling of a shear zone, from 1 to 2 feet wide, striking north 35 degrees west, dipping 40 degrees east; in an altered and pyritized rock resembling propylitized microdiorite. The minerals are chiefly sphalerite and pyrite, with a minor quantity of galena, in a gangue of barite and quartz. The ore is strongly oxidized, containing limonite and an abundance of mixed black manganese oxides, the latter suggesting the presence of rhodochrosite as a gangue mineral at depth. A small deposit of mixed manganese oxides occurs west of the shafts, where surface waters have leached manganese out of the vein and deposited the oxide in gravel. This deposit is stated[1] to contain 35 per cent manganese, but is not likely to be of commercial size.

The following assays are published in Annual Reports of the Minister of Mines:

Selected sample at collar of shaft.
Au 0·30 ounce; Ag 20·0 ounces; Pb 1 per cent; Zn 18 per cent.
Grab sample of whole dump.
Au 0·4 ounce; Ag 5·2 ounces; Pb nil; Zn 20 per cent.
Average sample of dump rejects from hand sorting.
Au 0·08 ounce; Ag 29·2 ounces; Pb 11·4 per cent; Zn 29·5 per cent.

Two cars of ore were hand sorted and shipped to a smelter in 1915.

McLean Vein

The McLean vein is exposed by means of a trench about 50 feet long, 2,500 feet southeast of the portal of the main adit. The vein is about 2 feet wide, strikes north 70 degrees west, and is practically vertical. The location and strike of this vein suggest that it represents a vein intermediate between the Chisholm vein and the portal vein system, but owing to the degree of faulting on the property, it may represent the continuation

[1]Ann. Rept., Minister of Mines, B.C., 1928, p. 171.

of one of the portal veins. The outcrop is strongly leached, consisting chiefly of quartz and manganese oxides, with some sphalerite and galena. The outcrop is too highly leached for definite correlation with the portal veins.

Main Crosscut Adit

The main crosscut adit was begun at an elevation of 2,684 feet on the southwestern side of Mine hill, on a bearing north 58° 04′ east, to crosscut the projection of the Wrinch veins at about 2,200 feet, at a depth of about 460 feet. The bearing of the adit is such that its projection would strike the Cole shaft at approximately 6,900 feet, at a depth of about 560 feet. On September 1, 1929, this adit had been driven 1,736 feet and had encountered a number of unexpected veins. The adit is timbered for the first 71 feet from the portal, after which timbering was only necessary in a few places where intense shearing was encountered. At 2,150 feet, the bearing was deflected to the northward, and the adit continued to a distance of 2,830 feet from the portal.

For the first 450 feet the wall-rock consists of fairly soft, light grey rock, which microscopic examination shows to be entirely propylitized, the original nature being quite unrecognizable, as there are no surface exposures for this part of the adit. This rock was probably microdiorite, but may include some andesite.

At 125 feet from the portal, the first of a series of five veins was encountered. These veins are all of the chalcopyrite-sphalerite type, and are called for convenience the "Portal veins." Their only surface indication was a piece of rich float. Some trenches were made in the heavy overburden, and high-grade mineralization was found in one cut, and considerable eastward drifting has been done on these veins, which are numbered according to their drifts.

No. 1 vein is situated 125 feet from the portal of the adit in a sheared zone 30 feet wide. The vein strikes north 56 degrees west, dips 30 degrees north, and has a width of about 4 feet, consisting of irregularly banded chalcopyrite and sphalerite in a gangue of rhodochrosite, quartz, and barite.

A sample of chalcopyrite from this vein assayed[1] Au 0·5 ounce; Ag 140·0 ounces; Cu 21 per cent.

A sample of mainly sphalerite with a little galena assayed[2] Au 0·04 ounce; Ag 2·6 ounces; Zn 21 per cent.

There are said to be about 11 ounces of silver for each per cent of copper, the highest ratio on the property. No. 1 drift followed the ore for 40 feet, when what appeared to be a cross vein was encountered. The original vein was followed for an additional 20 feet, when it was terminated abruptly by a strong post-mineral shear, in which drifting failed to locate the ore. The "cross-vein" is 1 foot wide, strongly banded chalcopyrite, sphalerite, and rhodochrosite, and is horizontal. It was drifted on for 20 feet parallel to the main adit, then the drift was deflected toward the north, holing-out in the adit 210 feet from the portal. The mineralization of this vein resembles that of No. 1 vein, but it differs in width and banding. It

[1], [2]Dept. of Mines, B.C., Bull. No. 1, p. 26 (1929).

is not yet known whether this vein is a mineralized cross-shear, in place; or whether it is a part of the general vein-system which has been flattened out by faulting.

No. 2 drift, located at 215 feet from the portal, follows a fairly flat vein dipping at a low angle to the north, which appears to be the same vein as that exposed in the side drift from No. 1 drift east. No. 2 drift follows the vein for 40 feet, when the ore is lost. A quartz-sphalerite cross-stringer may be located in a fault which has displaced the vein. After some 60 feet of drifting, good ore was found near the intersection of this drift with No. 3 drift.

No. 3 drift, located at 265 feet from the portal, follows a 2-foot vein striking due west, dipping 75 degrees north. This vein carries high values, but at about 30 feet from the adit it becomes involved in a complex fault system. At 60 feet from the adit a chalcopyrite-quartz vein from 8 to 10 feet wide is followed for 40 feet, when it is cut off by a shear zone 40 feet wide. This is the widest and most high-grade ore showing on the property; and it was in specimens from this point that the mineral alaskaite was first noted. Some 140 feet of additional drifting failed to locate the ore.

At 338 feet from the portal, the main adit strikes a 60-foot shear zone which is apparently the same shear as that which terminates the ore in No. 3 drift. At 380 feet a rather poorly defined and irregularly mineralized vein, 2 to 3 feet wide, striking north 70 degrees west, dipping 57 degrees north, is located in the wide shear-zone. This vein has a well-defined foot-wall; the hanging-wall consists of badly sheared rock. This vein may be the same as the strong ore showing in No. 3 drift, but the width and mineralization of the former are very inferior. The mineralization is apparent for 30 feet in the roof of No. 4 drift, then it is lost for about 30 feet. Mineralization can then be followed in the roof for about 50 feet, when the vein is cut by a 20-foot cross-shear. At one point in a short side-drift this cross-shear contains mineralization, which may be drag ore. When the writer left the property in September, 1929, No. 4 drift was being continued to the south with the object of crossing the complex fault system which involves the portal veins, in the hope of locating the extension of the high-grade ore showing in No. 3 drift.

No. 5 drift east is a 15-foot drift which follows a narrow but well-defined vein located 425 feet from the portal. This vein is only 3 inches wide, striking north 70 degrees west, dipping 64 degrees southwest. The mineralization is chiefly sphalerite and chalcopyrite.

The veins exposed in the first four drifts are all of the same type, i.e., chalcopyrite-sphalerite veins filling shear zones. They are roughly parallel, having an average strike of north 70 degrees west. The fault problem is very complex and cannot yet be interpreted fully, since all the development is on a single level, and there are no surface outcrops. There is a strong suggestion of repetition of veins by faulting, so that the writer hesitates to state that four distinct veins are represented. Although all of the same type of mineralization, these exposures differ greatly in width and degree of banding, but some variation in ore-shoots is to be expected in veins filling soft shear zones.

At 450 feet the wall-rock of the adit changes gradually from the light-coloured, highly propylitized rock to a darker coloured, mediumly propylitized microdiorite. This extends to the 650-foot point, where a 6-foot unmineralized shear zone is encountered. On the hanging-wall side of this shear, a light-coloured altered trachyte dyke 25 feet wide crosses the adit. Thence to the 750-foot point, the wall-rock is highly altered microdiorite, when it gives place to microdiorite showing a medium degree of propylitization. At 835 feet another altered trachyte dyke is encountered.

At 865 feet a shear zone 12 feet wide is encountered, having the above-mentioned dyke on the hanging-wall and highly propylitized microdiorite on the foot-wall. This shear was drifted on for 50 feet, but no mineralization was observed at the time of examination, although the company's assays show that some mineralization was encountered when drifting.

At 966 feet the adit encountered a vein 4 to 5 feet wide, striking north 25 degrees west, dipping 78 degrees west. This vein is well-defined, with much less shearing on the walls than in the case of the Portal veins, so that it has more of the appearance of a fissure vein. The mineralization consists chiefly of sphalerite, galena, and pyrite with a very minor amount of chalcopyrite, in a gangue of barite and chalcedony. Silver values are much lower than in the case of the Portal veins. This vein was followed by drifting for 35 feet to the north and 20 feet to the east.

Beyond this vein the wall-rock in the adit shows a much lower degree of propylitization.

A stringer 2 to 6 inches wide was encountered at 1,062 feet.

At 1,225 feet the adit encountered a vein striking north 65 degrees west, dipping 80 degrees southwest. The width varies up to 18 inches. The mineralization consists of narrow bands of chalcopyrite and sphalerite, in a gangue of chalcedony with a little rhodochrosite. This vein was followed by drifting for 35 feet to the east and 39 feet to the west.

At 1,484 feet a vein occurs which strikes north 27 degrees east, is vertical, and shows some mineralization over a width of 10 inches.

At 1,535 feet, a vertical vein strikes north 5 degrees west. The mineralization, over a width of 18 inches, consists chiefly of sphalerite and galena, with some chalcopyrite, in a gangue of quartz, rhodochrosite, and barite. Drifting was carried on for a short distance on both sides of the adit.

At 1,500 feet a 10-foot dyke of diabase porphyry intrudes the microdiorite. This dyke is probably related to the diabase dykes outcropping at the surface.

The adit had been advanced 1,737 feet when the writer ceased his examination. Mr. Lay states[1] that at 2,200 feet the bearing of the adit was deflected to north 4 degrees east in order to cut the Wrinch vein system nearer the ore disclosed on that property.

Mr. Turnbull (personal communication) states that vein No. 12 was struck at about 450 feet from the point of deflexion. "Sphalerite was the chief metallic mineral, more or less in blotches. In one place chalcopyrite occurred to the extent of 3 per cent across 3 feet." This vein is apparently the continuation of the main Wrinch vein.

[1]Op. cit., Bull. No. 2, p. 37 (1929).

Vein No. 13, encountered about 100 feet past No. 12, "showed 3 or 4 feet of fair ore on the foot-wall, but the balance was practically loose siliceous material, very wet, requiring timbering."[1]

Wrinch Veins (Silver Queen Group)

The Wrinch vein system is exposed on the sides of Wrinch canyon about half a mile northeast of the main camp. There are at least three veins, two being of the sphalerite-galena type, and the third and most important is of the silver-bearing chalcopyrite-sphalerite type.

Surface exposures on the sides of the canyon are more numerous than elsewhere on the companies' property. Isolated exposures of microdiorite and altered andesite are equally common. The andesite is interpreted as representing inclusions situated near the top of the microdiorite stock. Dykes of diabase porphyry intrude the microdiorite and andesite; and an 8-foot dyke of very fresh, fine-grained diabase crosses the canyon.

No. 1 vein is exposed on the west side of the canyon, immediately north of the large diabase dyke. The mineralization is less than 1 foot wide, consisting chiefly of sphalerite and galena with a minor amount of pyrite and very little chalcopyrite, in a gangue of quartz and rhodochrosite. The development consists of a drift 7 feet long.

Vein No. 1-A, visible in a small exposure, shows 2 feet of the same type of mineralization as vein No. 1, on the opposite side of the canyon, about 70 feet upstream. Veins 1 and 1-A are thought to be the same vein, faulted.

Vein No. 2 is stated[2] to occur some 200 feet upstream from No. 1, and to contain more sphalerite and less chalcopyrite than the main Wrinch vein. Some old open-cuts were found in this vicinity, but the vein was not exposed.

No. 3 drift west is on the northwest side of the canyon at an elevation of 2,990 feet, 450 feet upstream from No. 1 vein. This drift follows for 120 feet a rather irregular, curving, vertical vein in a shear zone in propylitized andesite. The shear zone is mineralized, over widths of 3 to 5 feet, with chalcopyrite and minor quantities of sphalerite and galena, in a gangue of rhodochrosite and quartz. The ore-shoots in the shear zone are irregular, with intervening waste in the form of gangue and silicified wall-rock, but samples over the total width of mineralization show fair values, silver being the most important metal.

Twenty feet from the face of the drift, the ore is cut off by a soda-trachyte dyke striking north 35 degrees west, and dipping 43 degrees east. To the naked eye the dyke rock and the altered andesite can scarcely be distinguished, but microscopic examination shows the dyke to be an entirely different rock, with well-defined trachytic structure. Since the vein has been traced on the surface for 400 feet by means of a series of open-cuts, the ore would probably be found by continuing the drift through the dyke, and side-drifting if necessary.

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[1]Turnbull, J. M.: Personal communications.

[2]Ann. Rept., Minister of Mines, B.C., 1923, 1924.

No. 3 drift east is 47 feet long and is situated immediately across the canyon from No. 3 drift west. In one place it exposes a quartz stringer 1 inch wide, carrying a small amount of pyrite and chalcopyrite, but nothing comparable with the vein in No. 3 drift west is exposed.

No. 4 drift east is on the southeast side of Wrinch canyon at an elevation of 2,990 feet, 90 feet upstream from No. 3 drift. The drift is 220 feet long and follows an irregularly but persistently mineralized shear zone in propylitized andesite. This shear zone has a general southeasterly strike, but is displaced and deflected by two strong post-mineral faults. The mineralization consists of irregular, imperfectly banded shoots of silver-bearing chalcopyrite, with some sphalerite and a little galena, in a gangue of rhodochrosite and chalcedony. At about 30 feet from the portal the drift strikes the foot-wall of the vein, which here dips 60 degrees to the northeast. Cross-cuts at this point show that the mineralization extends over a total width of at least 10 feet, including an ore-shoot parallel to the main vein, with intervening waste in the form of sheared wall-rock. The main drift follows the ore for 95 feet, where the vein is displaced 10 feet to the northwest by a strong cross fault with which is associated from 1 to 2 feet of gouge. The vein, which here has an average width of 5 feet, is followed for 50 feet, to where it is displaced to the northeast by a strong fault, the strike being deflected to the south. The ore is followed farther for 35 feet, to where the drift ends. A short crosscut shows microdiorite on the hanging-wall of the shear zone. Although the ore-shoots in this shear-zone are somewhat irregular, with intervening waste, the mineralization is persistent. The assay plan of the Federal Mining and Smelting Company (published in Annual Report, Minister of Mines, B.C., 1924, pt. B, p. 100) shows a fair grade of ore over mining widths. The values are chiefly in silver, with a little gold, with base-metal values in copper and zinc, and a little lead.

No. 4 drift west was driven in andesite immediately opposite No. 4 drift east, 7 feet of drifting failing to locate mineralization.

Summary. Veins 1 and 2 are of the sphalerite-galena type, and are of doubtful commercial importance. Their positions are such that they may be related to veins 10 and 11 of the main adit.

The veins exposed in drifts 3 west and 4 east are of the silver-bearing chalcopyrite-sphalerite type, carrying fair values over mining widths. It is believed that these are the same vein, displaced about 90 feet by a strong fault which is postulated as having determined the position of Wrinch canyon. The following evidence is presented in support of the above conclusion. (1) Wrinch canyon is a straight, narrow gorge roughly parallel to the faults that displace the vein in No. 4 drift. Such a gorge may well have been cut in the relatively soft shear-zone accompanying a major post-mineral fault. (2) No. 4 drift west fails to locate a vein on the opposite side of the canyon from No. 4 east. Similarly, No. 3 drift east exposes a mere stringer opposite the vein in No. 3 drift west. (3) Veins 1 and 1a appear to be the same vein, displaced at least 70 feet. (4) A diabase porphyry dyke exposed near the entrance to the canyon has been displaced about 100 feet. The younger, fine-grained diabase dyke crosses the canyon without displacement, but this dyke is very fresh in appearance and may be regarded as a post-fault dyke.

McKay Vein

The McKay vein outcrops at the surface on Mine hill at an elevation of 3,175 feet. The outcrop is near the line of the main crosscut adit, at a distance of 2,300 feet from the portal. Twenty feet of stripping exposes a vein 2½ feet wide striking north 45 degrees west, dipping 65 degrees northeast, and consisting of a gossan of manganese oxides, limonite, and quartz. The vein is exposed in a second cut 60 feet along the strike. Here the vein is 4 feet wide and has apparently been displaced 20 feet by a fault. The nearest rock outcrops are microdiorite. This vein is in such a position that it might represent the southern extension of the main Wrinch vein, but as only the gossan is exposed, the mineralization can not be correlated definitely.

Cole Veins

The veins are located on the Diamond Belle group of claims in relatively flat, drift-covered country having an average elevation of 3,300 feet. At least three roughly parallel veins of the sphalerite-galena type are exposed by trenches and shafts.

The most westerly vein is exposed by means of an old shallow shaft, filled with water. A shear zone 6 feet wide, with a northwesterly strike, contains a 3-foot vein on the foot-wall. The surface exposure is greatly oxidized to limonite and manganese oxides, so that the exact nature of the mineralization could not be determined, although sphalerite, galena, and barite were observed.

A second vein occurs 600 feet to the northeast. A series of trenches over a length of about 150 feet exposes a vein 2 feet wide, striking north 10 degrees west, dipping 80 degrees east. The mineralization consists of sphalerite, galena, and pyrite in a gangue of rhodochrosite and quartz. An additional trench about 50 feet to the northeast exposes what may be the same vein, faulted.

The principal vein occurs 900 feet northeast of the old shaft and 6,900 feet northeast of the portal of the main crosscut adit. The vein is from 3 to 4 feet wide, strikes north 60 degrees west, and dips 80 degrees southeast. It is exposed for a length of 400 feet by means of a series of trenches. The wall-rock is highly propylitized microdiorite. The Owen Lake Mining and Development Company sunk a shaft 80 feet deep on the foot-wall. This shaft was filled with water, but it is stated that 123 feet of drifting on the 75-foot level showed a continuous vein. The mineralization consists of strongly banded sphalerite, galena, and pyrite, in a gangue of rhodochrosite, quartz, and barite. The chalcopyrite content is practically negligible. The surface outcrop is well oxidized to limonite and manganese oxides. Mr. Lay states[1] "A sample was taken across 3 feet at one

[1] Op. cit., 1928, p. 171.

point which appeared to be more or less representative of the best mineralized portion; this assayed:

Au trace; Ag 2·6 ounces; Pb 9 per cent; Zn 12·5 per cent.

A sample of selected mineral assayed:

Au trace; Ag 7·8 ounces; Pb 24·5 per cent; Zn 24 per cent."

SNOWSTORM GROUP

The Snowstorm group, consisting of four claims staked by Helmer Larsen in 1928, is on the northeast side of Tiptop hill. The claims are reached by a good trail from the Owen Lake mine, a distance of 3 miles.

The rocks exposed on the claims consist of tuffs, breccias, and andesite porphyrite intruded by several narrow dykes of altered rhyolite. These dykes appear to be post-mineral and bear some resemblance to the post-mineral trachyte dykes at the Owen Lake mine, but contain more quartz than the latter.

The mineralizing solutions are believed to have been derived from the microdiorite stock, the nearest outcrop of the latter being 1¼ miles from the principal showing on the Snowstorm claims.

A sparse mineralization of chalcopyrite, pyrite, tetrahedrite, galena, and sphalerite occurs as scattered disseminations in the matrix of volcanic breccias and as stringers in shear zones and fissures. Two shear zones striking north 35 degrees west and north 70 degrees west contain small stringers of the above minerals, and the wall-rock contains rather sparse disseminations. A series of open-cuts exposes the mineralized zone for a width of about 200 feet. The wall-rock alteration, which is slight compared to that at the Owen Lake mine, is probably propylitization. Mr. Lay states[1] that a sample of selected portions of the mineralized zone assayed:

Gold, trace; silver, trace; lead, nil; zinc, 1 per cent.

IXL GROUP

The IXL group, owned by H. Wade, consists of two claims on the south and east sides of Tiptop hill, near the Snowstorm group.

The rocks are volcanic tuffs and breccias. Two shafts 8 and 10 feet deep respectively, have been sunk on two practically unmineralized shear-zones.

DICK GROUP

The Dick group of claims is 2 miles east of the northern end of Owen lake, on an upland surface with an elevation of approximately 3,500 feet, between Né-uch lake and O-kus-yel-da hill. The claims lie about 4 miles northeast of the Owen Lake mine; they are reached by a good trail as far as Tiptop hill, beyond which a very imperfect trail extends around the west side of the hill to the claims. The group consists of eight claims, owned by H. N. Monk. Two adjoining claims have been staked by H. Wade. At the time of examination no work had been done on any of the claims that had been staked during the autumn of 1928.

[1]Op. cit., 1928, p. 171.

The only rocks observed on these claims were tuffs and breccias. The discovery consists of a large boulder well mineralized with galena, sphalerite, pyrite, and quartz. This float bears some resemblance to Owen Lake mineralization, but its origin cannot be determined.

GRUBSTAKE GROUP

The Grubstake group, consisting of about forty claims owned by F. H. Taylor, P. Pouport, and C. Hansen, is on Tsa-lit mountain. The claims are reached by pack-trail from the northern end of Owen lake, a distance of approximately 5 miles.

The rocks consist of argillites, quartzites, and conglomerates, striking northwesterly and dipping to the southwest. These rocks are intruded by dykes of rhyolite and diorite. The granite stock on mount Nadina is 1½ miles from the claims, and a smaller body of granite occurs to the north of Tsa-lit mountain. The granite may, therefore, underlie the mountain at depth, and the proximity of the granite suggests that its magma was the source of the mineralizing solutions.

The minerals observed were chalcopyrite, pyrite, stibnite, galena, sphalerite, and quartz; with secondary chalcocite, malachite, azurite, limonite, and manganese oxides. The manganese suggests the presence of rhodochrosite below the oxidized outcrops. These minerals occur in a quartz vein in a shear-zone and as replacements in the matrix of conglomerate.

The principal showing is a quartz vein striking north 55 degrees east, near the boundary between Grubstake No. 2 and Grubstake No. 3 claims. The vein is irregularly mineralized over a width of 9 feet, the minerals being chiefly chalcopyrite and pyrite, with some sphalerite, galena, and stibnite and secondary chalcocite, malachite, azurite, limonite, and manganese oxides. The vein is exposed by means of a few open-cuts and one larger pit 7 feet deep. The surface extension had not been proved at the time of examination, the ground being drift-covered and, in places, marshy. A sample over 9 feet at the bottom of the pit assayed: Au 0·06 ounce; Ag 4·73 ounces; Cu 1·41 per cent; Pb 0·34 per cent; Zn 2·44 per cent.

A different type of mineralization occurs on the Grubstake No. 4 claim. This consists of scattered disseminations of pyrite, with a little chalcopyrite, chalcocite, and sphalerite in the matrix of conglomerate. The deposit is imperfectly exposed by means of a few open-cuts. A sample over 2·5 feet in one of these cuts assayed: Au nil; Ag trace; Cu nil; Pb nil; Zn 1·03 per cent. One hundred yards east of this deposit, a 6-inch quartz stringer contains pyrite and copper stains.

MINERAL DEPOSITS AT BUCK FLATS, BRITISH COLUMBIA

By A. H. Lang

A brief examination of Buck Flats district, 8 miles south of Houston, at the confluence of Buck river and Bob creek, was made at the close of the 1929 field season. The mineral deposits of this district are described in the Annual Reports of the Minister of Mines for the years 1916, 1927, 1928, from which some of the following information is derived. The history of mining in this district dates from the days of the Cariboo gold rush, when some placer gold was extracted from the lower reaches of Bob creek. The ruins of workings and cabins belonging to this period can still be seen. Since that time small-scale placer operations have been carried on sporadically by whites and Chinese, and assessment work has been done on lode claims staked more recently. The claims in good standing at the present time are close to the wagon road from Houston to Nadina River post office. This road is in good condition from Houston to Buck Flats, a distance of 8 miles.

The prevailing rocks of the district are tuffs and breccias of the Hazelton series and have a general northwesterly strike. These rocks usually consist of a fine-grained, purplish matrix enclosing angular fragments of cream-coloured feldspathic material. The canyon of Bob creek exposes a belt of light grey, hydrothermally altered volcanics some 2,000 feet wide, containing abundant disseminated pyrite and limonite. This altered belt is known locally as the "porphyrite dyke," but the rock resembles an altered tuff more than an intrusive.

An irregular intrusive body of greenish black diabase is imperfectly exposed on the Bellefield group on the ridge separating Buck river and Bob creek, and beside the road near the Buck River bridge. This rock, which varies from fine to medium grain, consists of phenocrysts of labradorite in a fine-grained groundmass of labradorite and pyroxene, the latter altered to chlorite and bastite. Ilmenitic magnetite altering to leucoxene is relatively abundant. This intrusive is possibly the source of the mineralization.

Tertiary lavas cap the distant ridges, and the stream beds contain many boulders of purplish black vesicular basalt.

The mineral deposits are in the form of narrow, irregular veins and stringers and disseminated replacements in the matrices of volcanic tuffs and breccias. The mineralization consists chiefly of galena, sphalerite, and pyrite with a gangue of chalcedony, quartz, and barite.

BELLEFIELD GROUP

This group, consisting of fourteen claims owned by R. Hayes and two claims owned by Mr. Weiden, is situated on Mr. Hayes' ranch on the ridge separating Buck river and Bob creek. The underlying rocks are cream-coloured and light purplish tuffs and breccias and outcrops of diabase are found near the top of the ridge. An irregular vein with an average width of 6 inches follows the hanging-wall of a narrow shear zone striking north 26 degrees east and dipping 80 degrees to the east. The minerals are galena, sphalerite, pyrite, chalcedony, and barite, with some limonite and black manganese oxide. The manganese in many cases occurs in dendritic growths in fissures, and suggests the presence of rhodochrosite as a gangue mineral. This vein is exposed by means of a shaft 12 feet deep. The region is heavily drift-covered and the continuity of the vein is not shown. Farther up the ridge several open-cuts expose breccias with the fragments silicified and the matrix replaced by chalcedony with a little disseminated pyrite and galena.

BUCK GROUP

This group, consisting of about twenty claims owned by V. Quinn, V. Carter, W. Armstrong, and T. Rush, is situated at the junction of Buck river and Bob creek. Two short adits have been driven on two narrow shear zones, the hanging-wall of each shear containing an irregular stringer of galena and sphalerite with a gangue of quartz and barite. Douglas Lay[1] states " A sample of selected mineral assayed: gold, trace; silver, 42·5 ounces; lead, 7 per cent; zinc, 7 per cent.

HORSESHOE GROUP

These claims, a relocation of the old Porphyrite dyke group, are owned by E. W. Barnum, E. E. Smith, and A. and M. DesBuissy. They are located on the belt of altered volcanics in the canyon of Bob creek, about 1 mile above its mouth. The rock contains disseminated pyrite, and may contain low-grade impregnations of gold from which the placers were derived, since it is stated that no gold was found in the stream above this zone.

A short adit has been driven into the right side of the canyon, exposing disseminations and small seams of pyrite, sphalerite, and a little galena, but no definite vein is exposed. Mr. Lay gives the following assays:

A sample from the seams alone assayed: gold, 1·4 ounce; silver, 2·2 ounces; lead, 0·4 per cent; zinc, 1·8 per cent.

A grab sample over 30 feet along the walls of the tunnel assayed: gold, trace; silver, trace; lead, nil; zinc, 3 per cent.

About 100 yards upstream, a second short adit has been driven in the left side of the canyon where a 3-inch stringer is stated to have assayed: gold, 0·06 ounce; silver, 41 ounces; lead, 3 per cent; zinc, 11 per cent.

PLACER DEPOSITS

No records of placer production from Bob creek are available. The gravels appear to be exhausted, although there is always a possibility of locating an old channel. Such an attempt is being made by Messrs. Carter and MacDonald, who are testing the ground by means of open-cuts.

[1]Ann. Rept., Minister of Mines, B.C., 1927, pt. C, p. 140.

GEOLOGY AND MINERAL DEPOSITS OF QUATSINO-NIMPKISH AREA, VANCOUVER ISLAND, BRITISH COLUMBIA

By H. C. Gunning

CONTENTS

Illustrations

INTRODUCTION

Attention has recently been attracted to the northern part of Vancouver island by operations at the Old Sport mine of Coast Copper Company, Limited, and by the discovery, in 1928, of spectacular surface showings of copper mineralization near Nimpkish lake. In spite of the fact that metal mining has been going on in the district for nearly 35 years, there is very little information available regarding the geology or mineral possibilities of those parts which lie more than a very short distance from the coast. Consequently, in 1929 the writer was instructed to make a reconnaissance examination of the geology, and to examine the mineral deposits of the region lying between Nimpkish lake and Quatsino sound. As this area is large and as transportation away from a few main routes is exceptionally difficult, it was obviously impossible, in one season, to obtain more than a general idea of the geology. The accompanying map (No. 2247) indicates essentially what was encountered in traverses and is not intended to be a finished product; it is published in the belief that any reliable information is better than none and in the hope that it will serve as a guide to the prospector and mining engineer in the district.

During the summer the writer was ably assisted by H. C. Horwood and Norman G. Freshwater. Without the frequent and generous assistance and co-operation of the management and staff of Coast Copper Company, Limited, and of Wood and English, Limited, much of the work would have been well-nigh impossible. Substantial aid was also rendered by the B.C. Pulp and Paper Company and by numerous residents of the district.

PREVIOUS WORK IN THE DISTRICT

The following bibliography contains the more important papers that have been written concerning the geology and mineral deposits of the district. George M. Dawson's work contains an abundance of valuable information and also describes in detail, greater than it is possible to obtain today, the results of exploration and drilling of the Suquash and Quatsino (Koskeemo) coal fields. The reports by Dolmage contain the most up to date version of the geology around Quatsino sound and the volume by Young and Uglow describes in detail many deposits of magnetite. Occasional geological notes and much valuable general information is found in "Extracts from Reports of the Provincial Crown Lands Surveys," published in 1901. The writer was fortunate in being supplied with unpublished manuscript maps prepared by Dolmage of the shore-lines of Quatsino sound and some of this information is incorporated in the map accompanying this report.

Crickmay, Colin H.: "Stratigraphy of Parsons Bay, B.C."; University of California Publications. Bull. vol. 18, No. 2, pp. 51-70 (1928).

Dawson, G. M.: "Report on Geological Examination of the Northern Part of Vancouver Island, with Adjacent Coasts"; Geol. Surv., Canada, Ann. Rept., vol. II, pt. B (1887).

Dawson, G. M.: "The Mineral Wealth of British Columbia"; Geol. Surv., Canada, Ann. Rept., vol. III, pt. R (1889).

Dolmage, V.: Geol. Surv., Canada, Sum. Repts. 1918, 1919, pt. B, 1920, pt. A.

Lindemann, E.: "Iron Ore Deposits of Vancouver and Texada Islands"; Mines Branch, Dept. of Mines, Canada. Pub. 47, 1910.

Young, G. A., and Uglow, W. L.: "The Iron Ores of Canada, vol. I, B.C. and Yukon"; Geol. Surv., Canada, Econ. Geol. Series No. 3 (1926).

Uglow, W. L.: "Genesis of the Magnetite Deposits near the West Coast of Vancouver Island"; Econ. Geology, vol. 21, pp. 352-363 (1926).

Minister of Mines, B.C., Ann. Repts., 1899-present.

The Vancouver sheet, Map 196A, of the Geological Survey, 1928, shows geology along the coast-line. Blue prints, covering the entire area on a scale of 1 mile to 1 inch, showing roads, trails, settlements, timber limits, and Crown-granted mining claims, may be obtained at a nominal price, from the Surveyor General, Victoria, B.C., and these are the best base maps as yet available.

NATURE OF THE DISTRICT

ACCESSIBILITY AND TRANSPORTATION

The northern part of Vancouver island is, from the point of view of accessibility, particularly favourable to prospecting and mining development. Adequate transportation from Vancouver is provided by three boats a week of the Union Steamship Company and one of the Canadian

Pacific railway. These boats call at Englewood and Port Hardy on the east coast of the island, the time from Vancouver to Englewood being about 15 hours and to Port Hardy about 21 hours. On the west coast a Canadian Pacific steamship makes three trips from Victoria to Port Alice every month, calling at Quatsino, Jeune Landing, and several canneries in Quatsino sound; and during the summer months a second boat is generally placed in service. This trip takes from 2 to 5 days, depending on weather and the amount of trade. An auto stage runs from Port Hardy to Stephens bay on Quatsino sound, 11 miles, connecting the east and west coasts. Englewood is the main camp and mill-site of the Wood and English, Limited, a logging company, and a logging railway extends from it to the northeast corner of Nimpkish lake where two tugs maintain connexions with two logging camps on the lakeshore. From Jeune Landing on Quatsino sound it is about 15 miles by truck and launch, in five stages, to the Old Sport mine and a wagon road is maintained between Port Alice and Victoria lake. Quatsino village, scattered along the north shore of Quatsino sound for several miles, is served by a wagon road and a similar road, barely suitable for cars, extends 8 miles westward from Holberg. Thence a trail continues some 4 or 5 miles to San Joseph bay and other points on the west coast. A 4-mile road, used by a tractor, leads to the Caledonia mine from the Stephens Bay-Port Hardy road. The main trails in the district are shown on the accompanying map. In addition it is possible to go by trail and canoe from Coast Copper to Port McNeill, following Three Lakes valley, but it is believed that the eastern end of this trail is hard to follow. It is also said that a trail has been blazed from Kokshittle arm to the head of Neroutsos inlet on Quatsino sound. All the trails are unsuited to pack-horses because of numerous swamps and a loose mantle of moss and soil which covers roots and rocks. Accordingly, away from the main roads or lakes all supplies are transported by back-packing. To travel across country, off the trails, is exceedingly difficult on account of exceptionally heavy growth of timber and bush and the rugged topography. With the exception of Nimpkish river none of the streams is navigable for any distance.

It is generally possible to hire launches at Quatsino village for about $12 a day—nothing short of a launch is suitable there for any extensive travel as sudden storms and bad currents are common. One cannot count on hiring launches during the summer on the east coast nor at any time on Nimpkish lake. The latter body of water is rather treacherous for rowboats or canoes, severe northerly or southerly winds being of almost daily occurrence. Between Jeune Landing and the Old Sport mine all transportation is supplied by Coast Copper Company.

Hotels exist at Port Hardy, Stephens Bay, Quatsino, and Port Alice and accommodation can generally be obtained through the courtesy of the company at Englewood. Jeune Landing is inhabited by two employees of Coast Copper Company and Holberg does not boast an hotel, although some of the settlers would probably provide for a visitor. A telephone system between Port Hardy, Stephens Bay, Quatsino, the Old Sport mine, Jeune Landing, and Port Alice, and other points, connects the community, by means of wireless, with the outside world. Port Alice is the site of a pulp mill of the British Columbia Pulp and Paper Company, Limited, and several small logging camps on Quatsino sound supply the company with timber.

The climate is well adapted to the production of vegetables and small fruits and the fish industry supplies many of the inhabitants with employment during the summer months. Fish are fairly abundant in many of the streams and lakes and deer and black bear abound in most parts of the district. There are also some fine herds of elk, now heavily protected by the government.

TOPOGRAPHY

From Quatsino sound to the north end of the island a series of rolling, but in places exceedingly rough, hills, seldom exceeding 2,500 feet in elevation, alternate with low-lying valleys and swamps. The whole is covered with a dense growth of hemlock, cedar, pine, and underbrush (*See* Plate II A). South of the sound, to the 50th parallel, the district is much more mountainous, although very few peaks attain an elevation of 6,000 feet (*See* Plate II B). Probably 95 per cent of the country is covered with timber and, with few exceptions, the mountains, in spite of their moderate heights, are rough, abounding in bluffs and steep-walled valleys. Between Nimpkish lake and the east coast very few points rise above timber-line. Nimpkish valley south of the lake is a broad, low-lying, heavily wooded tract spotted with numerous lakes. Particularly rough mountainous areas lie south of Atluck lake and from Tahsish valley to Kokshittle arm and Victoria lake. A long, bare-topped ridge extends down the east side of Raging River valley and Karmutsen range just west of Nimpkish lake affords a few good observation points. The streams either meander in flat, wooded valleys or abound in canyons and falls, so that, except at very low water, they offer very poor routes for travel.

CLIMATE

The climate is more or less typical of all but the southern part of the west coast of British Columbia. An abundant rainfall, approaching 100 inches a year, is generally concentrated between October and May, but sometimes persists throughout the summer months. As a general rule, however, pleasantly warm and dry days are expected in June, July, and August. As a natural consequence of such extreme precipitation the climate is mild. During the summer excessive heat is practically unknown and seldom do the lakes freeze over during the winter. The snowfall is generally light and does not interfere seriously with transportation. Thus the climate is one with abundant rain which renders outdoor work unpleasant during much of the year, but at no time prevents it or makes it excessively difficult. The rain, as well as supporting a luxuriant growth which is undesirable from a prospecting viewpoint, also supplies the numerous lakes and rivers with an abundance of water that, in many places, could be easily converted into power.

MINING HISTORY

Metal mining probably dates from the year 1897 when Messrs. Haslam, Mathers, and Stark staked several claims on extensive showings of magnetite on Nimpkish river, 5 miles south of Nimpkish lake. In the following year the Yreka, Teeta River Gold (Quatsino King), and other claims were located on Southeast arm, Quatsino sound. For several years afterwards these and other claims were actively developed by various mining concerns and interest centred chiefly in Quatsino district. Several shipments of copper ore were made from the Yreka, but the undertakings proved unprofitable in practically every instance and not until 1911, when copper was discovered near Elk lake, on claims now held by Coast Copper Company, Limited, did the district show promise of producing a commercial mining enterprise. Development has proceeded systematically at Coast Copper, especially since 1916 when Consolidated Mining and Smelting Company assumed control. All other properties have experienced a series of ups and downs, so that, on the whole, little attention has been given to the district, although a considerable amount of money has been spent annually on development and exploration. Consolidated Mining and Smelting Company has recently assumed control of the old June group, west of Alice lake, and, after an extensive diamond drilling campaign has commenced underground development. In the autumn of 1928 E. L. Kinman and associates discovered some spectacular copper mineralization on Copper creek, 3½ miles east of the south end of Nimpkish lake. A small prospecting rush followed and in less than two years some two hundred mining claims have been staked in the vicinity. Last autumn the original discovery was optioned by Consolidated Mining and Smelting Company and diamond drills have been employed during the winter.

During 1929 the following additional operations were under way in the district:

The Caledonia mine near Quatse lake was developed by Consolidated Mining and Smelting Company and in September the option was dropped.

The Alice Lake group, west of Alice lake, was developed by Messrs. Clancy and Kinsey of Quatsino.

The Millington group, near Holberg, was developed by its owners, Spooner Bros. and Associates.

The Quatsino Gold and Copper Company's claims south of Coast Copper were prospected and surveyed.

The Bowerman group, north of the west arm of Quatsino sound, was developed by the owners.

The Blue Ox group, south of Quatsino Gold and Copper, was drilled and abandoned by Consolidated Mining and Smelting Company.

The Big Chief and other claims, north of the Blue Ox, were prospected by Consolidated Mining and Smelting Company.

Numerous prospectors were active in the vicinity of Nimpkish lake and several groups of claims were staked and a certain amount of prospecting was done on the extreme northern end of the island. Certain copper claims on Kokshittle arm were prospected or developed and a fair amount of work was done on several claims on Zeballos river. Many of the old properties are Crown granted and lying idle.

The Suquash coal field on the east side of the island was explored by the Hudson's Bay Company as early as 1852 and the Koskeemo area on Quatsino sound received attention prior to 1883 and more recently. At present they are lying idle.

GENERAL GEOLOGY

By far the greater part of the region under discussion is underlain by rocks of the Vancouver group. This group, synonymous with Dr. Dawson's Vancouver series as defined in 1887, constitutes the oldest rocks that have been observed and consists of a thick assemblage of volcanic flows and fragmentals interbedded with limestones, argillites, quartzites, and other sediments. Intruding the Vancouver group are stocks, dykes, and irregular bodies of granitic rock which are believed to be closely associated, in time of intrusion, with the main Coast Range batholith, and which are termed, collectively, Coast Range intrusives. Numerous basic and acidic dykes are associated with these intrusives. Overlying the rocks of the Vancouver group in certain limited areas, generally adjoining the coastline, are conglomerates, sandstones, and shales of Cretaceous age. They are not known to be cut by the Coast Range intrusives. In several places they contain rather small seams of coal. These Cretaceous sediments are the youngest consolidated rocks that have been found in the area. Glacial deposits and Recent sands, gravels, and clays cover much of the low-lying ground. The following table summarizes the geology of the region.

Quaternary	Recent and Pleistocene	Superficial deposits	Sand, gravel, clay; glacial drift
		Unconformity	
	Lower Cretaceous		Sandstone, shale, conglomerate
		Unconformity	
Mesozoic	Late Jurassic?	Coast Range intrusives	Granodiorite, quartz-diorite, diorite, gabbro; granite
		Intrusive Contact	
	Jurassic? and Triassic	Vancouver group	Volcanics: flows of andesite, basalt, dacite, etc.; breccia tuff. Sediments: limestone, argillite, quartzite, tuffaceous argillite

VANCOUVER GROUP

As mentioned above, the Vancouver group consists of a great and, as far as is known, conformable, succession, of volcanic and sedimentary rocks. The volcanic rocks, including flows and fragmentals, form the large part of the group, but sediments are interbedded with them in many places. For purposes of description it is convenient to divide the group into two parts, namely, volcanics and sediments.

Volcanics of the Vancouver Group

The volcanic rocks of the Vancouver group present many problems that can only be solved by further and more detailed field work. It is undoubtedly advisable to discuss here not only those features which are rather definitely established as facts, but also some of the numerous as yet unsolved problems that confront the geologist working in these rocks. As stated above, the group consists essentially of flows and fragmentals. The coarser fragmentals are easily recognized in the field, but the finer grained varieties grade into sedimentary rocks and are in many cases exceedingly difficult to distinguish from the latter. The greatest problem of identification, however, lies in the flows, for these rocks exhibit considerable variation in composition and texture and, in addition, there are associated with them many intrusive varieties which they closely resemble. These intrusives are believed to represent feeders for overlying flows and consequently they properly belong in the Volcanic group. Unfortunately a large percentage of the flow rocks exhibit little or no flow structures. Because outcrops are poor over much of the area, one is frequently forced to attempt to classify the rocks of the group merely by their appearance, without knowing the structural relations. The similar appearance of intrusives and flows renders this an exceedingly difficult undertaking and the process is still further complicated by the fact that basic dykes, very similar in appearance to those connected with the volcanism, are known to cut the Coast Range intrusives of the area. As a result of all this, in examining outcrops one is frequently at a loss to decide whether the rock is a true flow, an intrusive connected with the vulcanism, or an altogether later intrusive rock. Nevertheless, certain facts may be given regarding the flows of the Vancouver group. They are predominantly intermediate to basic in composition, andesite and basalt being most abundantly developed. More acidic phases, including dacite and rhyolite, have been observed, but they form a very minor part of the whole assemblage. Typically the rocks are light to dark green or almost black. Flow structures are almost entirely lacking, but many beds of amygdaloid are developed, particularly in the basalts. The amygdules are filled with calcite, quartz, chlorite, epidote, and occasionally feldspar, and where quartz and epidote are developed the amygdules generally stand out prominently on weathered surfaces. Epidote, in specks and irregular areas up to several feet in diameter, is quite typically but by no means always developed. The common alteration, which is frequently quite extreme, is the development of chlorite with lesser amounts of sericite, calcite, and epidote. Typically the andesites are dense to finely crystalline, light or dark green rocks. Under the microscope they were found to consist of plagioclase which varies in composition from oligoclase to labradorite, small amounts of, or no, alkali feldspar, and brown to green pleochroic hornblende. Quartz is generally very sparingly developed or absent. Pyrite is commonly present as tiny crystals and chlorite, sericite, and calcite are alteration products. In the more basic varieties, where labradorite or andesine-labradorite is developed, augite more or less altered to hornblende (uralite) may generally be found. Magnetite, sometimes in skeleton crystals, was observed in the basic varieties also. Biotite is only very occasionally present. The basalts are more black than green in colour and are commonly amygdaloidal. Calcitic plagioclase, generally true labradorite, and augite are the essential constituents. Quartz is generally absent. Uralite, chlorite, epidote, and calcite are products of alteration. Pyrite and magnetite may or may not be present. The more acidic types, including dacite and rhyolite, are light green to grey in colour and dense or fine-grained, holocrystalline. The feldspars include orthoclase and plagioclase varying in composition from albite to oligoclase. Biotite is generally present instead of hornblende and quartz forms up to about 10 per cent of the rocks, being generally very fine grained. Apatite and magnetite were observed in several thin sections in small crystals. Epidote, chlorite, and sericite are alteration products. In several localities within the volcanics, notably on Victoria lake and in the vicinity of the Old Sport mine, there are considerable bodies of green to black porphyries in which white feldspar laths up to, but generally less than, an inch in length stand out prominently. Specimens from the Old Sport mine and from the east shore of Victoria lake were examined under the microscope and the feldspar phenocrysts were found to be labradorite near the andesine end. Augite was the next most abundant mineral in the Victoria Lake section and green hornblende in the Old Sport mine specimen. Magnetite was present in both. Chlorite, epidote, and sericite are alteration products. Thus it appears that these porphyries are basaltic to andesitic in composition and that their mineralogy is very similar to the flows with which they occur. They form irregular bodies in the lavas and are presumed to be an integral part of the volcanic series formed during cooling of large flows. Nevertheless, they closely resemble certain porphyry dykes which cut the volcanics so that their actual origin is somewhat doubtful. Coarse, even-grained masses of similar composition to the porphyries are also found in many places in the flows and may be classed with the porphyries in that they also seem to grade into the surrounding rocks and do not exhibit any intrusive contacts.

No well-formed flow structures were observed in the lavas. In one or two places structures resembling pillow lavas were seen, but, on the whole, this structure either was never developed or has been destroyed by subsequent metamorphism. One or two examples of flow contacts were found and in one case there was a slight flow structure (banding) near the edge of an acidic bed. It is remarkable, however, that even in areas of extensive outcrops contacts and banding are exceedingly difficult to find. Consequently it is well nigh impossible to obtain trustworthy structural determinations in the lavas. Also, although the rocks are extensively altered, yet, except locally near intrusive bodies and occasionally elsewhere, they are not extensively sheared.

The fragmental rocks of the Vancouver group include breccias and tuffs. The breccias are defined as those varieties that are readily seen, by the naked eye, to be fragmental. They consist of reddish, green, or grey fragments generally from 1 inch to ½ inch in diameter, but also attaining diameters up to several inches and less than ¼ of an inch, set in a variable proportion of fine-grained, green, grey, or red groundmass. Very seldom indeed is any bedding visible in these rocks. By microscopic study it was found that the fragments are largely andesitic to basaltic in composition and that they are surrounded by material which in some cases seems to be andesite or basalt very similar to the normal flows of the district and in other cases is a very fine-grained, semi-transparent, dust-like material which presumably is volcanic dust or ash. Not all the fragments are volcanic material, however; in many breccias particles of argillite and limestone, varying from dark grey to white in colour, were identified, and there seems to be every gradation between straight volcanic breccias and sedimentary ones. Many of the rocks are amygdaloidal. The tuffs are merely the fine-grained equivalents of the breccias and the same varieties may be recognized. They grade from ordinary greenish volcanic tuffs to grey and black tuffaceous argillites and the finer grained, partly sedimentary varieties are frequently well banded, causing their resemblance to normal sediments. Microscopically they consist of small fragments of volcanic and sedimentary rocks very similar to those that occur in the Vancouver group. A few distinctly calcareous varieties were noted. There can be no doubt that many of the banded varieties are water-lain deposits.

On the accompanying map flow rocks and fragmentals are not separated (Map 2247). Areas where the fragmentals are most abundantly developed include that section near the head and east of Elk river; on the shores of Victoria lake near the northerly end of the volcanic exposures and similarly on Neroutsos inlet south of Port Alice and at intervals on the west shore north of Port Alice; near the headwaters of Kilpala creek; and to a more limited extent east of the south end of Nimpkish lake. Elsewhere the fragmentals form a minor part of the areas mapped as volcanic rocks. On Bean shoulder, near the head of Bean creek, several small beds of spherulitic lava were noted. On weathered surfaces the spherulites stand out as rounded, grey nodules one-half inch or less in diameter. The spherulitic beds are intercalated with fine-grained, finely banded layers which are probably acidic lavas. The spherulites consist of radiating groups of feldspar with a small amount of intergrown quartz and are extensively altered to calcite and sericite.

Sediments of the Vancouver Group

Intercalated with the volcanic rocks at different horizons are limestones, argillites, quartzites, tuffaceous argillites, and gradations between these. In a general way it may be said that the sediments occur in rather well-defined zones which can be traced along their strike for many miles, although individual beds are apparently more or less lenticular, causing the thickness of the sedimentary zones to vary greatly. However, interbedded volcanic rocks in many places form a considerable part of these zones. Before the structure of the Vancouver group can be worked out the sediments will have to be mapped carefully and their successions established. Fortunately some of the limestones and quartzites and a larger proportion of the argillites are fossiliferous, and although in many places the fossils are too poorly preserved to be of use as horizon markers yet a few good collections have been made and more detailed work will undoubtedly produce valuable material.

Limestone is the most abundant sediment. Where it forms large and relatively pure beds it has been shown on the accompanying map. Small beds and impure argillaceous or carbonaceous ones are included with the argillites and quartzites and with the volcanic rocks. The purer and larger beds are white to grey and are generally distinctly crystalline. Exceedingly fine-grained beds form a small percentage of the whole and siliceous or cherty varieties are likewise sparingly developed. Every specimen examined by the writer effervesces freely in dilute hydrochloric acid. The most important limestone horizon in the area is that shown on the map along the east side of Neroutsos inlet and which continues southeast past Alice lake, Kathleen lake, and then across the valley of Elk river into Raging River valley. A traverse from Nimpkish lake to Tahsish river showed that similar limestone outcrops a short distance west of Atluck lake and this probably is a continuation of the above. Dolmage[1] suggests the name Quatsino limestone for this member. In its lower portion, in the vicinity of Kathleen and Alice lakes, this limestone contains small interbeds of lava and above it lies a mixed series of argillites, quartzites, and volcanics in which there are small beds of argillaceous limestone. The Quatsino limestone is the host rock for several mineral deposits, including the Old Sport and June mines, the Alice Lake group, and others and on Neroutsos inlet certain beds are quarried by the B.C. Pulp and Paper Company for their pulp mill at Port Alice. The continuation of the Quatsino limestone to the northwest of Quatsino narrows is not definitely established, as there is faulting of considerable importance in this vicinity. Other important beds of limestone occur above the Quatsino limestone in the vicinity of the Yreka mine on the west side of Neroutsos inlet and also at several places on Nimpkish lake. They are all similar in appearance, varying in colour from white to dark grey. The most extensive exposures on Nimpkish lake are found for about 3 miles north of Willow creek on the west shore and this formation has been traced up Nimpkish valley as far as the Klaanch group of claims, where it is still of a considerable thickness and continuing in a southeasterly direction. No geological work other than indicated on the map has been done between Nimpkish lake and the east coast of the island, but it is reported that limestone outcrops on Bonanza lake and there is limestone a short distance west of the head of Beaver cove.[2] A glance at the map shows that most of the mineral deposits of the area are found in limestone; the importance of following and prospecting beds of it cannot be stressed too much.

[1]Dolmage, V.: Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 32.
[2]Dawson, G. M.: Geol. Surv., Canada, Ann. Rept. 1886, pt. B, p. 57.

Argillites and quartzites, with interbedded volcanics and limestones, are indicated on the map. These two rocks vary in colour from light grey to black and are generally well bedded. The quartzites are hard and very fine grained, and are in many cases finely laminated. The most important argillite zone is exposed on the west shore of Neroutsos inlet and continues thence, south of Port Alice, past Victoria lakes and thence southeasterly. Southwest of Elk lake the zone was not definitely located, but inclusions of argillite were noted in the intrusive body shown on the map. Abundant outcrops were again observed on Blue Ox and Rainier creeks and they are assumed to be a continuation of the Port Alice-Victoria Lake horizons. Flows, tuffs, and breccias are interbedded with the argillites and impure to pure limestone lenses were noted in several places. A small bed of brownish chert was examined on the east shore of Victoria lake. Poorly preserved fossils were found in argillites and calcareous to tuffaceous argillites on Neroutsos inlet south of Port Alice, on Victoria lake, and on Rainier creek. On Rainier and Blue Ox creeks the rocks are locally extensively sheared and contorted and to a lesser extent, also, on Victoria lake. The only other marked development of argillite and quartzite is found near the south end of Nimpkish lake and there, also, fossils were found at several localities.

Structure of the Vancouver Group

The regional strike of the rocks of the Vancouver group is northwest and the general dip is to the southwest. Variations from this attitude occur and may be seen on the map acompanying this report. The most important variations are in the vicinity of Kathleen and Victoria lakes and near Port Alice and, to a lesser extent, near Nimpkish lake. In these localities there are important intrusions of granitic rock and it is evident, in the field, that the folding and contortion of the rocks of Vancouver group are directly connected with the intrusions. The general tendency seems to be a contortion and tightly compressed folding of the intruded rocks near the intrusives with a doming up of the former around the latter so that locally, near gigantic stocks and between adjacent ones, almost any attitude may be expected. There is not as yet sufficient detailed information to reveal the structure across the strike, but it is presumed that the rocks of the Vancouver group are compressed into a series of parallel overturned folds with the prevailing dip to the southwest. If this is not so we would be forced to conclude that there is a continuous succession of volcanic and sedimentary beds from the east and the west side of the island and the resultant thickness of the group would be so enormous that one is forced to discredit the possibility. Also, there is evidence in several places of repetition of beds due to tight folding and everturning.

There are many minor faults, showing displacements of a few inches up to about 200 feet in the Vancouver group. These are best observed where mining operations have given good exposures, as in the Old Sport mine. Many of these faults strike within the northeast quadrant and dip very steeply. Less is known about major faulting. In Quatsino sound, in the vicinity of the narrows, there is probably much faulting of major displacement and similarly important faults may later be found near Nimpkish lake. Four faults along which displacement of considerably more than 100 feet may have taken place are marked on the map (No. 2347). During the compressional movements which produced folding the rocks of the Vancouver group have behaved in different ways. The limestones are recrystallized and somewhat faulted. The flow rocks and the breccias are broken by faults and chloritized, but are very seldom sheared or crushed. They may have recrystallized to some extent as flow structures are generally absent. Of all the rocks the argillites and argillaceous varieties have been most susceptible to shearing and crushing and it is only in these rocks that important shear zones were observed.

Age of the Vancouver Group

The first fossil collections from the Vancouver group of northern Vancouver island were made by G. M. Dawson[1]. Dr. Dawson concluded that the "Vancouver series" was of Triassic age, but suggested that further work might reveal the presence of Carboniferous strata. Dolmage[2] collected fossils on the west coast of the island and the outstanding species was "*Pseudomonotis subcircularis*" which was taken to indicate a thin zone in the upper Triassic. In 1929 the writer collected fossils from sediments in the Vancouver group at three different localities—at the southwest corner of Nimpkish lake, on the west side of Victoria lake, and on Neroutsos inlet south of Port Alice.

Following is a preliminary report on the collections by F. H. McLearn of the Geological Survey:

"Fossil lot No. 1. Vancouver series, southwest corner of Nimpkish lake. On railroad grade 200 yards south of logging camp wharf.

Halobia sp.
Orthoceras? sp.
Ammonites, not well preserved.

Date. Triassic.

Fossil lot No. 2. 1,100 feet southwest of, and 800 feet stratigraphically above, lot No. 1.

Halobia? sp.

Date. Triassic?

Fossil lot No. 4. Victoria lake, west side, about ½ mile north of end of wagon road from Port Alice.

Pecten? sp.
Pinna sp.

Date. Jurassic?"

In addition, some undeterminate pelecypods were examined from the collection south of Port Alice. From the above it appears that in part the Vancouver group is undoubtedly Triassic, but that in the vicinity of Victoria lake it may possibly be Jurassic. This is about all that can be said for the area within which the writer has worked.

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[1]Geol. Surv., Canada, Ann. Rept., vol. II, pt. B, p. 9, et. sec. (1887).
[2]Geol. Surv., Canada, Sum. Rept. 1920, pt. A, p. 15.

Quite recently C. H. Crickmay[1] has published a report on that part of the Vancouver group that outcrops in Parson bay, on Harbledown island, east of Englewood. He finds that Noric beds of the Upper Triassic are overlain by Lower Jurassic strata of argillite and quartzite. Since the uppermost Triassic or Rhaetic is apparently missing he assumes a disconformity. Consequently, on Crickmay's evidence it appears that Lower Jurassic as well as Upper Triassic beds are included in the Vancouver group. Whether the Jurassic fauna occur in the Quatsino-Nimpkish area is as yet uncertain.

COAST RANGE INTRUSIVES

These rocks cut the Vancouver group and are not known to intrude the Lower Cretaceous sediments which are sparingly developed in the area. They are, therefore, presumed to be late Jurassic in age, but it is admitted that they may possibly be early Cretaceous. They form sills, dykes, stocks, and irregular bodies in the Vancouver group and are economically the most important rocks of the district as it is believed that the mineral deposits are directly associated with them. The larger bodies in the area are shown on the map (No. 2247). Additional bodies along the adjoining coast lines are shown on the Vancouver sheet, Map 196A, of the Geological Survey, Canada. The Coast Range intrusives are holocrystalline, igneous rocks which vary in colour from pink and brown to grey and dark greenish grey. They include granite, granodiorite, diorite, quartz diorite, and gabbro and associated with the larger bodies are many complementary basic and acidic dykes. The body at the end of Rupert inlet is a true granite, pinkish brown to grey in colour, and consists almost entirely of quartz, orthoclase, and a small amount of albite oligoclase. The rock is extensively carbonated and slightly chloritized. Dolmage[2] has classified the intrusion near the Yreka mine as quartz diorite. The body at the head of Neroutsos inlet is essentially a quartz diorite consisting of about 10 per cent quartz, much coarsely crystalline zoned plagioclase of about the composition of andesine, and altered crystals of augite, partly converted to uralite and chlorite. Apatite is sparingly present and the feldspars are sericitized. Iron ore forms numerous small grains. The body is considerably differentiated, however, and undoubtedly contains much granodiorite, and many large white to brownish dykes of quartz porphyry and feldspar porphyry are found around the periphery of the main body. The Victoria Lake stock is very similar to the Neroutsos Inlet one, but the granodiorite phase seems to be more abundantly developed. The more basic phases, which are also abundantly developed, vary from quartz hornblende diorite to quartz gabbro-diorite and there are also many acidic dykes in the neighbourhood of the main body. Very similar is the body southwest of the Old Sport mine. The more basic phase occurs along the northeastern edge and varies from normal gabbro in which the augite is almost entirely converted to hornblende, to gabbro which consists very largely of labradorite and which consequently approaches the composition of anorthosite. These two types are coarse grained and dark greenish grey in colour. The southern edge of this body is much more

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[1] "The Stratigraphy of Parson Bay, B.C."; University of California Press, Berkeley, California, 1928.
[2] Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 37.

irregular both in outline and composition than the northern part and includes, with more basic varieties, many large dykes of acidic granodiorite and smaller bodies of very fine-grained aplite. These three stocks, the Coast Copper, Victoria Lake, and Neroutsos Inlet stocks, are so nearly alike in appearance and composition, and are so closely spaced that there can be little doubt that they represent protrusions of one large body which, between them, is covered by rocks of the Vancouver group. This theory is supported by the fact that, in the intervening Vancouver group between the stocks there are many basic and acidic dykes which are believed to be differentiates of the main intrusions. The body which crosses Kilpala creek and outcrops on the west shore of Nimpkish lake is medium to coarse grained and rather uniform in composition. It consists of oligoclase and zoned plagioclase, about an equal amount of orthoclase and perthite, and quartz. Brownish hornblende and brown to green biotite are the principal accessories. Many small pinkish brown, slightly more acidic dykes cut the main body which is grey to greenish grey in colour. The large intrusion southeast of Nimpkish lake is essentially granodiorite, although parts of it closely approach granite in composition. Oligoclase or albite oligoclase, orthoclase, and quartz are the essential minerals and hornblende and biotite are the chief accessories. As in the Kilpala Creek body, there are many small, brownish aplite dykes in the main body. The intrusive on Smith creek has not been studied microscopically, but it is probably a hornblende granodiorite. There are many light grey quartz porphyry dykes in the vicinity. The Caledonia Creek intrusive, in the northern part of the area, is a brown weathering, grey, medium-grained, siliceous granodiorite cut by brown aplite dykes.

In the vicinity of most of the stocks there are many acidic, basic, and porphyry dykes. They are believed to be related in origin to the main intrusive bodies in that they represent differentiates from the same parent magma. The more acidic varieties are white, grey, or light green rocks of exceedingly fine texture and vary in composition from that of felsite to about andesite. Orthoclase or sodic plagioclase—albite or albite-oligoclase—and quartz are the chief constituents and pyrite is generally present. The basic varieties include green to almost black dykes which range in composition from andesite to diabase. Larger dykes of this class are true diorites. The porphyries include acidic, white or light grey to brownish quartz porphyry and feldspar porphyry, and basic feldspar porphyries which approach diabase or gabbro in composition. A few augite porphyries were observed, but they are by no means abundant. It is probable that most of these dykes post-date the larger intrusions. Green to black lamprophyres cut the granodiorite stock southeast of Nimpkish lake and a few fine-grained felsite dykes were found in the stock near Coast Copper. The relations of the acidic to the basic phases have not been determined. Some of the basic feldspar porphyries at the Old Sport mine are evidently later than the mineralization, and some of the felsites are mineralized and extensively altered to garnet, epidote, chlorite, etc. Also, it should not be forgotten that diabase dykes, similar to those that occur cutting the rocks of the Vancouver group, have been found to intrude[1] the Lower Cretaceous rocks on

[1]Dolmage V.: Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 33.

Quatsino sound. Although some of the diabases in the Vancouver group may belong to this period of intrusion all of them do not, for on Nimpkish lake a medium-grained, greenish grey diabase is altered by garnet, epidote, and other contact metamorphic minerals and consequently antedated the mineralization which is related to the Coast Range intrusives.

Near the larger Coast Range intrusives the limestones of the Vancouver group are locally recrystallized to coarse-grained marbles; in places they are replaced by contact metamorphic silicates and magnetites and occasionally they are slightly sheared. The volcanics are less altered, but in several places they were found to be sheared, granitized, and epidotized near a contact. Baking and shearing seem to have been the principal alterations in the argillites and quartzites. In many of the stocks numerous inclusions of volcanic and sedimentary material were observed, and they varied from hazy, ghost-like, granitized forms to sharp, well-defined fragments. Evidently replacement and stoping of the country rock have taken place, but the contortion and folding which, as mentioned above, are evident near most of the stocks, demonstrate that considerable pressure was exerted during intrusion and there is some evidence to indicate that the volcanics and sediments have been forced into more or less complexly folded, dome-like structures around and over the intrusive bodies. Locally, in the vicinity of intrusive bodies, the sediments, and particularly limestone, are extensively silicified.

In the vicinity of Neroutsos inlet and Alice and Victoria lakes many white or grey felsite and quartz porphyry dykes are quite pyritic and weather deeply to a soft, but coherent, light brown material which is frequently very finely banded in thin, light grey or white, and brown layers. The weathered rocks are peculiar in appearance and are mentioned here to avoid any difficulty that might be encountered in the field in classifying them, as it is frequently difficult to ascertain the action of the unweathered portions due to the depth to which weathering has proceeded.

CRETACEOUS ROCKS

The Cretaceous rocks that occur in the area were not examined carefully by the writer. The only area shown on the map is that which extends from the north side of Rupert inlet to Stephens bay and beyond. Conglomerates and sandstones are most abundantly developed. Shale is present in small amount and there are several small coal seams on the north shore of Holberg inlet. Dolmage mentions finding boulders of granodiorite in the conglomerate at Koprino harbour. Volcanic and granodiorite boulders which are very similar to the rocks of the Vancouver group and the Coast Range intrusives were noted by the writer on Rupert inlet. Although at no place was the contact between the Cretaceous rocks and the Vancouver group well exposed, yet it appeared that the former were separated from the latter by a sharp, angular unconformity and that the Cretaceous sediments have suffered little deformation since their deposition. They at present dip at very low angles and were probably laid down on a rolling, uneven surface on the already much folded rocks of the Vancouver group. A small fossil collection was made near the mouth of

Kewquodie river, some 10 miles from the entrance of Quatsino sound on the south shore, and F. H. McLearn has tentatively identified *Pleuromya, Goniomya,* and *"Pecten"*, which he concludes indicate Jurassic or Cretaceous age. Dolmage[1] has previously reported that these beds are correlated with the Upper Knoxville (Lower Cretaceous) of California.

GLACIATION AND RECENT DEPOSITS

The only post Lower Cretaceous geological record within the Quatsino-Nimpkish area is one of Pleistocene and Recent erosion and local Recent deposition. There can be no doubt that the region was heavily glaciated. Bedrock, where naturally or artificially exposed, is fresh or very slightly oxidized and at times retains the markings of glacial erosion. The upper outcrops on the Caledonia group, about 1,100 feet above sea-level, are deeply striated and grooved and parts of the magnetite have been well polished by passing ice. A few of the streams flow in typical U-shaped glaciated valleys, one of the best examples the writer has ever seen being the valley which runs from the head of Elk river to Tahsish river. This valley is remarkably straight, the bottom is broad and flat, and the walls rise abruptly on either side to elevations of 2,000 to 4,000 feet above the bottom. Mountain spurs running into the valley are beautifully truncated. At its head the valley rises abruptly about 1,000 feet to the Elk River divide. Stream gravels, clays, boulders, and sands cover large areas of low-lying ground and gravel and sand benches adjoin many of the valleys. Unsorted boulder clays and stratified glacial clays and sands are found between the outlet of Nimpkish lake and Englewood over considerable areas. The more important areas of recent and glacial drift are shown in part on the accompanying map (No. 2247), and may be assumed as covering much of the bottoms of all the larger valleys.

MINERAL DEPOSITS

CLASSIFICATION AND ORIGIN

There are no producing mines within the Quatsino-Nimpkish area. In the past a few small shipments of copper ore have been made, but no commercial success can be attributed to them. One property, that of Coast Copper Company, Limited, has been developed to a stage where future production is assured and several others are worthy of extensive exploration. Also, there are large, unprospected areas which may reasonably be expected to contain additional mineral deposits. Among the known properties copper deposits, containing chalcopyrite and bornite, rank first in importance. There are also several lead-zinc deposits and one or two attempts have been made to exploit gold-quartz veins. Magnetite is abundant at many localities and cobalt has been found in one place. Bog iron (limonite) is extensively developed on the north side of Holberg inlet and the Cretaceous sediments contain some small beds of coal. Limestone is quarried for use in the pulp mill at Port Alice and, if

[1]**Geol. Surv., Canada, Sum. Rept. 1920, pt. A, p. 17.**

the need arose, might supply building stone or flux for smelting operations. From a mining viewpoint the future of the district will no doubt depend on developments at the copper properties. For clearness and ease of treatment the writer has subdivided the known metallic mineral deposits into the following groups:

Pyrometasomatic copper and magnetite deposits
Gold quartz veins
Quartz-carbonate veins with sulphides
Lead-zinc replacement deposits in limestone
Copper deposits in basic lavas

In the following pages certain characteristics of the different groups are given and the constituent deposits are described in some detail. No attempt will be made to treat the coal resources of the region as the writer did not examine them, nor will the bog iron deposits be described. The latter are described by W. L. Uglow in the report on "Iron Ores of British Columbia," page 242, and the best information on the coal resources is contained in G. M. Dawson's report on the northern part of Vancouver island.

The location and occurrence of the metallic mineral deposits, excepting the copper mineralization in basic lavas, indicate clearly that they were formed by emanatious originating in the magmas of the Coast Range intrusives. Writing of his observations between Barkley and Quatsino sounds on the west coast Dolmage[1] says . . . "At the diorite contacts less copper and more iron are found, but at the granodiorite contacts copper predominates." This statement may well apply to the area in which he worked, but it does not seem to hold for the Quatsino-Nimpkish district. In this connexion it should be remembered that, as Dolmage noted, whereas in the southern part of the Barkley-Quatsino Sounds district the intrusions consist of two types, granodiorite and diorite, distinctly different in composition and age, yet,[2] "in the northern part (i.e., in the vicinity of Quatsino sound) these two types become so intimately intermixed that it is impossible to map them separately on the scale adopted." As this report indicates, the mineral deposits of the Quatsino-Nimpkish area are related to intrusions which vary in composition from granite to gabbro. At the June deposit near Alice lake, hornblende diorite is veined by copper sulphides and magnetite, at the Old Sport mine acidic, fine-grained dykes are mineralized with bornite and chalcopyrite and otherwise altered, and at the Nimpkish copper group the main intrusion of granodiorite is mineralized with veins of chalcopyrite, pyrite, and molybdenite, with, in one case, the development of considerable quartz and sericite in the intrusive. Also, at the Caledonia mine, the granodiorite has been somewhat altered near its contact by the mineralizing emanations and at the Teeta River gold claims, gold-bearing quartz veins cut the granodiorite. It appears that deposits of iron, copper, gold, lead, and zinc were formed by arising from the parent magma or magmas of the Coast Range intrusives and that the valuable minerals were deposited in part at least, after the intrusive rocks now exposed at the surface had solidified. Most of the

[1]Geol. Surv., Canada, Sum. Rept. 1920, pt. A, p. 19.
[2]Dolmage, V.: op. cit., pt. A, p. 16.

ore deposits were formed within rocks of the Vancouver group, particularly in limestone, but it is self evident from the above statement that important mineralization may extend into the Coast Range intrusives, although these latter rocks are not, on the whole, considered to be favourable hosts. Differentiation of the original magma, represented on the surface by a variable composition with a single intrusive body, or by a variety of basic and acidic dykes in the vicinity of the main intrusion, is believed to have been the process of prime importance in the formation of the mineralizing emanations. Consequently the vicinity of an intrusive body which exhibits a great variety of composition, either in integral parts of the main mass or in accompanying dykes, is believed to be more favourable prospecting ground than the vicinity of an intrusion of homogeneous composition or an area where few or no intrusive rocks appear. This, of course, providing the host or intruded rocks—in most cases members of the Vancouver group—are equally favourable in the different localities. Replacement has been the most important process in the formation of the ore deposits, and particularly so in the case of the copper-magnetite and lead-zinc mineralization. W. L. Uglow[1] has outlined, in excellent manner, the evidence for the formation of the magnetite deposits of the west coast of the island by replacement by tenuous solutions. His conclusions may be extended to include similar deposits in the Quatsino-Nimpkish area. Certain gold-quartz veins and quartz-carbonate veins carrying sulphides have been formed in part by filling of open spaces in the host rock, but even here replacement has frequently been quite extensive; and these deposits are of minor importance compared with the copper and lead-zinc deposits of the district.

PYROMETASOMATIC COPPER AND MAGNETITE DEPOSITS

Copper deposits of this class undoubtedly constitute the most important mineral asset of the district. The term pyrometasomatic[2], meaning, simply, formed by replacement with addition of substance, at high temperature, presumably by emanations issuing from an intrusive, is used in preference to the better known contact metamorphic, for the reason that the latter term is, and has been found to be, in the field, misleading, in that many of the deposits are not clearly related to a nearby intrusive contact but are more clearly controlled by some structure such as bedding or a sedimentary volcanic contact in the host rock. The deposits occur in limestone and less frequently in flows or fragmentals of the Vancouver group and are distinguished generally, but not always, by an abundant development of silicates such as garnet, epidote, diopside or actinolite, and magnetite or hematite. These minerals form irregular or continuous brown or green zones in the host rock and chalcopyrite, bornite, pyrite, sphalerite, pyrrhotite, molybdenite, and occasionally galena—one or more—occur as more or less discontinuous lenses, shoots, or impregnations in the zones. Two distinct types can be readily distinguished in the field.

[1]"Economic Geology," vol. 21, pp. 352–363 (1926).
[2]Lindgren, W.: "Mineral Deposits," 1928, pp. 781 and 827.

First, there are those deposits in which the silicates, oxides, and sulphides are clearly and closely related to the contact of an intrusive body of granitic rock. In this case the silicates, oxides, and any contained sulphides form irregular bodies in some host rock, most generally limestone, but occasionally volcanics, adjoining the intrusive contact. Thus, although the attitude of individual bodies may be controlled by the structure of the host rock to some extent, yet the whole zone of mineralization is controlled by the position of the intrusive contact. Nimpkish copper, part of the Caledonia, and probably the June are examples of the type of deposit.

Second, there are those deposits in which the mineralization has been localized entirely by some structure or structures, such as bedding, formational contacts, or pre-mineral dykes in the host rock. The contact of the intrusive rock has exerted no visible control on the location of mineralization other than that, if it cuts across the mineralized zone, it probably limits its extent in that direction. Typically such a deposit consists of a well-defined and fairly regular zone of silicates, oxides, and ore minerals, which follows the bedding of the host rock, or the contact of, say, limestone and andesite, or, less frequently, the border of a pre-mineral dyke or sill in the host rock. Coast Copper, part of the Caledonia, and parts of the Yreka and Smith groups belong in this class. As a consequence of direct structural control deposits of this type are more easy to prospect and develop than others, although the distribution of copper values in the silicate zone may be equally erratic in both cases. Theory would indicate and the known deposits support the conclusion that this type of deposit would be more easily formed where the bedding planes, which are evidently the most important controlling structure, of the host rock or rocks, are dipping towards the intrusive rock rather than away from it.

In all these copper deposits the formation of silicates and oxides by replacement of country rock has definitely preceded the introduction of the copper sulphides. Garnet, epidote, diopside, actinolite, magnetite, and hematite have been found in numerous places to be veined and replaced by chalcopyrite or bornite. Consequently the valuable metals are locally concentrated within the silicate-oxide zone and may be absent, in any significant amount, over large parts of it. The silicate zone should, then, be considered merely as an horizon which is favourable to mineralization and should be prospected accordingly. Pre-mineral dykes have occasionally supplied channels, near their contacts, along which the sulphides are concentrated, but this cannot be taken as a generally applicable factor.

In most of the copper deposits magnetite is a common gangue mineral. The magnetite forms solid lenses or disseminations in the mineralized zone. In many places, however, magnetite is found as relatively pure bodies without any important copper mineralization. Most of these bodies occur in limestone and have been found by replacement and they are generally lens-shaped or tabular. In volcanic rocks the magnetite tends to be more disseminated and mixed with original and secondary silicate minerals. If an iron industry, dependent or magnetite, is ever established on the coast these bodies, and the magnetite contained in such copper deposits as the Old Sport, may well become economically important. Today they are attracting practically no attention.

Summarizing, the pyrometasomatic copper and magnetite deposits are found in the neighbourhood of the larger Coast Range intrusives. They have been formed by replacement of some host rock, generally limestone, either immediately adjoining the intrusive contact or at some structurally favourable horizon which may be a considerable distance from the exposed intrusion. And the copper values are generally distributed rather erratically in a zone or zones of contact metamorphic silicates and oxides which may, in large part, be barren or very sparingly mineralized.

Old Sport Mine—Coast Copper Company, Limited

For several good reasons no attempt will be made to give an exhaustive report on this property. In the following paragraphs the writer wishes to outline those points that may apply to other deposits of the same class and that consequently would be of value to prospectors and operators in the district. The mine is on the southwest side of Elk lake. A road, broken by two stretches of water on Alice and Kathleen lakes, extends from Jeune Landing on Neroutsos inlet to the property, a total distance of nearly 15 miles. Auto trucks and gasoline launches are used for transporting passengers and supplies and are maintained by the company. The outcrops were first discovered in 1911. In 1913 several adjoining groups of claims were bonded to C. R. Wolfle of Spokane, and associates. The following year fourteen claims, including the Old Sport group, were bonded to W. Bacon of Spokane, Wash. In 1915 underground work, including the driving of a 500-foot crosscut tunnel, was carried out by the Quatsino Copper Company with William Clancy in charge. In 1916 Consolidated Mining and Smelting Company of Canada assumed control and organized the present company, and since then active development has been under way with the exception of a period of inactivity in 1921 and 1922. C. A. Seaton is now in charge at the mine. The property, consisting of about seventy claims, is on a steep and heavily wooded mountain side which slopes northeastward to Elk lake (*See* Plate III A). The portal of the main adit is 500 feet above sea-level and just over 100 feet above Elk lake. Development consists of about 4 miles of underground workings and many thousand feet of diamond drilling. The camp, on the shore of the lake, accommodates about sixty men and several families and is being steadily improved, a tennis court and a new staff-house being recent additions. It also boasts a really excellent garden. Electric power for lighting the camp and mine and for underground haulage is generated from Raging river which flows into the northeast corner of the lake.

On the surface, rocks of the Vancouver group are intruded by an irregular body of igneous rock which varies in composition from gabbro, approaching anorthosite, to quartz diorite and granodiorite. The northeastern contact of this intrusive extends approximately northwesterly along the top of the hill near the southwestern limit of Coast Copper ground and in this vicinity the rock is coarse grained and green to grey in colour. Under the microscope labradorite and augite partly converted to uralite were found to be the most abundant constituents. Apatite, brown biotite, chlorite, and epidote are very minor accessories and the feldspar is considerably sericitized. By a decrease in the amount of ferromagnesian minerals to almost zero the rock occasionally approaches the composition of anorthosite. A mile and more to the south the intrusion is more variable in composition and contains many dykes and irregular bodies of granodiorite and diorite; in places it contains much magnetite. More acidic phases, about quartz syenite in composition, were also noted in small amounts. Poor outcrops made it impossible to obtain reliable determinations of the dip of the contact, but in Canyon creek it appears to be almost vertical. It is possible that the whole body is a wedge-shaped or sheet-like mass rather than a normal stock in which the horizontal dimensions should increase in all directions at depth. Northeast of the gabbro, limestone with a few interbedded lava flows and cut by many basic dykes is exposed at intervals, and continuously in the bed of Canyon creek, for from 3,000 to 4,500 feet. It strikes almost due northwest and dips at from 30 degrees to 50 degrees to the southwest; that is, into the hill and towards the gabbro. The average dip in the mine to a depth of 1,100 feet is very close to 37 degrees. Within several hundred feet of the gabbro, however, exposures on Canyon creek indicate that the limestone is much contorted and tightly compressed into a series of almost vertical isoclinal folds. The limestone is grey to white in colour and is generally finely crystalline except near the intrusive or in areas of extreme contact metamorphism where it becomes very coarse grained.

On the northeast the limestone is conformably underlain by a thick series of andesite, basalt, and porphyritic flow rocks, andesite being the most abundant variety. The andesites are fine to medium grained, green, chloritic rocks and are occasionally amygdaloidal. Under the microscope they are generally holocrystalline and equigranular and consist essentially of feldspar and green to brownish hornblende. The feldspar is generally andesine, but in some cases approaches labradorite in composition and the rock is then more nearly a basalt. With increased calcium in the feldspar, augite generally appears in noticeable amount, but is much altered to hornblende and chlorite. Pyrite, sericite, epidote, and calcite are also present, but quartz is seldom to be found. Included in the volcanic rocks are irregular masses of basic feldspar porphyry in which the white or greenish feldspar phenocrysts stand out prominently in a green, fine-grained, or clearly crystalline base. They resemble certain porphyritic dykes which are found cutting the volcanics and limestone, but appear to grade into and form an integral part of the volcanics. In composition they closely resemble the latter and it is concluded that they have been formed during the period of volcanic activity. There are also many basic, fine-grained to porphyritic dykes in the volcanics and limestone. The finer grained, dark green varieties have been found to be mineralized in some places and they are believed to represent feeders for overlying flows. The porphyritic phases, which are not so abundantly developed, are not known to be mineralized and, as they cut through the ore zone, they are thought to be younger than the mineralization. Whether they are connected with the gabbro intrusion is not known. Other light green to white, more acidic dykes will be mentioned later.

The mineralized zone, which is being developed by Coast Copper Company, occurs at the contact of the limestone with the underlying volcanics. It has been exposed on the surface for about 3,000 feet by closely spaced open-cuts and has been picked up at intervals for an additional distance of a mile or more. Its width varies from a few feet to about 100 feet. Garnet, epidote, magnetite, and calcite are the chief constituents, but diopside, actinolite, and chlorite are also present. Quartz occurs sparingly, and particularly as small mineralized veins in parts of the foot-wall. Chalcopyrite and bornite, with occasional small quantities of pyrrhotite and pyrite, form veins, lenses, tabular bodies, and disseminations in the silicates and magnetite. The mineralized zone is divided, in most places, into two parts, a hanging-wall and foot-wall section, by a sheet of dark green to almost black basaltic rock which is thought to be a flow interbedded with the limestone. Its width is very variable, changing suddenly from 10 or 20 feet to 80 feet or more and it is not always found in the mineralized zone. This rock, which was determined under the microscope as a rather acidic basalt, forms the hanging-wall of the foot-wall section and is overlain in many places, but not everywhere, by a second hanging-wall section of the mineralized zone. The underlying foot-wall section is generally the most important. The main foot-wall of the deposit is in all cases andesite, although this rock has in places been silicified, or partly replaced by silicate, or converted to a rather soft brown or green rock in which chlorite and tiny nests of brown biotite are abundantly developed. Between the mineralized zone and the gabbro, in the limestone, are numerous small showings of silicate, magnetite, and chalcopyrite, but none of them appears to be of economic importance. They are found principally along basic dykes or at the contacts of flows interbedded with limestone.

The mine is developed on the fifth, seventh, eighth, tenth, and twelfth levels and adits connect Nos. 5 and 8 with the surface, the latter being the main haulage tunnel. A winze and raise have been connected to join the fifth, seventh, and eighth levels and the tenth and twelfth levels have been run from the main shaft from the eighth level. The No. 5 and No. 8 adits are 400 feet and 2,100 feet long, respectively, and both are entirely on the foot-wall volcanics. No. 8 level has explored the mineralized zone along its strike for a little more than 4,900 feet and the tenth and twelfth levels are (September, 1929) 3,300 and 2,100 feet long, respectively, and are largely under the south end of No. 8 level. The main shaft is at present being driven deeper and is now somewhere below the fourteenth level, that is, over 1,200 feet below the surface. It lies in the foot-wall volcanics. No. 5 level, the top one, is a little over 800 feet above sea-level and from 100 to 200 feet below the outcrop. The other levels are 200 feet apart with the exception of 7 and 8 which are 100 feet apart.

The accompanying plan and section (Figures 4 and 5) represent typical parts of the mineralized zone. The basaltic band which separates the zone into two parts is not everywhere present underground. At the mine it is termed the "included diorite". It is in places slightly mineralized or replaced by garnet and epidote, and, along certain thin zones it is here and there altered and somewhat silicified, to a light green felsitic rock. Amygdules were observed in it in a few places and for this reason it is presumed to be a flow. In thin section it is slightly more basic than the

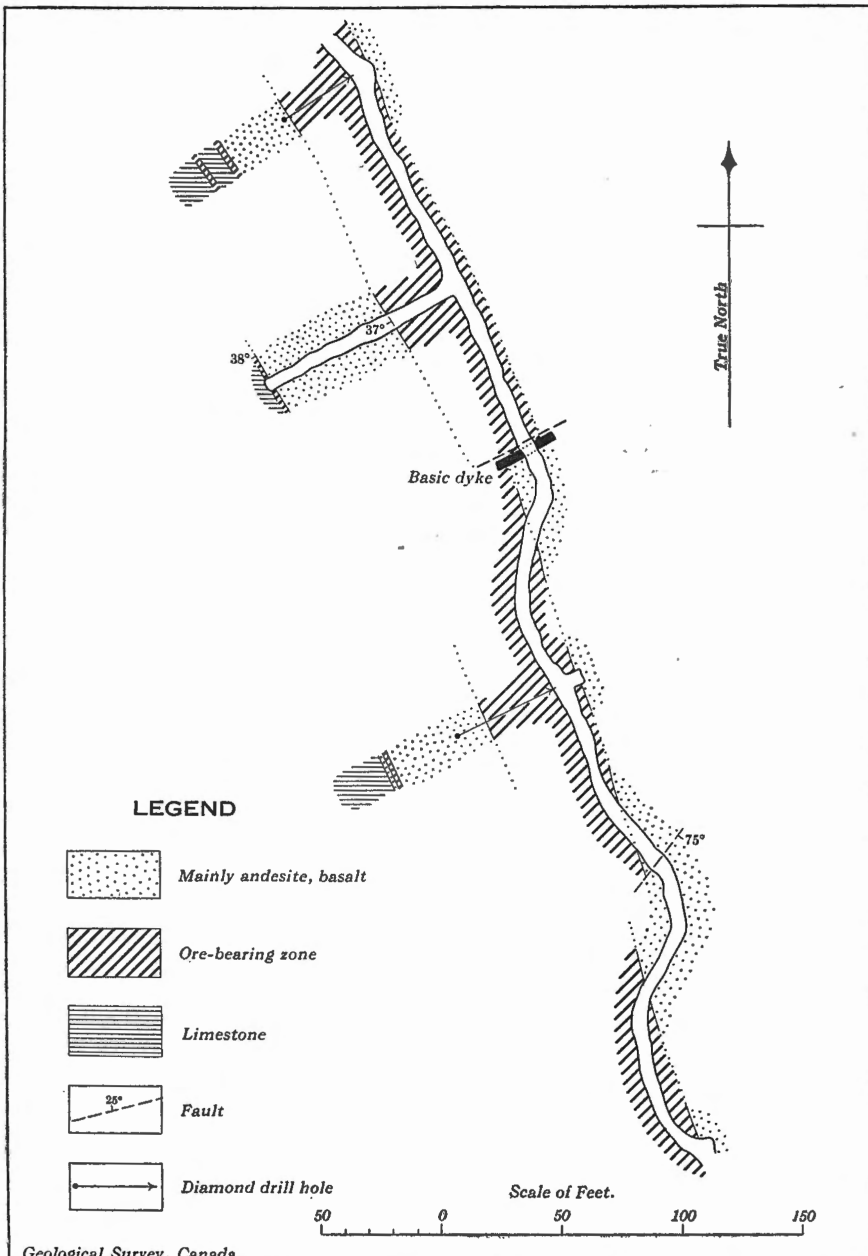

Figure 4. Generalized plan of part of No. 8 level, Old Sport mine, northern Vancouver island, B.C. (Partly from information supplied by Coast Copper Company, Limited.)

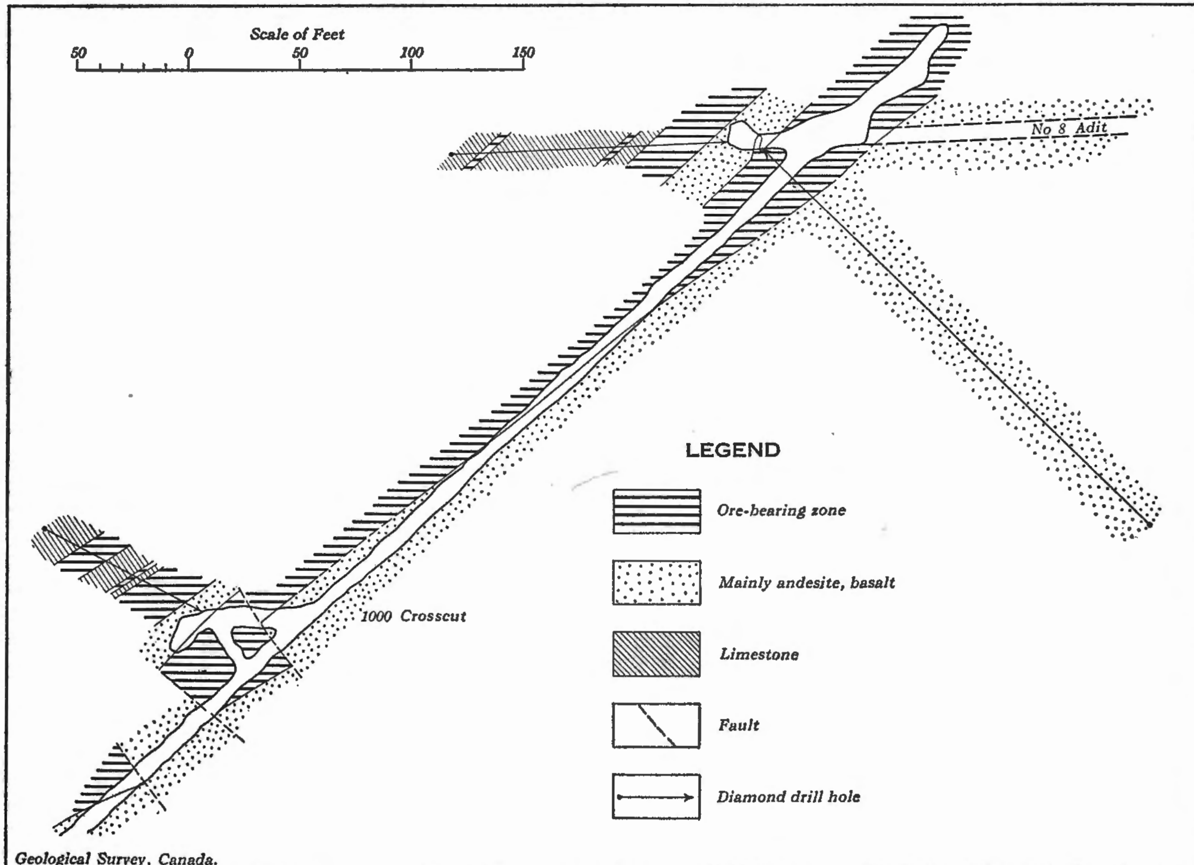

Figure 5. Generalized vertical section along main shaft, Old Sport mine, northern Vancouver island, B.C. (From information supplied by Coast Copper Company, Limited).

ordinary foot-wall volcanics, consisting of labradorite or andesine-labradorite and augite, and exhibiting a sub-ophitic texture. It is quite pyritic and is cut by microscopic veinlets of zoisite, alkali feldspar, and calcite. Where mineralization occurs above this basaltic band its hanging-wall is crystalline limestone and there can be no doubt that the silicates, oxides, and sulphides have replaced the limestone. In the foot-wall section of the zone, however, there is little evidence of any limestone left and, although certain evidence underground and on the surface indicates that this part of the ore zone has also been formed by replacement of limestone between the foot-wall volcanics and the upper basaltic flow, yet there are remnants of altered andesite surrounded by garnet, epidote, etc., and the foot-wall andesite is in some places partly replaced by these minerals. Consequently, although there is considerable coarse calcite in the mineralized zone, yet it is impossible to tell, on account of the complete nature of the replacement, how much of the original host rock was limestone and how much was volcanic.

Most of the ore found below the surface lies in the southern part of the mine—that is, south of the main shaft. It occurs as shoots in the silicate-magnetite zone, and much of the latter is barren or much too sparingly mineralized to constitute ore. In the two upper levels chalcopyrite was the only ore mineral detected by the writer, although it is reported that small amounts of bornite have been found. On the eighth, tenth, and twelfth levels, however, bornite, as well as chalcopyrite, is quite abundantly developed. As stated above, the sulphides form veins, lenses, and impregnations in the mineralized zone and also are found in quartz veins in the foot-wall and in the silicates and magnetite. The bornite, however, seems to be more abundant as veins and disseminated replacements in the magnetite than elsewhere. The veins and lenses of chalcopyrite vary in size from mere stringers to bands 2 or 3 feet wide, and occasionally wider, and a series of these may continue for 100 or even 300 feet along the zone. Pyrite and pyrrhotite are sparingly developed, the latter having been noticed by the writer in only two places in the main zone underground, particularly on the eighth level. It also occurs sparingly on the surface.

In certain parts of the mine there is in the mineralized zone an abundant development of a dense, very hard grey rock which is conveniently termed felsite. Its origin is not very clear. In most cases it is found as tabular or lenticular bodies, generally less than 10 feet thick, lying conformably in the mineralized zone. In a few places it is crushed and mineralized by veinlets of chalcopyrite and bornite, but when massive it is usually barren. Occasionally garnet is developed in it. Some of these bodies are all well defined and exhibit sharp contacts against silicates or magnetite, thus resembling sills or dykes, but in no case, in the thicker layers, could any chilled margins or noticeably coarser grained interiors be found. Where the adjoining rock is andesite the contacts are generally gradational and in several places the felsite includes shadowy areas that resemble altered, partly replaced, andesite. Also, it is not uncommon to find vein-like areas of the felsite extending into the foot-wall and clearly replacing it. Typically the rock is light grey and very fine grained, with or without a few visible feldspar crystals. Five thin sections from different parts of the mine indicate that it consists of a very fine-grained mass of plagioclase varying from pure albite to albite-oligoclase, a little orthoclase, and from to 15 per cent of quartz. There are generally a few corroded feldspar phenocrysts. Garnet, epidote, sericite, zoisite, chlorite, and hornblende are sparingly developed products of alteration. Apatite and titanite are accessories.

A specimen was collected from the south end of the tenth level where several small quartz veins occurred in a dense, dark grey, rather hard rock at the foot-wall of the mineralized zone. The original rock was probably andesite. A thin section across one small vein was prepared. In the hand specimen the vein, about $\frac{1}{4}$ foot wide, has altered the brown rock for about $\frac{1}{4}$ inch on each side to a very fine-grained, almost white substance which closely resembles typical felsite and which passes gradationally away from the vein, into normal brown wall-rock. The thin section showed that the vein consists of large, corroded quartz crystals set in a mass of well-crystallized green amphibole. On each wall of the vein is an almost continuous lining of tiny feldspar crystals, partly plagioclase, which must approach albite in composition as their index is distinctly lower than that of quartz and Canada balsam. For about $\frac{1}{4}$ inch on either side of the vein the rock is fairly clear in transmitted light and consists of a very fine-grained mass of feldspar and quartz crystals and the feldspar is similar to that along the walls of the vein. There are numerous aggregates of rutile or some other high index mineral and a few shreds of actinolite. Outside this is the normal, hazy, brown country rock which consists of an indeterminate mass including scattered areas of biotite, some chlorite and actinolite, and a few larger crystals of sodic plagioclase. The passage from altered rock to brown wall-rock takes place within $\frac{1}{32}$ of an inch, but is gradual within that range. There can be no doubt that quartz and feldspar were introduced by the vein and that these two minerals were developed within the wall-rock, resulting in an increase in grain size, a leaching of biotite and chlorite, and a consequent whitening of the rock. The writer believes that much of the felsite found underground was formed in a similar way, by replacement of original andesite or limestone by the introduction of feldspar and quartz. However, dykes of very similar material are found underground. They vary in colour from light grey to light green or greenish grey and are frequently mineralized or altered to garnet and epidote. Under the microscope it seems impossible to distinguish them from typical felsite described above.

It appears to the writer that, previous to the development of silicates and ore, a number of feldspathic dykes (felsite) were injected into the rocks of the Vancouver group and that at the same time emanations, probably from the same source, effected an extensive replacement of the country rock in the present mineralized zone, to form tabular bodies which much resemble many of the dykes. It is probable that the two processes, injection and replacement, were about contemporaneous. Later, silicates, magnetite, and the sulphides were introduced and where the felsite was somewhat crushed or fractured they veined and replaced it. But where the felsite remained massive and unfractured they found the surrounding country rock more susceptible to replacement; as this replacement by silicates and magnetite is about 99 per cent complete within the main zone the tabular bodies of felsite stand out with sharply defined contacts against these minerals. Just what relation the felsite bears to the gabbro is not as yet known—it may represent a late stage of igneous action.

Field evidence and polished surfaces indicate clearly that the sulphides were deposited after the various silicates and magnetite. Garnet and epidote have been found clearly veined by chalcopyrite and also by bornite. Magnetite is in many cases veined and replaced by the sulphides and particularly by bornite and it is also cut by small quartz veins carrying both these sulphides. Veins of asbestos, probably after actinolite, were found cutting magnetite and the asbestos is partly replaced by chalcopyrite, the fibrous structure being well preserved. Also there are coatings of chalcopyrite along tiny seams and joints in the magnetite. The relation of garnet and epidote to magnetite is not so clear; possibly the magnetite is a little the later. Neither do bornite and chalcopyrite exhibit any well-defined sequence. There is a slight indication that the bornite is the earlier mineral and this is supported by the fact that it is relatively more abundant in depth than near the surface. Nevertheless it may be assumed that these two sulphides crystallized within a rather limited range and are approximately contemporaneous.

As indicated in Figures 4 and 5 the deposit is offset both along the strike and down the dip by numerous faults. A maximum horizontal offset of 250 feet was observed in the bed of Canyon creek along a pre-mineral fault. Underground it seems that the largest displacements have occurred along fault planes that are tight and hardly noticeable, whereas in the cases of numerous faults that contain a few inches to a foot or more of gouge there seems to have been little actual offset along them. The problem of faulting in the mine is an important one and cannot be treated fully in a report of this nature; nor indeed, does the development as it exists today, on levels 200 feet apart vertically, permit of accurate correlation of faulting throughout the workings. Faulting is most intense in certain localized areas, particularly in the northern part of the workings and in certain rather narrow zones in the southern part. For long stretches underground, however, there is little or no important faulting and in these places the best ore-bodies have been encountered.

While No. 8 adit was being driven through the foot-wall volcanics it encountered a zone of mineralization some 1,300 feet northeast of the main mineralized zone. This Idaho vein has been developed by drifts for over 700 feet and consists of a replacement of pyrrhotite, pyrite, magnetite, and chalcopyrite in andesite. It is broken by faults into a number of rather small blocks, so that extraction might be rather costly. The maximum width of solid sulphide is about 3 feet and there is more pyrrhotite present than in the main ore zone, whereas contact metamorphic silicates, principally epidote, are rather sparingly developed. Quartz veins accompany parts of the ore.

June Group

This old group of claims was staked in 1899 and until 1907 was developed on a small scale by the Copper Mountain Mining and Development Company of Tacoma. It is reported that in the latter year 50 tons of ore, averaging 5·95 per cent copper, $2.50 in gold, and $1.60 in silver, was extracted. N. S. Clarke and associates did some work under lease and bond in 1916 and thereafter the property was deserted. In 1929 Consolidated Mining and Smelting Company purchased the property and did several thousand feet of diamond drilling and, in September, installed a portable compressor, erected a new bunk house, and commenced underground development.

The property is one mile east of Alice lake and one-half mile south of the north end of Victoria lake and is reached by trail from Alice lake or by an old trail from Jeune Landing. The showings are on two heavily wooded knolls which rise 200 feet along the surrounding rather flat country and have been developed by numerous open-cuts and shallow winzes and an adit about 450 feet long. Very little new surface work was done by the Consolidated Mining and Smelting Company. Bedrock is largely obscured by a heavy mantle of drift and consequently it was impossible to obtain a very clear conception of the occurrence. The following remarks are merely a brief account of some of the writer's observations.

Southward from approximately the summit of the two knolls the underlying rock seems to be largely intrusive. Northward a series of andesite flows and dark green, fine-grained tuffs overlie and are interbedded with limestone of the same belt that passes through Coast Copper ground. The limestone and volcanics probably strike northwest and dip at low angles to the southwest, although in the general vicinity they are lying in rolling, open folds so that dips in almost any direction might be expected. The intrusive rock is very variable in composition. The earliest phases, which form dykes and sills on the claims, and larger bodies a short distance to the south, are dark green hornblende diorites. Later phases are more acidic, varying from fine-grained, grey granodiorite to light grey or almost white feldspar porphyry and aplite. The exposures on the claims are probably the marginal phases of a large stock which on Victoria lake and elsewhere to the south varies from gabbro-diorite to granodiorite. The upper contact of the limestone follows around the lower northern slopes of the two knolls and between this and the intrusives, volcanics or dykes are exposed.

The mineralization consists of magnetite, chalcopyrite, bornite, and occasionally sphalerite and arsenopyrite, and garnet, epidote, chlorite, and other silicates. Quartz veins carrying pyrrhotite and other sulphides were noted in one or two places. The host rocks are volcanics, limestone, and hornblende diorite and the mineralization is evidently confined to a somewhat irregular zone adjoining the main intrusive contact. The hornblende diorite dykes are in part replaced by magnetite, chalcopyrite, and bornite and the sulphides are generally accompanied by small quartz stringers. The limestone is almost entirely silicified in a large cut near the camp. If the contact of the intrusive stock dips northward as would be expected then the deposit will also dip in that direction and, at greater depth the mineralization should be entirely in limestone, as the exposures on the claims are near the top of a thick band of that rock. Mineralization has been found for about 2,000 feet along the contact zone. Part of the property has been described in some detail by Uglow.[1]

Caledonia Group

This group consists of the Caledonia, Cascade, Blue Bell, Maple, Scotia, and Thistle claims. Prior to 1926 the original stakers, T. D. Harris and R. A. Grierson of Hardy bay, owned the property in conjunction with Mr. and Mrs. Murray C. Potts of Alert Bay. In that year the Caledonia Mines Company, Limited, with head office in Vancouver, was organized and active development was commenced. In 1929, after the company had done considerable open-cutting and tunnelling, Consolidated Mining and Smelting Company optioned the property and proceeded with development. In September of the same year the option was dropped and the small crew withdrawn. It is understood that the original company will proceed with development. The claims are on Caledonia creek, about 2 miles northwest of Quatse lake, and are reached over 6 miles of automobile road from Port Hardy and thence over 4 miles of tractor trail. The area is rolling and heavily timbered, the lower mine workings being about 750 feet above sea-level. Good camp buildings, including cookhouse, compressor shed, and blacksmith shop, stand near the workings. The property is mentioned in the Annual Reports of the British Columbia Minister of Mines, for 1923, 1925, 1926, 1927, and 1928.

A luxurious growth of timber and bush and a rather heavy cover of drift cover the claims, so that outcrops are scarce except in stream beds. Consequently it is difficult to obtain accurate information concerning the geology. It appears, however, that andesite and basalt flows, some fine breccias and tuffs, and one or more intercalated beds of limestone strike about north 80 degrees east and dip at variable but generally low angles to the south. This series is cut by a number of green andesitic dykes which are probably related in age to the Mesozoic vulcanism and is intruded, at the western and southwestern side of the group, by a stock of grey to pink granodiorite. The contact of the intrusive is quite irregular, many dykes and irregular bodies of granodiorite extending into the intruded rocks for short distances, and in a few places there has been extensive shearing and faulting near the contact. The flows in many places are amygdaloidal, but in many other places there are fine-grained or distinctly crystalline rocks of dark green or black colour. Unless outcrops are extensive, it is frequently impossible to tell whether they are extrusives or intrusives. It is believed, however, that dykes are relatively sparingly developed. Two thin sections of the flow rocks indicate a composition grading from andesite to basalt. The granodiorite consists of oligoclase and orthoclase, from 10 to 15 per cent of quartz, and the accessories chlorite, biotite, and magnetite.

Most of the development has been done on the Cascade mineral claim near Caledonia creek. There are two principal mineralized zones. The lower one consists of an irregular replacement of sphalerite, chalcopyrite, magnetite, specularite, bornite, pyrite, and galena, with quartz, epidote, and

[1]Geol. Surv., Canada, Ec. Geol. Series No. 3, 1926, p. 239.

garnet in limestone at or adjacent to the granodiorite contact. Occasionally the mineralization extends a short distance into the granodiorite which is then sheared and sericitized, but generally it stops at the contact. Three open-cuts have exposed a width of from a few inches to 4 feet of mineralization beneath a heavy cover of clay, gravel, and boulders. It appears that, in these cuts, the mineralization is confined to the lower portion of a thin bed of limestone which is underlain by volcanics and that the contact of the granodiorite is nearly horizontal. Drifting beneath these workings and raising therefrom to the westerly cut have indicated that, beneath the cuts, the granite comes into almost vertical contact with the volcanics along an irregular fault zone and that a few granodiorite dykes extend into the andesite, and no mineralization was found in the latter. Two hundred and fifty feet east, in the bed of Caledonia creek, in what may be a continuation of the above zone, there is an exposure of garnet, epidote, magnetite, and a little copper which is evidently a replacement of limestone adjoining the contact of the granodiorite; also a narrow, wedge-shaped body of the mineralization extends into the granodiorite about 40 feet. Drifting beneath this, from the same adit that passes underneath the first-mentioned open-cuts, exposed a rather poor mineralization in limestone adjoining the contact; and the ground is so disturbed and cut by irregular bodies of granodiorite that the work was discontinued. In the drift the limestone, in which the mineralization occurs, is partly silicified and some excellent specimens of amethystine quartz were collected from the mineralized zone. Where development has been done on this zone there seems to be very little chance of the mineralization extending down more than a very few feet as the limestone is dipping towards the granodiorite. It is probable, however, that the mineralization in Caledonia creek and that in the drift beneath it are two different leads, as the latter is some 20 feet vertically beneath the former and a short distance north of it, whereas the deposits are dipping at very low angles to the south.

Five hundred and fifty feet north and 300 feet vertically above these lower showings a series of pits have been made on a lead of magnetite, garnet, epidote, actinolite, a little quartz, and very little chalcopyrite. The lead attains a maximum width of about 20 feet. This mineralization has been exposed for nearly 1,000 feet by closely spaced open-cuts, but unfortunately no commercial values have as yet been obtained. It occurs at the top of a band of grey crystalline limestone, not more than 50 feet thick, which is underlain and probably directly overlain by andesitic lava flows, and strikes a little north of east and dips from 30 degrees to 70 degrees to the south. What is probably a continuation of the same zone is exposed to the east on the adjoining Scotia claim. There, however, the mineralization is at the base of the limestone and includes fair amounts of chalcopyrite, sphalerite, and galena. As noted underground, the limestone is in places extensively silicified to a fine-grained, grey, green, or purple rock.

There are additional showings of magnetite and silicates on the Blue Bell and Maple claims which lie to the north of the Cascade claim, but the writer saw nothing resembling commercial ore. It is possible that, without a guide, he failed to see the best mineralization. At several places in the two upper leads the outcrops have been heavily glaciated and much of the magnetite is lodestone.

The following assays of samples from the lower showings are given by Mr. Brewer.[1]

Claim	Width sampled	Gold	Silver	Copper	Lead	Zinc
	Feet	%	%	%	%	%
Cascade, grab sample	....	0·04	0·2	0·5	....	....
Cascade	30	trace	16·0	3·2	....	10·0
" No. 3A cut	10	"	12·0	2·5	1·0	5·0
" No. 1 cut	6	"	12·2	2·0	0·8	10·0
" No. 1B cut	2·6	"	6·5	0·5	trace	3·0

It seems that there is little hope of developing any quantity of ore beneath the lower showings on the Cascade claim (unless there be other beds of limestone at greater depth). It is possible, however, that the lower and upper showings on this claim are in the same bed of limestone and that between them, on the sidehill, the limestone is covered by the overlying volcanics. Consequently, there is a considerable area there which may be underlain, at no great depth, by mineralized limestone. However, as stated above, the upper mineralization on this zone does not appear to be of commercial value. On the Scotia claim, though, the mineralization on the same upper zone is somewhat better and, if further work is to be done, it might well be spent in prospecting this claim and attempting to define the position of the granodiorite contact to the east of Caledonia creek. If the contact, east of Caledonia creek, swings to the south instead of continuing in an easterly direction, the limestone, and probably also any mineralization in it, on the Scotia claim, would continue to a greater depth before being cut off by the intrusion than it does on the Cascade claim.

Yreka

This old property, on the west side of Neroutsos inlet, 2½ miles from the entrance, consists of about sixteen Crown-granted claims which were located in 1898 and 1899. The workings are on a steep, wooded hillside from 1,100 to 2,200 feet above sea-level. The property was worked until 1903 by the Yreka Copper Company and it is reported that 2,500 tons of ore was shipped. In May, 1903, Northwestern Smelting and Refining Company of Crofton, B.C., assumed control, but soon ceased work and from then until 1916 the property was deserted. In the latter year N. S. Clarke and associates, of Spokane, began work, erected camp buildings, and a 7,000-foot aerial tram to the beach and in the spring of 1917 shipped 900 tons of 3 per cent copper ore. They then closed down. In the winter of 1918 the property was bonded by Tidewater Copper Company, but, as far as is known, no extensive work was undertaken. At present the property is lying idle, the buildings and tram are badly disintegrated, the lower workings are in bad condition, and the old road from the beach to the mine is

[1]Minister of Mines, B.C., Ann. Rept. 1926, p. 323.

partly obliterated by alders and windfalls. Having no guide or map of the property, the writer made a hasty examination of the surface showings only. The property has been described in some detail in previous years[1] by Carmichael, Brewer, and Dolmage.

A hasty examination indicates that a thick bed of grey to white crystalline limestone is underlain by and interbedded with a series of grey to greenish grey, siliceous tuffs which contain disseminated pyrrhotite and that the tuffs are underlain, towards the beach, by andesitic flow rocks. The limestone strikes from north 60 degrees west to north 20 degrees west and dips from 30 degrees to 55 degrees to the southwest, or into the hill. These rocks are cut by many grey to white quartz porphyry and feldspar porphyry dykes and the limestone is in part extensively silicified to a grey jasperoid. Dolmage reports that, above the showings, the rocks are intruded by a stock of quartz diorite and a few dykes of this material were noted by the writer in the limestone. The limestone is replaced, across widths up to 75 feet or 80 feet, by garnet, epidote, and other contact metamorphic silicates which contain veins, irregular bodies, and disseminations of pyrrhotite, pyrite, and chalcopyrite. Magnetite was noted in quantity in but one place. Mineralization has been found over a vertical range of about 1,000 feet and it has evidently been controlled partly by the bedding of the limestone (*See* Plate III B) and in part by the dykes cutting the limestone. The old tunnels south of the surface showings and below them were not examined. The ore contains low silver values. It is reported in the 1928 report of the Minister of Mines, B.C., that there is a showing of galena ore between the mine and the beach.

The location of the property is extremely favourable to large low-cost operations. Also, to the northwest of the Yreka, in the same lime belt, several other properties, including the Edison group, were worked in the early days. Unfortunately time did not permit of an examination of these, but the writer feels that further prospecting and development in this belt might be well worth while; in this connexion it should be remembered that the properties when operated previously were developed principally from the viewpoint of producing copper ore of a shipping grade. It is possible that, as milling propositions, they might look much more attractive.

Quatsino Gold and Copper Company

This company, with head office in the Standard Bank Building in Vancouver, owns a large number of claims, including the Merry Widow and Independent groups, adjoining the Coast Copper holdings on the south. The same belt of limestone, with interbedded volcanics and cut by many dykes, which crosses Coast Copper ground, passes through the claims and is intruded, on the west, by the same gabbro-diorite stock. On the claims the limestone strikes from a little east of north to northwest and dips at from 15 degrees to 50 degrees to the west. There are many scattered showings on the property, but sufficient work has not been done in any one place to demonstrate the existence of important ore-bodies. The writer made a brief examination of the more important showings without a guide

[1]Minister of Mines, B.C., Ann. Rept. 1903 and 1916. Geol. Surv., Canada, Sum. Rept. 1918, pt. B.

and without an accurate map. There are several showings on the Independent group near Elk river and the most important is just south of the cabin on the Independent No. 3 mining claim, a little over 2 miles by trail from the portal of the Old Sport mine, at an elevation of about 700 feet. A 50-foot trench has exposed about 10 feet of pyrrhotite and pyrite with small quantities of chalcopyrite and bornite associated with epidote and probably replacing limestone in the vicinity of an andesite dyke or lava flow. In a shallow winze a short distance west there is 4 feet of pyrrhotite with pyrite and a little chalcopyrite and epidote and calcite. The limestone in which these minerals occur is not definitely proved to be in place. In the bed of Bean creek to the southwest and probably on the Young Sport No. 4 claim, a pronounced shear zone strikes north 50 degrees west and dips at 45 degrees to the northeast, cutting limestone. The hanging-wall is well defined and within 5 feet of it cobaltite, associated with calcite, and a little garnet and chalcopyrite, is disseminated rather sparingly and weathers to form the pink cobalt bloom erythrite. The limestone below the shear zone is much silicified and garnet, epidote, serpentine, pyrite, and a little graphite occur rather sparingly in it. A short distance east or downstream an adit had been started to intersect this showing at shallow depth. Some distance upstream magnetite, with a little copper, was noted in a zone of contact metamorphic silicates. It is understood that further work has traced this zone a considerable distance and it is said to be one of the most promising on the property. There are additional showings of magnetite and garnet and of pyrite on the sidehill to the northwest, but they have not been extensively prospected.

On the summit of the hill, 4,000 feet west of the workings on the Independent, at 2,400 feet elevation, and very close to the contact of the stock which here contains considerable magnetite, and probably on the Kingfisher and an adjoining claim, are several old workings which indicate an extensive mineralization of magnetite, pyrrhotite, pyrite, and chalcopyrite with silicates in limestone. There are many basic dykes in the vicinity and the limestone is in part extensively silicified. There is some doubt in the writer's mind whether these showings are on Coast Copper or Quatsino Gold and Copper ground. At other places on the claims there are additional showings which were not examined and in many places the limestone is almost completely silicified. In August and September the company was very wisely proceeding with the construction of an accurate claim and topographical map of part of the workings. Certainly, in view of the heavy timber on the claims and the scattered nature of the mineralization, a fairly accurate map is necessary before development can be intelligently proceeded with. It might be noted here that the most easterly showings examined by the writer, on the Independent No. 3 claim, are a considerable distance stratigraphically above or southwest of the southeasterly continuation of the limestone-andesite contact at which mineralization occurs on Coast Copper ground. This contact, if it holds its course as proved on Coast Copper ground and as found elsewhere by the writer, should pass through the extreme northeasterly corner of Quatsino Gold and Copper Company's holdings, on the Boulder canyon or Independent claim.

Nimpkish Copper Group

This group of about seventy claims is 3½ miles due east from the south end of Nimpkish lake on Copper creek, a tributary of Lime creek which flows into Nimpkish lake. The discoveries were made in September, 1928, by E. L. Kinman and associates and surface developments were carried out by them until September, 1929, when Consolidated Mining and Smelting Company assumed control. Since then diamond drilling, surface stripping, and some tunnelling have been done by the company. The writer examined the claims in June, 1929; later devlopment may have shed a somewhat different light on the property than is indicated in this report. The plan and section (Figure 6) indicate what could be ascertained of the general geology and mineralization at the time of examination. It should be borne in mind, however, that the showings are on a heavily wooded and largely drift-covered hillside and that consequently the map appears somewhat more complete than the outcrops warrant. The area mapped as limestone includes many lamprophyre and granitic dykes and the contact of the granodiorite is probably much more irregular than the figure indicates.

On the claims a thick bed of grey to white, medium-grained marble is underlain conformably by a series of green to greenish black andesite and basalt flows. The general strike is approximately east and west and the dip, where undisturbed by the intrusion, is from 5 degrees to 15 degrees to the south. Within several hundred feet of the granodiorite the strikes and dips are very variable and the limestone has been thrown into a series of tightly compressed folds. Whether the limestone is bowed up around or folded down against the granodiorite is as yet problematical, but the writer is inclined to believe in the former structure. On account of this complex folding near the granodiorite and because the upper limit of the limestone was not observed, it is impossible to estimate the exact thickness of the member. However, it outcrops from 1,900 feet to almost 3,100 feet elevation, so that a maximum thickness of about 1,000 feet is possible. It may be much thinner than this. The granodiorite which intrudes the limestone is a medium-grained grey rock and is cut by pink or brown aplite dykes. The microscope shows that it consists of plagioclase which was determined as albite-oligoclase, but which is commonly zoned, and a smaller quantity of perthite. Quartz forms 15 per cent or less of the rock and green to brown biotite and green hornblende are the principal accessories. Chlorite, epidote, apatite, and pyrrhotite were also noted. The rock may be termed a granodiorite, although it approaches the composition of granite. Fine to medium-grained, green lamprophyre dykes cut the granodiorite, limestone, and volcanics. They are thought to be related in origin to the granodiorite, although they are distinctly later. In composition they vary from andesite or diorite to diabase, consisting of plagioclase, a little orthoclase, some augite, and a small percentage of quartz. Hornblende, apatite, magnetite, and pyrite were noted and alteration to calcite, sericite, and chlorite makes it difficult to ascertain the exact original composition of the different varieties. Most of the dykes strike nearly due east and dip very steeply, probably following a system of jointing in the other rocks. One area of andesite, shown on the map, is apparently surrounded by granite and the writer could not determine whether it is a large dyke or a flow which probably would overlie the limestone.

The principal mineral showings occur in the limestone west of Copper creek in a belt, as far as known, some 400 feet wide adjoining the contact of the granodiorite. The exposures vary in elevation from 2,350 feet to 3,000 feet by barometer, and are found at intervals for 3,000 feet along the contact zone. The edge of the granodiorite is very irregular and the mineralization is apparently in some way related to it. No evidence could be found to indicate that the bedding of the limestone had controlled the mineralization, but future development may shed more light on this very evident possibility. In several cases rich ore was found along the walls of green lamprophyre dykes in the limestone. Pyrite, chalcopyrite, pyrrhotite, sphalerite, and molybdenite have been identified in the ore and chalcopyrite is by far the most abundant. Marcasite and covellite are secondary products and a few small stringers that may be bornite were noted under the microscope. The gangue minerals include magnetite, garnet, epidote, calcite, quartz, actinolite, chlorite, and sericite. Magnetite occurs intergrown with the silicates in a few places and as fairly pure tabular bodies in the limestone, but is not generally present in the ore. A green stain resembling greenockite (cadmium sulphide) on some of the sphalerite indicates that cadmium may accompany the zinc. The ore minerals occur chiefly as irregular replacement bodies in the limestone and no definite attitude has as yet been established. These bodies vary in size from mere stringers to solid masses 10 or 15 feet wide and many of them are almost pure chalcopyrite. Sphalerite is found intimately mixed with the copper or as relatively pure bodies. Pyrite and pyrrhotite are not generally abundant. Irregular blocks of limestone, showing little or no effect of the mineralization, occur throughout the ore and are frequently entirely surrounded by sulphides on the surface. These blocks range in diameter from a few inches to many feet. As a general rule contact metamorphic silicates are found in quantity only where granodiorite is exposed nearby; in many of the richer showings they are absent or very sparingly developed. Within the granodiorite, in the bed of Copper creek, chalcopyrite, molybdenite, and pyrite have been found along cracks or shear zones, sometimes accompanied by vein quartz and sericite. These showings are small and have not received any extensive development.

On the accompanying map (No. 2247) surface strippings and outcrops are shown and the more important ones are numbered. The most westerly showing, No. 1, is the largest on the property and exposed about 4,000 square feet of irregular mineralization of pyrite, chalcopyrite, pyrrhotite, and sphalerite in a gangue of limestone, calcite, epidote, a little garnet, and quartz. There is a small body of altered andesite at the south end of the showing. Clothier[1] states "the lower 15 feet will average 20 per cent or more copper, the next 15 feet probably 10 per cent, and the remainder shows bunches of chalcopyrite." Outcrop 2 consists of 2 to 3 feet of magnetite, garnet, and epidote at the contact of granodiorite and limestone and No. 3

[1] Minister of Mines, B.C., Bull. No. 2, p. 77 (1929).

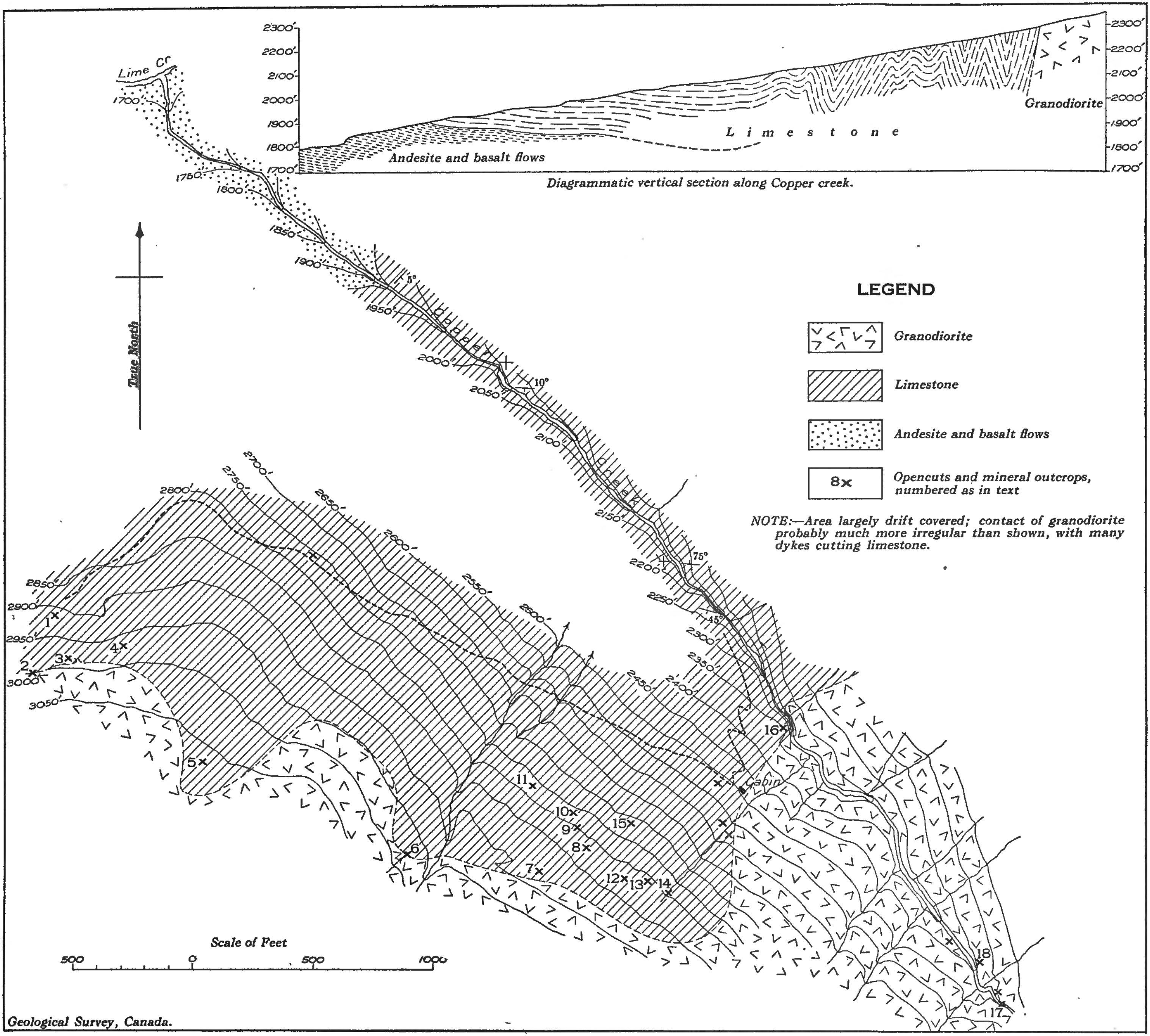

Figure 6. Nimpkish Copper group, Nimpkish lake, northern Vancouver island, B.C.

exposes 3 or 4 feet of mineralized material including pyrite, sphalerite, and chalcopyrite in limestone adjoining a sericitized granodiorite dyke. No. 4 is a tabular body of magnetite, partly exposed, and No. 5, on the edge of a sink-hole, is the western end of what appears to be a considerable area of sporadic mineralization in limestone, but no development had been done on it. At No. 6, on the edge of a sink-hole, there are several inches of chalcopyrite and zinc blende in limestone at the granodiorite contact and some richer, irregular replacement of zinc blende with copper farther away from the contact. The limestone here seems to be lying on flat, rolling folds and this attitude probably persists for some distance to the east, but the bedding is not well preserved. At No. 7, at another sink-hole there is a strong but very irregular mineralization of sphalerite, chalcopyrite, and pyrite in the limestone, but no mineralization could be found a few feet below in the wall of the sink-hole. No. 8 is a large stripping showing chalcopyrite, pyrite, sphalerite, and some pyrrhotite interspersed irregularly with limestone, but somewhat concentrated as rich copper ore along the walls of a lamprophyre dyke. There is a small outcrop of granodiorite, probably part of a dyke, at the southeast corner and silicates are quite abundant near it. No. 9 is an irregular showing of chalcopyrite and pyrrhotite and No. 10 is the richest zinc showing on the property; chalcopyrite occurs sparingly in the sphalerite and, as in 8, there is a small lamprophyre dyke, slightly mineralized, in the zinc blende. No. 11 may represent a continuation of No. 9, but the ground between these two similar showings is drift covered. No. 12 is a small outcrop of chalcopyrite, sphalerite, and pyrite in limestone; it is heavily oxidized. No. 13, a large outcrop, contains an apparent vein, 3 to 5 feet wide, trending south of east, in crystalline limestone which strikes almost due east and dips at 20 degrees to the south. The vein contains chalcopyrite, pyrrhotite, pyrite, and a little sphalerite. No. 14 is a small, rusty outcrop and it reveals about 10 feet of silicates adjoining 5 to 10 feet of gossan covering silicates and calcite with chalcopyrite and pyrrhotite. This showing contains more pyrrhotite than was noted elsewhere and adjoins the contact of a small body of granodiorite. The two cuts on either side of No. 15 consist principally of silicates, with a few small bodies of chalcopyrite, near granodiorite. No. 16 is on the edge of the canyon of Copper creek and exposes a rich showing of chalcopyrite in limestone with small blocks of limestone in the ore. Clothier[1] states that 25 feet will run about 20 per cent chalcopyrite carrying about $3.50 to the ton in gold values. No. 17 is a narrow shear zone in sericitized and kaolinized granodiorite, mineralized, for about 75 feet, with quartz and small amounts of pyrite, chalcopyrite, and molybdenite, and the first two sulphides also form veinlets and disseminations in the altered granodiorite near the vein. No. 18 is a large, rusty outcrop of pyrite in the wall of the creek bed. There are other small showings of copper, zinc, and molybdenite on the creek.

At other places on the claims, well removed from the mapped part, there are showings of magnetite and sulphides which were not examined in detail. They indicate a widespread mineralization in the limestone and at two places, on Lime creek and on the sidehill east of Lime creek, silicates,

[1]Op. cit.

magnetite, and sulphides were noted at the contact of the limestone and the underlying volcanics. Possibly this contact should be examined and prospected more thoroughly.

It is evident that the sulphide bodies in the limestone are rich and widespread and also that they are extremely irregular in outline and size. This irregularity will undoubtedly lead to much difficulty during development. The size and attitude of the different bodies have not been determined. The question that development must answer is whether these bodies are individually large enough or collectively sufficiently closely spaced to constitute ore-bodies. Mineralization similar to that exposed on the surface, that is, irregular replacement bodies surrounded by and containing blocks of limestone, may reasonably be expected to occur at depth as long as the limestone persists. In the underlying volcanics, however, the mineralization will assuredly be of a different character. Just what the difference will be is difficult to say, but the volcanics in this district do not, on the whole, constitute a very favourable host for mineralization. The dip of the granodiorite contact, evidently an important factor in the control of mineralization, must also be determined by development below the surface, as it cannot be determined accurately from outcrops. It will probably prove to be steep but very variable, after the fashion of the contact as exposed on the surface.

Smith Group

This group of claims is on Smith creek $1\frac{1}{2}$ miles northeast from the mouth of Lime creek and was being staked by Messrs. Smith and Storey when the writer visited it in July, 1929. Consequently no development work had been undertaken. The writer has taken the liberty of applying the name of the senior partner to it. On the claims, banded grey quartzite and argillaceous quartzite, striking northwest and dipping 40 degrees southwest, are underlain by not more than 200, or 300 feet of grey, crystalline limestone which lies conformably on top of a considerable thickness of andesitic and basaltic volcanic rocks. The whole assemblage is cut by numerous felsite, quartz porphyry, and feldspar porphyry dykes which have a predominant trend of north 70 degrees east. At several places in the limestone, and particularly near these dykes, small quantities of pyrite and chalcopyrite are associated with garnet, epidote, and other silicates. A few hundred feet southwest of Smith creek the sediments and volcanics are intruded by a body of grey granitic rock which is probably hornblende granodiorite. At the contact of this body and limestone, there are rusty outcrops containing contact metamorphic silicates, and pyrrhotite, magnetite, pyrite, and a little chalcopyrite and sphalerite. Also, at the contact of limestone with the overlying quartzites there is an abundant development of silicate. Although nothing that could be considered ore was observed by the writer the possibilities of discovering richer mineralization were considered to be excellent, as the owners claim to have traced the mineralization for a considerable distance to the north and south along the granitic contact. The limestone-quartzite contact is a favourable structure and also offers interesting possibilities for prospecting. Under the microscope the sulphides were observed to have replaced fibrous ferromagnesian gangue minerals.

Klaanch Group

This old group contains eight claims known as the Vulcan, Sardine, Letitia, Magnet, Klaanch, Nimpkish, Iron Crown, and Rhoda. The original discoveries were made in 1897 by Jim Haslow and the Mathers brothers and three claims were staked that year, by these men and John Mathers and John Stark. John Mathers, of Sandspit, Queen Charlotte islands, is still part owner. The property was developed by yearly assessment work until 1904 when it was Crown granted. The last claim, the Rhoda, was staked and Crown granted in 1919 and no work has been done on the group in recent years. A trail leads to the property from Anutz lake and the claims are staked in the above-mentioned order from northwest to southeast. The area is low-lying and heavily wooded and large parts of it have been burned over and are now covered with an exceedingly dense growth of small evergreens. The property has been described by Young[1] and Lindemann[2].

On the property a zone of magnetite with minor quantities of silicates, pyrite, and chalcopyrite occurs as a replacement at the contact of limestone on the southwest and basic volcanics on the northeast. The contact trends northwesterly through the middle of the group and is poorly exposed, but has been picked up in several places at outcrops or by open-cuts and winzes for about 9,000 feet. At the southeast end of the group the volcanics are intruded by a stock of granodiorite. The writer did not examine the Rhoda, Iron Crown, or Nimpkish claims, but in a creek bed a few hundred feet west of Nimpkish river on the Klaanch claim abundant magnetite containing irregular, small quantities of pyrite and very little chalcopyrite is partly exposed. The magnetite occurs as disseminations in volcanics and fairly pure replacement bodies, up to 10 feet or more in width, in crystalline limestone. On the adjoining Sardine claim to the northwest no exposures were found, but on the next claim, the Magnet, an old shaft and open-cut expose the mineralized zone for a width of 25 feet. It consists of magnetite and more pyrite than was observed on the Klaanch and is at the same volcanic-limestone contact which here seems to be standing almost vertical. On the Sardine, just northeast of the Letitia, it is reported that mineralization has been uncovered, but the old cuts could not be found. On the next claim, the Vulcan, near the southeast boundary, there is a small outcrop of quartz and pyrite. This showing is probably about 4 or 5 feet wide and contains a little chalcopyrite and magnetite. A sample of the richer pyritic material was collected in the hope that it might carry gold. The assay, made by the Division of Chemistry, Mines Branch, Ottawa, gave the following results: gold, trace; silver, trace; copper, 0·45 per cent. The deposit is apparently of importance only as a potential source of magnetite. The change from heavy magnetite mineralization at the southeast end, near the granodiorite, to siliceous, pyritic material on the northwest, farther away from the granodiorite, is interesting and noteworthy.

[1]Young, G. A. and Uglow, W. L.: Geol. Surv., Canada, Econ. Geol. Series No. 3, 1926, p. 64.
[2]Lindemann, E.: "Iron Ore Deposits of Vancouver and Texada Islands, B.C., Mines Branch, Dept. of Mines 1910, pp. 19-20.

Other Magnetite Deposits

Magnetite occurs on all copper deposits that have been described in this report. It is found intergrown with silicates and sulphides, as disseminated replacements in volcanics, and a fairly pure tabular replacement in limestone, also occasionally in basic members of the Coast Range intrusives. If the need arose, and if the material could be beneficiated to produce a suitable iron ore, large tonnages could be extracted from a deposit like Coast Copper during copper mining operations. Under present conditions, however, the magnetite deposits of the area are attracting little attention.

Other Showings Near Nimpkish Lake

At the time of the writer's visit to this area there were numerous prospectors in the field and it is understood that several promising showings have since been uncovered. On the east shore of Nimpkish lake, 3½ miles from the southern end, a fine-grained, greenish grey dyke from 2 to 6 feet wide and lenticular in outline along the exposure strikes nearly due east and dips at 65 degrees to the north, cutting flat-lying crystalline limestone which, a short distance north, strikes northeast and dips gently to the southeast. Immediately above the dyke from 6 to 10 feet of garnet, epidote, actinolite, etc., have replaced the limestone; below it the same material forms an irregular zone from 2 to 4 feet wide. Massive, black tourmaline forms small bunches in the silicates and there is a small quantity of pyrite. Several hundred feet up to the hill to the east of the lake a similar and possibly the same silicate zone was noted by the writer and it seemed well worth attention in the hope of finding copper or zinc sulphides. The dyke is a fine-grained diorite consisting essentially of calcic andesine and hornblende partly altered to chlorite. There may have been augite in it originally and it is slightly porphyritic.

Copper King Group (Atkins Cove)

The two claims of this group are just inside the entrance of Atkins cove in Neroutsos inlet, on the west shore. The owner is F. G. Patterson of Quatsino. No work has been done in recent years and the old workings, consisting of a shaft and several open-cuts, are badly caved. On the claims, fine-grained siliceous and otherwise altered grey to white limestone strikes northwest and dips from 20 degrees to 25 degrees to the southwest and is overlain by a series of volcanic flows and fragmentals. About 150 yards northeast of the contact the limestone is sparingly mineralized along cracks and joints and is partly replaced by chalcopyrite which is converted at the surface to green and blue carbonates. The limestone is slightly pyritic and small amounts of pyrite accompany the chalcopyrite. The old workings indicate that the mineralized zinc trends a little north of west, but no idea of the importance of the mineralization could be obtained. A pronounced jointing in the overlying volcanic rocks trends north 35 degrees east and dips at 45 degrees to the southeast and might be mistaken for bedding planes. The property is not included in the group of pyrometasomatic copper deposits. Contact metamorphic silicates are lacking and it is far removed from any known body of granitic rock.

Paystreak Claim

The Paystreak No. 1 claim is beside the trail to the Quatsino King and 165 feet above sea-level. It was staked in July, 1929, by S. Hegglun, but was evidently worked a number of years ago. The dump of an old shaft, now flooded, contains a considerable quantity of pyrrhotite, black sphalerite, some pyrite, and very little chalcopyrite in a gangue of quartz, chlorite, and chloritized rock. Just below, in a small creek, there is a large, rusty cropping of pyrrhotite, and a few yards upstream a stripping exposes 4 feet and less of pyrrhotite, sphalerite, and pyrite in a partly silicified green rock which is probably an andesite flow and which appears to strike due north and dip 45 degrees to the west.

GOLD QUARTZ VEINS

Several attempts have been made to develop gold-quartz veins, with but little success. From 1907 to 1912 there was a certain amount of activity in the vicinity of Klaskino inlet and Lawn point on the west coast and it is reported that Klaskino Gold Mines, Limited, shipped 100 sacks of gold ore in 1911. The writer was informed by residents of Quatsino that native gold occurred in small, high-grade pockets in quartz veins, but was unable to visit the locality. Today there is no activity in the vicinity of these old workings. The only property of this type within the Quatsino-Nimpkish map-area is the Quatsino King on Neroutsos inlet.

Quatsino King (Teeta River Gold)

This property is one of the oldest in the district. It was staked about 1898 by C. Nordström and G. Sorensen of Quatsino and was developed by them for several years. In 1910 and 1911 it was worked by the Teeta River Gold Mining Company of Vancouver, but was dropped after about $10,000 had been spent. The latest work consisted of diamond drilling by Granby Consolidated in 1917. This company intended to use the ore as a siliceous flux and had hoped that it would carry sufficient gold to pay for handling, but apparently the results they obtained were not satisfactory. Since then the property has been deserted; the old trail from the beach is in bad shape and all the buildings have fallen down.

The deposit occurs in an altered and faulted series of tuff, breccia, and limestone of the Vancouver group. These rocks are cut by many acidic dykes which vary from felsite to quartz porphyry and feldspar porphyry, and also by grey lamprophyres. A short distance west of the upper showing a large body of granodiorite outcrops, and dykes of it are found in the vicinity of the workings. The largest exposure, a quartz vein about 16 feet wide and slightly mineralized with pyrite and chalcopyrite in specks and veinlets, is 1,300 feet above sea-level. The vein apparently strikes about north 30 degrees west and dips about 60 degrees to the northeast. Two hundred and seventy-five feet below, an adit has been driven 230 feet on what is presumably the same vein. Near the portal it is similar to the surface showing, but towards the face, where granodiorite dykes appear, it is faulted and quite irregular. There are two other smaller adits and a second open-cut, but sufficient time was not available to correlate correctly these different workings. However, if the quartz and accompanying silicified rock do not carry commercial gold values, there is probably little hope for the property as the chalcopyrite is not sufficiently abundant to encourage development as a copper property.

One other deposit might be placed in this group. In years gone by a little work was done on the Yankee Girl claim on Red island in Rupert inlet. Pyrite occurs along cracks and joints in a dense, dark grey, silicified rock that resembles a sediment and is accompanied by quartz and calcite. An old shaft was sunk a few feet on a narrower seam, containing these minerals, at the west end of the island, and it is reported that there is also an adit on the property. Presumably the deposit was developed in the hope of obtaining commercial gold values from the pyrite and quartz.

QUARTZ-CARBONATE VEINS WITH SULPHIDES

There are a few small deposits in the district which consist of irregular and rather discontinuous veins of quartz and carbonates including calcite and a ferruginous variety which is probably ankerite, mineralized with sphalerite and chalcopyrite. They are found in sheared argillite and calcareous argillite and, as yet, do not appear to be of any great economic importance. In addition to the two properties briefly described below the writer has seen specimens of slightly pyritic argillite veined with calcite, from Nimpkish river a short distance south of Nimpkish lake, which were said to contain gold values. The deposit was being prospected in the summer of 1929.

Blue Ox

The eight claims of this group are on Blue Ox creek, 5 miles south of the Old Sport mine, and are owned by Messrs. George and M. H. Adams. Consolidated Mining and Smelting Company optioned the claims and did some open-cutting and diamond drilling in 1929, but then dropped their option. On the claims a series of argillites, calcareous argillites, and quartzites is cut by many basic and acidic dykes. The sediments are extensively sheared and contorted so that their attitude is very variable. A shear zone, trending due north through the centre of the group, is extensively but very erratically mineralized with veins, stringers, and lenses of quartz and carbonate which carry similarly erratic veinlets and pockets of chalcopyrite and sphalerite and a little pyrite. This mineralized zone has been exposed at intervals by open-cuts for about 2,400 feet. At the south end, in Blue Ox creek, the vein, after being offset about 25 feet by a fault, enters light greenish grey andesite. The surface showings do not leave one with the impression that the deposit is of much commercial importance.

Rainier

Consolidated Mining and Smelting Company holds a large number of claims, including the Big Chief, and Elk groups, on Rainier creek, and the writer has, for convenience, shown them on the map as the Rainier group. The claims cover a large area of rugged, heavily wooded country and have received only a little prospecting. On the north side of Rainier creek there is much grey to white crystalline limestone which is presumably a continuation of the band that passes through Coast Copper and Quatsino Gold ground to the north. On the south side of the stream argillites, impure limestones, quartzites, and some volcanics are contorted and sheared and cut by numerous dykes. Near the head of the creek there is a small intrusion of granodiorite or diorite and there are also many dykes of similar material. On the basis of a very hasty examination it seems probable that there is a fault of major importance in the bed of Rainier creek, separating the argillites from the limestone to the north.

At 1,950 feet elevation, on the south side of Rainier creek, the company has uncovered a number of small quartz calcite veins, containing rock fragments, chalcopyrite, zinc blende, and pyrite in a shear zone about 12 feet wide in the argillite series. The largest vein exposed was 8 inches wide, but the entire mineralization was quite irregular. The sediments just above the cut strike north 50 degrees east and dip 45 degrees to the southeast. On the north side of the stream, some distance west of the above showing, a large stripping exposes an irregular replacement of pyrrhotite, pyrite, and chalcopyrite in altered crystalline limestone. The main mineralization, in a zone about 4 feet wide, appeared to strike about north 35 degrees west and dip at a fairly low angle to the southwest.

LEAD-ZINC REPLACEMENT DEPOSITS IN LIMESTONE

Deposits in limestone of sphalerite and galena, with or without pyrite, pyrrhotite, arsenopyrite, or chalcopyrite, have been found at a few places. The sulphides occur as irregular bodies in the limestone and have been formed by replacement. As is so frequently the case in this type of deposit it is difficult to determine the factors that have controlled deposition and consequently development is generally a matter of considerable difficulty. The continuity of the mineralization in any direction is nearly always doubtful. The most important controlling structures are apt to be the bedding of the limestone, or pre-mineral dykes in the limestone, or the contacts of limestone and other interbedded rocks. The deposits are believed to have been formed by vapours or solutions arising from deep-seated magmas of the Coast Range intrusives, but they are a lower temperature type than the pyrometasomatic copper deposits of the district and consequently may be expected at a greater distance from exposed intrusions of granitic rock. When they are found in close proximity to these intrusions pyrrhotite and sphalerite are apt to be more abundant than pyrite and galena. In addition to the two properties described below the *Bowerman group* on the north side of Holberg inlet, near the head of Spruce creek, may be mentioned. The writer did not visit this property, but it is described in the annual report of the Minister of Mines, B.C., for 1922, where it is recorded that galena, zinc blende, and pyrite were identified in a zone, possibly 200 feet wide, consisting of breccia, quartz, and calcite.

Alice Lake Group

This group of six claims is a little less than a mile west of Alice lake and half a mile south of the road from Jeune Landing to Alice lake. It is owned by Messrs. Wm. Clancy and W. D. Kinsey, of Quatsino, B.C. Discovered in 1924, it has been worked since then by the owners, two short adits, one raise, a shallow winze, and several open-cuts comprising developments to date. The workings are on a heavily timbered northeastern mountain slope at an elevation of about 1,000 feet. Outcrops are scarce, but in the general vicinity crystalline dark grey to white limestone is the pre-

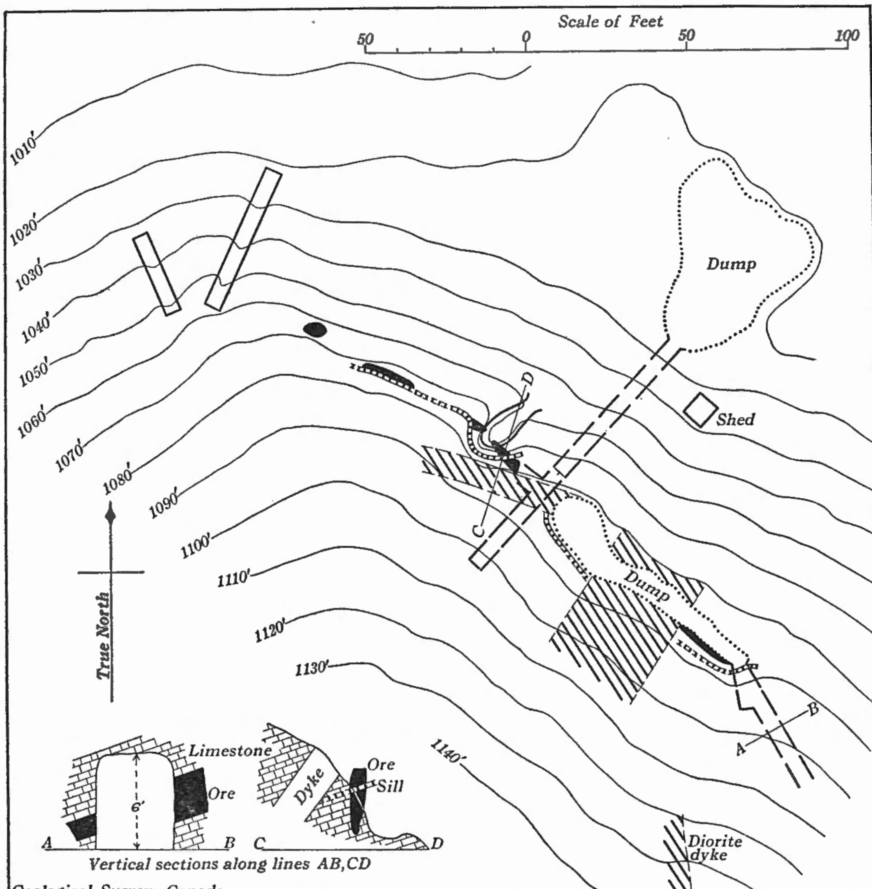

Figure 7. Plan of Alice Lake group, northern Vancouver island, B.C. Except for dykes and sills (shown by diagonal line tint) the country rock is limestone. Outcrops of ore are shown by solid black.

dominant rock. There are also many dykes and sills which vary in colour from green to white and in composition from diorite and andesite to felsite. The limestone lies in a series of gentle folds, dipping at low angles to the northeast or southwest and striking to the northwest. There are probably occasional interbeds of lava or fragmentals, but none was noticed in the vicinity of the workings.

The accompanying plan and sections (Figure 7) illustrate the occurrence. The vein was originally found along the side-hill where the dump of the upper adit now exists and is at present covered with broken rock. In the shallow winze just northwest of the end of the dump it is exposed in vertical section. At the top of the cut it is from 2 to 3 feet wide and is vertical; 15 feet below, near the bottom of the winze, it thins to 1 foot and then suddenly ceases. It is a replacement body in limestone and it is cut by a narrow sill of felsite which is unmineralized (*See* section C-D). The lower adit was driven underneath this section of the deposit as shown, but encountered no ore and is entirely in limestone with the exception of one small andesite dyke and a felsite sill 30 feet from the portal. Recent work has been directed to the development of the southeasterly continuation of the vein and the upper adit has been driven (September, 1929) 48 feet on it. The adit follows a bedded replacement in limestone which is from a few inches to 4 feet wide with the exception of one place where the ore petered out for a few feet. The ore, consisting of well-crystallized pyrite, galena, and sphalerite, with more or less coarse calcite, follows along the drift about breast high (*See* section A-B) roughly following the bedding but cutting across it in detail in many places. Sometimes the sulphides have entirely replaced the limestone across 2 or 3 feet, at others they are disseminated in it rather sparingly, and they frequently exhibit a nodular zoned structure with an outer layer of pyrite surrounding a core of galena. The ore in the winze is similar to that in the adit except that it contains some arsenopyrite. Examination of the ores under the microscope reveals small areas of a light grey mineral, probably tetrahedrite, in the galena, and small stringers and specks of chalcopyrite in the sphalerite. Mr. Clancy states that ore from the upper adit will average about $14 in gold, 10 ounces in silver, 12 per cent lead, and 8 per cent zinc.

The diorite dyke above the upper adit consists of andesine, a small amount of augite, accessory calcite, chlorite, hornblende, epidote, and pyrite and a moderate amount of a perthitic intergrowth of plagioclase and alkali feldspar. It might best be termed an augite diorite. The small, light greenish grey felsite sill on the upper dump was found to consist of a very fine-grained intergrowth of albite-oligoclase, calcite, sericite, and pyrite and the andesite dyke on the lower adit, which is similar in appearance to the large dyke cutting across the upper dump near the portal of the adit, consists largely of very fine-grained plagioclase about the composition of andesine, calcite, and about 1 per cent of fine-grained quartz.

The ores have probably been formed by replacement of limestone by solutions or emanations arising from the magma of a large stock exposed on and south of the adjoining June group. Although the dykes on the property are not, apparently, directly connected with the mineralization, yet they are probably derived from the same source and are of some structural importance. The small sill just northwest of the winze has evidently exerted some control on the mineralization as sulphides are concentrated just below it for a short distance. Also, as the dykes are quite numerous and as they are unmineralized, where they cut the deposit they will hinder development. The large diorite dyke west of the upper adit may thus become an important structural unit, as the deposit in the adit is dipping gently towards it. The bedding of the limestone has evidently exerted some control in localizing the mineralization, but, as in many deposits of this class, apparently no one structural feature is sufficient to explain the vagaries of the deposit. The old maxim, "follow the ore" seems to be the only safe way to develop such a property.

Messrs. Clancy and Kinsey also own two claims, the Sunset and Sunrise, a short distance from the shore of Neroutsos inlet in the bay east of Frigon island. They report that the mineralization is somewhat similar to that on the Alice Lake group, but that they have done very little work on the deposit.

Pilgrim

This claim, apparently also called the Peerless, adjoins the Amazon claim of the June group on the southeast and is owned by Henry Sherberg of Quatsino. The showings are about 250 yards southeast of Amazon river in heavily timbered country and are exposed by open-cuts in two places. The country rock is crystalline limestone of the same belt in which are the June and Coast Copper deposits; cut by aplite and quartz porphyry and also basic dykes. The main contact of the dioritic stock which outcrops on Victoria lake and Amazon river cannot be far to the southwest of the workings. The northwesterly showing consists of about 8 feet of a mixture of pyrrhotite, sphalerite, arsenopyrite, and a little galena with calcite and quartz replacing limestone beside a 78-inch rusty quartz porphyry dyke. A little less than 100 yards to the southeast a large stripping has exposed, for about 40 feet, heavy mineralization similar to the above, but containing more dark brown zinc blende and also pyrite. Zinc blende and arsenopyrite are in part beautifully crystallized. The width of the cut is about 15 feet and it probably cuts diagonally across the zone of mineralization; several dark grey dykes are exposed. A rough banding in parts of the ore which may be due to replacement of bedded country rock suggests that the deposit may dip rather flatly to the northeast. It is reported that Consolidated Mining and Smelting Company drilled the property some time ago, but did not obtain satisfactory results at depth. A grab sample[1] taken in 1916 from ore on the dump assayed: gold, 0·02 ounce; silver, 2 ounces; copper, nil; zinc, 37 per cent; and iron, 26·8 per cent.

COPPER DEPOSITS IN BASIC LAVAS

The basaltic lavas of the Vancouver group are occasionally mineralized with small amounts of chalcopyrite, bornite, or native copper. These minerals occur as small specks in amygdules or in tiny veins in the rock and are generally much too meagre to be of commercial importance. In a few places, however, the copper is sufficiently abundant to have led to prospecting or exploration. Two deposits of this class are described below and in them bornite is the most abundant ore mineral. Native copper, which, in most deposits of this class elsewhere, is the most important copper mineral, is absent or very sparingly developed. However, on the south shore of Holberg inlet, 3½ miles east of Holberg, native copper was

[1]Minister of Mines, B.C., Ann. Rept., 1916, p. 343.

noted as minute flakes and specks associated with quartz, calcite, and prehnite, in an altered, chloritized, amygdaloidal basalt. A little work has been done on this showing, but it does not appear to be persistent and the greatest width noted by the writer was a little over 2 feet. Similar mineralization has been noted elsewhere on the island.[1]

These deposits evidently belong to that group of mineral deposits in which native copper, and less frequently bornite and chalcopyrite, is associated with quartz, calcite, zeolites, and other minerals in basic lavas. Deposits of this class are numerous, but many of them are of no commercial importance. The most generally accepted theory of origin today is that the deposits have been formed as an after effect of eruptive action by circulating waters which produced a concentration of copper from the minute amounts of that metal that are generally present in basic lavas; and that the temperature of formation is low, probably not greater than 250 degrees C. Thus, no deep-seated origin, connected with intrusive rocks, is assigned to them. Concerning the distribution of copper values in the lavas it has been found that particularly amygdaloidal zones, frequently at and parallel to the top or the bottom, of flows, are most heavily mineralized, but also that veins cutting across the flows are occasionally of economic importance. In addition, although much of the copper is contained in amygdules yet the rock itself is occasionally replaced by sulphides or native copper.

Millington Group

This group of six claims is owned by Messrs. D., E., and J. Spooner and Pobling of Holberg, B.C., and ten additional claims in the vicinity are held jointly by Mrs. K. Spooner, the Spooner brothers, and Messrs. J. Cordy and Chris. Sundropp. The holdings are about 3 miles west of the head of Holberg inlet and a short distance south of Spruce creek. From Holberg they are reached by using the auto road for nearly 3 miles and from it a good trail leads to the property, Spruce river being crossed on a cable chair. The property was discovered about 1916 and has been worked for several years by the present owners. To date three adits have been driven near the bed of Crackerjack creek at the east end of the property and open-cuts have been made on different parts of the claims which cover a well-wooded and rather low-lying mountain ridge. In 1928 Consolidated Mining and Smelting Company optioned the property and, after putting in two diamond drill holes, neither of which encountered any ore, dropped their option. The owners are again proceeding with development.

The mineralization consists essentially of bornite as disseminations and stringers in a dark green amygdaloidal basalt. Associated with the bornite are occasional small amounts of chalcopyrite and pyrite and some old assays indicate a little zinc. At the surface the bornite is extensively altered to chalcocite and covellite. The amygdaloidal exhibits very little structure, but it probably forms part of a considerable thickness of basic extrusives striking approximately northwest and dipping from 20 degrees to 30 degrees to the southwest. The base of the rock is very

[1]Dept. of Mines, B.C., Bull. No. 2 (1929). Prelim. Rev. and Sum. of Mining Operations, p. 78.

dark green and the amygdules are almost black or white, standing out clearly on the weathered surface and consisting of amphibole, serpentine, quartz, calcite, or epidotes. Near several of the showings the basalt is altered to a light green, soft, chloritic material in which the white quartz amygdules stand out in prominent relief. Some faults were noted, but no major displacement has been proved.

Bornite has been found at several places in a zone running northwesterly across the claims (*See* Figure 8). It occurs, as noted above, in veins, generally less than 6 inches wide and quite discontinuous, cutting across the apparent strike of the basalt and also disseminated, particularly in amygdules. The sulphide is concentrated, in several places, along narrow zones which are more strongly amygdaloidal than the surrounding basalt and which follow the strike of that rock. The richest showings are in the bed of Crackerjack creek. In one place a stripping, 40 feet long, exposes a heavy mineralization in a zone about 10 feet wide. A distinct shear zone, trending north 80 degrees east and dipping steeply north, is exposed across the cut and along it the basalt is converted to a dull red, somewhat brecciated material. A second cut, 50 feet southeast or upstream, exposes a slight mineralization and two other cuts 150 feet farther upstream show a maximum width of 2 feet of bornite in stringers $1\frac{1}{2}$ inches or less in width along a narrow shear zone. Forty feet vertically below and 45 feet northeast of the first-mentioned cut an adit was run in a southwesterly direction for 43 feet and encountered the downward continuation of the north 80 degrees east shear zone. The latter was drifted on for 87 feet, but no mineralization other than a few scattered specks of bornite in the south wall was encountered. The crosscut, continued 16 feet southwest and then turned to the east for a few feet, encountered nothing but basalt. The work was done in the belief that the mineralization followed the shear zone and, when such proved to be not the case, was discontinued. Additional mineralization has been exposed by strippings on the steep hillside some 250 feet to the northwest and an adit has been driven a few feet. Here there is a zone, some 10 feet wide, which is irregularly mineralized with bornite and chalcocite. Not much sulphide is visible, but the writer is informed that some very fair assays have been obtained and it is quite possible that the material is richer than it appears to be, for much of the copper may be in the form of dull, earthy chalcocite which would be difficult to detect in the dark coloured amygdules. A rough banding indicates that the mineralized zone most probably trends about north 40 degrees west and dips about 25 degrees southwest or into the hill, following the bedding of the basalt. This, however, is by no means certain, but is sustained by the fact that additional mineralization has been found farther northwest, on the Superior claim, in what would be the correct position under such a theory. A horizontal drill hole, shown on the map (Figure 8) was put in by Consolidated to pass under the above-mentioned short adit and failed to encounter any ore. As there has been some discussion as to the importance of this result the writer has made certain calculations based on the figure. Thus, assuming the probable strike of north 40 degrees west and dips of 20 degrees, 25 degrees, and 30 degrees to the southwest for the mineralized zone, it appears that, if the hole proceeded

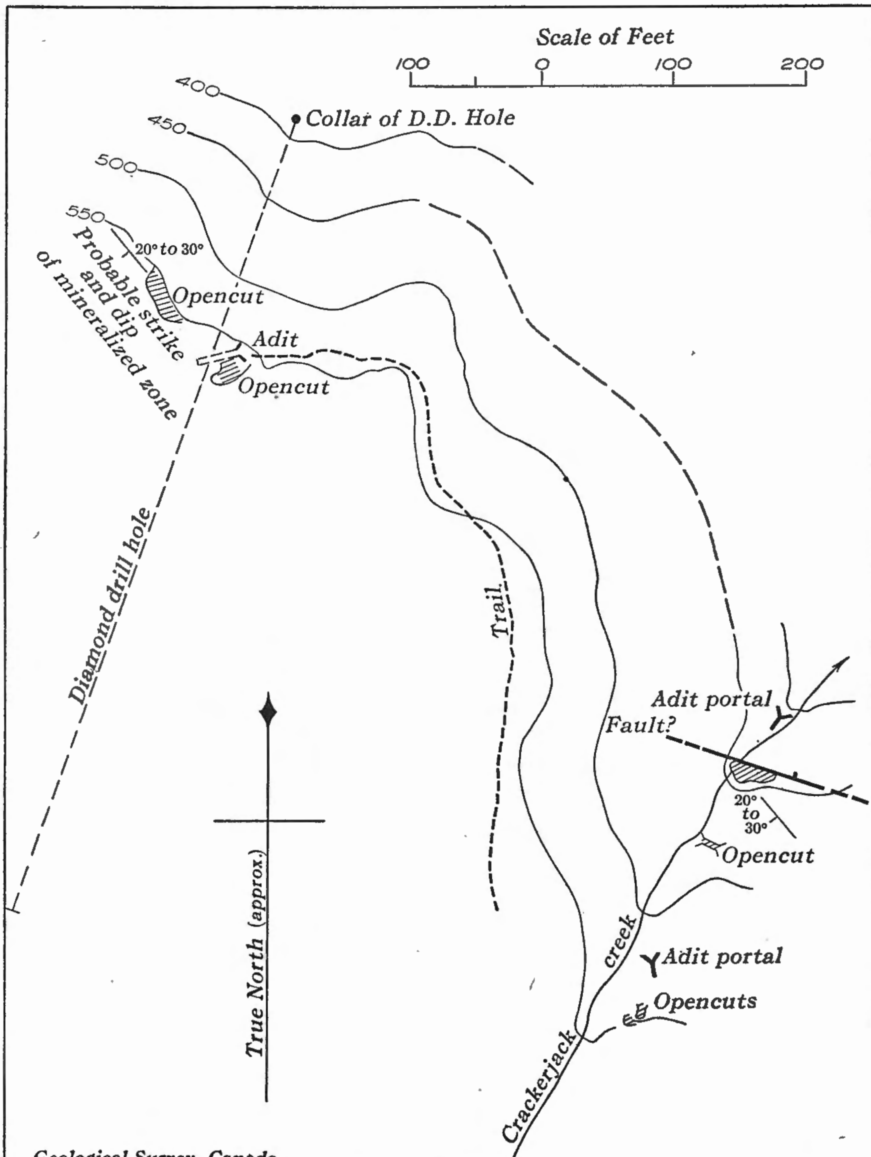

Figure 8. Plan of part of Millington group, northern Vancouver island, B.C. Outcrops of scattered mineralization are represented by diagonal line tint.

in a straight line from the collar and if the mineralized zone continued on depth with a dip of 25 degrees, the diamond drill should have passed through the zone 620 feet from the collar or 16 feet from the end of the hole. Also, if the zone continued down on a dip of 20 degrees the hole would not encounter it for another 100 feet. Similarly, if the zone persisted on a dip of 30 degrees the diamond drill should have cut it 535 feet from the collar. As there is no certainty regarding the exact attitude of the mineralized zone and as there is likewise no proof that the drill hole proceeded on a straight course, it seems evident that the results do not prove a great deal other than that no ore was encountered along the actual line of the drill hole. It might be well to add that a diamond drill might quite conceivably pass through a mineralized zone of this type without encountering any ore.

Some of the bornite from the Superior claim contains a number of small, round, radiating groups of a greenish grey to brown mineral which, with microscope and blowpipe, was identified as prehnite ($H_2Ca_2Al_2(SiO_4)_3$). Individual groups of crystals are about $\frac{1}{8}$ inch in diameter and, with the metallographic microscope, were found to be partly replaced by bornite, the latter itself largely altered to chalcocite and covellite. Prehnite is closely related to zeolite, and with them is commonly found in the zeolitic copper deposits in basic lavas. The abundance of bornite and the lack of native copper at the Millington are peculiar for this class of deposit. Although no great persistence of mineralization has yet been proved it is possible that one or more horizons in the lavas might be found to carry commercial quantities of copper; otherwise the best that can be expected is a small production of high-grade bornite ore from some of the rich but small surface showings. It is stated that the ore will average about $1 in precious metals per ton of 3 per cent or 4 per cent copper ore.

Rupert Claim

This claim on the south shore of Rupert inlet was staked by C. Nordström and an associate, of Quatsino. In 1910 the Canadian American Exploration Company was proceeding with development by driving a crosscut adit. No work has been done since then. Mr. G. Nordström of Quatsino reports the original stakers shipped 6 tons of 8 per cent copper ore in 1908. The old tunnel is partly flooded and an old shaft at the portal is completely so. The writer noted a few quartz-calcite stringers carrying a little bornite near the portal of the adit in a purple, sheared andesite. A short distance west, green amygdaloid is everlain by limestone and the adit was evidently driven towards this contact.

SUMMARY AND CONCLUSIONS

The most important mineral properties of Quatsino-Nimpkish area are pyrometasomatic copper deposits. One property is developed to a stage where future production is assured and a few others are worth extensive development. In this type of deposit chalcopyrite and bornite are rather irregularly distributed in zones and irregular masses of garnet, epidote, and other silicates and magnetite or hematite. Only occasionally are the silicates and oxides absent or sparingly developed. Occasionally zinc blende is an important constituent of the ores. The mineralization is found most commonly as a replacement of limestone; less commonly in volcanic rocks, in close proximity to stock-like bodies of intrusive rock which varies in composition from gabbro to granodiorite. Consequently, in prospecting particular attention should be paid to areas underlain by limestone near granitic intrusions or where complementary basic and acidic dykes are abundantly developed. Areas underlain entirely by volcanic rocks are apparently not favourable prospecting grounds, although the writer feels that if these rocks were extensively sheared, as is not often the case in Quatsino-Nimpkish area, in the vicinity of intrusions there should be a fair likelihood of finding replacement sulphide deposits. In amygdaloidal basalts, of course, mineralization similar to that described above under "Copper Deposits in Basic Lavas" might be expected at any point regardless of the presence or absence of intrusive rocks. The limestones also contain galena-sphalerite replacement deposits which, like the copper deposits, are related in origin to the Coast Range intrusives, but, being formed at a lower temperature, are apt to be further removed from exposed intrusive bodies than the copper deposits. The only mineralization so far found in argillites and associated sediments are rather erratic quartz-carbonate veins carrying small amounts of sulphides. Although gold values are generally low in the deposits of the district yet a few important exceptions, both in sulphide deposits and quartz veins, indicate that it is important to have samples of new discoveries assayed for the precious metals.

Much of the northern part of Vancouver island has never been carefully prospected in spite of the fact that it is so readily accessible from Vancouver and other west coast centres. Although admitting that copper deposits of the type which have been found there are frequently very erratic and difficult to develop, yet, in view of past accomplishments, location, and opportunity for new discoveries, the writer feels that the district has not received the attention which it deserves. The area east and southeast of Nimpkish lake, as far south as Campbell river, is largely unprospected. Not much is known about the geology of this area, but, from what is known to the south, east, and north, and from information gained from prospectors and one or two old publications, it is safe to assume that a series of volcanic rocks, limestones, and other sediments of the Vancouver group is intruded by bodies of granodiorite and associated igneous rocks. Consequently it is reasonable to assume that mineral deposits, similar to those found elsewhere in the district, will sooner or later be discovered. A second area of some promise to the prospector lies on the continuation of the Quatsino limestone belt southeast of Elk lake. This limestone belt in all probability continues from Elk lake up the Raging-Tahsish valley and on to Zeballos and Tasis rivers. During the past few years several deposits have been staked on Zeballos river, but the more inaccessible parts of the belt are still unprospected. Between the Quatsino limestone and Nimpkish valley is a great assemblage of volcanic rocks, which so far as is known to the writer, does not appear to offer much encouragement to prospecting.

THE SERPENTINE BELT OF COQUIHALLA REGION, YALE DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes

CONTENTS

Illustrations

GENERAL STATEMENT

The latter half of August and the first week in September, 1929, were spent by the writer in examining recent discoveries of gold occurrences in Coquihalla area[1] and vicinity, Yale district, British Columbia.

These discoveries are mostly located along the contacts of serpentine with other members of a zone of rocks which, for convenience in this report, will be referred to as the *serpentine belt*. This belt averaging, in the area explored, something over half a mile wide and nowhere much exceeding one mile, has been traced both to the northwest and southeast across Coquihalla area and for several miles beyond (Figure 9). Its most characteristic, most conspicuous, and, from the point of view of recent discoveries, most interesting, constituent is *serpentine*,[2] a secondary rock which, in this case, is regarded as having formed from a peridotitic intrusive—the transformation having been effected principally by magmatic vapours and solutions accompanying intrusion both of the peridotite and of the associated less basic, diorite and gabbro, rocks. Other members of the belt include fine-

[1] Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, "Coquihalla Area, B.C."

[2] *See* footnote, p. 176.

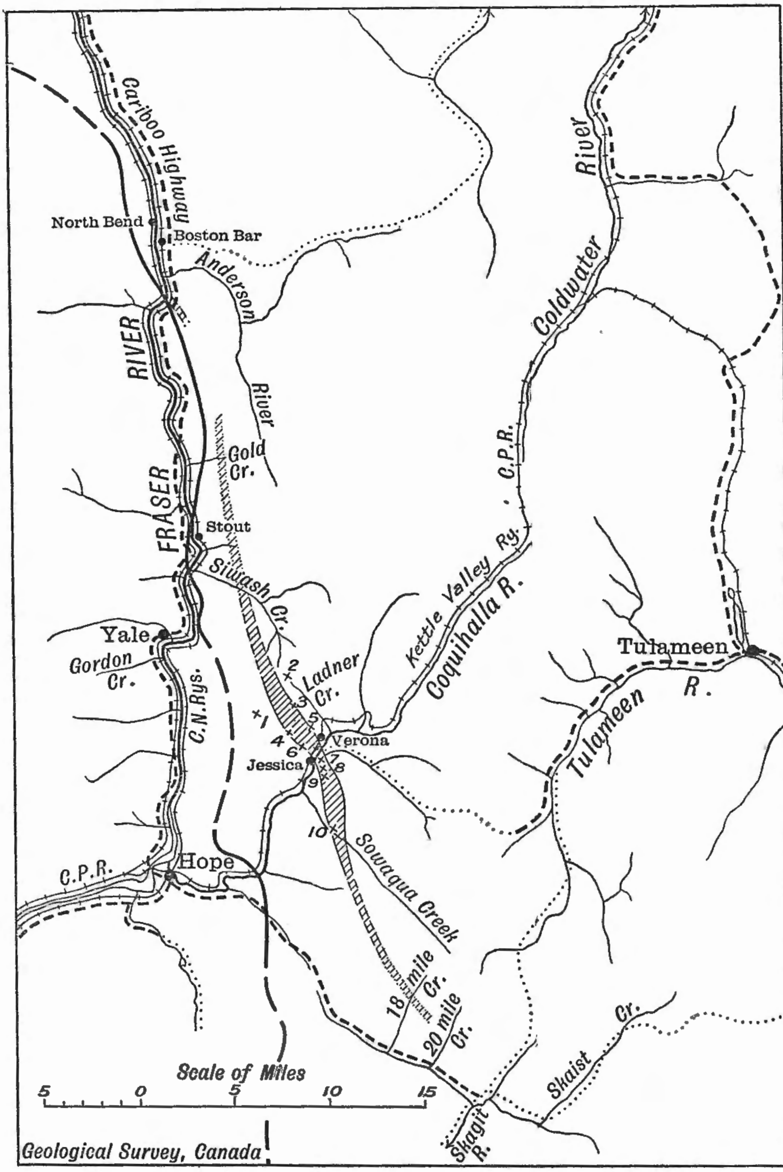

Figure 9. Index map showing position of serpentine belt in Coquihalla and adjacent areas, Yale district, British Columbia. Extent of serpentine belt is shown by line tint; the eastern contact of the Coast Range batholith is shown by a heavy line; the principal properties are shown by crosses, No. 1 Mammoth Holdings, Limited; No. 2, Home Gold Mining Company, Limited (Pipestem mine); No. 3, Aurum Mines, Limited (Aurum mine); No. 4, Hope Gold Mines, Limited (South Fork group); No. 5, Dawson Gold Mines, Limited (Emancipation mine); No. 6, Hope Gold Mines, Limited (Fifteen-mile group); No. 7, Columbia Metals, Limited; No. 8, Reward Mining Company, Limited; No. 9, Dalhousie Mining Company, Limited; No. 10, Peer River Placer Company, Limited.

grained volcanic rocks, chiefly greenish or greyish green meta-andesites; a varying proportion of volcanic tuffs, breccias, and tuffaceous sediments; occasional dykes of quartz porphyry or syenite porphyry; and minor bodies of a " white-rock " intimately associated with the serpentine.

HISTORY OF RECENT EXPLORATIONS

Until recent years prospecting for gold in the vicinity of the serpentine belt had been mostly concerned with the discovery and investigation of quartz veins or siliceous zones occurring either in the Ladner slate belt, which adjoins the serpentine belt to the northeast, or in volcanic members and tuffaceous sediments of the serpentine belt itself. To the southwest of this belt, again, some prospecting had also been done on quartz veins in cherty and argillaceous sediments of the Cache Creek series. On the whole the results attained in these operations were disappointing in that the richer veins were mostly small, irregular, and discontinuous, whereas the larger veins and siliceous zones appeared generally too low grade to be of commercial interest. Work was, however, carried on at intervals on a number of properties, the discovery, now and then, of small bodies of rich ore, serving to stimulate flagging interest and renew confidence in the district. Early in 1928, however, the discovery, on the Aurum property, of rich gold ore in a talcose shear zone following the northeasterly contact of a large body of serpentine, aroused more than ordinary interest in that it called attention to a rock that was not only known to be widespread but that heretofore had attracted comparatively little attention. Claims were staked rapidly over several miles of a strip of country in which serpentine was known to occur. A number of other discoveries followed in quick succession. These were mostly far less encouraging than that at the Aurum, but each, nevertheless, was able to show some free gold either in hand specimens or in the pan. Outside interests were soon attracted and group after group of claims passed into the hands of different companies formed quickly to acquire and develop holdings in the serpentine belt. Extravagant hopes were raised and exaggerated claims advanced to retain and promote this interest. Serpentine, a rock previously viewed with slight interest, became at once the apparent mother lode of the districts' gold. Disappointments of the past were now credited to indifference to this rock. Though the nature of the new discoveries was little understood it seemed clear enough that merely to have a claim staked on serpentine was sufficient to give it advanced prominence and any discovery of talc in this serpentine was *ipso facto* evidence of a forthcoming mine. In an amazingly short time a network of trails traversed the serpentine belt. Several hundred claims were staked; many were surveyed; and exploratory work was rapidly pushed ahead. Talcose seams were uncovered at a great number of points within and along the borders of the serpentine body. Adits were commenced on these and any trace of gold or sulphide mineralization heralded as a favourable indication of more substantial values ahead. At this juncture a timely warning to operators not to be stampeded into incautious expenditures was sounded by the Resident Engineer of the district in an able report[1] in which operations on several properties were

[1]Nichols, H. G.: Dept. of Mines, B.C., Bull. No. 1, pp. 28-33 (1929).

carefully scrutinized. It was noted that only a small proportion of the recent exploratory and development work had uncovered anything of material value and except at a few places had, in reality, afforded but little encouragement. At these few places, however, some very attractive gold mineralization had been discovered and, thereby, fostered a spirit of optimism in respect to the entire belt. When visited by the present writer the peak of the excitement had been reached and a modicum of cold reasoning was taking its place. In the face of successive discouragements afforded by numerous initially hopeful prospects the realization was borne upon the operators that all was not gold that was talc and that the serpentine belt might not be such a potential source of gold mines as was first assumed. Questions were being raised as to why rich gold ore occurred at one place in this belt and not at another where conditions appeared to be identical and reasons for its occurrence at all were being sought on the chance that some valuable clue or clues might therein be made available for further explorations.

GEOLOGICAL RELATIONSHIPS OF THE SERPENTINE BELT

The volcanic and sedimentary members of the serpentine belt form the uppermost members of the Cache Creek series as developed in Coquihalla area. This series, from correlation with Dawson's Cache Creek series to the northwest[1] and Daly's Hozameen series to the southeast,[2] is thought to be late Palæozoic, probably Pennsylvanian, in age. It is formed of a succession of greenish volcanic rocks intercalated with much banded and massive chert, considerable slaty argillaceous rocks, and some limestone. To the northeast the Cache Creek rocks of Coquihalla area are overlain by a series of dominantly black, slaty rocks referred to in an earlier report[3] as the Ladner Slate belt. These rocks are thought to be of Jurassic and probably Upper Jurassic age.[4, 5] The contact between the two series is consequently regarded as unconformable, though there is but little structural evidence to indicate such an important time interval. The two series have suffered about equal deformation during periods of batholithic intrusion in Late Jurassic, Cretaceous, and Tertiary times. Intrusives related to, probably, the Cretaceous period are represented in the serpentine belt by peridotitic rocks from which the serpentine developed; by numerous smaller intrusions of diorite and, less commonly, gabbro; and by occasional more acid dykes.

[1]Dawson, G. M.: Geol. Surv., Canada, vol. VII, pt. B, p. 43 (1896).
[2]Daly, R. A.: Geol. Surv., Canada, Mem. 38, pp. 500–504.
[3]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, pp. 45–53.
[4]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 52.
[5]A collection of fossils obtained by the writer this year at an elevation of 1,675 feet, ¾-mile from Verona on the tractor road leading to Aurum mine, was examined by McLearn of the Geological Survey who submits the following preliminary report.

"Indeterminate ammonoids
Belemnites sp.
Indeterminate pelecypods
Age Jurassic?"

DESCRIPTION OF PROPERTIES

Properties Northwest of Coquihalla River

AURUM MINE

References

Nichols, H. G.: Ann. Rept., Minister of Mines, B.C., 1926, pp. 186-197: 1928, pp. 225-227, Dept. of Mines, B.C., Bull. No. I, pp. 29-31 (1929).

Location and Ownership. Aurum mine (Plate IV A) is located on the south fork of Ladner creek, 4 miles by road from Verona on the Kettle Valley railway.

The property (*See* Figure 10) consisting of Aurum No. 1 to No. 6, Idaho, Tramway, Monitor, and Annex claims, and Sylvia B and I.X.L. fractions, all surveyed, is under option to and being developed by Aurum Mines, Limited, care of Ashworth Anderson, 435 Richards street, Vancouver, B.C. It covers much of the ground originally occupied by both Idaho[1] and Snowstorm[2] groups, the present survey and consolidation having been effected in 1926.

History and Development Work. Surface prospecting in 1927 on Aurum No. 1 claim revealed astonishing values in free gold in a talcose shear zone which follows the northeast contact of a large body of serpentine, a rock that hitherto had received comparatively little attention on either this or adjoining properties. An adit (No. 1) (Figure 11), driven to investigate this discovery, encountered two small shoots of spectacular ore, one near and the other about 125 feet from the portal. No. 2 adit started in the spring of 1928 at a point 90 feet below the other was successful in discovering valuable ore at a position corresponding with that of the southern occurrence in the adit above. At the lower level this ore persisted over a length of 65 feet. Work on No. 2 adit, however, failed to reveal ore-mineralization at a position relative to the northern of the two discoveries made in No. 1 adit, though the possibilities of locating some such occurrence had not been exhausted. Several tons of high-grade ore from the southern body, or bodies, were sacked and stored at the mine and a great many spectacular specimens placed in circulation. As a result, principally, of these discoveries on the Aurum, public attention was again focused strongly on Coquihalla area, but with the difference that this time interest has been attached mostly to talcose shear zones following the contacts or cutting across a body (or bodies) of serpentine within a belt of rocks which, for convenience, has been referred to as the serpentine belt.

Subsequent work at Aurum mine, including the projection of Nos. 2A, 3, and 4 adits (*See* Figure 11) at 40, 125, and 230 feet respectively below No. 2 level, has been attended by certain difficulties and disappointments which, considering the unusual features of the occurrence and the fact that this property was the first in the district on which important development of

[1]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, "Coquihalla Area, B.C.", pp. 143-144.
[2]Idem, pp. 140-142.

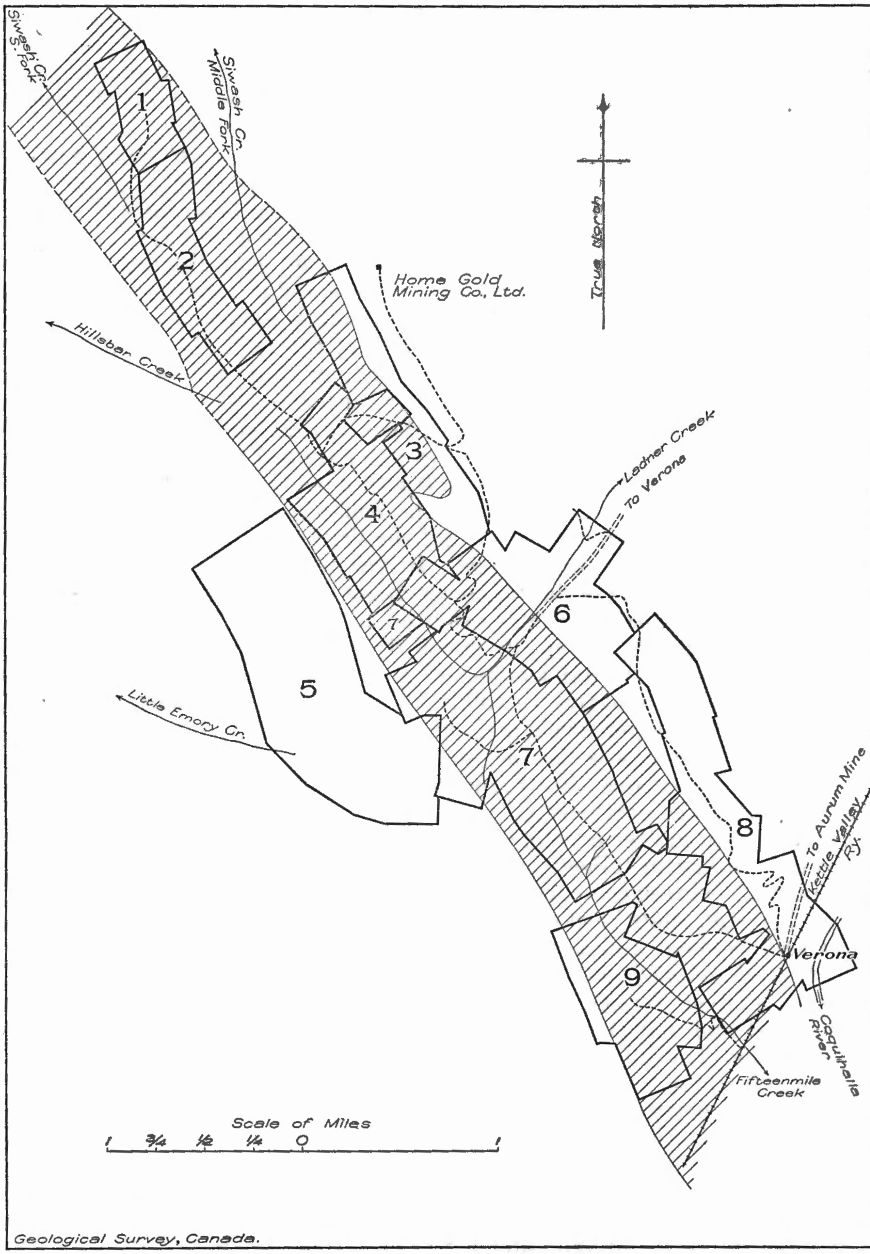

Figure 10. Index map of properties in the vicinity of Verona station and Ladner creek, Yale district, British Columbia. No. 1 and No. 4, Spencer holdings; No. 2, Spider Peak group; No. 3, Montana group; No. 7, South Fork group, and No. 9, Fifteenmile group, Hope Gold Mines, Limited; No. 5, Mammoth Holdings, Limited; No. 6, Aurum Mines, Limited; No. 8, Dawson Gold Mines, Limited; serpentine belt is shown by diagonal ruling.

this type of deposit was attempted, are hardly more than might be expected. In the end the management had gained a certain familiarity with the extent, structure, and character of ore deposition. They have found ore on No. 3 level of similar character to and situated below the shoot on No. 2 level, a discovery that affords encouragement for further exploration.

In view of the apparent regularity of dip of the talcose seam down to No. 2 level, No. 3 adit was driven to pick it up at an additional depth of 125 feet. The adit was driven as a crosscut, at an angle of about 35 degrees to the vein, for a distance of some 80 feet, where it encountered a strong-looking shear striking north 15 degrees west (true) and dipping 50 degrees to the east. Beyond this point the work intercepted a siliceous zone, several feet in width, carrying much vein quartz and some values in gold. Tunnelling was continued along the southwest wall of this zone for about 130 feet, the wall being marked by a line of fracture, in some places quite strong, and, in its direction, corresponding closely with the trend of the talc seam above. The fact that vein quartz had been encountered along portions of the hanging-wall of the talc seam above was assumed to afford considerable assurance of its identification with the fracture being followed in No. 3 level. Neither the wall-rocks nor the dip of the fracture on No. 3 level, however, corresponded with those above, nor did the drift encounter the talcy filling so characteristic of the upper levels. It was felt, though, that once under No. 2 level ore-body these discrepancies might adjust themselves and in the meantime the silicified zone was expected to lead to this ore-body. Tunnelling at some 200 feet from the portal discovered a strong shear carrying appreciable talcy rock and leading off to the west of the zone of quartz. Before, however, attempting to follow this, and still influenced by the dip of the vein in the upper levels and the position of the quartz in relation to this vein, a crosscut was run northerly for about 70 feet cutting entirely across the siliceous zone (*See* Figure 11) and was well out into the belt of sediments that lies northeast of the outcrop area of serpentine. No other evidence of vein matter or vein structures being discovered in this direction, it was determined to follow the talcy shear encountered near the mouth of the crosscut. This shear curved towards the west, fraying out as it did so into rather soft, slaty rocks. No mineralization of interest was noted in following this shear and as the wall-rocks were still sedimentary types the shear was abandoned and the adit continued westerly as a crosscut for a distance of about 60 feet to where it intersected a heavy, talcose shear dipping east and underlain by serpentine. This shear much resembled that of Nos. 1 and 2 levels, but a survey showed that it lay west of the shear developed in these upper levels (*See* Figure 11, vertical section AB). It appeared that between Nos. 2 and 3 levels the talcose shear had followed the periphery of the serpentine body which had first taken a decided roll to the southwest and then righted itself to dip steeply northeast at No. 3 level. Some indication of such a roll had already been noted by the management in previous developments on No. 2 level. There, where the ore-body was first encountered, about 80 feet from the portal, it had been observed that the talcose shear came into the tunnel at an angle from the southwest; that it was unusually strong at this point; and that the dip of the sheared, talcy ground indicated a change from a westerly to easterly dip,

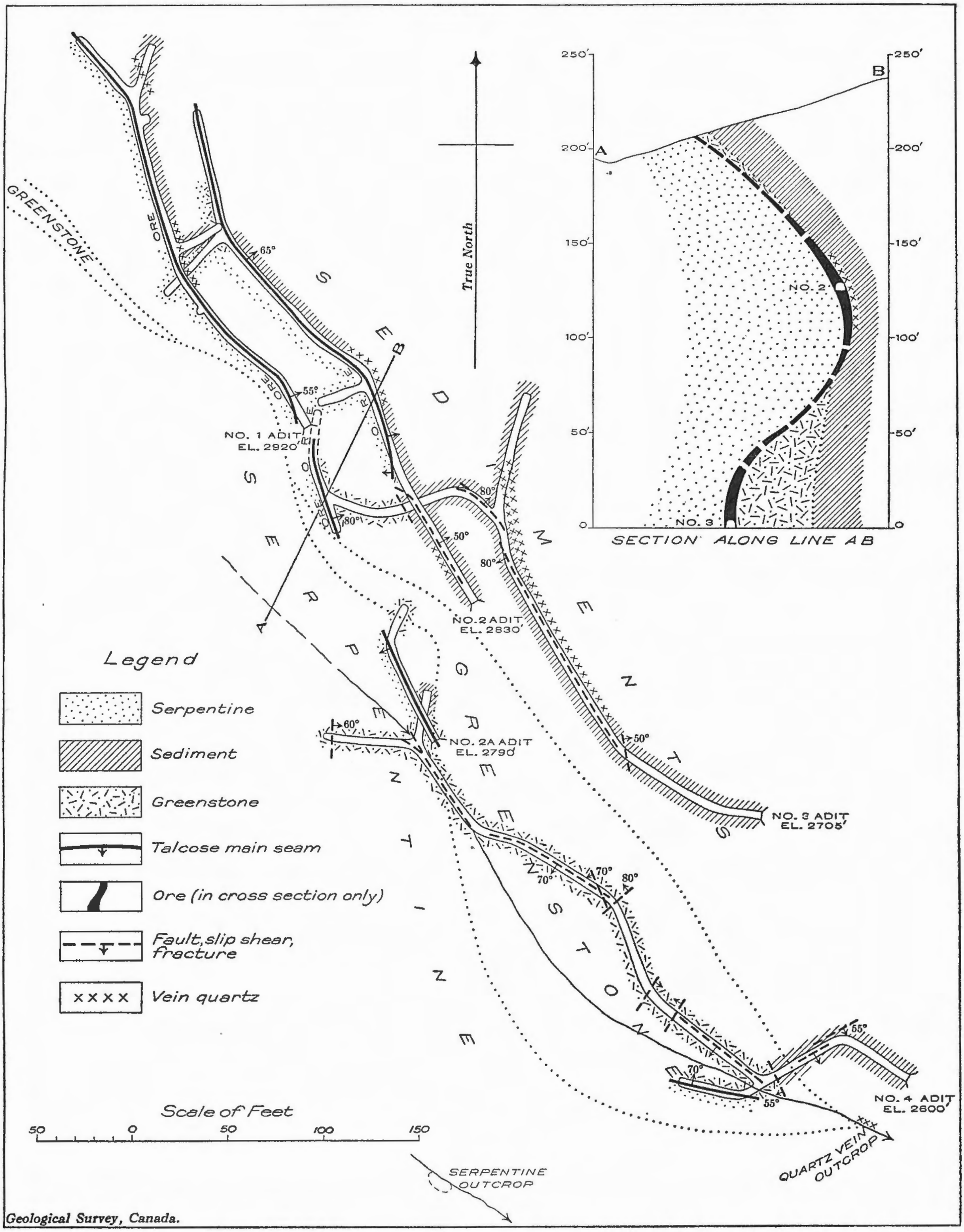

Figure 11. Plan and section of Aurum mine (tape and compass survey), Yale district, B.C.

the heavy body of talc rolling, apparently, over a nose of more massive greenstone rocks. The probability of such a roll was being investigated by No. 2A adit at the time visited.

Simultaneously with the projection of No. 3 adit, No. 4 was being advanced from a point 105 feet below. The position chosen for this lowest level had been governed not by the dip of the talcy seam in the upper two levels but by the position of the serpentine contact which is exposed in the creek bed 30 feet southwest of No. 4 portal. The adit was started as a crosscut to reach this contact, but when within less than 10 feet of its objective was diverted along a small and rather talcy shear dipping southwesterly in greenstone rocks, which was mistaken for the main talcose seam at the serpentine contact. This mistake, more obvious now than at that time, was not corrected until No. 4 adit had been projected to its present extreme length. For a distance of 55 feet before reaching the innermost forks of the adit (*See* Figure 11) the level followed quite a strong talcy seam dipping 50 degrees southwest. This talc is reported to carry some free gold. At the forks of the adit the ground was badly sheared and included a considerable width of more or less talcose material. The fork to the north was driven across this sheared ground until at the face it encountered a change from greenstone to sedimentary rocks. The other fork passed through more or less altered massive greenstones, some quite granular in appearance, but has not been carried far enough to reach the serpentine contact. Subsequently, however, the crosscut from the portal was continued for the few feet necessary to reach this original objective, and at the time visited, a drift had been advanced for 35 feet along the talcose seam which invariably follows this contact. In general it may be said that although the projection of No. 4 adit has included a regrettable amount of apparently " dead " work, this work has nevertheless thrown light on some interesting problems connected with serpentinization of the country rocks and distribution of mineralization.

Geology. The country rocks of Aurum mine workings include four types which may show either well-defined or gradational boundaries. The typical rock of each type is readily recognized, but there are many places, particularly in the underground workings, where it is difficult to form definite conclusions as to which type is represented. The four types may be briefly referred to as serpentine, greenstone, sediments, and talc.

Serpentine is widely exposed to the southwest of the mine workings where it forms part of the main serpentine body of the serpentine belt. A portion of its northeasterly contact is indicated approximately on the accompanying mine map (Figure 11), its position being inferred partly from a few surface exposures and partly from developments underground. The rock has a characteristic dark green colour and is mostly quite massive and densely textured. Along the contact, however, it is badly sheared; in some cases beautifully polished; and, over an average width of several feet, is partly altered to talc. The contact surface with rocks to the northeast is peculiarly irregular, having a rolling or hummocky form with well-rounded contours. Contact relations with adjoining rocks are largely obscured by shearing and alteration, but at a few points have provided strong evidence of the serpentine crosscutting other members of the belt. Microscopic studies also support the view that this serpentine is an altered, basic, intrusive rock.

The term "greenstone" has been applied as a matter of convenience to rocks of greenish grey colour, which, as exposed at Aurum mine, are mostly of volcanic origin and chiefly flows and flow breccias. In composition they may be regarded as meta-andesites, rocks originally possessing the composition of andesites. They are so altered by processes tending towards the production of abundant secondary products, including such greenish minerals as chlorite, epidote, uralite, and serpentine, that the original composition has been largely obscured and the rocks have been given the colour by which they are distinguished. Associated with the meta-andesites, and separable from them only by their moderate to finely crystalline texture, are minor vaguely defined bodies of greenstone which may be intrusive into the others and, in consequence, are referred to as diorite. Such rocks, doubtfully intrusive in this case, were encountered towards the more northwesterly face of No. 4, and also near the face of No. 1, adits. On No. 4 level they are in part involved in heavy shearing and mostly appear to be quite extensively altered to serpentine, talc, calcite, and chloritic and saussuritic products.

The contact of the greenstones with the overlying "sedimentary" rocks to the northeast is commonly quite difficult to distinguish, particularly as the latter near this contact are tuffaceous types of much the same composition as the underlying greenstones. Higher up in the series the sediments become darker, more argillaceous, more distinctly bedded, and, in general, more characteristically sedimentary in appearance. They are mostly quite massive, though including some thinly bedded and comparatively fissile beds. A distinctive type is a light grey, rather sandy to dense-textured, rock carrying abundant angular fragments of greenstone and chert varying up to several inches in diameter. These fragments much resemble members of the Cache Creek series as exposed southwest of the serpentine belt (*See* Map 1897, Coquihalla River area, Yale district, B.C). The matrix of this rock appears quite tuffaceous. Outcrops of this rock are exposed on the switch-back trail leading from one to other of the several adits.

The "talc" developed at Aurum mine follows chiefly along the periphery of the serpentine and forms a seam in which the ore-bodies have been discovered. This seam varies in thickness from less than a foot to several feet, being thickest in the vicinity of rolls in the serpentine wall. It is chiefly dark green to greyish green and varies in composition and hardness according to its purity. All gradations from foliated, lamellar, serpentine types showing a beautiful polish and dark green colour (marmolite), to others in which the serpentine is partly to completely changed to talc, can be seen. The alteration has probably been effected through reaction of ascending silica-bearing solutions permeating the sheared zone along the contact of the serpentine with more resistant adjacent rocks. The chemical reaction may be expressed thus:

$3MgO, 2SiO_2\ 2H_2O$ (serpentine) $+ 2SiO_2 = 3MgO, 4SiO_2, H_2O$ (talc) $+ H_2O$.

The source of the silica is regarded as probably the same as that which has supplied the quartz of the quartz veins in the vicinity. The occurrence of sulphides and native gold in both the talc and the quartz veins is also attributed to essentially the same siliceous emanations.

Besides the main talc seam, minor occurrences of talc or talcose rocks were encountered in operations underground and appear to indicate that talc may develop in quite different rock types including members of both greenstones and sedimentary rocks. The reactions in these cases would be more complicated than that indicated above, involving first a transformation of the original rock to serpentine or chlorite schist and, subsequently, the further alteration of these secondary minerals to talc.

Aside from the four rock types mentioned above as occurring at Aurum mine workings, the property of this company on its more northeasterly side extends into a broad belt of slates or slaty rocks included in an earlier report with the Ladner Slate Belt.[1] A general discussion of these rocks and their relations with those of the serpentine belt is reviewed in a subsequent section of the present report.

Mineralization. Interest in developments at Aurum mine has been principally concerned with occurrences of high-grade free gold ore in the talcose seam following the periphery of a large body of serpentine. The gold is not distributed at all evenly in this seam, but is mostly concentrated in pockets and vein-like forms. The intervening and much the greater parts of the talc seam, although commonly showing from a trace to a dollar or more in gold values, have, as yet, proved too low grade to be commercially valuable. Sufficient work has not been done on Aurum mine to deduce a satisfactory explanation for the position of the richer parts of the talc seam, but there is a strong suggestion in work to date, that this is, in part at least, related to irregularities in the contact surface of the serpentine body. This relation is suggested by the cross-section (Figure 11), which intersects gold ore at Nos. 2 and 3 levels. The extent of the mineralization above or below these levels has not been investigated, so that neither the actual width of the talcose seam nor the contained values can be properly indicated on the figure. It seems highly probable, particularly in view of developments on No. 2 level, that the greatest width of talcose rock will be found where the seam rolls either to the northeast or southeast and that it will narrow appreciably in the intervals of more regular dip. It is less certain how the gold values will behave in these intervals. This is an extremely important point and one that could be quite readily investigated by raising on the ore from either Nos. 3 or 2 levels. The unwillingness to thus directly explore the ore occurrences must be regarded as largely responsible for much of the difficulty experienced in determining the position of the talc seam and the location of ore at the different levels.

The gold content of Aurum ore is mostly free. The valuable metal is associated in different places with one or more of the sulphides: pyrrhotite,[2] pyrite, chalcopyrite, arsenopyrite (mispickel), and (?) millerite. The proportion of gangue minerals, other than the talcose seam filling, is small,

[1] Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 45.
[2] It is likely that some pentlandite (nickel-iron-sulphide) is associated with this pyrrhotite.

though, in those rich parts of the ore-shoots where arsenopyrite is abundant, calcite and quartz are also present in more or less conspicuous amounts. Both gold and associated sulphides commonly occur as polished films over slickensided surfaces of serpentine and talcose rock. The films in such cases are mostly exceedingly thin, so that, in the case of gold for example, actual values may in reality be much less than appearances would seem to indicate. The gold may, however, form in plates, thin wedges, or irregular prongs, each of comparatively substantial thickness varying up to one-eighth inch or more of the solid metal. This gold may also conform with irregular slip surfaces of the associated talcose rock and in such cases presents the appearance of having been rolled in with the rock. Ore of this character is, of course, immensely rich, small, hand-picked specimens carrying up to several dollars worth of the free metal. Not uncommonly, too, gold occurs as small, roughly corrugated, beads distributed sporadically in more massive bodies of the talcose rock. A fourth and exceedingly rich type of gold ore occurs in association with arsenopyrite. In this type the mispickel forms a heavy concentration of crystals arranged in a succession of more or less well-defined bands each a small fraction of an inch in width and separated by partings of calcite, quartz, and foliated talc. The native gold favours certain of these bands and occurs either disseminated or as thin, vein-like segregations of particles varying from dust-like points to grains, short wire, or leaves of more substantial size.

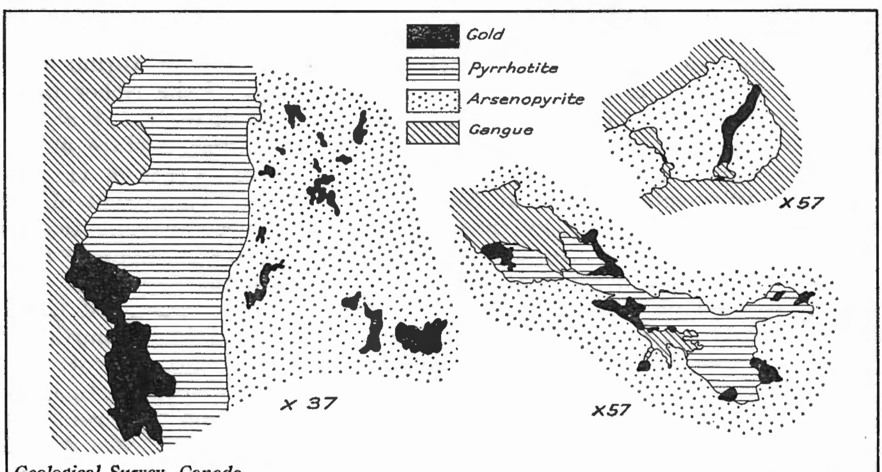

Figure 12. Camera-lucida drawings of polished surfaces of specimen of rich gold ore, Aurum mine, Yale district, B.C.

The gold occurs mostly in the gangue, but, in part, is distributed through crystals of arsenopyrite (Figure 12). This type of ore was discovered on both No. 2 and No. 3 levels, in both cases a few feet west of the line of the cross-section A-B (Figure 11). On No. 2 level it formed a small, lens-shaped body close to the hanging-wall of the talc seam. In No. 3 adit it occurred in more vein-like form within the body of the talc extending for several feet along the roof of the adit with an average width of from 1 to 2 inches. At the time of visit, this paystreak appeared to be widening at the face of the adit and further drifting since that time is reported to have revealed a larger body of this ore. Such a discovery would be most heartening to the management and would encourage development to greater depth.

Of the associated sulphides pyrrhotite is the most generally abundant. It occurs most conspicuously in thin, scaly aggregates filming the slickensided surfaces of the talc and serpentine and bearing, itself, every evidence of having been scoured in the slickensiding process. It appears to have been deposited as thin films filling tiny cracks in the serpentine and talc and to have been secured during subsequent deformative movements. Pyrrhotite also occurs in more crystalline and massive form associated with vein quartz in the Aurum workings.

Chalcopyrite (copper pyrites) is comparatively rare, but locally forms crystalline aggregates and tiny veinlets disseminated through the wall-rocks and associated principally with the more quartzose vein matter. It is quite a negligible constituent of the talcose seam.

Pyrite is a more common sulphide, but is associated with vein quartz or disseminated through adjoining greenstone and sedimentary rocks rather than in the serpentine or talc.

The association of arsenopyrite with native gold has already been noted. Aside from this occurrence arsenopyrite is also a notable constituent of quartz veins elsewhere on this property.

Specimens purporting to have come from the Aurum mine were noted in which surfaces of highly slickensided serpentine carry a sprinkling of thin, needle-like crystals of millerite[1] (capillary pyrite, hair sulphide) or sulphide of nickel (NiS). Elsewhere within the serpentine belt similar occurrences were noted and are of interest in that they indicate a concentration from the serpentine itself, since in this rock traces of nickel have on analysis proved to be present.

The iron sulphides are in places oxidized to hematite and limonite. The peculiar dark reddish colour produced in some cases by this process and the report that both native mercury and cinnabar had been detected in workings within the serpentine belt led the writer to have tests run on a couple of specimens on which the reddish stain was most pronounced. The results of these tests furnished by Mr. Poitevin of the Mineralogical Division, Geological Survey, indicated that no cinnabar was present, but that the stains were due entirely to oxidation of pyrite, weathered crystals of which could be recognized within the stained areas.

Genesis of the Ores. In a general way the problems connected with ore deposition at Aurum mine are those of the entire serpentine belt. These more general problems receive attention in a subsequent section of this report. It is the intention here to consider rather the more specific relations between ore mineralization and country rocks in an effort to secure some appreciation of the origin of the former and some explanation of its character as revealed in work done up to the present.

[1]Identified by Eug. Poitevin, Geol. Surv., Canada, Mineralogical Division.

In the more general discussion of the serpentine belt it is pointed out that until 1928 lode gold mining in the vicinity of this belt had been mostly confined to prospecting and development of auriferous quartz veins; that these veins had received most attention within the area occupied by Ladner Slate belt, but that they had also been discovered in greenstones and tuffaceous sediments of the serpentine belt as well as in underlying cherty and argillaceous rocks of the Cache Creek series; and that the serpentine member of this belt had received comparatively little attention, mostly because very little vein quartz or other evidence of mineralization had been discovered in it. It is indicated further, that this serpentine itself is a secondary rock; that its formation antedated the period of mineralization and resulted from the alteration of a basic, probably peridotitic, intrusive or intrusives which followed a zone of structural weakness and now forms the most distinctive member of a belt of rocks herein referred to as the serpentine belt; that other basic intrusives ranging in composition from diorite or quartz diorite to gabbro followed and in part may also have accompanied the more basic peridotitic intrusions; and that the closing stages of this period of intrusion are marked by incursion of metalliferous solutions and vapours carrying, among other constituents, the gold content of the ore deposits.

It is also suggested that the development of shear zone in or along serpentine contacts followed partly as a consequence of squeezing movements resulting from the increased bulk of the serpentine over the original rock from which it formed, and is partly due to regional deformation; that these shear zones subsequently formed channels for infiltration of ascending mineralizing solutions and vapours which at much the same time were effective in partly changing the serpentine to talc; in depositing a part of their gold and sulphide content; and in carrying away excess water, which the transformation to talc provided (*See* Formulæ, page 152), and depositing vein quartz along with more or less gold and sulphide minerals in the more open fissures and fractures of the adjoining rocks. Part of the vein quartz occurring in rocks adjoining the serpentine body was probably obtained through the alteration of the serpentine; much of it may have been derived from the adjoining greenstones and sedimentary formations; and some of it is, doubtlessly, magmatic.

The ideas outlined above, when applied to Aurum property, indicate: (1) that the deposition of vein quartz, carrying sulphides and some gold values, in the vicinity of the serpentine is related in time and origin to the formation and mineralization of the main talcose seam as well as other talcose rocks in the mine workings; and (2), that the comparative abundance of vein quartz in rocks adjoining the serpentine is, largely, a consequence of peculiarities in rock structure which in the case of the serpentine has provided very limited channels for easy deposition as contrasted with the more open and regular passages afforded by adjacent rocks.

Future Possibilities. The future of Aurum property is largely dependent upon whether development is to be confined to the main talcose seam, and production, therefore, derived from isolated but rich shoots of gold ore or whether elsewhere in ground adjoining the serpentine contact some large body or bodies of low-grade commercial ore may be proved up.

Developments to date clearly indicate that the talcose seam, as a whole, is much too low grade and that unless certain clues to the position of ore-shoots (such as, for example, the structural peculiarities of the serpentine contact, or the relations of ore deposits to adjacent or nearly gold quartz veins) may afford competent guides, the exploration of the talc seam for such ore-shoots may prove entirely too expensive to afford ultimate profit, even though it be assumed that other ore-shoots would be discovered. To date it may be said that little is known about such ore-shoots; that only one, and that not necessarily continuous between levels, has been developed to any considerable depth, and that such clues as are available for the discovery of other shoots have not yet been satisfactorily tested. On the other hand the ore encountered on No. 2 and No. 3 levels is exceedingly rich and there are reasonable chances for it extending to greater depths. There are also other places convenient to present workings where chances for finding more ore seem favourable. The northern shoot on No. 1 level is either missing or has not been picked up at the level of No. 2 adit and is worth further investigation. The various sinuosities of the serpentine contact have only been investigated. The serpentine contact against vein quartz in the creek bed 30 feet south of the portal of No. 4 adit also affords a favourable place for ore deposition. Should other ore-shoots than those already discovered be found at Aurum mine and reasonable clues to their occurrence be deduced there remains a long stretch of serpentine contact to be carefully investigated, extending to the southeast across the south fork of Ladner creek and northeast well beyond present workings.

The possible discovery of large, low-grade deposits seems limited to further investigation of a system of quartz veins or highly siliceous zones on this property. A part of one such quartz vein or silicified zone is exposed in Aurum workings. Considerable prospecting was done years ago on similar deposits on Idaho and the old Pittsburg claims and it appeared at that time that operations conducted on a sufficient scale on this system of quartz veins might be successful. Recent more spectacular discoveries have directed attention from these earlier workings, although they have not been entirely lost sight of. It would seem an opportune time to settle once and for all the question of the commercial value of the vein quartz on this and adjoining properties by undertaking a careful program of sampling. Comparatively rich shoots or pockets are known to occur on these quartz veins, but are of little practical value unless employed to sweeten the average values of large bodies of this quartz. Evidence that such large bodies could be mined with profit would undoubtedly be most encouraging in its relation to future operations on this property and would materially affect the program of development.

That the talc and talcose rock developed on this and adjoining properties may eventually find some commercial use should be kept in mind. This talc is a mottled, mostly impure, foliated variety varying from light grey to dark green; appears on the whole to be fairly free of grit, and mostly possesses a smooth, greasy feel in powdered form. The chief impurities are sulphides, imperfectly altered serpentine, and, locally, quartz. Complete physical and chemical tests should be applied on bulk samples of this talc if any market for the product appears reasonably assured.

EMANCIPATION MINE

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Location and Ownership. The Emancipation mine is situated on the northeastern slope of Coquihalla valley at an elevation of 2,650 feet or 1,200 feet above the Kettle Valley railway at Verona. The mine is operated by Dawson Gold Mines, Limited, with head office at 922 Standard Bank Building, Vancouver, B.C. Messrs. W. E. Williams and J. T. Johnston are president and secretary respectively, and Mr. A. C. Ward is superintendent at the mine. The property includes thirteen surveyed mineral claims (*See* Figure 10), aggregating 530 acres of mineral lands, and embraces the Emancipation and Packard groups of six claims and one fraction, and seven claims, respectively. The workings are situated near the centre of the property and mostly on Emancipation claim between elevations of 2,400 and 2,800 feet.

Historical Summary. Emancipation mine has had a checkered history in which periods of energetic exploration and development have been followed by others of inactivity and depression. Until the more recent discoveries in Coquihalla area this mine occupied a position of first importance among the properties situated near the western contact of Ladner Slate belt and interest in it has fluctuated in general with interest in a number of properties associated with this belt.[1]

Originally owned by a partnership of three, M. Merrick, Wm. Thompson, and H. Beech, and worked largely under their direction from about 1915 to 1919 inclusive, it has since been operated by a number of companies including the Liberator Mining Company, Director Mining Company, and now by Dawson Gold Mines, Limited, all of Vancouver. The present organization was created from that of the Director Mining Company by increase of capitalization, the property now being incorporated at $2,000,000 comprising 2,000,000 shares at $1 par value.

Records of production show that ore to the value of about $40,000 has been shipped from this property. The chief productive period extended from May, 1916, to December, 1920, in which time some 95 tons having a net value of $34,000 were shipped, mostly to Tacoma. Several hundred tons of ore averaging about $15 to the ton were left on the dumps and partly for the purpose of recovering these values a small mill was erected on the property in 1920. This mill has a capacity of about 12 tons in two shifts and employs a Fairbanks Morse Engine burning petroleum.

[1]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, pp. 133-148.

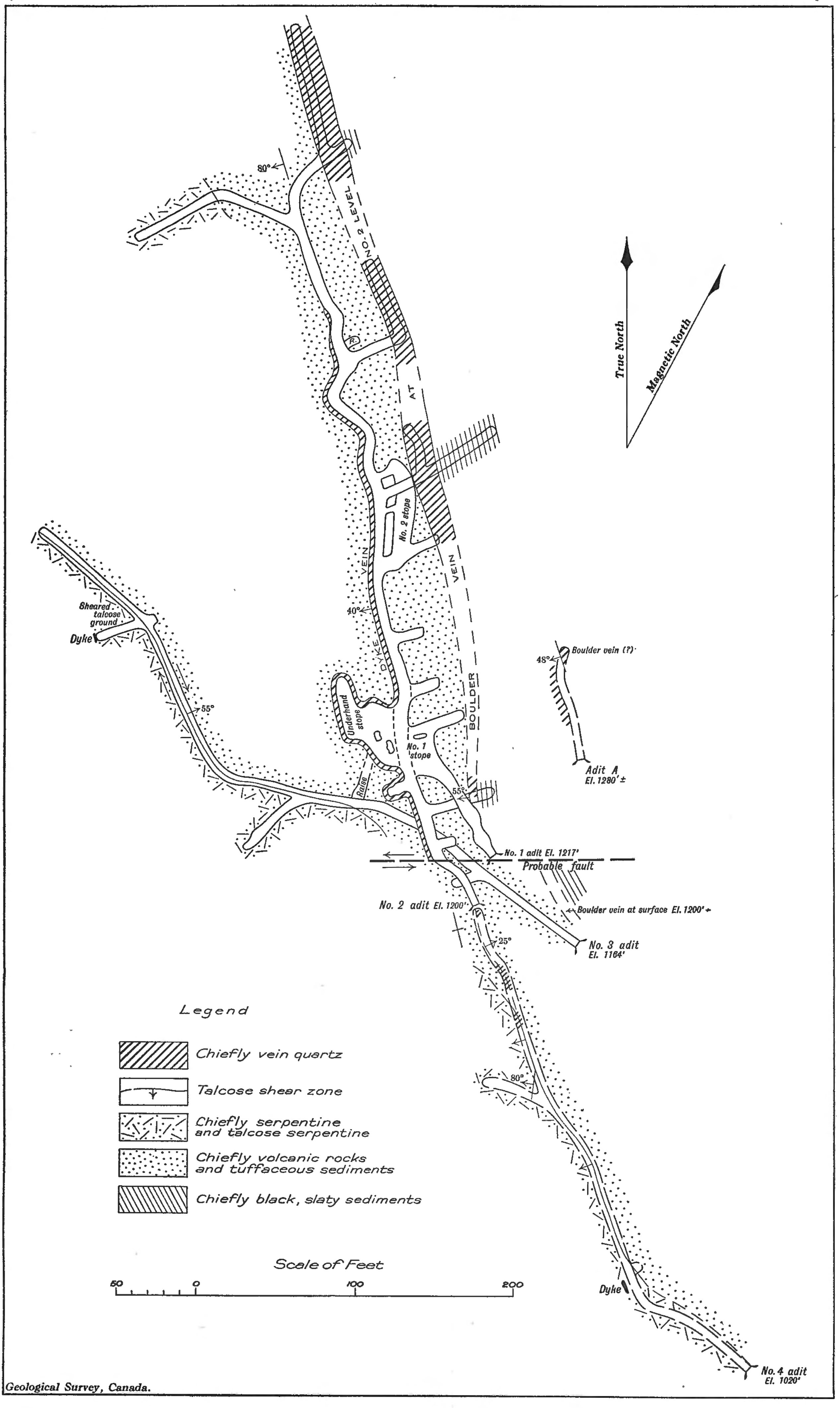

Figure 13. Plan of Emancipation mine, Yale district, B.C.

Geology and Mineralization. The geology and mineralization of Emancipation mine have been discussed at some length in a number of earlier reports. Briefly it may be stated that interest on this property has been chiefly centred on a zone or belt of rocks, some 50 feet wide, which includes an abundance of vein quartz. At the principal workings (Figure 13) two distinct veins are recognized, known respectively as the "Boulder" and "Dyke" vein. The Boulder vein occupies the foot-wall wall section of the zone; follows very nearly along the contact between slaty members of Ladner Slate belt, and more or less greenish volcanic and tuffaceous rocks of Cache Creek series; has an average and fairly persistent width of about 10 feet; and carries low values in gold. The Dyke vein, on the other hand, forms the hanging-wall of the zone; lies within rocks of the Cache Creek series; is comparatively narrow and less regular than the other vein; but carries better average values than the Boulder vein, and, locally, has provided a small tonnage of rich gold ore. Between these veins are other irregular veinlets and small lenses of quartz, including one of more prominence than the others, known as the "Flat" vein or lens, which dips in an opposite direction and at a lower angle than the others. Its intersection with the Dyke vein is coincident with the most important shoot of ore developed on this vein. Both Dyke and Boulder veins have about the same strike of north 15 degrees west and both dip southwest at angles which in the case of the Boulder vein are about 55 degrees, and, on the whole, a few degrees steeper than the Dyke vein. The Flat vein, where it is best exposed in underground workings, strikes north 55 degrees west and dips 45 degrees northeast.

Above the main workings, the surface work has indicated the continuity of the Boulder vein over a vertical range of at least 200 feet, but in this direction and at about this elevation above the main or No. 2 adit (Figure 13) other large outcroppings of vein quartz have been discovered whose relations to the Boulder and Dyke veins are not entirely clear, though some attempts have been made to correlate them.[1] The structure is, however, obscured partly by faulting and partly by original irregularities of quartz deposition.

In the main workings the Dyke vein is cut off below No. 2 level by a fault coincident with the northeasterly contact of the serpentine body of the serpentine belt. This fault was investigated a number of years ago when driving No. 4 adit (Figure 13) and its relation to the serpentine contact has since been confirmed by development work on No. 3 level. The Boulder vein, too, loses its identity below No. 3 adit where its continuity and character have not been established.

Recent Developments. Recent developments have been partly directed towards exploring the continuity of the Dyke vein on and below No. 2 adit; partly towards determining the character of the Boulder vein on No. 2 level, and partly towards investigating the serpentine contact.

Work on the Dyke vein has been largely restricted to the vicinity of No. 2 level which has been projected to a total length of over 600 feet. In this distance the vein is continuous for over 300 feet from the portal

[1]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 138.

and has an average width of about 1 foot. Beyond this point, however, it frays out into a series of tight stringers leading off into the roof rocks. The vein filling up to this point is mainly quartz associated with more or less crushed wall-rock. Some calcite is present and is conspicuous in the richer parts of the vein. A few nodules of slightly pink albite are associated with the other gangue minerals. The quartz is mostly turbid and streaked with inclusions of wall-rock and concentrations of sulphides. In general the hanging-wall is well defined and has furnished an excellent guide in drifting and stoping operations. The values are chiefly concentrated in shoots, one of which, encountered at 90 feet from the portal and extending along the level for 50 feet, has been largely stoped out above the level and has provided most of the ore hitherto shipped from this mine. Some underhand stoping has also been on this shoot and, recently, connexions established by a raise from No. 3 level. Another but less important shoot was picked up 220 feet from the portal, continues for 65 feet along the level, and has been stoped on above (Figure 13).

The principal ore minerals are pyrrhotite, arsenopyrite, pyrite, and chalcopyrite in about this order of abundance. Other minerals include free gold, enargite, and a grey, probably silver-bearing mineral of doubtful identity. In the richer parts of the shoots free gold was quite conspicuous and afforded spectacular specimens as well as providing high-grade ore. The gold carries silver values in the ratio of about 1 ounce silver to 6 ounces gold. Microscopic studies indicate that pyrite and, probably, pyrrhotite were early minerals; that gold and arsenopyrite succeeded them and were deposited contemporaneously; that all of the ore minerals replace quartz, but that the associated calcite was probably formed subsequent to the iron sulphides. Chalcopyrite is a later mineral than pyrite or pyrrhotite and may have been deposited about the same time as the gold and arsenopyrite.

From No. 2 level five crosscuts into the foot-wall rocks have reached the parallel Boulder vein which in turn has been drifted on for varying distances (*See* Figure 13). These drifts are interesting in showing the character of this vein at greater and greater depths beneath the surface. Towards the portal and in the first couple of crosscuts the vein is composed of nearly solid, milky-white quartz carrying a very sparse dissemination of sulphide particles, including pyrite, arsenopyrite, and chalcopyrite. Farther from the portal the vein matter contains more and more abundant inclusions of the wall-rocks, partly replaced by the quartz, until at the face of No. 2 level these inclusions about equal the proportion of silica. Coincident with the appearance of inclusions is an apparent more or less proportional increase in sulphide materials which, though never concentrated to the extent of those encountered in the richer parts of the Dyke vein, become appreciably more abundant towards the face of the adit. The values are also stated to improve in this direction, a feature which, from the common association of gold with sulphides, might be expected.

Other work at the mine has included some investigation of the serpentine contact, work that appeared desirable in view of recent discoveries on other properties, notably Aurum mine. The investigation was conducted chiefly on No. 3 adit which, commencing at a convenient point below No.

2 level, was first run as a crosscut towards the Dyke vein and then carried as a drift along a strong, talcose shear zone which follows the periphery of the serpentine body and dips northeasterly at an average angle of 55 degrees. From this drift Nos. 2 and 3 crosscuts (Figure 13) were run into the foot-wall for distances of 50 and 30 feet respectively, encountering strongly sheared and partly altered serpentine and at the face of No. 3 crosscut what appears to be a diorite dyke. The geological associations of the talcose shear zone drifted on in this level are almost identical with those encountered at Aurum mine. In both properties the same contact of the main serpentine body is being explored; in both a heavy talcose shear follows the serpentine wall and dips, in general, northeasterly; in the workings on both properties the slickensided surface of the sheared talcose rock is commonly smeared with sulphides, chiefly a nickeliferous pyrrhotite; at both properties traces of gold may be found on assay of samples taken almost anywhere in the talc seam. Free gold has also been noted and occurs mostly as minute, polished films on the slickensided surfaces of the talc. Whereas, however, at Aurum mine local concentrations of values have provided ore-shoots, no such comparatively rich bodies have been found in Emancipation workings. Careful sampling by the management every 2 feet along the course of the drift has indicated an average value of between 50 cents and $1 in gold, to the ton. Values rarely exceeded $1 and then not by much and yet, on the other hand, samples showing no trace of gold were even rarer. The principal associated sulphide is nickeliferous pyrrhotite, but in places, as near the face of No. 3 drift, chalcopyrite is present instead. A specimen of talcose rock carrying this chalcopyrite was found to contain no nickel and no visible pyrrhotite. Other sulphides include pyrite, arsenopyrite, and millerite. Residual magnetite and chromite from the serpentine are also present. Calcite is locally a conspicuous gangue mineral.

Future Possibilities. The future of Emancipation mine is dependent partly on the economic extraction of the gold content of the quartz veins on the property and partly on the possibilities of the talcose shear which follows the serpentine contact.

The quartz veins have been, in the past, the chief consideration on this property and probably will so continue to be in the future. Sampling by the management would appear to indicate that the part of the Dyke vein remaining above No. 2 level averages about $12 a ton in gold and that below this level the chances of extracting a small tonnage of higher grade ore on the downward continuation of the ore-shoots are promising. The Boulder vein, on the other hand, is admittedly low grade. At the best it probably will not average more than $5 to $6 a ton. This vein might be mined and milled as a whole, or only those portions carrying the better values stoped out. The vein could, for example, be crosscut from near the portal of No. 3 adit beyond the "probable" fault (Figure 13) and drifted on northwesterly to where it should be intersected by the so-called "Flat" vein referred to before. That this intersection might provide a concentration of values is suggested by the fact that at the intersection of the Flat and Dyke veins an important body of ore was discovered.

In any case developments have reached a point where the quartz veins can be readily mined and where a large tonnage of such material as indicated above is available. Depending upon the average values of the quartz bodies the tonnage milled should not only be sufficient to pay mining and treatment costs, but also permit considerable contemporaneous exploratory work and should, in the end, afford reasonable expectations of profit. Sufficient work has been done both underground and at the surface to provide opportunities for careful sampling of the vein quartz and determination therefrom as to what the mill capacity should be—bearing in mind that the tonnage from the Dyke vein above, and probably also below, No. 2 level, is limited to a few thousand tons at most and that consequently the Boulder vein or other large, low-grade bodies of quartz must be expected to furnish most of the future tonnage.

Exploratory work would include further work on the quartz veins to determine their continuity and character at depth and their possibilities at intersections of crossing veins or other points where concentration of values might be expected. It might also include further work on the serpentine contact. Developments on No. 3 and No. 4 levels, insofar as this contact is concerned, have afforded little in the way of clues to more important mineralization. On the other hand the presence of consistent traces of gold along this contact on No. 3 level does suggest that somewhere, possibly nearby, conditions favourable for concentration of values may occur. By analogy with discoveries at Aurum mine it would appear that these conditions might involve either rolls in the serpentine wall[1] or the presence of auriferous quartz veins alongside the contact. A closer inspection of the serpentine contact at the surface may reveal such conditions and afford some guide to further explorations.

PIPESTEM MINE

References

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Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1920, pt. A, pp. 34-35.
Cairnes, C. E., Geol. Surv., Canada, Mem. 139, pp. 145-146.
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Location and Ownership. The Pipestem mine, property of Home Gold Mining Company, of Vancouver, is situated on the divide between the Middle forks of Ladner and Siwash creeks at an elevation of approximately 4,300 feet above sea-level or 2,850 feet above and 5 miles by road and trail from Verona. The trail generally followed leads off from the Aurum mine tractor road about 3 miles from Verona.

The property (*See* Figure 10) includes six claims, but the workings are mostly confined to one of these, the Pipestem No. 1 claim. These workings (Figure 14) include open-cuts, one shaft 30 feet deep, and two adits representing some 500 feet of crosscutting and drifts. When previously examined by the writer neither of the adits had been driven, but encouragement for further development had been lent by the high gold assays returned

[1]It will be observed (Figure 13) that this wall dips in opposite directions on Nos. 3 and 4 levels.

from mineralized vein quartz and adjoining wall-rock obtained in the open-cuts and in the shaft. It was consequently a matter of some interest to note what the more recent developments had disclosed.

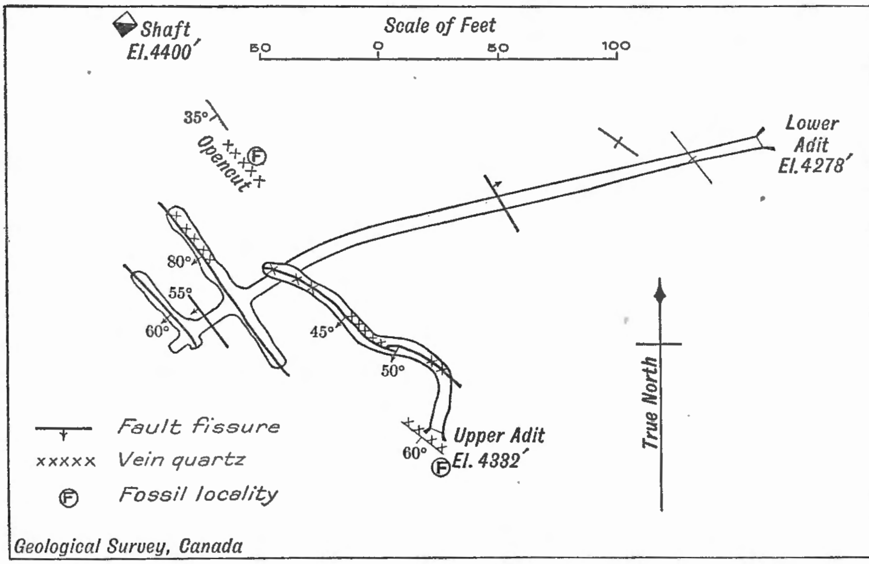

Figure 14. Sketch plan of Pipestem mine (Home Gold Mining Company, Limited), Yale district, B.C.

Geology. The Pipestem mine is situated entirely within the Ladner Slate belt, but not far from the contact with rocks of the serpentine belt (Figure 14). The principal formation at the mine is a rather massive dark grey to black, tuffaceous sandstone or greywacke varying from close-grained to finely conglomeratic. Under the microscope a specimen from near the southeast face of the first drift from the lower crosscut adit was found to contain a large proportion of carbonate replacing the other constituents which included a few grains of quartz, considerable partly altered feldspar, and many composite grains of volcanic and other rocks. Surface exposures of this rock alongside the open-cuts and near the portal of the upper adit contain an abundance of the fossil Belemnites, partly on the basis of which the rocks of the Ladner series have been regarded as of Jurassic age. This is the principal rock exposed in all the workings except near the portal of the long crosscut which is started in quite slaty rocks and angles across these for about 30 feet before entering the more massive greywacke. The sediments have an average and fairly consistent northwesterly strike and southwesterly dip, the latter steepening from about 35 degrees at the surface to 55 or 60 degrees and even higher dips underground. In addition to these sedimentary rocks a porphyry dyke about 15 feet wide is exposed about 200 yards south-southeast of the mine workings and seems to strike towards them. This dyke is a massive, grey, porphyritic rock which under the microscope is seen to carry large crystals of quartz and plagioclase (albite-oligoclase) in a fine-grained groundmass composed of feldspar and quartz. Some mafic mineral, probably amphibole, has been entirely altered to chloritic material. A few grains of sulphide, probably pyrite, are also present. Other dykes similar to this are stated to outcrop within a few hundred yards to the northwest of the mine workings.

Early Development Work. Early work on this property is summarized in a former report[1] which may be quoted as follows:

> "Surface work has been confined chiefly to a richly mineralized vein on Pipestem No. 1 (claim). There two open-cuts have been made where the quartz vein varies in width from 6 inches to 2 feet. Along the course of this vein the slate walls are so heavily mineralized as to increase the actual width of the paystreak from 50 to 100 per cent. A specimen of this country rock showing exceptionally heavy sulphide mineralization was assayed by the Mines Branch, and ran 3·76 ounces in gold......... In line with the two open-cuts which are about 150 feet apart (The eastern lies just above the portal of the "upper adits" (Figure 14), a shaft 30 feet deep has been sunk at a point farther to the northwest This intersected a couple of quartz stringers about 4 inches wide which are heavily mineralized......... The principal ore vein has been traced by a series of open-cuts and natural exposures for several hundred feet both to the northwest and southeast of the rich shoots. To the northwest it forms a series of long, narrow lenses of quartz at most only a few inches wide, but towards the southeast it widens considerably and at two different exposures observed averages 3 feet in width. In neither of these directions, however, is that heavy mineralization noted which is so characteristic of the chief surface showings......... The principal sulphide is pyrite, occurring as well-defined cubes, many several millimetres in diameter, in the quartz gangue, and also impregnating the adjoining slates. Some arsenopyrite is also present......... The quartz gangue carries the chief values. In it, gold occurs both in visible and microscope particles. Some silver is also present, but apparently in no fixed ratio to the gold."

More Recent Developments. Since writing the above the upper and lower adits (Figure 14) have been driven. The upper adit, 115 feet long, follows, mostly, the somewhat irregular course of quite a strong fault fissure dipping southwesterly at 45 to 50 degrees and carrying considerable quartz and some disseminated sulphide which has been partly oxidized. The adit was run to pick up and follow, if possible, the high-grade vein quartz exposed in open-cuts at the surface. The results of this tunnelling are not convincing either as regards mineralization or correlation with surface exposures.

The lower adit crosscuts five strong fault fissures at 30, 114, 234, 247, and 258 feet respectively from the portal. All have nearly the same strike, averaging north 38 degrees west, and all but the second have either vertical or southwesterly dips. In both their strike and dip these fault fissures tend to coincide with cleavage or bedding structures of the enclosing rocks. The three intersected towards the face of the adit all carry more or less vein quartz and two of them have been drifted on for distances aggregating 125 feet. Towards the northwest face of the drift on the first of these three fissures, quite a lot of quartz was encountered across a width of nearly 3 feet, this quartz including a considerable proportion of partly replaced wall-rock. The fissure stands nearly vertical, the southwest wall is particularly well-defined, and against this lay about 6 inches of solid

[1] Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 145.

quartz with mixed quartz and wall-rock extending outwards from the wall for another 2 feet or more. Well-defined striæ on the southwest wall indicated that the quartz body probably raked to the northwest at a comparatively low angle and hence in the opposite direction might possibly be correlated with vein quartz encountered in the upper adit. The siliceous material in the lower adit is sparingly mineralized by arsenopyrite and pyrite. A sample taken across a width of 32 inches, including the 6 inches of solid quartz, was assayed by the Mines Branch, Ottawa, and reported to contain gold at the rate of 0·10 ounces Troy to the ton. Where drifted on to the southeast of the main crosscut very little quartz was seen in this fault fissure. The other fault fissures dip southwest at angles of 55 and 60 degrees respectively. Some drifting has been done on the latter which carries a little quartz. The values, if any, obtained in this work, are not known.

Conclusions. The results attending the work underground on this property have not been as encouraging as might have been expected from the initial discoveries and operations at the surface. The high values obtained from samples taken in the open-cuts and shafts are, apparently, confined to small shoots which either do not extend for more than a few feet from the surface or else because of some pronounced rake or other structural peculiarity have not been picked up in the lower adit. Although no special accuracy can be attached to the accompanying Figure 14, which is the result of a rapid pace-compass survey, it seems of sufficient value to indicate that vein quartz does persist down to at least the main crosscut level; that the quartz encountered at the portal and within the upper adit may correspond with quartz seen in drifts on the two fault fissures on the level below; and that if the high-grade ore discovered at the surface does tend to form in shoots raking northwesterly, neither of the drifts on the lower level has been advanced far enough to pick them up. Future mining programs for this property would appear to have little choice but to mine out as economically as possible any high-grade ore left at the surface, hoping that such operations may disclose further mineralization carrying sufficient values and extensive enough to warrant more systematic development.

HOPE GOLD MINES, LIMITED

References

Nichols, H. G.: Dept. of Mines, B.C., Bull. No. 1, p. 28 (1929).
Dept. of Mines, B.C., Bull. No. 2, p. 49 (1929).

Location and Ownership. The above company, identified with A. B. Trites of Vancouver—George F. Johnson, 608 Pacific Building, Secretary, has acquired a number of claims within the serpentine belt extending almost continuously from the Kettle Valley railway, between Jessica and Verona, northwesterly for about 5½ miles to Spider Peak mountain situated between the Middle and South forks of Siwash creek, a tributary of Fraser river. These holdings may, for convenience in discussing the more important showings and developments thereon, be subdivided into four groups of claims, and these designated as the Fifteenmile, South Fork, Montana, and Spider Peak groups respectively (*See* Figure 10).

Fifteenmile Group

This group of nine claims is situated mostly in the drainage basin of Fifteenmile creek which cuts across the group on its northeast side. Much of the property is underlain by serpentine, but on the southwest it extends into territory occupied by cherty and slaty members of the Cache Creek series. The group has been referred to as the "Pacific group" in recent reports by the Government Resident Engineer. The principal workings are located near the centre of the group and near the contact of the serpentine with the Cache Creek rocks. A good pack trail leads from the railway just south of Fifteenmile bridge to a substantial camp at an elevation of 2,500 feet or about 1,050 feet above the railway at Verona. The property is heavily forested and at the workings the ground slopes steeply (about 40 degrees) towards Fifteenmile creek 800 feet below the camp.

Work to date has been concerned with a series of four talcose seams striking north 35 degrees west and dipping southwest, or into the hill, at about 50 degrees. The uppermost seam was uncovered at a point on Dundee claim about 50 feet above the camp. It follows beneath a decomposed dyke in serpentine and averages about 6 inches of crushed talcose gouge in which occasional free gold is reported to have been seen. The seam has been traced in this relation to the overlying dyke rock for the entire length of the claim. No significant ore, or sulphide, mineralization was noted at various places where this seam was examined.

Below the camp a width of several hundred feet of serpentine and associated dyke rocks has been efficiently sectioned by ground-sluicing. Three other talcose seams at vertical distances of 150, 250, and nearly 300 feet, respectively, below the camp, have been thus exposed and some work done on each. The highest of these is known as the "main" seam and has provided many specimens showing free gold. The gold appears chiefly as thin, polished films on smooth, slickensided surfaces of talc or talcose serpentine, but is also associated with chalcocite in stringers or small, nodular masses of a "white rock"[1] composed partly of coarsely crystalline diopside and carrying a little yellowish garnet. This seam includes up to 50 feet of sheared and altered serpentine, but values are stated to be mostly concentrated in a width of about 2 feet of talcy rock lying close to the hanging-wall. The hanging wall-rock is a decomposed, dyke rock about 20 feet wide which farther northwest is fresher in appearance and about the composition of hornblende diorite. Two samples were taken across parts of this dyke rock and assayed by the Mines Branch, Ottawa; one, from across 8 feet of oxidized rock above the main open-cut, gave no trace of gold; the other taken 100 feet or so farther northwest where the dyke is comparatively fresh gave a trace of gold, but no platinum, chromium, or nickel. At 250 feet below the camp a wide, talcose seam has been exposed on Le Brad claim. It has about the same strike and dip as the others and is about 50 feet wide. A sample across 4 feet of very talcy gouge near the hanging-wall was assayed by the Mines Branch and gave no trace of either gold or platinum. Still another seam of similar talcy material and

[1]*See* discussion of this "white rock", pp. 78-82.

about 7 feet thick is crosscut about 30 feet below the last. No free gold was observed in this. In climbing up to the camp from the "main" ledge a composite sample of serpentine was taken across a width of about 200 feet. Care was taken to select only typical massive serpentine. This sample assayed by the Mines Branch gave: gold, trace; platinum, none; nickel, 0·22 per cent; chromium, 0·26 per cent. About 50 feet below the camp small stringers, an inch or so in width, of diopside-rich "white rock" conspicuously mineralized, in places, with chalcocite and free gold, were observed. These appeared to follow fractures in the serpentine and although selected specimens would carry high values in gold such occurrences could hardly be regarded as otherwise commercially important.

Interesting features on this property relate first to the common association of free gold with stringers of the so-called "white rock," to which more complete reference is given in subsequent pages of this report; and second to the peculiar colour of the gold. Where the white rock occurs as narrow vein-like stringers it is largely composed of coarsely crystallized diopside and contains, here and there, small lumps of chalcocite associated with free gold. Copper stains generally surround the sulphide and draw attention to its occurrence. Where the white rock, on the other hand, forms larger bodies, commonly lens-shaped, it is mostly fine-grained and such small gold values as it may contain appear to be accidental to the rock rather than of genetic significance. The coarsely crystallized diopside stringers, however, appear to have been introduced subsequent to the larger masses of white rock and to have brought their copper and gold content with them. The colour of the gold on this group is distinctly reddish as contrasted with other properties where it has a more normal appearance. The common association of the gold on these claims with the copper mineral chalcocite (or possibly other copper minerals) suggests that its colour may be due to the presence of a small proportion of copper as an alloy with the gold.

The most likely showing on this property, from a commercial point of view, is that exposed on the so-called "main" ledge where it would appear that further work is justified in order to prove whether any considerable body or bodies of the ledge can be depended on to provide reasonable values. If investigation should fail to indicate such possibilities for this ledge it seems hardly likely that the other showings on this property will be found worthy of further attention.

South Fork Group

This group of claims lies partly west of the Aurum property and extends southeasterly to include the upper basin of Fifteenmile creek where it is separated by less than a claim length from the Fifteenmile group. The principal workings are located along the south branch of the South fork of Ladner creek and principally on the Gold Fish No. 4 claim. A camp has been established there at an elevation of 3,100 feet. A good trail connects with Aurum camp and thence with the railway at Verona. A short cut to this station follows a foot trail to the east of Fifteenmile creek.

The property is mostly underlain by the serpentine body which is intersected here and there by dykes of diorite or kindred rock, varying from 1 foot or 2 feet to 15 or 20 feet wide, and by more irregular bodies of similar intrusive rocks. The principal workings include two adits, whose portals are 350 feet apart and lie at elevations of 3,200 and 3,300 feet, respectively. Judging from a rather hurried examination, these adits (comprising about 550 feet of drifts and crosscuts) follow a zone 50 to 80 feet wide composed of altered serpentine and ribbed by two or more diorite or quartz diorite dykes varying from 2 to 10 feet or more wide. This zone of composite rocks has been subjected to strong shearing, and subsequent hydrothermal alteration, with the result that its constituent members have been largely altered to talcose and talc-carbonate rocks. On either side the zone passes into massive serpentine within which occasional small bodies and dyke-like masses of fine-grained "white rock" are encountered. The talcose ground so abundantly developed within the zone of alteration necessitates immediate and strong timbering to support it. On No. 1 level specimens of altered dyke and talc-carbonate rock have been obtained showing a conspicuous amount of free gold. The lower adit, started partly to explore this discovery at depth and partly to investigate the intervening ground, found a little free gold in a 2-foot dyke encountered at 240 feet from the portal. A crosscut driven 30 feet to the east from this point intersected nothing but sheared talcose rock. A sample taken along this crosscut was assayed by the Mines Branch, Ottawa, and found to contain no trace of either gold or platinum. The other objective, namely, to get under the gold-bearing rock of No. 1 adit, had not been reached when the property was visited and judging from the survey made at the time was not advancing in the right direction. To determine the exact position of the face of No. 2 adit with respect to this showing on No. 1 level a more accurate survey would have to be made. It would, however, appear desirable, before undertaking further expensive development work on this property, to first follow the gold-bearing rock on No. 1 adit and obtain thereby more precise information as to the extent, character, and values of the deposit and its structural relations with respect to enclosing rocks.

In addition to the above work some exploration of talcose shear zones in serpentine was being made at a couple of other nearby points on this property. This work was yielding no encouragement in the way of mineralization.

Montana Group

This group includes a row of six claims and one fraction, all surveyed, extending northwesterly from Idaho claim of the Aurum property to west of Pipestem mine (Figure 10). The group follows the northeastern contact of the serpentine belt. So far as is known very little recent development has been done and that chiefly on Montana claim where older workings[1] had disclosed a small, gold-bearing quartz vein in greenstone (volcanic rocks). The property is favourably situated with

[1]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 144.

respect to the slate-greenstone contact and it is not improbable that careful prospecting will reveal more substantial bodies of quartz whose average tenor will be found sufficiently attractive to induce further exploration.

Spider Peak Group

This group includes four claims and two small fractions, all surveyed, and extends northwesterly along the divide between Hillsbar creek and the North fork of Siwash creek. It lies within the serpentine belt and is underlain partly by greenstone (volcanic and intrusive); partly by serpentine; and, in the vicinity of Spider peak on Gold Nugget and 3X claims, by a mass of quartz-carbonate-mariposite rock subsequently referred to in this report (page 180). Quite a little exploratory work has been done on this group, but very little development attempted. Near the southwestern boundary of the Georgia No. 2 claim and at an elevation of about 4,300 feet an open-cut along a strong, mineralized fault striking north 80 degrees east and dipping 40 degrees to the north provided some 2½ tons of ore which was shipped to Tacoma, Wash., and is stated to have carried $9 in gold. The wall-rock is massive, fine-grained, greyish green diorite which apparently forms quite a large body in this vicinity. This rock carries a sparse dissemination of sulphides, including, probably, both pyrite and arsenopyrite, with which the gold values are thought to be associated. Apparently the valuable portion of the deposit had been mostly exhausted by these small operations. Further explorations have been mostly confined to the body of quartz-carbonate mariposite rock which carries abundant vein quartz and a sparse dissemination of sulphides. So far as is known no mineral concentrations of commercial importance have yet been discovered in this rock and any prospects that the property may have would appear to lie in the direction of finding low-grade bodies of sufficient size to justify operations on a large scale.

SPENCER HOLDINGS

A couple of groups of claims adjoining those of Hope Gold Mines, Limited, are under option to Col. Vic. Spencer of Vancouver. One of these groups includes some eleven surveyed claims and fractions lying southwest of the Montana group and drained by the South fork of Ladner creek. This property is believed to be underlain chiefly by serpentine, but along the northeastern flank includes considerable bodies of greenstone of both volcanic and intrusive origin. Quite a little exploratory work has been done, mostly on the more central claims of the group. A camp has been established on Earl fraction at an elevation of about 3,700 feet or 1,200 feet above Aurum mine camp, to which a pack trail leads from the Spencer group. On the Birdseye claim, about 300 feet above camp, some work was being done on a crushed zone in greenstone (probably volcanic rock) striking northwesterly and dipping from 35 degrees to 65 degrees to the northeast. This zone has two or more branches of irregular width and doubtful continuity and contains narrow quartz stringers associated with some calcite and, locally, quite a heavy dissemination of sulphide, chiefly arsenopyrite. One small pocket is stated to have provided $600 worth of gold ore. A specimen of vein matter carrying abundant arsenopyrite was examined on the possibility that it might contain some telluride of gold. No trace of such a mineral was noted and the conclusion was that whatever gold values the specimen might contain were either free or closely combined with the arsenopyrite. Some five open-cuts along the zone have failed to locate any appreciable quantity of such well-mineralized vein matter and it would appear that efforts might be better directed to exploring the vicinity for larger bodies of quartz in which more persistent, if less spectacular, values might be found.

Other explorations have been conducted farther to the southeast on the Georgia fraction in the vicinity of the contacts of the main serpentine body with volcanic rocks and diorite dykes. Surface work in this section has uncovered talcy seams along such contacts, but has failed to pick up any encouraging mineralization.

KEYSTONE GROUP

The Keystone group of eight claims is the property of a partnership of eight, of whom O. E. Hicks, Laidlaw, B.C., is principal owner. The group is situated in the upper basin of Hillsbar creek, the workings lying between 500 and 800 feet below the summit of the divide between this creek and the South fork of Ladner creek. Work to date includes several open-cuts on a talcose seam following the contact of a quartz-porphyry dyke in the serpentine body near its southwest contact with cherty and slaty members of the Cache Creek series. Values in gold are reported to have been obtained from this seam, though no free gold was observed. The seam contains some exceptionally pure talc and is otherwise interesting in that slickensided surfaces in places carry abundant needle-like crystals of millerite. The quartz porphyry dykes which cut the serpentine on this property are similar to light-coloured, minor intrusives occurring in the serpentine belt southeast of Coquihalla river.

MAMMOTH HOLDINGS, LIMITED

This organization, of which U. O. LaBelle, care of J. Leckie and Company, Cambie street, Vancouver, is secretary, owns the Mammoth-Snow Shoe group of sixteen claims and fractions. This group occupies the divide between the South fork of Ladner and Little Emory creeks and, towards the south, extends into the basin at the headwaters of Eleven-mile creek. The latter stream is a tributary of Coquihalla river, whereas Little Emory creek drains into the Fraser.

The property lies southwest of and about parallel with the serpentine belt. It is underlain chiefly by massive to well-banded cherty sediments, some slaty beds, and a small proportion of greenish andesitic volcanic rocks (greenstone)—all members of the Cache Creek series. Occasional acid and basic dykes intrude these rocks. Attention on this property has been confined mostly to a strong zone of shearing, developing considerable talcose rock in which specimens showing free gold are reported to have been found. The associated rocks are greenstone and serpentine. The former is a fine-grained, greenish, andesitic volcanic rock, whereas the latter appears to be an altered basic intrusive which has been partly sheared, and altered to talc. This talcose rock is, in places, heavily mineralized, chiefly by nickeliferous pyrrhotite. The shear zone extends across the precipitous divide between Little Emory and Elevenmile creeks, but most of the exploratory work has been done on the western slope. Here at an elevation of about 4,350 feet an open-cut has exposed over 5 feet of mineralized talcose rock within which free gold was stated to have been found along a certain narrow slip. A sample was taken across 4 feet 8 inches of this talcy rock, without noting any free gold. This sample was assayed by the Mines Branch, Ottawa, and reported to contain: gold, none; platinum, none; nickel, 0·11 per cent; chromium, 0·17 per cent. The width of talcy material appeared to be a maximum for the shear zone as developed for at least a considerable distance above and below this point.

A few hundred feet east of this showing and about 200 feet lower down the hill is another though smaller shear zone developed in similar rocks. A little work has been done on this without, so far as is known, finding any gold values.

The association of talc with serpentine on this property is analogous with associations in the main serpentine belt. The character and mineralization of the talc are also very similar to those on properties in the main belt and the erratic deposition of values constitutes but another feature in common.

PROPERTIES SOUTHEAST OF COQUIHALLA RIVER

A number of properties southeast of Coquihalla river have recently received considerable attention in the light of their association with the serpentine member of the serpentine belt. The belt has been staked in this direction for several miles and at a number of places traces of free gold have been found. On none of these properties, however, with the exception of certain placer holdings on Sowaqua creek, have values to date been sufficiently attractive or consistent to warrant more extensive development and on some exploratory work has been discontinued.

Columbia Metals, Limited

References

Nichols, H. G.: Dept. of Mines, B.C., Bull. No. 1, p. 32 (1929).
Nichols, H. G.: Dept. of Mines, B.C., Bull. No. 2, p. 49 (1929).

The Columbia Metals Company, Limited, of Vancouver, owns a number of claims southeast of Coquihalla river near the northeast contact of the serpentine belt. The principal workings are situated within 150 and 300 feet above, and ¼ mile from, the river and about a mile from Jessica station. The underlying rocks are chiefly serpentine, or altered forms of serpentine, and basic dyke rocks of about the composition of diorite. Mineralization associated with shear zones in serpentine or altered serpentine, and occurring mostly along one or other walls of the dyke rocks, has furnished some incentive for exploratory and development work. This work has included several open-cuts and one adit 50 feet long. About 160 feet southeast of the portal of the adit an open-cut has exposed a shear zone of talcose rock about 10 feet wide, in which small, lens-like bodies of zinc blende up to 6 inches wide were found associated with other sulphides including pyrrhotite, pyrite, and chalcopyrite. The zone strikes northwest and stands nearly vertical. The northeast wall is a fine-grained greenstone, probably dyke rock, and the other wall is serpentine. This zone would appear to be the one picked up by the adit 50 feet below, where it has a maximum width of between 50 and 60 feet and is composed of sheared talcose rocks including, towards the centre, a mass of altered dyke rock 7 feet wide carrying considerable disseminated chalcopyrite. A sample of this latter rock was stated to have assayed between 3 and 4 per cent copper, less than $1 in gold, and gave a trace of nickel. The copper pyrites is partly altered to black, sooty alteration products in which sulphate of iron and other by-products may be distinguished. Developments would appear to indicate that this mineralized rock forms a lens or chimney-shaped mass within more sheared and talcose material. The northeast wall of the zone, as developed by the adit, is a massive, medium-grained diorite dyke composed essentially of diallage and albite-oligoclase plagioclase with considerable leucoxene, magnetite, chlorite, and a little amphibole. The other wall is an altered serpentine composed largely of talc and brown ankeritic carbonate. Other narrower talcose shear zones were also being investigated, and a little free gold is reported to have been seen in these operations. The average gold content of both these and the main shear zone appears, however, to be too low to be of commercial interest and the small, local concentrations of other sulphides hardly lend encouragement to more ambitious developments.

Reward Mining Company, Limited

Reward Mining Company, Limited, of 475 Howe street, Vancouver, owns a large group of claims extending southeasterly from Coquihalla river (southwest of the holdings of Columbia Metals) to and across Sowaqua creek and mostly situated within the limits of the serpentine belt. Preliminary prospecting has been done on this property at a number of places without encountering attractive values; although traces of free gold have been noted and assays up to $1 or more in gold have been obtained from a variety of samples obtained in part from dyke rocks, in part from quartz veins, and in part from serpentine or talcose rocks. A little placer gold was also found on the margin of Serpentine lake situated on the divide between Coquihalla river and Sowaqua creek at an elevation of 3,500 feet. The lake is underlain and surrounded by serpentine intersected by occasional dioritic dyke rocks. The occurrence of the gold is attributed to local concentrations from the disintegration and erosion of nearby rocks and is not thought to have provided any deposits of importance.

Dalhousie Mining Company, Limited

References

Nichols, H. G.: Dept. of Mines, B.C., Bull. No. 1, pp. 32-33 (1929).

This company, with head office in Vancouver, has been prospecting a group of claims situated along the southwestern contact of the serpentine belt between Coquihalla river and the summit of the divide northeast of

Sowaqua creek. The principal workings lie between 500 and 900 feet above the river and include several hundred feet of trenching, one adit 60 feet long, and several pits and open-cuts. The work was designed to investigate systematically all phases of both serpentine and associated dyke rocks—particular attention being paid to localities where mineralization was more likely to be of economic importance, such as in shear zones, quartz veins, or in the more massive rocks where sulphide minerals were observed. The work exposed two or more quartz porphyry dykes intersecting the serpentine in a general northwesterly direction. Along one or other walls of these dykes more or less shearing has occurred, one such shear being investigated by the adit mentioned above. This shear strikes north 25 degrees west and dips 60 degrees southwest; has a quartz porphyry hanging-wall and serpentine foot-wall; is over 10 feet wide; and is composed chiefly of crushed serpentine and talc with some vein quartz carrying a little greenish mica (probably mariposite). It is stated that near the centre of the shear a thin stringer of quartz carried visible free gold. Elsewhere on the property, however, no discoveries of economic significance have been reported.

Peer River Placer Company, Limited

References

Davis, A. W.: Ann. Rept., Minister of Mines, B.C., 1922, p. 143; 1923, pp. 162-163.

Location and Ownership. The Peer River Placer Company, with head offices at 410 Rogers Building, Vancouver—Clyde M. Cass, Managing Director—owns ten placer leases on Sowaqua creek. These extend over a length of between 2½ and 3 miles, beginning about 2½ miles from, and 400 feet above, the mouth of the creek and rising 700 feet to an elevation of 2,100 feet above sea-level at the upper end of the property. The average stream gradient in this distance is, consequently, over 5 per cent.

The property has been recently acquired by the present organization from Capt. J. D. Fullbrook and associates who have been doing more or less work each year since the first leases were located in September, 1921. A wide, well-graded trail about 5 miles long leads from Jessica station to a substantial camp (Plate IV-B) on the north bank of Sowaqua creek near the lower end of the property.

Geological Environment. Within the property limits Sowaqua creek cuts entirely across the serpentine belt and into the formations on either side. The serpentine belt is here composed chiefly of serpentine intersected by a number of both large and small dykes, or less regular masses of diorite and a few dykes of quartz porphyry. The adjoining members of the Cache Creek series to the southwest are chiefly cherty sediments with some intercalated, slaty rocks. The Ladner Slate belt to the northeast is composed mostly of dark grey to black slates interbedded with more massive argillaceous sediments which strike about north and south and stand nearly vertical.

Sowaqua Creek

Sowaqua creek is a large tributary of Coquihalla river, maintaining a strong flow at all times of the year but subject to the great fluctuations in volume characteristic of mountain streams in regions of irregular and heavy precipitation. In spring and autumn freshets due to melting snows and heavy rains are common, and sometimes prolonged. July and August are the driest months, following which the creek is low, can be forded on foot at almost any point, and would probably not average more than 20 feet wide in the lower 4 miles. At high water, however, the creek may increase its volume to more than three times its minimum flow and becomes a torrent which can be controlled only with great difficulty. The stream bed is strewn with large and small boulders that would interfere materially with large placer operations both in respect to their removal and disposition. On one or other, but mostly the north bank of the present stream bed within the limits of this property, the ground rises to form low-lying benches up to several hundred feet wide which are partly covered at high water. The amount of drift underlying both these benches and the stream bed itself is evidently great, as shaft work to date has failed to reach bedrock, though one shaft was sunk to a depth of 60 feet. Bedrock outcrops in places along the creek, within the placer ground, but is mostly concealed by glacial drift and alluvium. The valley bottom and slopes are mantled by a heavy forest growth which would necessitate much expense to clear and would, consequently, be a handicap to placer operations unless some profit could be realized from the sale of the better timber.

Exploratory and Development Work. Placer operations have been handicapped by lack of sufficient funds for adequate exploration and development work and have been conducted more or less haphazardly, with the result that although some attractive results have been obtained there is little evidence to indicate whether the better values obtained persist through any considerable width and depth of ground; or are confined mostly to relatively narrow paystreaks at one or more horizons in the drift deposits; or whether attractive values may not occur on or near bedrock.

Exploratory work on this property has been done chiefly in the vicinity of the camp and has included three or more shafts, a number of shallow pits, and some surface sluicing. These operations are stated to have yielded some $4,400 in gold and $600 in platinum. The deepest shaft has been sunk for 60 feet below the water-level of Sowaqua creek. It is stated to have carried 19 cents in gold per cubic yard in the first 12 feet—composed chiefly of a blue clay carrying fine, angular gravel; 80 cents in the next 12 feet; and from 50 to 60 cents in the next 32 feet. The values obtained in the last 4 feet are not known. Except for the upper 12 feet, the shaft passed through rather well-sorted, small gravels and coarse sands. Another shaft 22 feet deep, sunk from bench level a few feet above the creek and within ½ mile upstream from the camp on the right bank of Sowaqua creek, is stated to have averaged $2 to the cubic yard.[1] Sluicing

[1]*See also* test No. 2 by Resident Engineer.

operations, again, on surface gravels accumulated near the mouth of a tributary stream coming into the north bank of Sowaqua creek near the camp, are said to have provided $1,100, chiefly in gold, in one month's operations by two men.

Some tests were made of this ground early in December, 1923, by the Resident Engineer, who reports:

"*No. 1 Test:* Ground-sluice No. 3 lease (¼ yard put through rocker); riffle concentrates, 19 cents a yard in gold; blanket concentrates, 16·6 cents a yard in gold and 1·1 cents in platinum; total value of gravel, 36·7 cents a yard.

No. 2 Test. Windlass shaft on right side of creek on bench (⅛ yard put through rocker): riffle concentrates, 13·3 cents a yard in gold and 0·6 cent in platinum; blanket concentrates, 437 cents a yard in gold, 1·3 cents in silver, and 1·3 cents in platinum; total value, 453·5 cents a yard.

No. 3 Test. From 10-foot shaft near left bank of creek (¼ yard put through rocker); all concentrates together, 2·4 cents a yard in gold.

In making the above tests it was assumed that, for every yard of material such as was handled above, half a yard exists as boulders."

Geological History and Source of the Deposits. An interesting feature of the deposits is that, whereas the stream bed is strewn with heavy wash including an abundance of large boulders, these boulders appear to be mostly confined to the surface. The 60-foot shaft, for example, encountered only one large boulder, the rest of the material being fine gravel, coarse sand, clay, or mixtures of the three. The explanation lies in the correct interpretation of the history of the formation of these unconsolidated deposits. During the glacial period great quantities of drift accumulated in the valley of Coquihalla river and its tributaries. Towards the close of the period and as the ice gradually withdrew farther and farther up the main valleys this glacial drift was re-assorted by the great volumes of water provided largely by the melting ice. The succession of materials deposited by the streams as the ice gradually retreated up the valley would, in the main, probably be the normal one in which heavy wash lain down immediately in front of the ice (at the source of stream supply) is covered by a succession of material decreasing in size as the ice front moved up the valley. Local variations were doubtless provided by one of a number of conditions involving slides, contributions from tributary streams, torrential rains, etc. Accumulation of the deposited materials would be rapid and heavy owing both to the abundance of morainal debris left by the retreating ice and the great volumes of water which its melting would provide. With the withdrawal of the ice, however, the principal source of such debris would also disappear; the stream would clear appreciably and be thus enabled to carry much of the finer debris out of the district. Conditions then approached those of the present time when only the larger materials, boulders, etc., accumulating from more casual and more recent agencies, such as slides, freshets, and tributary streams remain in the beds of these swiftly flowing mountain streams. Such agencies have thus provided a second period of accumulation of boulders—a condition encountered at the surface of the present stream beds. In general, then, the sequence from bedrock up may be expected to be much as outlined, namely, heavy wash succeeded by considerable thicknesses of comparatively fine and partly sorted materials, overlain in turn by recent boulder wash.

The source of the placer gold and platinum on this property is consequently to be regarded as glacial to the extent that most of it at least has resulted by concentration from glacial debris that contained some placer gold derived from the erosion of bedrock or ancient placers. The rocks from which the previous metals were derived may be located, in part, entirely outside of the basin of Sowaqua creek. It is likely, however, that the underlying rocks of this basin provided much of metal content of the placers—particularly where such content is found in the surface or near surface wash.

Possibilities. The possibilities of this property cannot be forecast until more consistent sampling has been done and a better idea of average values obtained. Results to date have been encouraging so far as values are concerned, but too little has been done to say whether future operations should be undertaken on a large or small scale. Enough, however, is known to warrant, in the writer's opinion, a careful program of boring and sampling. Borings should be extended to bedrock, unless the depth is excessive, in a sufficient number of places to determine the depth, character, and average value of the ground. In the end it may be found that carefully planned, small-scale operations will be more likely to yield a profit than those conducted on a large scale. Should the results of systematic sampling appear to justify operations on a large scale—and in the writer's opinion such average values should approach or, preferably, exceed $1 per cubic yard—the initial heavy expenditures and physical difficulties involved in mining on a large scale, by dredging, hydraulicking, or by some other method, must be clearly realized. Among these difficulties the great fluctuations in volume of Sowaqua creek, the heavy surface wash, the depth to bedrock and the down-stream gradient at bedrock, the possibilities for disposal of tailings, and the heavy forest growth are of prime importance.

DESCRIPTION OF FORMATIONS OF SERPENTINE BELT

SERPENTINE[1]

Extent

The most interesting member of the serpentine belt, from the point of view of more recent discoveries, is serpentine. Traverses across and along the belt, facilitated now by numerous trails, have shown serpentine to be a more abundant and more persistent rock than had formerly been supposed. It appears, in fact, that this rock forms a continuous dyke or sill-

[1] That the reader may not be confused by the use of such terms as "serpentine," "serpentine belt," "serpentine member," "main serpentine body," and also, references to minor occurrences of serpentine in the serpentine belt, it is suggested that he keep in mind, first, that the *serpentine belt* is composed of a variety of rocks; and second, that an abundant and conspicuous member of this belt is a serpentine rock which, itself, forms an almost if not quite continuous belt or, at any rate, a close succession of long, sill-like masses within, and probably for several miles on either side of, Coquihalla area. This is the serpentine referred to in this report under such terms as "the serpentine (or main serpentine) member," "serpentine (or main serpentine) body or bodies," or mass or masses or, more simply, "serpentine," and should not be confused with minor occurrences of serpentinized or partly serpentinized rocks which are dealt with more specifically in discussing alterations affecting members of the serpentine belt other than those that provided the main serpentine member. In other words, and unless specifically stated to the contrary, the "serpentine" referred to in this report is the serpentine of the main serpentine member of the serpentine belt.

like mass, or possibly, close succession of masses, extending entirely across Coquihalla map-area and for some miles, in either direction, beyond (Figure 9). This serpentine varies in width, occupying, in some sections, most of the serpentine belt, but in others associated with a large proportion of other rocks.

To the southeast of Coquihalla river the northeastern contact of the serpentine body crosses Sowaqua creek about 2½ miles above its mouth near the Peer River Placer Company's camp. The other contact crosses about a mile farther up this creek. Southeast of Sowaqua creek, the same body, or succession of bodies, has been traced and prospected for a distance of 10 miles or more to where it crosses the valley of Eighteenmile creek. Beyond this locality its continuity is thought to be interrupted by a body of granodiorite[1] beyond which its presence is problematic. It is uncertain, for example, whether it appears again in the vicinity of Twentythreemile camp or Skagit river and no mention of the occurrence of serpentine is made in reports covering that section of Cascade mountains lying between this camp[2] and the International Boundary.[3]

Northwest of Coquihalla river serpentine has been traced across Coquihalla area and is believed to form a nearly if not quite continuous belt or succession of outcropping masses to and across Siwash creek a mile below the main north and south forks. Still farther northwest its course is less certain. Large outcrops of serpentine occur about 3 miles or so up Gold creek, a stream emptying into Fraser river about 14½ miles below Boston Bar. Serpentine is also exposed in cuttings along the Cariboo highway 1½ miles south of Anderson river. It seems likely that this serpentine is related to the serpentine in Coquihalla area and at intermediate points, though it is doubtful whether exposures are continuous for this distance. A sample of the serpentine from the Cariboo highway was reported by the Mines Branch, Ottawa, to contain no gold or platinum, 0·21 per cent nickel, and 0·26 per cent chromium. Under the microscope this serpentine appears to have formed from an olivine-rich peridotite in which pseudomorphs and partly altered crystals of olivine and a doubtful pyroxene may be recognized. What may represent a spur from, or a dyke more nearly parallel to, this main serpentine body appears in a cutting along the Canadian National railway less than a mile north of Stout (Figure 9). Here a few feet of serpentine has been partly altered to talcose rock along a strong shear zone which shows some mineralization but little or no gold values. The continuity of this serpentine is obscured at this locality by later batholithic intrusives.

Structure and Origin

Structurally this serpentine follows what appears to have been a zone of weakness in the associated rocks, a zone coincident not only with the general northwesterly trend of the rock formations on either side but also with the direction of principal deformation of these rocks. This zone of

[1]Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1922, pt. A, map facing p. 120.
[2]Camsell, C.: Geol. Surv., Canada, Sum. Rept. 1911, pp. 115-123.
[3]Daly, R. A.: Geol. Surv., Canada, Mem. 38, pp 479-506.

weakness developed against a massive, resistant, formation of the Cache Creek series composed chiefly of strong, cherty sediments. This formation bounds the serpentine belt on the southwest and forms conspicuous, cliffy topography along the contact, as on either side of Coquihalla river in vicinity of Jessica; at the head of the South fork of Ladner creek; and up Sowaqua creek. During the period or periods of deformation accompanying batholithic intrusion in Coquihalla and adjacent areas the less competent members of Cache Creek series, lying northeast of the cherty formation, yielded more readily to mountain-building stresses and consequently suffered more intense shearing. This physical description was accompanied by alteration facilitated by ascending thermal solutions and gases released by the underlying magma and contemporaneous intrusions. The persistent association of the serpentine of the serpentine belt with a greenish volcanic member of Cache Creek series led the writer, in an earlier examination of this area, to the conclusion that the serpentine had probably developed through alteration of the greenstone. Certain difficulties in this interpretation were, however, recognized and, though no positive evidence was obtained at that time, it was suggested as a contrary solution to the problem, that possibly the serpentine might represent an altered basic intrusive,[1] related in time and origin to bodies of diorite which were abundantly exposed within the serpentine belt. Recent more particular studies of the problem have supported this latter interpretation. They have shown that the serpentine member of the serpentine belt is an altered basic intrusive having, originally, the composition of peridotite or an olivine-rich pyroxenite; that it was intruded as a sill-like mass or, succession of masses, along a zone of weakness coincident with a belt of greenish altered volcanic rocks and tuffaceous sediments, thought to represent the uppermost members of Cache Creek series in Coquihalla area; and that the intrusion of this basic serpentinized rock was followed and possibly also accompanied by other intrusions less basic in character and having, on the whole, the composition of diorite.

Lithology

The serpentine is typically a dark green, in some cases yellowish green, massive, dense-textured rock showing, here and there, lustrous light green crystalline aggregates of bastite (altered enstatite). Small metallic points and areas of magnetite and chromite are also visible, but rarely of appreciable size. Occasional minute veinlets of chrysotile (asbestos) have been noted, but so far as field observations went, are of no commercial importance. Under the microscope this serpentine has been identified as antigorite, but varies considerably in appearance according to the character or " stage " of serpentinization to which the rock has been submitted. All " stages " show the same complete serpentinization of the rock, but in the first or magmatic stage, a stage regarded as having been reached early in the history of the basic intrusive and commencing even before that rock had completely consolidated, the best image of the original structures is retained. Slides depicting this stage are beautifully

[1]Cairnes, C. E.: Geol. Surv., Canada Mem. 139, p. 36.

clear showing under plane transmitted light an almost colourless or slightly greenish rock carrying an abundance of tiny black crystals of magnetite arranged in more or less symmetrical pattern bordering original crystals or following the cleavages of, chiefly, olivine and enstatite and presenting thereby what is commonly referred to as a mesh structure. Between crossed nichols the slide breaks up into an aggregate of clear anisotropic serpentine blades showing characteristic low birefringence colours with here and there well-defined pseudomorphs of olivine and enstatite, the former recognized chiefly by their rounded outlines and irregular cleavage cracks and the latter by their crystal outlines, well-defined cleavage, and the preservation of certain distinctive optical properties. This stage of serpentinization may be referred to as "mash antigorite." Subsequent stages of serpentinization are superimposed on the first and are the result chiefly of rearrangement of the rock textures by juvenile and meteoric waters circulating through the rock at any time subsequent to its consolidation. This circulation has been facilitated by fracturing or deformation of the serpentine and is consequently the more pronounced where the rock has been most sheared. In these later stages the initial mesh structures are partly to completely destroyed; pseudomorphs of earlier minerals are less well preserved; and the serpentine takes on a closer texture composed at first of a myriad of small blades of serpentine commonly crossing each other more or less at right angles and presenting the appearance of a fine lattice-work. Subsequently, and as a result chiefly of the action of meteoric and consequently, low temperature, solutions even lattice structures are lost and between crossed nicrols the slide appears almost or quite isotropic due to the overcrowding of minute, scale-like bodies of serpentine. This stage may be referred to as the "colloidal stage." It may appear along fractures surrounding blocks of massive serpentine, the interior of which grades from lattice-antigorite on the outside to typical mesh structures within. It is also common in sheared or foliated varieties of serpentine or where the serpentine is being further altered to talc or to quartz-carbonate rock. Aside from these occurrences it may be pointed out that colloidal serpentine is characteristic of other serpentines or serpentinous rocks developed in the serpentine belt and formed mostly by reactions of low temperature solutions on chloritic material which, in an earlier stage, developed by alteration of basic igneous rocks carrying a large percentage of such mafic constituents as pyroxene or amphibole. Further references to alterations of this sort will be made later in this report.

Alteration

Alterations of the serpentine are many and have affected both large and small bodies of this rock. Surface alteration is mostly confined to a thin veneer which is commonly lighter coloured than the body of the rock and appears to be chiefly the result of bleaching by sun and exposure, in general, to the atmosphere. Bodies of the serpentine that are particularly rich in iron content are commonly stained brownish-red with iron oxide. Thin, bluish white and rather pearly films of another type of serpentine, somewhat resembling chrysotile, commonly coat fractures or joint-planes within the rock.

More extensive alterations of the serpentine have resulted from its deformation and subsequent invasion by juvenile and meteoric solutions. Three quite distinct products have resulted from such alterations. In one the serpentine along zones of shearing has by addition of silica and subtraction of water been partly changed to talc. In another, large bodies of serpentine have been altered to carbonate quartz-mariposite rocks[1] stained reddish or buff-brown at the surface by formation of iron oxide, but, on fresher fractures, showing an abundance of the bright green, chrome-bearing mica, mariposite.[2] These rocks are laced in all directions by a network of quartz veins and also contain an abundance of free quartz as an integral part of their composition. A third type of alteration has been recognized in which the serpentine has largely passed over to a rock composed chiefly of talc and carbonate.

Alterations of the first type are of particular present importance as it is in the talcose shear zones that recent discoveries of free gold have been made. The origin of the gold is ascribed to ascending thermal solutions related to the same magmatic source as the basic intrusives of the serpentine belt. These solutions in rising towards the surface along fractures or other lines or zones of weakness in the overlying rocks, may have derived a considerable portion of their silica content from the adjoining wall-rocks. Reactions with serpentine along zones of shearing resulted in partly changing the serpentine to talc by addition of silica and might be expressed in the terms of the following equation: $3MgO,2SiO_2,2H_2O$ (serpentine) $+2SiO_2=3MgO,4SiO_2,H_2O$ (talc) $+H_2O$. At about the same time the sulphides and free gold carried in solution would be partly precipitated, depending on such conditions as temperature and concentration. Excess silica might also be deposited here as free quartz, or carried out into more open fractures of adjoining rocks to be precipitated there as quartz veins also carrying more or less sulphide and gold values. The origin of the sulphides appears to be in part magmatic, but also probably in part referable to the serpentine and adjoining rocks. The nickel sulphide millerite and any pentlandite or other nickel minerals associated with pyrrhotite may have derived their nickel content from the serpentine, analyses of which invariably show an appreciable amount of this metal. Arsenopyrite, however, seems more likely attributable to magmatic sources.

Alterations of the second type are pronounced within one fairly definite area in the serpentine belt at the headwaters of the South fork of Siwash creek. Here a prominent bluffy peak locally known as Spider peak (sometimes called Spidle peak) (Figure 10) is largely composed of a reddish weathering rock which on fresh fractures has a distinctly bright greenish cast due to the development of abundant, bright green flakes and shreds of mariposite, whose colour is attributed to a small percentage of chromium. The principal constituents of this rock are carbonate and quartz and the rock as a whole is intersected by a network of prominent quartz veins lending something of the appearance of a spider's web and hence responsible for the name assigned to the peak. The carbonate is an ankeritic whitish

[1]*See* footnote, p. 181.
[2]This mineral is probably mariposite and belongs in the mariposite-fuchsite-muscovite group which forms part of a gradational series.

to light-buff variety weathering to iron oxide which has stained the outcrops a conspicuous buff-brown. A sparse dissemination of sulphide, chiefly pyrite, is present and could be seen in a thin section of this rock. Qualitative tests show no nickeliferous sulphide. This type of alteration[1] seems to have been effected chiefly by carbonization of the serpentine through the agency of ascending thermal carbonated waters. The equation in its simplest form might be represented thus: $3MgO, 2SiO_2, 2H_2O$ (serpentine) $+3CO_2=3\ (MgO, CO_2)+2SiO_2\ \ 2H_2O$ in which the magnesia content of the carbonate is replaced by more or less iron obtained partly from the decomposed serpentine and partly (?) from the magnetite associated with it. Similarly the chromium content of the green mica was probably obtained from disseminated chromite in the serpentine. In this connexion it is interesting to note that little magnetite or chromite were observed in this rock as compared with the unaltered serpentine. The excess silica forms much of the body of the rock as well as developing veins through it. Much of this silicia was probably obtained almost in situ from the altered serpentine mass, but some was doubtlessly picked up by ascending thermal waters from serpentine or other rocks not immediately involved in the alteration. The sulphides are probably of juvenile origin, as is also the small value in gold obtained from these rocks. No mineral deposits of economic value, however, have been found, a feature explicable on the basis of extreme dilution through comparatively large bodies of quartz and quartz-carbonate rock.

The third type of alteration in which the serpentine has been changed to a rock composed largely of talc and carbonate with very little quartz is represented by several occurrences along what may eventually prove to be a more or less continuous belt or zone extending for some distance down Fifteenmile creek, thence across Coquihalla valley to the property of Columbia Metals, Limited, and from there over the summit to the southeast and down to Sowaqua creek along the small tributary valley draining Serpentine lake. This zone would cross Sowaqua creek a little above the Peer River Placer Company's camp. The carbonate mineral constitutes, roughly, about half of the rock; is an ankeritic variety weathering buff, and, by reason of its comparative hardness, stands out on the surface of the rock above the interstitial talc. Along its contacts this rock appears, in places, to grade into, and at others to be rather sharply defined against, the serpentine. The reason of its occurrence is uncertain, but the relations suggest that alteration followed a line of fracturing in the serpentine, permitting easier reaction of ascending thermal solutions carrying carbon dioxide. The reaction, in its simplest form, might be expressed thus: $2(3MgO, 2SiO_2, 2H_2O)$ (serpentine) $+3CO_2=3MgO, 4SiO_2, H_2O$ (talc) $+3(MgO, CO_2)$ (carbonate of magnesia) $+3H_2O$ in which the magnesia content of the carbonate is partly replaced by iron oxide derived from the altered serpentine. This type of alteration, like the others, is accompanied by some mineralization including a variety of sulphides such as pyrite, chalcopyrite, sphaler-

[1]There is a possibility that this peculiar rock may have formed from greenstones or from both greenstone and serpentine rather than serpentine alone, though the latter type of metamorphism appeared from a brief study of the field relations to be the more obvious one.

ite, and traces of gold. In places the sulphides have been concentrated to an extent to excite interest from the point of view of their possible commercial value. Exploration has, however, shown these occurrences to be small and of no regular shape or continuity and though low values in gold have been found these were not sufficiently encouraging to warrant more extensive development.

Mineralization

Mineralization associated with the main body of serpentine may be regarded as representing two types: one constituting an integral part of the original rock from which the serpentine developed; and the other introduced or formed during or subsequent to serpentinization.

Minerals of the first type include: magnetite, chromite, nickeliferous silicates, and platinum and may be referred to as original minerals. Those of the second type comprise asbestos, talc, carbonates, quartz, sulphides, and native gold and may be considered as subsequent minerals. Some of the subsequent minerals are derived in part from pre-existing original minerals. Others appear entirely foreign to the rocks in which they occur.

Original Minerals. None of these has yet been discovered in concentrations in the serpentine sufficient to constitute pay-ore. Both magnetite and chromite are common accessory minerals disseminated through the serpentine in black grains or crystals difficult to distinguish from each other except by chemical tests. Magnetite is, of course, magnetic, whereas chromite is not, but the two minerals appear to be commonly intergrown so that this distinction cannot always be applied. The magnetite mostly occurs in small crystals or in granular masses rarely exceeding a small fraction of an inch in diameter. Chromite, however, may occur in much larger masses, as is apparent from the reported discovery of blocks of the solid mineral up to several inches in diameter in serpentine outcropping on the east side of Sowaqua creek on the hillsite above the Peer River Placer Company's camp. Two samples of serpentine taken across widths of several hundred feet near the northeast and southwest contacts of the serpentine belt have, on analysis, shown appreciable amounts of both chromium and nickel averaging 0·23 per cent of the former and 0·21 per cent of the latter. The nickel probably occurs as a primary constituent, replacing magnesia of the principal silicates, olivine and enstatite, composing the peridotitic rock subsequently altered to serpentine. Some platinum has been discovered in placer operations on Sowaqua creek and at the mouth of this creek and may have been derived from the serpentine, though analyses of those samples mentioned above have revealed no trace of this metal. It seems possible, however, that the platinum may be more concentrated in certain portions of the serpentine than others and that these portions have yet to be discovered. It is suggested, for instance, that serpentine which carries the heavier segregations of chromite might likewise carry appreciable platinum and though it is quite unlikely that such serpentine would provide pay ore, its recognition, from the point of view of placer accumulations in streams cutting across them, might be of considerable economic importance.

Subsequent Minerals. The subsequent minerals associated with serpentine include those of present economic interest, as well as others that may at some time become important assets to the district. Tiny veinlets of asbestos (chrysotile) are commonly observed in hand specimens of serpentines and thin sections of them. These are not commercial, but the origin and composition of the rock are such that more important occurrences of asbestos might be expected and should be looked for. Talc is extensively developed along shear zones in and bordering the main serpentine body and is also associated with carbonate in more massive bodies within the serpentine. Though mostly impure as a result either of incomplete alteration of the serpentine or the presence of carbonates and, more locally, quartz and sulphides, these talcose rocks may one day be of commercial value. Those interested in the possibilities of this substance should acquaint themselves with its characteristics and uses, [1], [2], and in case a suitable market for the product is available, should endeavour by careful sampling and testing to reach a definite conclusion as to what uses these particular talcose rocks may be best adapted. The principal carbonates are ankeritic types (carrying chiefly magnesia and lime but including more or less iron, and possibly some manganese) and occur most abundantly, either associated with quartz and mariposite, as in the vicinity of Spider peak, or associated with talc as in occurrences previously referred to between Fifteenmile and Sowaqua creeks. It is quite unlikely that these carbonates will ever have any particular value, though the rocks in which they occur may find some use as ornamental stones for interior decorative or other purposes.[3,4] Abundant vein quartz was observed within areas of serpentine only in the vicinity of Spider peak. Other such areas may, however, be discovered. The uses of pure silica (quartz) are varied, but this mineral can rarely be expected to pay to mine alone. As a by-product, however, and where developed in sufficient quantity, some use might be made of this gangue material.[5,6] The sulphides occurring in the serpentine are of present interest only in their relation to contained gold values or their association with occurrences of free gold. None of the sulphides, including pyrrhotite (and pentlandite), pyrite, chalcopyrite, arsenopyrite, sphalerite, millerite, or galena, is of itself sufficiently concentrated in bodies of a size requisite to constitute pay-ore. Gold is the one important mineral associated with the serpentine. It occurs largely in the free state, but in part is combined with sulphides. This gold content of the ore deposits is regarded as essentially magmatic in that it was deposited, either free or combined with other minerals, from juvenile aqueous solutions rising from the depth of some magmatic chamber connected with batholithic intrusives of the period, and in particular the

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[1]Spence, H. S.: Mines Branch, Dept. of Mines, 1922, "Talc and Soapstone in Canada."
[2]Wilson, M. E.: Geol. Surv., Canada, Econ. Geol. Series, No. 2, "Talc Deposits of Canada."
[3]Parks, W. A.: Mines Branch, Dept. of Mines, Canada, "Building and Ornamental Stones of Canada", vols. I-V, 1912-17.
[4]It might also be pointed out that some such uses might be found for the serpentine itself which is largely quite a massive rock of attractive dark green and slightly mottled colour. This rock should take an excellent polish and might be found suitable for a variety of purposes. Convenience to the railway and the short haulage to Vancouver are factors in favour of such considerations.
[5]Eardley-Wilmot, V. L.: Mines Branch, Dept. of Mines, Canada. "Siliceous Abrasives."
[6]Cole, L. Heber: "Silica in Canada, Its Occurrences, Exploration, and Uses"; Mines Branch, Dept. of Mines, Canada.

intrusives of the serpentine belt. Further and more complete discussions of the occurrence and association of this valuable metal are given elsewhere in this report. Polished surfaces of rich arsenopyrite-gold ore from Aurum mine show an intimate association of mispickel, gold, and, in one specimen (Figure 12) pyrrhotite, indicating that these three minerals were deposited at about the same time, though some of the gold appears to have been precipitated after the arsenopyrite had crystallized out.

Correlation and Comparative Studies

Serpentine of much the same origin and, probably also, age as that occurring in the serpentine belt of Coquihalla area, is not an uncommon rock in southwestern British Columbia, though in most places its occurrence has not been regarded of special economic interest.

In Coquihalla area at least one narrow dyke of serpentine has been found on the property of Mammoth Holdings, Limited, and is referred to more fully in the report on this property.

Southeast of Coquihalla area, again, and about 2½ miles southwest of the main serpentine belt, a long and nearly parallel, dyke-like body of serpentine is reported to cross Eighteenmile creek and to come down to the Hope-Skagit road about 20 miles from Hope or between 2 and 3 miles from Skagit river. This body is stated to be over 100 feet wide and to have much the same appearance as the rock from the main serpentine belt. Explorations along this dyke have so far failed to reveal any mineralization of economic importance.

Another occurrence of serpentine is reported on Gordon creek[1] about half a mile west of Fraser river and 2 miles south of Yale. This serpentine " forms a band about 500 feet wide striking north and south. It is a dense black rock showing occasional grains of chromite, and so shattered and broken that good samples are hard to obtain." Some claims have been staked for asbestos on this serpentine, but no references to other mineralization are given.

Much larger bodies of serpentine occur in Bridge River country where their origin is ascribed to alteration of basic igneous rocks which McCann[2] is inclined to regard as principally, at least, of extrusive or volcanic origin and of the composition of basalt, although forming also, in part, from porphyritic equivalents of peridotite, whereas Drysdale[3], though including them tentatively with the Shulaps volcanics, regards them as having formed from peridotites which may intrude the associated volcanic rocks and be of Lower Cretaceous age. These serpentines are commonly reddish weathering rocks carrying small segregations of chromite and veinlets of asbestos. Deposits of magnesite are also associated with their alteration and specimens of the nickel-iron alloy, awaruite, collected from the gravels of Bridge river by Poitevin[4], are thought to have been derived from these serpentines. These occurrences of serpentine in Bridge River district

[1]Camsell, C.: Geol. Surv., Canada, Sum. Rept. 1911, p. 111.
[2]McCann, S.: Geol. Surv., Canada, Mem. 130, p. 27.
[3]Drysdale, C. W.: Geol. Surv., Canada, Sum. Rept. 1915, p. 79.
[4]McCann, W. S., Geol. Surv., Canada, Mem. 130, p. 78.

line up in a general way with the main serpentine belt of Coquihalla area and the outcropping on the Cariboo highway and it is not unlikely that further exploration would discover other bodies of serpentine in areas intermediate between Fraser and Bridge rivers.

In Tulameen district east of Coquihalla area a large body of dunite and peridotite has been partly altered to serpentine and forms the core of a much larger mass of intrusive rocks grading outwards through pyroxenite and gabbro to granodiorite.[1,2] The dunite and peridotite from this area have provided the platinum content of the Tulameen placer deposits. It seems likely that the serpentinized peridotite of Coquihalla and adjacent areas is related to the same magmatic source as the basic intrusives of the Tulameen, though the processes of differentiation and serpentinization vary considerably depending largely on the original composition of the altered rocks.

It is interesting to compare analyses of serpentines, from these and other localities in the world, whose origin is ascribed to processes similar to those that developed the serpentine of Coquihalla area. For comparative purposes the following five analyses are of special interest.

	I	II	III	IV	V
SiO_2	41·58	41·54	41·86	40·08	38·84
TiO_2	....	....	....	....	....
Al_2O_3	2·60	2·48	0·69	2·11	0·10
Fe_2O_3	7·22	....	....	1·13	6·49
FeO	....	1·37	4·15	1·70	3·60
MgO	36·80	40·42	38·63	37·90	36·90
CaO	0·00	....	....	0·20	Trace
K_2O }	....	....	....	0·10	0·13
Na_2O }	....	....	....		
H_2O- }	12·67	14·175	14·16	1·35	0·27
H_2O+ }				13·89	13·03
Cr_2O_3	....	....	0·24	....	0·37
MnO	....	....	0·20	....	0·14
NiO	....	0·04	Trace	....	0·16

Analysis No. I is of a specimen of antigorite serpentine obtained from the type locality, Valle d'Antigorio, in Piedmont, Italy.[3]

Analysis No. II was of "A particularly pure-looking, light green, marmolitic serpentine" from New Idria, California,[4] and analyses III of light-green, massive serpentine from Sulphur Bank, California.[5] Analysis No. IV was of typical serpentine from the Black Lake-Thetford area, Quebec,[6] and No. V of massive serpentine from Coquihalla area, B.C.[7]

The greatest variation in these analyses lies in the proportions of iron, a feature depending partly on the amount of free magnetite in the rock and partly on the amount of ferrous iron combined with the serpentine

[1] Camsell, C.: Geol. Surv., Canada, Mem. 26, pp. 49–82.
[2] Poitevin, E.: Geol. Surv., Canada, Sum. Rept. 1923, pt. A, pp. 84–101.
[3] Bonney, Prof. T. G.: Quart. Jour., vol. LXI, p. 699 (1905).
[4] Becker, Geo. F.: U.S. Geol. Sum., Mon. XIII, 1888, "Geology of the Quicksilver Deposits of the Pacific Slope,' pp. 110–111.
[5] Idem.
[6] Poitevin, Eugene, and Graham. R. P. D.: Geol. Surv., Canada, Mus. Bull. No. 27, p. 6.
[7] Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, p. 35.

mineral, antigorite. In this respect it will be noted that the Coquihalla serpentine carries a particularly high iron content and that this iron is almost entirely in the form of magnetite (Fe_3O_4). The low alumina content in this analysis is also noteworthy as suggesting that the peridotitic rock from which the serpentine formed was probably singularly free of aluminous silicate minerals. The presence of chromium and nickel in the analyses where these metals have been determined also points to the origin of the serpentine from magnesian eruptives.[1] Unfortunately no analyses of the Tulameen or Bridge River serpentines have been made, but an analysis of less altered dunite from the former area[2] shows 3·42 per cent Fe_2O_3; 6·69 per cent FeO; 0·10 per cent NiO; and 0·07 per cent Cr_2O_3, testifying to the high proportion of iron and appreciable amounts of nickel and chromium that would doubtless be found in analyses of the more completely serpentinized rock. As pointed out on an earlier page of this report, the presence of appreciable amounts of both nickel and chromium is a characteristic feature of the serpentine in Coquihalla area.

GREENSTONES

The term "greenstone" is here employed as a matter of convenience to include greenish to greyish green igneous members whose colour has resulted chiefly from alteration of original mafic minerals (such as pyroxene, hornblende, and biotite) to greenish secondary products such as chlorite, epidote, and serpentine.[3] Genetically the greenstones include members of both volcanic and intrusive origin, the former having, in general, the composition of andesite or meta[4]-andesite and the latter that of diorite, meta-diorite and gabbro.

VOLCANIC ROCKS

The volcanic members constitute a variable proportion of the serpentine belt, their relative abundance across any particular section of the belt being in inverse ratio to the amount of serpentine and other intrusive rocks present. These volcanic rocks have been included with the Cache Creek series of Coquihalla area on a basis of correlation from neighbouring districts. They are consequently referred to a late Palæozoic period of extrusion and, therefore, regarded as considerably older than the intrusive rocks with which they are associated.

Lithology

In part these volcanics are dense, fine-grained (aphanitic) rocks which, in places, preserve flowage lines or fragmental structures characteristic of lavas, flow breccias, and pyroclastic types. Even under the microscope the original composition of these rocks, owing to the abundance of secondary products, is rarely determinable, and it is quite likely that rocks of different original composition are included. Of these two fairly distinct representa-

[1]Clarke, F. W.: "Data of Geochemistry"; U.S. Geol. Surv. Bull. 695, p. 609.
[2]Camsell, C.: Geol. Surv., Canada, Mem. 26, p. 53.
[3]This serpentine must not be confused with that of the main serpentine body previously described.
[4]Meta—a prefix used to signify that the mineral and chemical composition of the original rock has been modified by alteration.

tives may be recognized; one a more or less altered and fairly basic type in which are numerous grains of partly uralitized pyroxene (probably augite), a little primary hornblende, an abundance of chloritic material and considerable partly to completely altered plagioclase feldspar; and the other a less femic and largely recrystallized rock composed mostly of small, clear laths of acid plagiocase with interstitial material represented mostly by secondary minerals such as calcite, zoisite, epidote, chlorite, and serpentine. Both types may carry a little accessory magnetite and more or less secondary sulphides of which pyrrhotite and pyrite are the most generally conspicuous. Commonly, and particularly towards the northeast flank of the serpentine belt, outcrops of greenstone possess a distinctly fragmental texture characteristic of either pyroclastic or flow breccia rocks.

Contact Relations

All gradations appear to exist between such fragmental types and other rocks possesing a more distinctly bedded appearance—rocks that are included with the sedimentary members of the serpentine belt. In many cases it is difficult to distinguish volcanic rocks from sediments, particularly underground where colour differences and peculiarities of weathering cannot be applied. Contacts with intrusive dioritic rocks are in some places distinct and leave little room for doubt as to the mutual relations. In many cases, however, it is extremely difficult to determine whether a certain greenstone outcrop is volcanic or intrusive, or whether it may not include members of both types. These difficulties are partly due to similarities in the original composition of both volcanic and intrusive rocks; partly to similar alteration processes as a result of which both rock types are included in the general term "greenstone," partly to difficulties in finding diagnostic contact phenomena; and partly to the finely crystalline character of some of the intrusives which, in consequence, cannot be distinguished from the more massive outcrops of volcanic rocks. In general, then, where other criteria were absent, fine-grained greenstones have been regarded as volcanic rocks and medium to coarser textured rocks as intrusive. Certain petrographic distinctions peculiar to each cannot be applied without microscopic study.

One of the best illustrations of the contact relations between intrusive and extrusive "greenstones" is provided by a wide, rocky bluff exposed west of the Emancipation mine road above the wide flat which lies 200 feet above the railway. Following this bluff westerly, outcrops of greenish grey, massive, fine-grained rocks, showing here and there fragmental textures and in other respects resembling volcanic rocks, are first encountered. Continuing in this direction the outcrops are found to include an increasing proportion of coarser-grained rocks which can be seen to definitely invade the older volcanics. The invasions are numerous and in every direction and indicate increasing saturation of the volcanics by the intruding magma. The intrusives appear to be mostly dioritic types and many are quite coarsely crystalline. Before reaching the first small creek (Hoodoo creek) west of Tangent creek and within a distance of about 200 yards of the Emancipation mine road a core of intrusive rock more uniform in texture and more basic in composition is encountered. This rock appears to take the form of a plug, or possibly a laccolithic mass, from which the surrounding intrusive material has radiated into the enclosing volcanic rocks. Further reference to the composition of these intrusives and to their contact relations with the serpentine body situated still farther to the west and southwest is made in a subsequent section of this report dealing particularly with intrusive rocks. The relations exhibited along this bluff show remarkable irregularity in the contacts of intrusive and volcanic rocks and indicate that the former reached their present position, in part at least, by gradual saturation and replacement of the overlying rocks. Variations in the composition of both intrusive and intruded rocks are partly accounted for by these relations; and the difficulty in many cases of making an effectual separation of the two rock types is well illustrated.

Contact relations of the volcanic rocks with the main serpentine exposures are in some places quite sharp, but in most places are obscured either by deformation or alteration or combinations of these processes. Such contacts are masked by a zone of shearing involving chiefly the serpentine, but affecting the greenstone to some extent. It is along such zones that the serpentine has been subsequently altered to a more or less talcose rock in which rather extensive impregnation by sulphides, chiefly pyrrhotite, has occurred, together with local concentrations of other ore minerals. The greenstones in the same shear zones are also more completely altered than elsewhere, the alteration involving more or less complete chloritization with, in part, subsequent changes to serpentine and talc.

Alteration and Mineralization

Alteration of the volcanic rocks is attributed in part to contact metamorphism; in part to reactions set up by thermal solutions and vapours; in part to circulating meteoric waters; and in part to dynamic metamorphism. The effects may be separate or overlapping, or the agents may work together to produce a combined result. Direct contact with invading intrusives has in extreme cases, as we have seen, resulted in saturation of the volcanic rocks with invading material to the extent that original textures, structures, and composition of the older rock are partly to entirely changed. There is, however, no marked zone of contact metamorphism in the volcanic rocks in the vicinity of intrusives, though evidences of thermal metamorphism are occasionally noted. Small crystals of tourmaline here and there, and, at one point near the head of the South fork of Ladner creek, large pinkish crystals of axinite,[1] point to pneumatolytic reactions in the vicinity of the dioritic intrusives. Processes involving extensive development of saussuritic products (zoisite, albite, epidote) or albitization alone were probably active under high temperatures, succeeding intrusion and facilitated by deformations of this period. Subsequent lower temperature alteration processes such as chloritization, carbonatization, the formation of serpentine, talc, and vein quartz, and the introduction of sulphide and other ore minerals, are thought to be characteristic of lower temperature conditions involving reactions and depositions from ascending juvenile aqueous solutions assisted in part by circulating meteoric waters.

[1]Cairnes, C. E: Geol. Surv., Canada, Mem. 139, p. 40.

Mineralization of the volcanic rocks has been coincident in time with mineralization of older members of the serpentine belt and the adjoining slaty members of Ladner series. Vein quartz is much more abundant in these greenstones than in the serpentine. This feature is partly attributed to differences in rock structures which in the case of the greenstones were, as a result of deformation, more open to circulation of either ascending or meteoric waters than the serpentine bodies and presented more continuous and open fissures or fracture zones for deposition of the quartz. The quartz itself may be partly magmatic, but may also have been derived largely from the greenstones themselves or partly from other formations traversed by ascending thermal solutions. The quartz, too, has replaced the wall-rocks—evidence of this being particularly pronounced in siliceous zones where the widths, in consequence, are variable and the walls ill-defined. The siliceous vein matter carries most of the gold-bearing sulphide and free gold values and is commonly associated in the richer deposits with more or less calcite. In a general way it appears that the mineral content of a quartz vein is inversely proportional to its width, though this does not imply that all narrow quartz veins are rich nor that all large veins are proportionately low in values. The narrow veins, however, appear as a whole to be those in which the siliceous solutions carried more concentrated values, whereas, other factors being at all equal, these solutions appear to be diluted in proportion to the amount of quartz deposited at any particular place.

INTRUSIVE ROCKS

The intrusive rocks (diorite, meta-diorite, and gabbro) are also included with the " greenstones " of the serpentine belt. Their similarities with the volcanic rocks, leading at times to great difficulties in separation of the two types in the field, have already been pointed out. Otherwise they are distinguished from volcanic types by their origin, which is intrusive; by their age, which is considerably younger than the other greenstones; and, commonly, by their texture which is phanerocrystalline, that is, composed of crystals (of both dark and light-coloured minerals) sufficiently large to be recognized with the naked eye.

Petrography

Petrographically these intrusives present some unusual and distinctive features. In many cases they are greatly altered, but in other instances they are comparatively fresh and show quite a variation in mineral composition ranging from diorite or possibly quartz diorite to gabbro The common assemblage of minerals includes varying proportions of pyroxene and amphibole, plagioclase feldspar, more or less abundant chloritic and saussuritic products, and, generally, considerable accessory ilmenite and magnetite. The characteristic pyroxene is diallage which in the more basic types constitutes a large proportion of the rock. In that plug or laccolith west of Emancipation mine road, mentioned in discussing contact relations with volcanic rocks, the diallage has a slightly pinkish cast and is probably a titaniferous variety. This rock otherwise carries an abundance of ilmenite which forms large areas cutting across other minerals and consequently appears to be one of the last minerals to crystallize out. It is partly altered to leucoxene. The chief amphibole is hornblende which, in some rocks, appears to be a primary mineral forming well-defined and, commonly, twinned crystals, but in other specimens is secondary after pyroxene, forming borders around or completely replacing crystals of this mineral. The orginal feldspars are invariably more or less altered, but are generally determinable. Their average composition except in the more gabbroic rocks is about that of albite-oligoclase. The common and generally abundant accessory minerals include ilmenite and magnetite, the former showing more or less alteration to leucoxene. The abundance and large development of ilmenite and the fact that it cuts across or replaces other primary minerals are phenomena characteristic of the microscopic study of these rocks.

Alteration

The alteration of the intrusive members of the greenstones is especially interesting in view of their close association in many cases with the main body or bodies of serpentine. Aside from the common presence, in even the less altered rocks, of more or less abundant saussurite, zoisite, calcite, chlorite, and less commonly, epidote, some of the specimens examined were found to be completely altered to carbonate-talc-chlorite (or serpentine) rocks which, in a few instances, carried a heavy dissemination of sulphide. The analogy between this more complete alteration and that affecting portions of the main serpentine body is quite striking, though the processes involved are essentially different—in that the original rocks were quite unlike in composition and mostly at least of slightly different age. The period of extensive alteration of the dioritic intrusives, however, is thought to correspond with that of the alteration of the main serpentine mass (or masses) and the alterations themselves are attributed to the same or similar meteoric and low temperature thermal solutions. The serpentine developed in the intrusive rocks is, for example, very like that colloidal type described in discussing the lithology of the main serpentine member of the serpentine belt. In most cases it is indistinguishable from some types of chlorite and may easily be confused with that mineral. The abundant carbonate developed is mostly a magnesium-bearing variety and its relation with the talc, in certain of the thin sections examined, indicates that the talc is replacing it. Curious anomalies arise from this replacement in which talcose areas still retain some of the optical properties of the carbonate, so that in places it is difficult to differentiate these two otherwise quite unlike minerals.

Contact Relations

Contact relations of the intrusive rocks have been partly discussed in dealing with other members of the serpentine belt. Contacts with the main serpentine exposures, however, remain to be considered. In part the intrusive greenstone rocks form dyke-like bodies or ribs within outcrop areas of serpentine. These dykes vary from a few feet to 50 feet or more wide and some of them appear to be continuous for distances measurable in miles. These more persistent dykes strike northwesterly or about in line with the serpentine belt. Other dykes again cut across the formational trend and in some cases extend beyond the limits of the belt into adjacent formations of Cache Creek and Ladner series. Contacts with serpentine are abundantly exposed and in most cases are marked by more or less shearing of the component rocks, particularly the serpentine, and the development of a more or less talcose rock in which some ore mineralization has been discovered, as in the case of the Hope-Gold and Columbia Metals properties. In other places, however, the dyke-like character of the intrusives is not so evident and contacts with the serpentine afforded some puzzling relations in the field. In some instances an apparent gradation across a width of a foot or more existed between serpentine and diorite and serpentine and gabbro, so that it appeared probable that both rocks originally formed parts of the one intrusive which had been serpentinized only so far as its mineral composition or other conditions were favourable. When examined microscopically, however, this possibility finds less to support it in that the altered contact portions of the diorite or gabbro were only partly serpentinized or may, in reality, carry very little serpentine, that this serpentine is of the colloidal type and is associated with other alteration products, such as chlorite, talc, and carbonate, which would develop under conditions quite different from those responsible for the magmatic serpentinization of the main serpentine body; and that the presence of minerals such as ilmenite, leucoxene, partly altered or recrystallized feldspars, and other saussuritic and chloritic products, suggests that the altered portions of the diorite or gabbro were originally not different from the less altered intrusive farther from the contact.[1]

Such serpentinization, therefore, as the diorite or gabbro intrusives have undergone along or in the vicinity of their contacts with the main serpentine body, or bodies, is regarded as having taken place long subsequent to the initial (or main) stage of serpentinization of that body and as having been effected under comparatively low temperature conditions.

Further evidence in support of the view that the main serpentine body is distinctly separate from the diorite and gabbro intrusives is provided by the results of certain analyses made by the Mines Branch, Ottawa, and which are as follows:

—	A	B	C	D	E
Gold	trace	trace	trace	....	none
Platinum	none	none	none	none	none
Nickel	none	0·20%	0·22%	0·16%	0·21%
Chromium	none	0·22%	0·26%	0·37%	0·26%

A. Composite sample of dioritic intrusives from eight widely separate localities in the serpentine belt.

B. Sample of serpentine across a width of 500 feet at the northeastern contact of the serpentine belt near Emancipation mine.

C. Sample of serpentine across a width of 200 feet near the southwestern contact of the serpentine belt on the Fifteenmile group of claims, property of Hope Gold Mines, Limited.

D. From complete analysis of a specimen of typical massive serpentine obtained in the basin of Fifteenmile creek (C. E. Cairnes, Geol. Surv., Canada, Mem. 139, p. 35).

E. Sample across belt of serpentine 100 feet wide exposed along Cariboo highway 1½ miles south of Anderson river.

[1]An interesting example of serpentinization of a comparatively acid intrusive under low temperature conditions is afforded by outcrops of a coarse-grained, gneissic batholithic intrusive exposed in Canadian National Railway cuttings a mile north of Stout (Figure 9). Under the microscope this rock is composed of clear feldspar, both orthoclase and albite-oligoclase, with interstitial colloidal isotropic serpentine replacing all the mafic constituents of the rock and attacking the salic ores.

These analyses, though incomplete, are of interest in that they indicate the appreciable and fairly consistent amount of both nickel and chromium in the serpentine and their absence in the less basic associated intrusives. On the other hand analysis " D " shows no titanium in Coquihalla serpentine, whereas microscopic studies of the dioritic intrusives from this locality have revealed an abundance of ilmenite as well as other titanium-bearing minerals. The presence of traces of gold in both dioritic and serpentine rocks is of interest, but has not the significance of the other elements mentioned in that it is mostly of more local occurrence and may or may not be present in selected specimens of either rock type (*See* other analyses in this report).

Analysis " E " is of special interest in that it shows much the same amounts of both nickel and chromium, as do the analyses of serpentine from Coquihalla area, and in itself lends some support to the view previously expressed that the serpentine from this area is related to if not actually continuous with, that at Fraser river (Figure 9).

Mineralization

The diorite and gabbro intrusives of the serpentine belt may carry visible disseminated sulphides including chiefly pyrite and, locally, chalcopyrite. Samples of such mineralized rock generally show, on assay, traces of gold (analysis A page 191) probably associated with the sulphides.

SEDIMENTS

The sedimentary members of the serpentine belt form an irregular assemblage of beds along its northeasterly flank. In places they are missing, but in other sections they have an apparent thickness of several hundred feet. They are, for example, well exposed in the vicinity of Aurum mine and in cliffs bordering the north edge of the flat above Verona. At Emancipation mine workings they narrow to a few yards where the main serpentine body cuts into them. These sediments mark a transition from a period of volcanism to one of sedimentation in which the sedimentary detritus is made up mostly of reworked volcanic materials.

Age and Contact Relations

The sediments are, therefore, regarded as of approximately the same age as the volcanic members of the " greenstones " and have been included as uppermost members of the Cache Creek series in Coquihalla area.

Contacts with the volcanic members are transitional, grading from flows and flow breccias through pyroclastic types to tuffs, breccias, and tuffaceous sediments. Contacts with all other members of the serpentine belt are intrusive. The only other contact is with the basal members of Ladner series which overlies Cache Creek series to the northeast. This contact is, perforce, to be regarded as unconformable in the light, chiefly, of palæontological evidence which places the Ladner series in the Jurassic and Cache Creek series, at least in part, in the Upper Palæozoic. Structurally and stratigraphically, however, the break is less obvious as both series have undergone about equal deformation and parallel each other in their major structures.

Lithology

Lithologically, these sediments are greenish to greyish-green or grey rocks, mostly massive, and moderately coarse grained. Angular fragments of chert and volcanic rocks are abundant in some beds. Others are distinctly pyroclastic in appearance. They are distinguished in these respects from the Ladner series and particularly from the Ladner Slate belt[1] whose basal members are dominantly dark grey or black, fine-grained, rusty-weathering slaty rocks.

Mineralization

The sediments of the serpentine belt are mineralized in much the same fashion as adjoining members of Ladner Slate belt. Quartz veins carrying sulphides and, occasionally, free gold, are found in both series and developments until recently have been mostly confined to such discoveries. On the whole the vein quartz deposits are less regular, though on the average probably larger than those living between slate walls. This seems due partly to less regularity in the rock structures of the sedimentary members of the serpentine belt and partly to the fact that these sediments were more readily replaced than the slates. The vein quartz deposited in both the sedimentary and volcanic members of the serpentine belt tends to form as siliceous zones along lines of fracturing or dislocation in these rocks. The size of the deposit is largely determined by the amount of replacement the ascending siliceous solutions have been able to effect and the walls, as a result, are apt to be poorly defined, whereas in the adjoining slate belt the quartz has formed more regular, sill-like masses following fractures or fissures which have developed chiefly along directions of cleavage or bedding. Veins that cut across these structures are, on the whole, much smaller and more irregular than those that conform with them. On the other hand the smaller quartz veins in both slate and serpentine belts are apt to be more heavily mineralized and provide higher grade ore.

MINOR ACID INTRUSIVES[2]

Quartz-porphyry and Syenite Porphyry

Under this caption are included a number of dykes which intersect members of the serpentine belt as well as formations on either side. Most of these dykes were observed in that section of the serpentine belt that extends to the southeast of Coquihalla river. They occur, for example, on the property of Dalhousie Mining Company; in the vicinity of Serpentine lake; on different claims situated between Serpentine lake and Sowaqua creek; and on either side of this creek in the vicinity of the Peer River Placer Company's camp. Dykes of similar character were also seen on the Keystone group of claims in the serpentine belt and at Pipestem mine at the head of the Middle fork of Ladner creek.

These minor intrusives average several feet wide; strike in various directions though favouring a general northwest-southeast course; and

[1]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, pp. 45-53.
[2]Cairnes, C. E.: Geol. Surv., Canada, Mem. 139, pp. 109-114.

stand at high to vertical angles. They are light coloured, medium to fine-grained rocks in which orthoclase and acid plagioclase and, in most cases, quartz are the essential constituents. They appear to represent a late phase of the period of batholithic intrusion represented, at an earlier date, by the more basic eruptives of the serpentine belt.

The dykes are commonly sparingly mineralized by disseminated pyrite, and, occasionally, arsenopyrite or other sulphides and samples of more conspicuously mineralized portions will assay from a few cents to a dollar or more per ton in gold values. In most cases this mineralization appears to be primary. In places, however, these dykes have been cut by quartz veins and considerably altered by vein-forming solutions. During such processes quite a little of the green mica, mariposite (previously noted in connexion with alterations of serpentine), was formed and more sulphides added. In no instance, however, did there appear to be sufficient mineralization to excite commercial interest.

White Rock

Another type of rock which may be best included with the minor acid intrusives, though its origin and original composition are both somewhat obscure, is a highly altered rock which, as encountered in the field, suggested some direct relation to the serpentine. This is a light or cream-coloured, massive, and mostly fine-grained rock referred to locally as " white rock." It occurs in lenses or kidney-shaped masses, or in irregular, vein-like forms within bodies of serpentine. Contacts with the latter are mostly sharply defined and conspicuous by reason of contrast in colours. Interest in the " white rock " is centred chiefly in the fact that here and there it has been found to contain visible free gold. Other minerals include small grains or lumps of the copper sulphide, chalcocite, which is commonly associated with the gold. Copper stains surround the sulphide and draw attention to its presence. A curious feature of the mineralization is that it is most conspicuous, not in the larger bodies of white rock but in comparatively small masses or narrow stringers, an inch or so wide, composed chiefly of coarsely crystallized white diopside carrying here and there small groups or individual grains or crystals of a yellowish garnet. These small masses or stringers are commonly quite distinct from the larger bodies of finer grained white rock and appear to owe their origin to somewhat different and slightly later processes.

The more massive type has a clay-like odour and adheres to the tongue. Under the microscope it is seen to be composed chiefly of a cloudy mass of light-coloured secondary products through which may be distinguished numerous grains of a partly decomposed mineral resembling pyroxene, but difficult to identify. The groundmass appears to be largely kaolinized feldspar but may include other materials. The origin of this rock may be attributed to one of three processes. It may represent an acid differentiate from the peridotitic intrusive (from which the serpentine body or bodies formed) subsequent to the intrusion of this basic magma; or it may have been intruded into the peridotite or serpentine; or finally, it may represent highly altered inclusions of volcanic rock (andesite) caught up by the peridotite. The presence, for example, of abundant small grains or crystals of pyroxene suggests a possible relation to andesites of Cache Creek series in which this mineral is commonly abundant. Each explanation, however, finds support from observations to date, though probably more detailed study would definitely eliminate one or more of them. The serpentine surrounding bodies of this white rock is commonly sheared and the meagre mineralization of the white rock is coincident, in the instances noted, with mineralization in the serpentine. The ore minerals were, therefore, probably introduced subsequent to the formation of the white rock or at about the same time as the coarsely crystallized copper-gold-bearing stringers were formed.[1] A large sample of typical " white rock " was obtained from a lens 5 feet thick occurring in serpentine close to the left bank of Sowaqua creek a short distance above the camp of the Peer River Placer Company. This sample was assayed by the Mines Branch, Ottawa, and found to contain no trace of any of the following metals—gold, platinum, nickel, chromium, and copper.

COMPARISON WITH THE MOTHER LODE DISTRICT OF CALIFORNIA.[2, 3]

The geology and ore deposition of the serpentine belt and adjacent formations of Coquihalla area present many striking comparisons with the Mother Lode district of California as the following extracts, taken from a late report by Knopf,[3] will show. These extracts are given verbatim, except for the words within brackets which call attention to the application of Knopf's conclusions as applied chiefly to Coquihalla area.

"The rocks traversed by the Mother Lode system consist mainly of steeply dipping slates, schists, and greenstones, and include some intrusive masses of serpentine. They form a series of belts that trend northwest, parallel to the course of the range.

The oldest rocks belong to the Calaveras formation of Carboniferous age and of sedimentary origin. They consist of black phyllites, not far removed from black slates in appearance, with subordinate quartzite and limestone (Cache Creek sediments except that in Coquihalla area cherts or "cherty quartzites" are the dominant rocks). Associated with the Calaveras formation are green schists (Cache Creek greenstones), which are of particular interest, for many of the noted mines of the Mother Lode system occur in them. They generally contain chlorite or amphibole, or both, to which they owe their prevailing grey-green colour.

The youngest stratified rocks of the belt make up the Mariposa slate (of Jurassic age and comparable with Ladner series of Coquihalla area). Black slate with less greywacke and minor conglomerate....are the normal members of the formation. Greenstone, chiefly in the form of tuff and breccia, is associated with the Mariposa formation; it occurs in thick belts with little or no intercalated slate, and it is also intimately interbedded with Mariposa slate and greywacke....(comparable with the volcanic greenstones and sediments of the serpentine belt of Coquihalla area, though here these rocks are regarded as part of the Cache Creek series).

In late Jurassic or early Cretaceous time the region of the Sierra Nevada felt the onset of the Cordilleran revolution (as in Coquihalla area). The rocks were isoclinally

[1]An interesting comparison with, and possible solution to, this problem is afforded by occurrences of similar rocks in the serpentines of the Thetford-Black Lake area, Quebec. In this area Poitevin (Poitevin, Eugene, and Graham, R. P. D.: Geol. Surv., Canada, Mus. Bull. No. 27, pp. 11-12.) regards the "aplites" (corresponding to the massive, fine-grained "white rock" of Coquihalla area) as differentiates from the magma which provided the peridotites (from which the serpentines formed). He also considers the minerals diopside, grossularite (garnet), etc., were held in solution by aqueous vapours and volatile constituents and that these vapours, etc., obtained the materials essential to the formation of the lime-silicate minerals by dissolving out monoclinic pyroxenes, calcite, etc., from the walls of fissures in the peridotitic rocks—these pyroxenes, etc., not being required in the transformation of the peridotites to serpentine.

[2]Ransome, F. L.: U.S. Geol. Surv., Folio 63, "Mother Lode District Folio", 1899.

[3]Knopf, Adolph: U.S. Geol. Surv., p. 157, "The Mother Lode System of California", 1929.

folded and then were invaded by a succession of plutonic rocks, beginning with peridotite, which was soon altered to serpentine, and ending with granodiorite (a succession corresponding to Coquihalla area and vicinity).

The gold deposits are of two principal kinds—quartz veins and bodies of mineralized country rock. Although the quartz veins, especially those that are enclosed in slate (as in Ladner Slate belt), are similar from one end of the belt to the other, the ore-bodies of mineralized country rock show far more individuality and more geologic complexity than was expected (as in Coquihalla area).

The ores are of low or moderate grade averaging $7 a ton. Sulphides make between 1 and 2 per cent of the quartz ore and double or triple that amount in the ore-bodies of mineralized country rock (a feature notably true of the mineralized talcose shear zones in the serpentine belt of Coquihalla area). They consist almost wholly of pyrite with minor arsenopyrite, zinc blende, galena, chalcopyrite, and tetrahedrite. The telluride petzite appears to be restricted to the portion of the Mother Lode in Calaveras and Tuolumne counties. (No telluride has yet been identified in Coquihalla area.) Arsenopyrite is fairly common in Amador county. Galena and petzite indicate good ore, but the others are indifferent indicators. (Arsenopyrite is probably the best indicator in Coquihalla area.)

The (quartz) veins swell and pinch abruptly; in the lenticular expansions the filling is quartz; at the edge of lenses, either along the strike or dip, the massive quartz filling becomes more and more admixed with slate or pinches down to a gouge filled fissure....The ore occurs in shoots generally short but persistent in depth. The shoots as a rule have a steep pitch or "rake" which may be either north or south. The ore-shoots are considerably wider than adjacent portions of the vein, as well as containing more gold to the ton....

The gold is believed to have come from a deep-seated magmatic source, the quartz came largely from the adjacent wall-rock, and the water by which these substances were carried in solution came partly from the magma and largely from the meteoric circulation.... (This interpretation would apply equally well to the gold deposits of Coquihalla area.)

It is unsafe to generalize for the whole Mother Lode belt as to the influence of the nature of the wall-rocks on the tenor of the ore. Valuable ore-bodies have formed in rocks of many kinds. Probably the only valid generalization is the one made by Ransome that paying veins may occur in any rock with the possible exception of serpentine. However, the slate appears to be more favourable than the greenstone, and veins wholly enclosed in greenstone are likely to be of low grade....

....The wall-rocks of the Mother Lode veins have been profoundly altered by the ore-forming processes. Large volumes of rocks have thereby been transformed. Carbonatization (ankeritization) was the chief effect regardless of whether the rocks were slate, greywacke, quartzite, conglomerate, talc, schist, or serpentine....Gold also migrated into the wall-rocks....

Serpentine and the augitic greenstones were the most susceptible to ankeritization. (*See* section of this (Coquihalla) report on "Alterations of Serpentine".) The ankeritized serpentine....makes up belts hundreds of feet thick, generally tinted a delicate green by the presence of the chromiferous potassium mica mariposite." (Compare with occurrence of this mineral at Spider peak.)

CONCLUSIONS

The occurrences of gold ore associated with serpentine in Coquihalla area have contributed a most interesting variety to the numerous types of gold deposits in British Columbia. Nowhere in geological literature descriptive of serpentine rocks, has the writer been able to find reference to mineralization of an analogous character.[1] Judging, however, from

[1] Since writing the above the writer has received an interesting communication from Mr. H. G. Nichols, Resident Engineer of the Central (No. 3) district, British Columbia, who reports that at the Republican mine adjoining the Eagle Shawmut at the southern end of the Mother Lode belt in Tuolumne county, California, rich pockets of gold in flake form and pyramidal crystals were found in shears in the body of serpentine lying on the foot-wall of the main slate belt.

developments to date, these occurrences of gold are mostly of scientific interest rather than commercial importance. Though free gold has been observed at a great number of places both within and along the contacts of the main serpentine body, at only one property, the Aurum, has it yet been proved to be sufficiently concentrated in bodies large enough to afford reasonable encouragement to development work. Elsewhere its appearance has provided some interesting specimens, but its occurrence has been so erratic as to give but little expectation of providing substantial bodies of pay-ore. At the Aurum mine the richest ore is associated with a heavy concentration of arsenopyrite, a sulphide which elsewhere in quartz veins in the serpentine and adjoining slate belts has long been regarded as a most hopeful indication of gold values. In this connexion it may be pointed out that, at Aurum mine, the heavy, talcose shear zone carrying the gold ore comes in close contact on the upper two levels with a wide and persistent siliceous zone composed largely of vein quartz carrying considerable pyrite, some arsenopyrite, and low values in gold. Although the localization of the rich gold ore in the talcose shear on this property may be explained on a basis of structural control based on irregularities of the serpentine contact (*See* account of the Aurum mine) the origin of the gold and arsenopyrite would seem to be that of the nearby mineralized vein quartz, the processes involved in the metamorphism and mineralization of the serpentine being essentially contemporaneous with those providing the adjacent vein quartz. This association, in the writer's opinion, furnishes the most valuable clue to the presence of appreciable gold ore in or alongside the serpentine body, without which the occurrences of free gold in the serpentine are likely to be so small and so sporadic as to be of little commercial interest.

In a more general way the future of the district, insofar as the serpentine belt and adjoining formations are concerned, appears to be still dependent, in great measure, on the deposits of vein quartz which heretofore have received the most attention. Further operations will, in this case, either be considered satisfactory with development of occasional small shoots of rich ore or will endeavour by some careful system of sampling to reach a conclusion as to whether or not the average values of large bodies of vein quartz and mineralized country rock may justify operations of greater magnitude. Such large bodies of low-grade material are known to occur on a series of adjoining properties, but too little is known of the average values to permit an opinion as to whether these might or might not be worked either individually or collectively at a profit. A careful program of sampling would doubtless entail an expenditure of several thousand dollars. By joining forces in such a program, however, the property owners should, in the end, come to a definite conclusion as to whether their holdings warrant the installation of some common plant or plants capable of handling a tonnage sufficient to yield a profit on the investment and at the same time permit a reasonable amount of exploratory work where indications point to the possible occurrence of other deposits.

GEOLOGY AND ORE DEPOSITS OF NICKEL PLATE MOUNTAIN, HEDLEY, BRITISH COLUMBIA

By H. S. Bostock

CONTENTS

Illustrations

INTRODUCTION

Nickel Plate mountain, named after the chief ore deposit in it, the Nickel Plate mine, contains the main productive mineral deposits of Hedley district in southern British Columbia. The livelihood of Hedley has for some time depended upon the Nickel Plate mine and, consequently, when this ore deposit has apparently neared exhaustion the geological study of the known ore deposits and the search for possible new ones on the mountain have become of local importance. Besides the interest from an economic point of view there is also the unusual character of the deposits and rocks which make them of particular attraction to students of geology. In the following report the geology, of the Nickel Plate mountain as a whole, of a restricted area on its summit, and of the Nickel Plate ore deposit, is dealt with. All these features have already been described by C. Camsell in his report on Hedley district in Memoir 2 of the Geological Survey, 1910. Here, however, much additional detail geological information is given of the area covering the summit of Nickel Plate mountain and of the Nickel Plate ore deposit.

FIELD WORK AND ACKNOWLEDGMENTS

During the season of 1926 a brief examination of the underground workings and a topographical and geological surface map of the top of

Nickel Plate mountain were made. In 1928 four weeks were devoted to the underground workings of the Nickel Plate mine. The levels and stopes were mapped on a scale of 30 feet to the inch. The datum elevation used is based on that of Camsell's topographical map of Hedley district. It shows the elevations as exactly 100 feet lower than the map of the British Columbia Land Survey on which the elevations are based on the North American datum.

In 1926, able assistance was rendered by Mr. R. B. Brock throughout the season and in 1928 by Messrs. E. C. Hay and C. N. Taylor. The writer further desires to express his appreciation and gratitude for the many courtesies extended to himself and the members of his party by the officials of the Hedley Gold Mining Company, particularly Mr. Gomer P. Jones, General Superintendent, Mr. B. W. Knowles, Mine Superintendent, who not only assisted in gathering information but provided every convenience to facilitate the work. He is also indebted to the members of the faculty of the Department of Geology of the University of Wisconsin who provided the facilities for laboratory work and assistance in the preparation of the report.

HISTORY

The history of the Hedley mining camp has been one of gradual rise of development and of more gradual fall. Following the discovery of the rich placers of Cariboo district in 1859, prospectors from the California gold fields found their way north, principally by sea and up Fraser river, but also up Columbia and Okanagan rivers and thence to the Cariboo. From the latter route some branched off to the west, going up Similkameen river along which they discovered gold placers. In the early sixties placers were found near the mouth of Twentymile (Hedley) creek, but they were soon worked out and forgotten. The first mineral claims were staked in 1894, but serious prospecting did not begin until 1897. After the staking of a number of claims, including the Sunnyside and Nickel Plate, samples of the surface ore of the Nickel Plate were exhibited in the New Westminster Fair, where they attracted the attention of Mr. M. K. Rogers. He visited Hedley and later bonded the four claims, Nickel Plate, Bulldog, Sunnyside, and Copperfield. Consistent work was started on these claims in January, 1899, and within a year the claims were purchased through him by Marcus Daly. The claims were thoroughly prospected and the road built from Penticton to the Nickel Plate. In October, 1902, the incline and the tramway were built to transport the ore down to the Similkameen. The erection of the mill and the Hedley Creek flume, for power, was also carried out and in May, 1904, the operations began. In the meantime, other claims had been taken up and a great deal of development work was going on in the neighbourhood, but no actual mining was done by anyone except the Daly Reduction Company. In 1909, the Great Northern railway was built connecting Hedley to Princeton, Keremeos, and Oroville. The population was then about 200.[1] During the few years after 1909 Hedley rose to its crest. Active prospecting was carried out on many prospects in the immediate district and a considerable amount

[1]Camsell, C.: Geol. Surv., Canada, Mem. 2, p. 16.

of development was done on many of the properties, including the Kingston group on the west side of Nickel Plate mountain. Hedley was then a flourishing town boasting of as many as seven hotels and having a floating population that rose into the thousands. The Nickel Plate and Sunnyside properties, however, produced all the ore. No other commercial bodies were discovered and prospecting became less encouraging. With the closing of the Sunnyside workings the Nickel Plate mine became the sole source of ore and livelihood for Hedley, and the town has been gradually deserted by those not connected with the operation. Up to 1909 the Nickel Plate and Sunnyside mines had been operated with a record lack of development and exploration, the ore being chiefly drawn out through the glory holes.

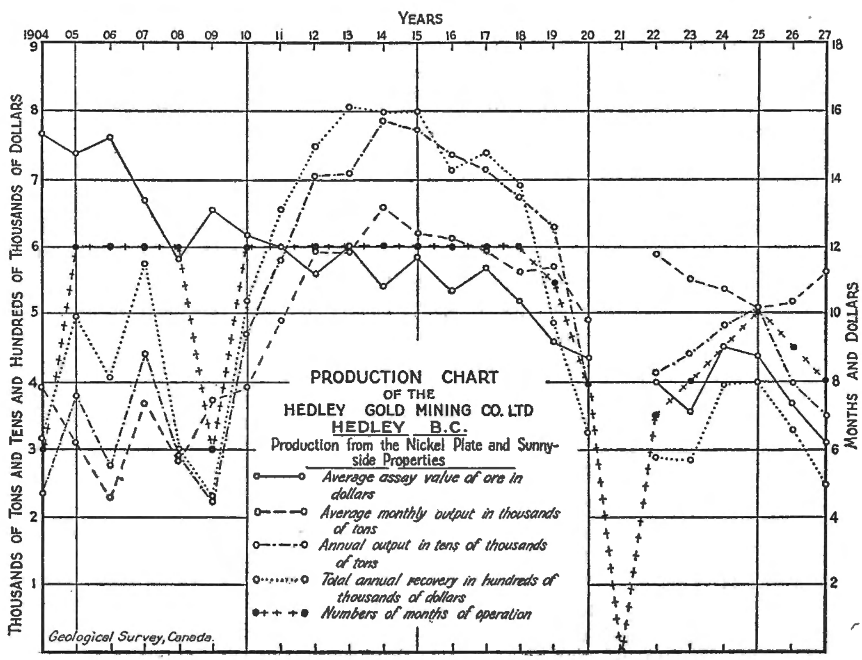

Figure 15.

In 1911, No. 4 adit was opened up and the tramway built to it. In 1913 the Dickson incline was begun and in 1914 it had been sunk 700 feet. The beginning of the same year the dam across Similkameen river was built at Hedley and some 16,000 feet of fluming for the power plant was constructed down river on the southwest bank. Since 1920 mining has stopped during the winter months on account of the difficulties of maintaining sufficient power when the streams are low and contain drift ice. In 1921 the milling and mining operations were closed down for over a year except for development as mining had been carried too far in advance.

In recent years a great deal of diamond drilling has been done on the surface as well as underground in the search for new ore-bodies and the continuations of the known ones. Though the mine has never had a large reserve of ore in sight during the last few years, the reserves have been kept far enough ahead for operations to continue. The total production to 1927 was approximately $11,522,800 in gold. The records of the production of the Nickel Plate and Sunnyside mines from the beginning are given on the accompanying chart (Figure 15), the figures for which were supplied to the writer by the Hedley Gold Mining Company.

SITUATION AND COMMUNICATION

Nickel Plate mountain is in Osoyoos mining division and lies about 27 miles north of the International Boundary and 1½ miles west of the 120th meridian. The mountain forms a section of the northeast wall of the great trench-like valley of Similkameen river at the bottom of which lies the town of Hedley. Hedley is on the Great Northern railway and is situated between Keremeos, 17 miles to the southeast, and Princeton, 25 miles to the northwest. From Hedley the upper parts of the mountain are reached by the incline and tramway of the Hedley Gold Mining Company, or by two trails, one starting just north of the cyanidation mill and the other about ½ mile west of Cahill (Eighteenmile) creek. From the east the locality may be reached by the Nickel Plate road which joins the Keremeos -Penticton highway. The mine is 13 miles from the road junction and 32 miles from Penticton. The mine road is usually open from June to October.

GENERAL FEATURES OF THE DISTRICT

Nickel Plate mountain lies on the southern border of the Interior plateau of British Columbia. Broadly speaking the surrounding country consists of a high, rolling surface which rises from the north and west where it is at elevations of 5,000 to 6,000 feet to the 7,000 and 8,000-foot summits of the Okanagan range on the south and east. This surface is deeply trenched by the valley of Similkameen river in its southeasterly course. At Hedley the floor of this valley lies over 4,500 feet below the 6,250-foot summit of the mountain which forms a high and prominent part of the wall of the valley. The country bordering Similkameen valley has been similarly dissected, but to a less degree, by tributaries such as Hedley and Cahill creeks, in ratio to their size. The valley of Similkameen river has been thoroughly gouged out to a U-shaped, glaciated valley into which the smaller streams drop abruptly from hanging valleys. The more level parts of the country are covered by a sheet of glacial deposits, but on the hillsides along the valley large areas of bedrock are exposed forming cliffs and crags in many places.

Nickel Plate mountain forms a high ridge projecting southwest from the side of Lookout mountain which is the dominant point in the immediate neighbourhood. Together they stand considerably above the adjacent country to the south and west and form a step up towards Okanagan range, the main ridge of which lies 6 miles to the east. The sides of Nickel Plate mountain are steep and very little level ground is to be found upon it. The northeast and southeast sides are the gentlest and run down with an average slope of 16 degrees to the valley of Cahill creek. The west and northwest sides are the most precipitous and drop abruptly into the deep valley of Hedley creek and its tributary box canyons, of which Windfall canyon on the northwest of the mountain, together with a tributary valley on Cahill creek, cuts the connexion with Lookout mountain down to the narrow neck of Windfall ridge. The west side drops from the summit for over 4,000 feet on an average slope of 32 degrees. The south and southwest sides form roughly three steps of increasing depth and steepness down into the valley of Similkameen river. At the foot of the top step the ridge is narrowed by Horsefly gulch cutting into the west side and forming the southern limits of the part of the mountain containing the productive mineral deposits.

GENERAL GEOLOGY

GENERAL STATEMENT

Hedley district lies in an area of westward dipping Triassic sedimentary rocks which have been intruded and almost surrounded by large bodies of igneous rocks of later Mesozoic and early Tertiary ages. Roughly 6 miles to the east and separated from Hedley by large batholiths of these intrusives lies a section of other sedimentary strata, dipping steeply southeasterly and apparently of slightly greater age. Farther southeast lies an area of highly metamorphosed strata containing still older rocks and to the east of this again, on the west of Vaseaux lake, the nearest outcrops of the gneissic rocks of the Shuswap terrain occur. The remnants of a once continuous blanket of sedimentary and volcanic strata of approximately Eocene age cover most of the bordering Interior plateau to the east, north, and west and are sparsely patched over the higher ground in the vicinity of Hedley upon these folded and truncated strata and igneous bodies. An area of these rocks lies 3 miles northwest of Hedley. Thus Nickel Plate mountain stands in an area of the older rocks exposed by the erosion of a part of this blanket. It forms a part of the west limb of a large anticlinal fold whose axis strikes roughly north-south and the east limb of which lies some miles to the east of the mountain, the continuity of the strata of the fold being broken by large bodies of igneous rocks located along its axis and about the west side particularly.

As a whole Nickel Plate mountain resembles a great layer cake. It is composed of westward tilted strata intruded by innumerable sills, dykes, and larger igneous bodies, and stands upon a solid base of plutonic rock.

These features give the steep southern face the banded appearance that led G. M. Dawson to call it Striped mountain. The oldest of these rocks is the group of sediments of Triassic age, which form the greatest volume of the mountain. This group consists of a section of consolidated sediments including besides true sediments a large proportion of contemporaneous volcanic materials generally of explosive origin. The remaining igneous rocks are all younger and intrusive into this group. These intrusives make up a large proportion of the volume of the mountain covering nearly one-quarter of the area of the map. They include bodies of many varieties which may be classed as batholiths, stocks, apophyses, and dykes and sills.

The main divisions of these rocks are given in the table following. The information on the general features of these broader divisions is to great extent taken from the report by Mr. Camsell and his nomenclature is adhered to. Some additions have been put in and also some modifications made with regard to the age of the sedimentary section in the light of the recent fossil determinations.

Table of Formations

Quaternary.........	*Stream and glacial deposits*
Post-Triassic.......	*Granite.* The contact of a batholith of granite striking east and west lies 1½ miles north of the Nickel Plate mine
	Granodiorite. Composing the batholith forming the base of Nickel Plate mountain *Diorite-gabbro Complex.* Comprising stocks with innumerable sill and dyke apophyses
Triassic...........	*Unnamed section* of sedimentary and volcanic strata containing Triassic fossils. These strata apparently form a conformable upward extension of the formations of the Hedley section given below, but are cut off by granitic intrusion at Stirling creek 4 miles west of Hedley
	Aberdeen formation. Consisting of interbanded cherty quartzites, limestones, siliceous argillites, and volcanic materials all in thin beds. Thickness, 3,000 + feet
	Red Mountain formation. Consisting essentially of beds of volcanic materials—fine tuffs to coarse breccias regularly bedded. Essentially local and quickly pinching out between true sediments. Thickness, 1,200 feet max. (The lowest breccias of this formation form the youngest and topmost strata of the sedimentary section of the mountain)
	Nickel Plate formation. Consisting of the massive Kingston limestone on top, with thin-bedded, interbanded limestones, and quartzites in the middle and the massive Sunnyside limestone at the base. Thickness, 1,300 feet
	Redtops formation. Consisting of interbanded limestones, cherty quartzites, siliceous argillites, tuffs, and some breccia resting on a massive limestone, the base of which is cut off by granitic intrusion

AGE AND CORRELATION OF SEDIMENTARY STRATA

The sedimentary section, of which the strata of Nickel Plate mountain are a part, was correlated by G. M. Dawson on lithological grounds with the lower Cache Creek group of Kamloops map-area in which Carboniferous fossils are to be found. Later, C. Camsell in his report in 1910 adhered to this correlation, basing his conclusion on the lack of palæontological evidence and the similarity of these rocks in lithology and sequence to those of the original Cache Creek group. In 1919 some fossils were found by S. J. Schofield[1] in the Nickel Plate formation, which were determined by E. M. Kindle and Frank Springer as Mesozoic, between the limits of the Jurassic and Triassic. This places the Nickel Plate formation in the general horizon of the Nicola series. During the recent field work fossils were discovered at five localities in the Nickel Plate formation, as well as in one horizon several thousand feet higher in the section. The collections made from the Nickel Plate formation in 1925 and examined by F. H. McLearn gave indefinite results. They contained fragments of crinoid stems and pelecypods of indeterminable age and "Arcestes"? of Triassic? age. The determinations of the collections made in 1928, however, are more definite and ratify the Triassic age of these strata.

The following report was submitted by F. H. McLearn on the collections made in 1928.

Nickel Plate Formation: Kingston limestone horizon on the base of the Red Mountain formation. Locality: north side of Windfall canyon; elevation 5,500 feet.

> *"Halobia"* sp.
> *"Nautilus"* sp. Age Triassic

Nickel Plate Formation: top of Sunnyside limestone 100 yards southeast of the tipple; elevation 5,400 feet.

> *"Halobia"?* sp. Age Triassic
> Fossils too fragmentary for diagnosis
> Same 100 feet lower
> *"Halobia"* sp. Age Triassic

Unnamed Formation: horizon probably 5,000 to 6,000 feet higher than the Nickel Plate formation. Locality: 2½ miles west of Hedley, on the south side of Similkameen river; elevation 3,850 feet, on the west side of Henry creek.

> *"Disiotropites"?* sp.
> *"Halobia"*
> *"Isocrinus"* sp. Age Triassic
> Same general locality, piece of float.
> *"Avicula"* sp.
> *"Myophoria"?* sp. Age probably Triassic

The fossils from the unnamed formation were found in blocks of limestone in a coarse conglomerate similar to that containing the fossils in Windfall canyon which will be described later. This conglomerate is apparently local and not over 50 feet thick. The strata above and below are similar and show no sign of an unconformity or any change. The

[1]Schofield, S. J.: Geol. Surv., Canada, Sum. Rept. 1919, pt. B, p. 38.

whole section of strata from the granodiorite at Stirling creek to that at the base of Redtop formation at Hedley, though in places much folded and fractured, is taken to be conformable and to represent a continuous period of deposition in the Triassic.

INTRUSIVE IGNEOUS ROCKS

The main features of the igneous rocks of the mountain as a whole are briefly given below, but they are more fully described by C. Camsell in his report on Hedley district.

The igneous intrusive rocks of Hedley district all have a bearing on the geology of Nickel Plate mountain. They include batholiths, stocks, apophyses, and sheets and all are intrusive into the Triassic sediments after deposition had ceased. Their main divisions have been named above. The rocks of the diorite-gabbro complex are the oldest intrusives and form four stock-like masses as well as several smaller irregular bodies and a great number of sheet-like apophyses. Three of the stocks lie outside Nickel Plate mountain to the northwest and west.[1] These are of a relatively uniform quartz diorite and are due to a single period of intrusion. The fourth stock occurs on the southwest side of the mountain and is of a composite nature being made up of a separate intrusion of the two main types of the complex, quartz diorite and gabbro. An additional smaller body of gabbro also occurs in the mountain forming Climax bluff and is of particular interest as being the nearest large body of this complex in the vicinity of the ore deposits. The variations of the complex include quartz diorite, diorite to gabbro, as well as diorite porphyries and gabbro porphyries with all gradations between the respective members of the series. The most common type of this complex as a whole is a diorite or quartz diorite.

"Its constituents are plagioclase feldspar and green hornblende, with a smaller proportion of orthoclase and quartz. . . . The gabbro is of uniform texture and composition, and is white or very pale green in colour. It is composed of plagioclase feldspar and very pale greenish pyroxene, which proves to be diallage".[2]

Besides the transitional relations, the gabbro is found intrusive into the diorite, but the difference in age is very slight. The diorite and gabbro are closely consanguinous.

The granodiorite intrusion occurs as a large batholith which extends several miles at least to the southwest of Hedley. It forms the base of the mountain on the south and southeast where its gently sloping contact truncates the sediments and the sills of the diorite-gabbro intrusion which dip more steeply west. A few isolated outcrops occur on the lower slope of the east side of the mountain and a few dykes extend from it, the largest of which cuts across the mountain in a northwest direction at the Central station.

"It is a rather basic granodiorite and is more nearly related to diorite than to granite. It is a uniform rock of coarse granitic texture and even grain and is made

[1]Camsell, C.: Geol. Surv., Canada, Mem. 2, p. 73 (1910).
[2]Ibid., p. 48.

up of orthoclase and plagioclase feldspar, the latter in excess, and quartz, hornblende, and biotite.

The dyke rocks of Hedley district are of various kinds and of different ages, some being cut by the granodiorite batholith, and others intrusive into it."[1]

But none has been found older than the diorite gabbro complex.

Approximately 1½ miles north of the Nickel Plate mine beyond Lookout mountain, the sedimentary strata are cut off by the edge of a large body of granite which extends for several miles to the northwest and west. It has been found to intrude the granodiorite and forms the youngest large intrusive in the immediate region. However, no apophyses of this body are found nearer to Nickel Plate mountain and it is doubtful whether it can have had any bearing on the presence of the ore deposits. These intrusive rocks are then younger than the Triassic sedimentary rocks. In the neighbouring country to the east similar intrusives are unconformably overlain by, and pieces of them are included as boulders in, the basal conglomerate of the Eocene strata. Thus the age of these rocks lies between the Triassic and the Eocene. The intrusion of the diorite-gabbro complex has been referred to the period between "the close of the Jurassic and the end of the Laramie" and the granodiorite intrusion to post-Laramie.[2] The granodiorite, however, has been found by the writer to be intruded by a granite which is older than Eocene sediments; the granodiorite and granite belonging to the same general period of intrusion.

GEOLOGY OF THE SUMMIT OF NICKEL PLATE MOUNTAIN

INTRODUCTION

The commercial ore deposits, as already mentioned, have been found in a restricted portion of the top of Nickel Plate mountain. The area, in which their outcrops lie, is shown in the accompanying map (No. 2248) and the geological features of this locality are described in the following detailed account. As this area is included in Camsell's 1,000-foot scale map of Hedley district and since his report in Memoir 2 published in 1910 covered the whole district very completely, much of the following account is based on his work, as is also much of the information given here concerning the occurrence of the rocks outside the limits of the area examined by the writer.

The map-area covers the top of the mountain, the upper slopes of the south and east sides, and a portion of Windfall ridge which extends to the north. It does not, however, cover all the ground underlain by the underground workings of the Nickel Plate mine. Its greatest extent stretches north and south along the east slopes and as the strike of the strata is approximately north-south and the dip 23 degrees west the map shows the horizontal projection of an inclined natural section of the structure on this side. A typical vertical section across the strike through the central portion of the map-area shows approximately 1,000 feet of sedimentary material and 350 feet of intrusive sheets of the diorite-gabbro types in the form of sills. To this must be added 350 feet of strata lying above those of this section in the northern part of the map-area to make up the total thickness of strata in the area.

[1]Ibid., p. 49.
[2]Ibid., pp. 94 and 104.

The sedimentary rocks of the map-area include the upper part of the Nickel Plate formation and the lower part of the Red Mountain formation. Besides the diorite-gabbro intrusives there are a number of other dyke rocks of later date. No representatives of the granodiorite have been found on the surface here, though some outcrops of this rock occur about 1,000 feet to the east of the map-area and the granodiorite is reported to be met with in the deepest drill holes to the northwest.

LOCAL STRATIGRAPHICAL SECTION

The portions of the Nickel Plate and Red Mountain formation included in the map-area have been divided into seven divisions for the purpose of mapping those horizons in which the ore deposits occur. The boundaries between these divisions are not sharp and the divisions have been traced by their broader differences. Over most of the map-area metamorphism has been so intense that all but the broader physical features of their original character have been masked. Their original composition can be judged only from the silicates and other metamorphic minerals which compose them now and which are functions of the phenomena of metamorphism as well. The characteristic megascopic features as they occur are described below under the headings of the divisions. The microscopic features are given together in a subsequent paragraph.

Generalized Tabular Section

The divisions are summarily given in the following table.

Red Mountain formation.....	*Red Mountain formation, 300 feet* within the area. Coarse, tuffaceous breccia beds, limestone breccias, subordinate beds of fine conglomerate, and fine tuffs
	Summit beds, 300 feet. Thinly bedded, fine-grained quartzites with a large volume of intercalated wedges of breccia containing blocks of these rocks and limestones
	Upper siliceous beds, 180 feet. Composed almost entirely of thinly banded, fine quartzite beds of light and dark bands (but of more uniformly light colour where altered) and a small proportion of fine and coarse fragmental strata
Nickel Plate formation.......	*Nickel Plate productive beds, 200 feet.* Thinly banded beds of fine-grained quartzite, impure limestones, and limestones. Now altered to lime silicates, etc. In contrast with those adjacent to it this division is essentially calcareous and contains abundant coarsely crystalline metamorphic silicates.
	Lower siliceous beds, 170 feet. Dominantly thinly banded, fine quartzite beds with a smaller proportion of impure limestone layers than the adjacent divisions, but more calcareous than the upper siliceous beds
	Sunnyside productive beds, 200 feet. Interbedded, impure limestone, pure limestones, and fine quartzite beds, the first being predominant
	Sunnyside limestone, 100 feet within the area. Blue-grey, and white crystalline limestones

DETAILED DESCRIPTION OF DIVISIONS

Sunnyside Limestone. The beds of the Sunnyside limestone in the map-area form the gentler slopes and are consequently hidden under a mantle of glacial debris, so that only a few outcrops occur. These are composed of a compact, light blue-grey, rather fine-grained limestone and a grey or white crystalline and crumbly limestone in beds from 6 inches to several feet in thickness. The total thickness of the limestone is 300 feet or more, but only the upper beds occur within the area. Two collections of fossils were made from these beds south and east of the tipple.

Sunnyside Productive Beds. Toward their top, the beds of the Sunnyside limestone become thinner and interbedded with impure limestones and thin quartzite beds, as well as in many cases carrying in them sand grains and pebbles of black chert. They form the less homogeneous, impure limestone division, the Sunnyside productive beds, in which the Sunnyside ore deposits occur. East of the tipple these beds are relatively unaltered and are mainly of dark grey, impure limestones with fewer beds of lighter limestone and numerous narrow beds of a black, very fine-grained quartzite of cherty appearance. Along the tramway on the Bulldog claim they are intruded by sills of the gabbro porphyry type and have suffered metamorphism. Here they consist of light buff and grey crystalline limestones in which, in some cases, fossil forms are still preserved. The limestone beds are 2 to 30 inches thick and interbedded with light grey quartzite beds which are usually a few inches thick, but several attain thicknesses as great as 4 feet. The quartzites are extremely fine grained and cherty in appearance. They show thin banding in shades of colour as the consequence of changes of composition and texture. The variations of limestone and quartzite are still preserved in the more intensely metamorphosed zones about the ore deposits. Here the beds consist of white crystalline limestone, of dark greenish metamorphic silicates, and thin, dark or light grey seams of quartzite still of cherty texture. The fossils discovered by S. J. Schofield[1] came from these beds and one collection was also obtained from them by the writer. The thickness of these beds is taken as approximately 200 feet from the base of the beds exposed in the glory hole of Sunnyside No. 4 to the top of those of Sunnyside No. 2. The scarcity of outcrops of the lower part of this division and of the Sunnyside limestone below makes the lower limit arbitrary.

Lower Siliceous Beds. Above the Sunnyside productive beds for approximately 170 feet in the section, the thinly banded, fine-grained quartzite beds are predominant, though some impure limestone beds occur among them. They are best exposed just north of the tipple. Here they consist of beds of 6 inches to 3 feet or more in thickness. The quartzite is thinly banded in shades of light brown and greenish grey and is interbedded with more calcareous layers and a few beds carrying pebbles. They are intruded by an almost equal thickness of diorite porphyry sills and have suffered considerable metamorphism as a result, though it is in this locality that they appear least altered. Tracing these beds northward they

[1]Schofield, S. J.: Geol. Surv., Canada, Sum. Rept. 1919, pt. B, p. 38.

may be distinguished from the divisions above and below them by their fine grain and siliceous characteristics and by the presence of only a minority of beds of coarse, metamorphic silicates representing the more calcareous beds. This division is more distinct in the southern part of the area than in the neighbourhood of the Nickel Plate mine.

Nickel Plate Productive Beds. The lower siliceous beds are followed by the strata in which the Nickel Plate ore deposits occur. These beds north of the Nickel Plate fault are relatively unaltered, but only a few scattered outcrops occur. These are of banded beds of light grey to black, very fine-grained quartzites. The bands are from $\frac{1}{40}$ inch to 2 inches or more thick. The lighter bands in places contain a small amount of carbonate. A few narrow bands of pebble coarseness and a few beds of grey, impure limestone also outcrop in this locality. The limestone beds are from a few inches to a foot or more thick. They are softer than the banded quartzites and as a consequence form fewer exposures in proportion to the quartzites. South of the Nickel Plate fault the beds of this division are intensely metamorphosed. They are composed of garnet, epidote, and other metamorphic silicates, as well as crystalline carbonate, quartz, and iron sulphides. These minerals for the most part preserve the banding of the original rocks by variations in colour owing to different proportions of brown garnet, green epidote, sulphides, etc. The banding is also indicated by variations in the coarseness of crystallization. Massive beds up to 2 and 3 feet in thickness, in which the constituents are more or less uniformly distributed, may represent the impure limestone beds. Weathering gives these metamorphosed beds a dark brown colour in contrast with the white gabbro sills and the white and light grey siliceous beds. Beds of fine-grained siliceous material, in which the metamorphic silicates are too fine grained to be visible are in a minority in this division. The total thickness of this division is approximately 200 feet.

Upper Siliceous Beds. For approximately 180 feet above the horizon of the No. 1 ore-body of the Nickel Plate mine, the sediments are dominantly of the thinly banded quartzite type. Where they are least altered north of the Nickel Plate fault they consist of thinly banded, fine-grained, black and white quartzites in general similar to the banded beds of the division directly below. The beds, however, seldom show any sign of carbonate except a few beds of impure limestone, a few inches thick. Several fine-grained conglomerate and pebble beds 6 inches to 3 feet thick occur among them. Over most of their exposure, which is to the southwest of the Nickel Plate fault, they are intensely altered and consist of massive beds, in which the banding shows up in shades of dirty white and greenish grey. The greenish beds become brown when weathered. In several places breccias which in some cases show a very vague stratification, occur among these beds. They are composed of angular fragments, 2 to 9 inches long, of the same light-coloured, fine-grained, banded rock, variously oriented and surrounded by smaller fragments of the same rock, all of which are cemented into a solid mass of uniform strength and hardness. Metamorphic silicates have not developed in the beds of this division to anything like the extent that they have in the underlying division; this difference is an important distinction. The top of this division is placed where breccias form a prominent part of the strata.

Summit Beds. At the top of the upper siliceous beds, quantities of coarse breccia occur intercalated with banded quartzite beds similar to those forming another division just described. The proportion of breccia reaches a maximum of 50 per cent in the vicinity of Climax bluff. It decreases to the northeast until west of the Nickel Plate mine and breccias are much in the minority. The breccias are of two varieties, one similar to that described in the paragraph above, though sometimes containing blocks as large as 2 feet long. The other is conspicuous for the quantity of metamorphic silicates and coarse calcite present in it. At the base of the division on the Exchange fraction a thickness of 90 feet of coarse breccia of this second variety occurs. It is formed of large and small fragments of banded quartzite and coarsely crystalline limestone. The matrix is composed of brown silicate, chiefly garnet, with patches of green epidote and radial actinolite. The metamorphism is more intense at the base where large fragments of limestone have been crystallized into single anhedral crystals of calcite into which euhedral crystals of clear quartz as large as ¾ inch across, as well as crystals of garnet and epidote, project from the surrounding matrix.

North of the Nickel Plate fault this division is represented by the banded quartzite already described in the previous paragraph. The coarse breccias are represented here by only one coarse fragmental bed 5 feet thick or slightly more, and carrying at its base fragments as large as 2 to 3 inches in their greatest dimension.

The thickness of this division is difficult to determine, because, even though the top is well defined on Windfall ridge, the beds are similar to those below and without the presence of breccias among them no change is apparent. The base, however, is taken at 300 feet below the Red Mountain breccias, which is at an horizon in agreement with the base farther south.

Red Mountain Formation. Only a small section of the lower strata of this formation occurs in the northern part of the area and none occurs south of the Nickel Plate fault. These strata consist predominantly of course breccias. The base of the formation is placed at the bottom of the lowest massive band of breccia which is excellently exposed on the trail leading west over Windfall ridge. This breccia consists of a vaguely stratified mass of angular fragments embedded in a matrix of light grey, buff, or greenish colour, composed of fine, sandy, and tuffaceous particles with scattered grains of coarser sand and chert pebbles. The cement is partly calcareous. The fragments are chiefly of limestone, but also of the banded siliceous rocks. The maximum dimension is generally from 3 to 6 inches, but occasional blocks 2 and 3 feet long occur. Weathering produces a honeycombed effect due to the leaching out of the limestone fragments sometimes as much as an inch below the more resistant matrix around them. A lens of fine pebble conglomerate with a calcareous matrix and in which the cherty pebbles stand out in marked relief upon the weathered surface, occurs near the base of the breccia. Going upward the breccia becomes more calcareous, both as regards the fragments and the cement. Coarse breccias of grey or of buff limestone, which show their fragmental character only on the weathered surface by reason of the almost exact similarity between fragments and matrix, are among the uppermost beds here. In the cliffs of the Windfall canyon to the west, these limestone breccias form a well-marked band which occupies the horizon of the Kingston limestone and in which fossils have been found.

Microscopic Characteristics. Within the area studied the strata are intensely metamorphosed except over a small part of the area lying north of the Nickel Plate fault. For this reason, it is necessary to turn to the work done by C. Camsell in the larger area to get an idea of the characteristics of the unaltered rocks. The results of his microscopic studies are given below.

"*Microscopic Features.* Sections of the massive, dark blue Sunnyside limestone show the rock to be made up almost entirely of small grains of calcite. Dark, opaque, probably carbonaceous matter, is distributed through it in such a way as to give an appearance of flow structure to the section. A few quartz grains, hornblende crystals, and some chlorite, as well as some iron oxide, complete the constituents of the section.

The white crystalline limestone which forms the top of the Sunnyside limestone member is seen to be composed of large calcite crystals with quite a large proportion of quartz grains......Pyrite, pyrrhotite, and iron oxides are sparingly seen in sections of the white limestone.

Unaltered sections of the banded rocks of the middle portion of the Nickel Plate formation (this includes the divisions here from the Sunnyside productive beds up to the base of the Red Mountain formation) are difficult to obtain, and those that we have give little additional information. The siliceous bands, however, are shown by the sections to be of two kinds. One is a typical quartzite made up of small, rounded grains of quartz, while the other, which is also found as thin bands in the massive limestone members, is a very fine-grained rock, composed of almost isotropic silica, with a distinctly banded appearance. Associated with this silica are small grains and aggregates of epidote, and a few small crystals of arsenopyrite.

While the field study of these rocks (the Red Mountain formation) proves the stratified nature of the beds, the microscopic examination brings out their fragmental origin. The breccias are seen to be made up of angular fragments of different kinds of rocks of various sizes embedded in a very fine-grained groundmass. Fragments of glass are very common, which have been somewhat devitrified. Other fragments are made up of an aggregation of small quartz grains, or an indefinite brown biotite mass. Large crystals of plagioclase, as well as some orthoclase feldspar, with vague indefinite boundaries, are common, as also clear, glassy quartz, with rounded or corroded borders. There is much light coloured pyroxene in some sections occurring in small grains in segregated areas. Frequently, brown biotite of secondary origin has been developed out of the groundmass, as a result of metamorphism, and some silicification has also taken place. Some samples are cut by many small stringers containing feldspar. Pyrrhotite is everywhere very abundant, and especially in the small stringers. Some arsenopyrite is also present."[1]

The features that have been found in thin sections of specimens obtained by the writer from the less altered outcrops of the banded rocks are given below.

The thinly banded quartzite of the Nickel Plate productive beds is made up primarily of fine quartz and carbonate in variable proportions. The finer, darker bands are dominantly fine quartz with less carbonate disseminated in a fine-grained form. In this material occur clouds of very fine,

[1]Camsell, C.: Geol. Surv., Canada, Mem. 2, pp. 60 and 64 (1910).

opaque, dust-like material, the larger specks appearing to be sulphide. Small, angular fragments of quartz and of feldspar showing albite twinning occur scattered through the materials of the darker bands. In the lighter bands the quantity of carbonate is greater and is in some cases more than that of the quartz. The quartz in many cases occurs as large, anhedral crystals branching out among the other constituents and in some cases surrounding them. The same opaque dust occurs, also, but only in small quantities. Some of the material of the dark bands was crushed and heated for an hour, to bright red, under oxidizing conditions. The rock changed to a slightly lighter colour with a distinctly brown tinge and from this it is concluded that the colour is probably due to finely divided iron sulphide rather than to carbonaceous matter. The thin sand and pebble bands show fragments of coarse carbonate and of aggregates of quartz, but the majority of the fragments appear to be of volcanic origin. They consist of devitrified glass, some of light colour and showing microlites, whereas others show crystals of plagioclase feldspar and quartz in a dense, nearly opaque groundmass. The majority of the fragments show a great deal of alteration to secondary carbonate, quartz, and sulphides, chiefly pyrrhotite but with some chalcopyrite.

The sections of the more finely banded black and white quartzites of the Summit beds under the microscope show an even finer grain size as a whole and a more varied mineralogical composition. They contain very much less carbonate than the banded rocks just described. The bands are thinner, sometimes only $\frac{1}{50}$ inch thick, though continuing for several inches. The dark bands vary from a bluish black to a brownish black. Those of bluish hue are made up of fine fragments of quartz and feldspar scattered in a very fine mosaic of quartz with clouds of dust-like, opaque, material which appears to be fine sulphide as indicated by the results obtained after subjection to tests like those referred to in the previous paragraph. A certain amount of carbonate, hornblende, and sulphide are also distinguishable. The brownish bands are composed of extremely fine-grained quartz and biotite. A few larger fragments of quartz and small patches of sulphide and chlorite are scattered through them. The white bands examined show a rather coarser granular texture exhibiting gradation in size across the bands. The individual grains consist of rounded patches of very fine quartz and sericite, single crystals of quartz and occasionally of plagioclase feldspar. The interstices are filled by very pale green hornblende, chlorite, sericite, quartz, zoisite, carbonate, and sulphides. Pyrrhotite is the chief sulphide, but chalcopyrite and arsenopyrite also occur.

The altered state of these banded rocks makes their original composition difficult to judge. The presence of the volcanic fragments in the coarser beds and the small fragments of feldspar throughout suggests that much of the material may have been of volcanic origin. The presence of much biotite in the brownish black bands suggests the presence of original argillaceous material. With the abundance of carbonate in some of the bands these factors make any simple name insufficient in describing them. For simplicity's sake, however, as well as on account of their hard, resistant qualities and the presence of quartz as the chief constituent of the majority of the bands, the term banded quartzite has been used for them.

The tuffaceous constituents point to the beginning of the volcanic activity in the neighbouring region before it broke out in the immediate vicinity at a slightly later date, forming the great thickness of volcanics of the Red Mountain formation which lies directly above.

GENERAL STATEMENT

In the area under consideration nearly all of the intrusive rocks belong to the diorite-gabbro complex. These intrusives are represented by the diorite porphyry and gabbro porphyry phases and occur as a large member of small, sheet-like bodies. Besides these intrusives, however, a number of dykes of different varieties, including camptonite, keratophyre, and andesite, are present, particularly about the Nickel Plate mine and to the north of it. The granodiorite does not outcrop within the area, but is described later on because of its possible relation to the ore deposits.

DIORITE-GABBRO COMPLEX

In the map-area small bodies of the rocks of this complex, in the form of sheets, make up a very large proportion of the volume of the mountain. Several of these were traced to their source in the parent stock and proved to be apophyses.[1] From this all these sheets that have the same general relationships are taken to be apophyses. A few of these cut across the beds of the intruded strata in a truly dyke-like manner, but most of them have the structure of sills following the bedding planes. The majority of the apophyses are distributed up the dip of the sedimentary beds eastward from the stocks which lie in the west side of the mountain and correspond approximately in composition to those from which they extend. The apophyses, however, are composed of porphyritic phases more exactly described as diorite porphyry and gabbro porphyry. The northern of the stocks is composed of gabbro and the southern of diorite. In correspondence with this the gabbro porphyry apophyses are confined almost entirely to the area directly about the summit of the mountain east of the gabbro stocks and the diorite porphyry farther south, though diorite porphyry apophyses also occur on the north side of the area containing the gabbro porphyry. No sharp line can be drawn between the areas of gabbro porphyry and those of diorite porphyry, since transitional gradations occur between them.[2] For the purposes of mapping, in the south the Horsefly fault has been chosen as dividing the diorite porphyry on the south from the gabbro porphyry on the north. Similarly in the north the Nickel Plate fault has been taken as dividing the gabbro porphyry on the south from the diorite porphyry on the north.[3] The positions occupied by these two faults correspond very closely to where the boundaries between the two rock types would have been placed if the faults had not existed. Thus, in the central part of the map-area, where the outcrops of the ore deposits occur, the sheets are primarily of the gabbro porphyry type.

[1]Ibid., p. 157.
[2]Ibid., p. 79.
[3]Ibid., p. 94.

The majority of the sheets which are in the form of sills parallel to the bedding planes of the sediments rarely dip under 20 degrees and range up to vertical. Where the sediments show folding and crumpling the intrusives show sympathetic structures.[1] All faults, as yet discovered, displacing the sediments, have a similar effect upon the sills. The sills vary in size from less than an inch to 90 feet in thickness. Many of the individual sheets are remarkably uniform in thickness and persistent in extent. The majority appear to pinch out gradually, but some narrow abruptly and the adjacent beds are warped accordingly. The sheets in the form of dykes cut the bedding, strike approximately east-west, and range up to 60 feet in thickness.

Only the very edge of the gabbro stock of Climax bluff enters the map-area and here the rock resembles the apophyses. No part of the diorite stock to the southwest lies within the area. The account of the relations existing between dioritic and gabbro phases of the stocks as given by Camsell is repeated here because of its general bearing on the relations of the varieties of the apophyses to each other.

"As previously stated, there are two main types of rocks in the complex—a quartz diorite and a gabbro. The former composes the bulk of the complex, and occupies the main central portions of all three stocks, while the latter is in smaller volume, either in the same stock with the quartz diorite, or alone. Where the two occur in the same stock, and are in contact with each other, a great number of narrow tongues of gabbro are found projecting into the quartz diorite, and ramifying through it. The contacts, however, are not sharp, but show a decided blending of one rock with the other, giving just such an effect as might be expected if the gabbro were intruded into the quartz diorite before the latter had thoroughly solidified. Such contacts indicate an intrusion of the gabbro, slightly later than the quartz diorite." [2]

Such variations as occur in the mineral composition of the quartz diorite stocks are always towards a more basic rock approaching the gabbro in composition.

"While contacts of the quartz diorite show a thorough transition to gabbro over a distance of an inch, or few inches, there is also a longer, but just as complete, a transition through their apophyses, which gives the same result." [3]

"The gabbro itself, where it appears as cores in the quartz diorite, or as isolated bodies, is generally uniform throughout, and shows no tendency to differentiate to more basic forms." [4]

From the intrusive relation of the gabbro into the diorite, the confinement of the diorite porphyry apophyses to the borders of the diorite stocks, and the distribution of the gabbro porphyry apophyses not only about the gabbro stocks but also in association with diorite stocks long distances from the gabbro stocks, Camsell concludes that the gabbro is a slightly later differentiation product of the original magma that gave rise to the diorite.

On the other hand, the change of the quartz diorite of the stocks and of the diorite porphyry of the apophyses to more basic phases, seems, in the main, to take place along the contacts with calcareous sediments and suggests that the gabbro perhaps owes its basic character to the assimila-

[1]Ibid., p. 89.
[2]Ibid., p. 87.
[3]Ibid., p. 88.
[4]Ibid., p. 89.

tion of quantities of the highly calcareous Nickel Plate formation, particularly the massive Sunnyside limestone through which it rose without very marked structural disturbance.

With regard to the relative ages of the diorite-gabbro complex and the other intrusive rocks Camsell makes the following notes:

"It is noticed here that the granodiorite sends off apophyses into the quartz diorite and often holds fragments of the latter in its own body. Again, many contacts show the granodiorite truncating sheets of diorite porphyry.

No contacts of gabbro with granodiorite are ever seen, but an example of a small roof pendant of sedimentary rocks, in which is a dyke of gabbro, resting on and completely surrounded by granodiorite, is sufficient to establish the relative age of these two rocks.

The diorite gabbro . . . rocks are also known to be cut by lamprophyre, keratophyre, and rhyolite dykes."[1]

The age of the intrusion of the diorite gabbro complex is put down as Mesozoic by Camsell.[2]

Diorite Porphyry. The diorite porphyry is typically developed and well exposed near the tipple. Here the sills are from less than a foot to 60 feet thick and make up about 50 per cent of the strata capping the ridge. Owing to their hardness they form the prominent outcrops and, due to their dark colour, they stand out against the light coloured sediments. The interiors of the bulk of the sheets are formed of a dark grey rock composed of irregularly scattered, dark coloured hornblende crystals of lath-shaped form, some half an inch long, and smaller, less abundant crystals of feldspar in a very fine-grained groundmass.

"These feldspars are basic andesine in composition and frequently show zonal structure. They are always idiomorphic, and of variable size, passing gradually into the feldspars of the groundmass. . . . The hornblendes are long and lath-shaped, and show no transition in size to the hornblendes of the groundmass. . . . The groundmass is holocrystalline, and made up of small laths of feldspar and hornblende, and shreds of brown mica. Some orthoclase is present in the groundmass. Accessory minerals are titanite, arsenopyrite, pyrrhotite, and some quartz, the sulphides being usually quite abundant."[3]

To this may be added that pyrrhotite is particularly abundant as an accessory in the diorite porphyries.

At the contacts for a few inches the phenocrysts of hornblende are smaller and arranged roughly parallel to it, whereas those of feldspars are missing and the groundmass is practically white. Camsell makes the following reference to the reactions that took place along the edges of the diorite bodies.

"The effect on the diorite has been a slight basification along the contact, and the formation of pyroxene in addition to the hornblende with the complete elimination of quartz. The presence, also, of some lime silicate at the immediate contact might indicate the absorption of some material from the sedimentary rocks."[4]

Gabbro Porphyry. The rock of the sheets in the major and central portion of the map-area is very similar to the gabbro and is a gabbro porphyry. It forms the prominent outcrops and in contrast with the diorite

[1]Ibid., p. 91.
[2]Ibid., p. 94.
[3]Ibid., p. 81.
[4]Ibid., p. 86.

porphyry shows up white against the dark colour of the metamorphosed mineralized sediments. In thickness the sills vary from a fraction of an inch to 90 feet. The rock is very resistant and tough. It is almost white and finer grained than the diorite porphyry. Typically it consists of phenocrysts of pale green or colourless pyroxene and white feldspar in a very fine white groundmass.

"The thin section shows generally a porphyritic structure with phenocrysts of feldspar and pyroxene in a fine-grained but crystalline groundmass. The feldspars are labradorite with the characteristic zonal structure. The pyroxene is white or very pale greenish, and is in broad, tabular idiomorphic crystals identical with the pyroxene of the stocks, which is a diallage . . .[1]

The groundmass is fine grained, and made up of small crystals of plagioclase and grains of light coloured pyroxene, with some titanite and much sulphide mineral which is generally arsenopyrite."[2]

Camsell notes that along the contacts there is no basification as in the case of the diorite and that there is ". . . a very evident silicification on the contact of quartzite by absorption of quartz . . ."[2]

Transitional Porphyry. Within the area the typical quartz diorite type does not occur, but in the porphyry apophyses the transition can be traced from the diorite porphyry to the gabbro porphyry. Approaching the Horsefly fault from the south along the tramway the hornblende phenocrysts become fewer and the groundmass slightly lighter in colour.[3] On the north side of the fault the transition has gone so far that the sheets are distinctly gabbro in general type, but still contain scattered, long, black hornblende crystals. Farther towards the north these hornblendes are so scattered that they lie several inches apart and at the glory-hole of the Nickel Plate mine are often missing, whereas in the sill on the summit of the mountain they no longer occur at all. This transition does not take place along the sills as much as from sill to sill of successively higher horizons. Camsell describes the transition microscopically as follows:

"As the type approaches the transition to diorite porphyry, the hornblendes increase in quantity and thin sections of these show phenocrysts of both hornblende and pyroxene, with the labradorite embedded in a fine-grained groundmass, composed of feldspar and pyroxene grains."[4]

Accompanying this distribution in variation of composition is the fact that as the outcrops are followed northward along the east side of the map-area, the lowest sills end to the south of those of the horizons above them which extend successively farther and farther north.

North of the Nickel Plate fault a dyke-like body outcrops cutting across the ridge approximately east and west. It is composed chiefly of the dark diorite porphyry type, but the body is not uniform and much of it is lighter in colour like the transitional varieties. On the slope directly to the northeast of it, the other sheets are also transitional in type, though those of the lowest horizons there are dark and typical of the diorite porphyry.

[1]Ibid., p. 85.
[2]Ibid., p. 87.
[3]Ibid., p. 88.
[4]Ibid., p. 86.

Though the most thoroughly gabbro porphyry types occur on the top of the mountain, some small sills showing a tendency towards the diorite porphyry composition are also found there, but these make up only an insignificant quantity of the sills in that part.

In the Nickel Plate mine workings a number of sills and a vertical dyke—which is apparently the same as that directly over it on the surface—of the diorite-gabbro porphyries, have been encountered. As a whole these sheets are of the transitional porphyry varieties, but nearer to the gabbro porphyry than the diorite porphyry. The sills are not all of the same phase of transition and the individual sheets in some cases vary in composition throughout their extent. The sills of the highest horizons here are those at the glory-hole. They are very close to the gabbro porphyry phase. In going down into the lower workings of the mine which occur in lower horizons to the northwest, it is found that the sills that lie at lower horizons are in general nearer to the diorite in composition than those above them. This change, however, is not always apparent and in one instance at least it is locally reversed, as in the case of the lowest sill encountered in the workings, which appears to be close to the gabbro porphyry. Another irregularity found particularly in the lower sills is that some parts of a sill differ considerably in composition from others. In one case it was noted that a sill was composed of a phase close to the diorite porphyry along the upper contact and of a phase close to the gabbro porphyry in its lower part, whereas in another section of apparently the same sill this order was reversed. Similar, though less marked, instances of this variation in composition occur also in other sills. In a number of places the sills contain patches of darker hornblende bearing material which are surrounded by lighter material and which appear to represent xenoliths of a more dioritic phase in a gabbro phase. The borders between the two phases appear to grade into each other across a space of 1 or 2 inches.

In vertical section the sills are distributed in such a manner that those of the higher horizons extend farther up the slope of the beds, overlapping well beyond those below them.

The characteristics exhibited by these intrusives underground agree with those found on the surface and indicate the same relationships between the gabbro porphyry and the diorite porphyry. Both on the surface and underground it appears that the earlier sills were of the more acid phases and were intruded at lower horizons in the sedimentary strata. The later sills as a general rule appear to have followed successively higher horizons and to have extended farther to the east and northeast. The migration of the intrusive magma upward into higher horizons was accompanied to some extent by the change in composition from acid to basic particularly during the intrusion of the more basic phases.

Metamorphism

The diorite porphyry seldom shows any alteration and is characteristically fresh. In a number of places, however, small veinlets of pyrrhotite occur in it, on both sides of which the rock is altered along a zone approximately an inch wide and composed of a mass of light, mottled greenish material. Along their contacts, too, alteration is not often marked in the adjoining sediments. Even where they make up as much as 50 per cent or more of the volume of the strata, the most marked alteration in the sediments is a lightening in colour and in some cases silicification where they adjoin the diorite porphyries. Within the map-area no extensive alteration to metamorphic silicates or mineralization with sulphides have been formed adjacent to these intrusives.

The gabbro porphyry varieties, however, are accompanied by the most intense metamorphism which is described by Camsell as follows:

"The most marked metamorphism is seen in the gabbro apophyses, where these have been intruded into the sedimentary rocks, and where ore-bodies have been formed. This metamorphism takes the form of a replacement of the pyroxene of the gabbro by secondary feldspar and by calcite. The secondary feldspar is here an unstriated potash feldspar, always clear and fresh. It occurs in small grains, replacing the pyroxene crystals by attacking them from the outer border and projecting inward. In the early stages of this process, there is often seen a core of pyroxene surrounded by a ring of small feldspar crystals, all pointing inward toward the centre of the pyroxene. When this process has been completed the result is a pseudomorph after pyroxene composed of an aggregation of feldspar grains. In other instances the secondary feldspar develops irregularly through the pyroxene crystals, so that a sort of poikilitic structure is developed. The same feldspar fills fissures which traverse the gabbro. These are always minute, and are not apparent except under the microscope.

In the same manner as the feldspar replacements, calcite also replaces pyroxene and fills small fissures in the gabbro. The source of the calcite is apparent, and is undoubtedly in the sedimentary rocks into which the gabbro has been intruded. The presence of the alkali feldspar, however, is not so easy of explanation, but it is probably connected with certain phenomena following the intrusion of the gabbro apophyses."[1]

In addition to this, the presence of garnets and other metamorphic silicates along fracture planes in the gabbro porphyry sills was noted in a number of places by the writer. In the Nickel Plate mine and in the glory-hole of the Sunnyside No. 2 mine the gabbro porphyry sills are in some places mineralized with arsenopyrite in small veinlets, as well as in the disseminated form close to their contacts.

As a rule the sediments are also intensely metamorphosed over large areas where they adjoin the gabbro porphyry intrusives. The calcareous strata have been most altered. Masses of coarse silicates, among which are garnet, epidote, diopside, tremolite, wollastonite, and occasionally axinite, have been developed in them. The impure limestones show more metamorphism than the pure limestones which now consist chiefly of coarse calcite. The fine-grained siliceous beds retain their general character but are rendered much lighter and more uniform in colour. Although the areas of intense metamorphism coincide very closely with the general distribution of the gabbro porphyry intrusives in a few places it was noted that the intruded rocks adjacent to them are very little altered even where their composition appears to have been favourable for the development of metamorphic silicates. The areas of mineralization with the sulphides occur within the areas of metamorphic silicates among the gabbro porphyry intrusives, but much of the silicate areas show no sulphide mineralization.

[1]Ibid., p. 87.

Granodiorite. The nearest outcrops of the granodiorite occur 1,000 feet southeast of Sunnyside No. 4 mine dump at an elevation of 5,200 feet. The same rock is reported in the bottom of one of the deeper drill holes 4,000 feet to the northwest of the Nickel Plate glory-hole at an elevation of 3,037 feet. From this evidence, as well as that of the exposures at the base of the mountain, it is thought that the granodiorite probably underlies the area at depths of about 3,000 feet.

The characteristics of the granodiorite have already been fully described by Camsell. As no outcrops occur in the map area only those items in Camsell's account which may have some bearing on the determination of the source of the ore mineralization are quoted here.

"The portion appearing on the map forms only a small fraction of a large batholith which extends outside the area to the east and south and many miles to the west . . . .

This is the latest consolidated formation in the district [This does not include the granite several miles north of Hedley], and cuts all others. From its mode of origin and the way in which it is seen to underlie the sedimentary rocks on the slope of Similkameen valley, it is to be expected that its underground development will be much greater than that shown on the surface, and it may be found to form the floor on which most of the rocks of the district rest.

The normal rock of the granodiorite is light coloured and medium grained (millimetre grained) in texture. It is made up of two kinds of feldspar and quartz, with hornblende or biotite or both . . . . generally hornblende predominating . . . . It contains many rounded or oval-shaped basic segregations and is frequently traversed by small veinlets of feldspar or quartz.

. . . . the granodiorite is fairly uniform in texture and composition throughout all parts of its body, except the immediate contact phase . . . . It is made up of plagioclase, orthoclase, quartz, hornblende, and biotite as the essential constituents.

Plagioclase is the most abundant constituent, and is an oligoclase in composition . . .and shows very little alteration. . . . Orthoclase is much less abundant and is generally slightly turbid from decomposition and the formation of small flakes of mica throughout the crystals. There is a frequent intergrowth of the orthoclase with quartz resulting in micrographic structure.

Quartz is less abundant than the feldspar. It always has irregular outlines, and occurs in interstices between the other constituents, being the last to form. It is always clear, fresh, and glassy, and extinguishes sharply.

. . . The hornblende is dark green, and pleochroic, and idiomorphic toward the quartz, feldspars, and biotite. Biotite is dark brown, and also strongly pleochroic, and frequently shows a rim of magnetite. It appears in shreds and flakes, which are occasionally bent and altered to chlorite.

Of the accessory minerals, titanite is most abundant . . . . Other accessories are small grains and crystals of apatite, zircon, magnetite, and pyrite.

The amount of metamorphism, either regional or contact, undergone by the granodiorite, is very limited indeed. There is a slight decomposition and alteration visible in the thin sections of the feldspar constituents, and a slight straining and bending of the biotite flakes, but apart from this, the rock is almost perfectly fresh. As it is the latest large igneous intrusion in the district, and it is only cut by small trachyte dykes, it has suffered no contact metamorphism whatever.

. . . Small fissures, a fraction of an inch in width, which have become filled with quartz or feldspar, and contain also some sulphide mineral, traverse it everywhere.

The granodiorite is known to cut every rock formation in the district, except the andesite dykes, and these alone cut the granodiorite. . . . These contacts are generally sharp, and show no tendency to transition from one rock to the other. Its contact with the sedimentary rocks is well shown in a natural section. . . . This section shows the sedimentary strata, with included sheets of diorite porphyry . . . truncated by the eruptive granodiorite.

It is difficult to estimate the amount of contact metamorphism that has been induced in these sedimentary rocks by the granodiorite, for we know, from comparison, that a great deal of metamorphism must have already been induced in them by the intrusion of the diorite-gabbro and its apophyses. It is certain, however, that the granodiorite must have had a great influence in bringing about the result that now obtains in these sediments. It is noticed here as in the case of the diorite and gabbro contacts, that the banded sediments, whether quartzite, limestone, or tuffs, show much more alteration than the massive limestones. In the former, there appears to have been an introduction of silica often in a chalcedonic form, and which may have gone to form the lime silicates, while in the latter there has merely been a crystallization of calcite near the contact, without the formation of any lime silicates.

A slight mineralization accompanies the granodiorite on these sedimentary contacts, but it is relatively insignificant, when compared with that which accompanies the gabbro, or even the diorite contact.

The metamorphism induced in the massive diorite formation is very slight indeed. The effect seems to have been much greater in the dyke forms of the diorite, where they occur as sheets in the sedimentary rocks."[1]

Dyke Rocks

Besides the intrusives already mentioned a number of dykes of other varieties occur within the area. The majority are found in the immediate vicinity and to the north of the Nickel Plate mine. They form steeply dipping or vertical sheets. In size they are usually only a few feet, and never over 20 feet, thick. As a rule they are not persistent, though several have been traced between 300 and 800 feet. Among them three varieties have been distinguished—camptonite, keratophyre, and andesite—all of which are intrusive into the rocks of the diorite-gabbro complex as well as into the Triassic sediments.

The camptonites occur north of the Nickel Plate fault. They strike between west and northwest and many change in direction along their outcrops within these limits. In two cases they were found to follow fault planes. In hand specimens they are dark purplish brown with visible crystals of hornblende and feldspar. They are fine grained and some have a porphyritic texture with hornblende and feldspar occurring as phenocrysts. Patches of pyrrhotite surrounded by light coloured haloes are quite common in them. Under the microscope the chief constituents are found to be plagioclase, hornblende, and biotite.

"The plagioclase crystals are medium basic, and show no zonal structure as in the plutonic rocks. Albite twinning is not very common, or else it is obscured by the formation of secondary minerals. Twinning after the Carlsbad law, however, is very common. . . . In the typical camptonites, chlorite is very abundant, and, with some calcite that occurs with it, is the result of alteration.[2]"

In addition a little quartz is present. Pyrrhotite is present in many cases and occurs in patches about which alteration has taken place in the ferromagnesian minerals, changing them to colourless patches of chlorite and carbonate.

"In age, the lamprophyres follow, apparently at a short interval, the intrusion of the stocks of diorite and gabbro, but they are not found intrusive into the granodiorite."[3]

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[1]Ibid., pp. 94-104.
[2]Ibid., p. 106.
[3]Ibid., p. 106.

A single dyke of keratophyre was found in the area. This is the dyke which crosses the Nickel Plate glory-hole. It has already been described by Camsell as follows:

"In the hand specimen, the rock is dark, fine grained, and dense, and of a slightly porphyritic structure, showing phenocrysts of glassy quartz and twinned feldspar embedded in a dark and almost glassy groundmass . . . . . . it is found as a dyke 4 to 6 feet wide . . . . . It has no uniformity of strike, but in the above locality it seems to curve about so as to form the arc of a quadrant.

Under the microscope, the rock is seen to be made up almost entirely of feldspar, both as phenocrysts and in the groundmass. Its structure is porphyritic and the prevailing phenocryst is an acid plagioclase, which cannot be determined more specifically, large, clear, glassy phenocrysts of quartz are also present, but are much less abundant than the feldspar, and these invariably show rounded and corroded outlines with embayments of the groundmass in them. The texture of the groundmass is very fine, though crystalline, the individuals being very irregular in outline and intergrown with each other. The constituents of the groundmass are largely feldspar, all untwinned, and of an apparently alkaline variety. Some quartz is also present in the groundmass, and a ferromagnesian mineral which is probably hornblende. Accessories, in the form of sulphides, are sparingly present, but on account of the proximity of the ore-bodies may be of secondary origin.

The age of the rock is determinable only within wide limits. It is known to cut the Palæozoic [now known to be Triassic] sediments, and the intrusive sheets and apophyses from the diorite and gabbro stocks. On the other hand, it is cut by the andesite dykes which are the youngest rocks in the district. From its general character and appearance it is probably older than the granodiorite, and until further evidence is obtained is tentatively referred to the period following the eruption of the stocks of diorite and gabbro."[1]

From the fine-grained character and the composition of this rock it is doubtful whether the mineralization of the ore-bodies would have made much change in it, so that the general lack of mineralization in it cannot be taken as conclusive evidence of its age. It is believed, however, that the dyke is younger than the ore-body, since under the views advocated later in this report, the dyke if present prior to mineralization would have acted like a dam and the distribution of the ore in the rock adjacent to it would have shown its influence as such, whereas the ore-body has been found to continue on both sides of it apparently regardless of its presence.

The andesite dykes are light to dark green, fine-grained, porphyritic rocks. They have been found in the Nickel Plate mine and on the surface in the neighbourhood of the glory-hole. Among them, two chief varieties occur. The dykes of one variety are dark and contain large, black, euhedral hornblende phenocrysts and some feldspar phenocrysts. The dykes are 10 feet or less in width and some have been traced over 400 feet. They all strike between north 10 degrees west and north 5 degrees east. Under the microscope the groundmass is seen to be composed dominantly of plagioclase feldspar of the composition of andesine. Both albite and Carlsbad twinning are present and the crystals show a very marked flow structure, as well as a tendency toward ophitic texture. With the feldspar crystals are small crystals of hornblende and a quantity of extremely fine-grained, almost isotropic material in the interstices. The hornblende phenocrysts are a brown to green pleochoric variety and in some cases

[1]Ibid., p. 107.

very much larger in size than the hornblende in the groundmass. They are commonly twinned and seldom show any sign of cleavage in the thin section. The feldspar phenocrysts are considerably altered and contain patches of carbonate and chlorite evidently of secondary origin. They lack zoning, show very little twinning, and appear to be of the same composition as those of the groundmass. A little pyrrhotite also is present.

The second variety of andesite dyke rocks are lighter in colour and in the hand specimen lack the conspicuous, large, black hornblende characteristic of the dykes just described. Pyrrhotite is conspicuously abundant and in one case was noted to be abundant in the wall-rock adjacent to one of these dykes. Under the microscope the rocks are seen to owe their lighter colour to a slightly greater proportion of feldspar and the alteration of the hornblende to lighter chlorite. Hornblende phenocrysts are present, but not conspicuously so. The texture and composition otherwise are the same as that of the dykes just described. The strike of these dykes, however, varies more and ranges from north to north 30 degrees east. The relative ages of the two types of andesite dykes are not known, but probably the two types are closely associated in age. Minute veinlets of unstriated feldspar were found in them where they cut the ore deposit. Similar veinlets in the ore are described by Camsell.[1] The dykes are unaffected, however, by the general metamorphism and mineralization that accompanied the formation of the ore-bodies which extend on either side of them regardless of their presence. From this they are considered to be of more recent age than the metamorphism and mineralization. Camsell writes regarding the age of these rocks as follows.

"In age, the andesites are the youngest consolidated rocks in the district. They are known to cut the Palæozoic now considered to be Triassic sedimentary rocks, as well as the diorite and gabbro stocks and the granodiorite. They are, therefore, at least Tertiary in age . . . ."[2]

Surface Deposits

The steepness of the mountain on the west side affords little space for surface deposits other than the great masses of talus that are caught in the canyons. On the top, and eastern, and southern, slopes, however, a thin mantle of glacial drift covers every locality where the slope becomes gentler, concealing particularly the softer rocks that is, the sediments, and making the outcrops of the sills all the more pronounced. A few large glacial erratics of granite and granodiorite are scattered over the mountain top.

STRUCTURAL GEOLOGY

General Statement

In its broader aspects the structure of the top of Nickel Plate mountain is monoclinal since it forms a part of the west limb of the large anticline mentioned previously. The general strike is a little east of north and the average dip about 23 degrees west. A typical section shows that the volume of the top of the mountain above the 5,500-foot contour is made

[1]Ibid., pp. 145, 154.
[2]Ibid., p. 110.

up of approximately two-thirds sedimentary strata and one-third intrusive sheets of the diorite-gabbro porphyry types. Though a few dyke-like bodies of these rocks cut directly across the beds, by far the greater part of the sheets are in the form of sills following planes between adjacent beds. A few later dykes cut the beds and sills, but they form only a very small proportion of the total volume. Below the horizon of the Sunnyside productive beds, in the massive Sunnyside limestone, the intrusive sheets, from what has been seen to the east of the area, are absent. Finally, the base of the mountain at elevations of 3,000 to 4,500 feet very probably stands on granodiorite as already mentioned.

Folds

The strata are slightly arched in the general form of a very gentle anticline pitching a little north of west. The strikes on the northern side swing to the northeast and on the southern side to north-south. This structure is indicated in the north-south cross-section accompanying the map. The general character is not symmetrical, but shows a bending down of the beds on the north accompanying the dying out of the sills. This major structure is modified by a number of small folds and faults. The minor folds strike approximately northwest. Each stratum of the mountain may be pictured as a slightly arched sheet sloping approximately west with wrinkles running diagonally across and down to the northwest.

The dips on the limbs of the minor folds are seldom steeper than 45 degrees, and from their general character the folds are best described as warps. The best known of these minor folds is that along which the Nickel Plate mine workings extend. The folds vary in size, but the distance from crest to crest of the anticlines on the average is in the neighbourhood of 350 feet. Besides the gentle folds a number of small, abrupt crumples occur. They are small, sharp twists in the bedding and are difficult to trace in any particular direction. Fracturing sometimes occurs on their crests. Their relation to the larger warps is doubtful as they occur in all parts of the anticlines and synclines without destroying the persistence of the larger structure at the warps. The crumples are particularly plentiful along the zone between the Nickel Plate glory-hole and those of Sunnysides Nos. 3 and 4.

The gabbro porphyry and diorite porphyry sills follow the bedding of the sediments and show the same folds in a general way so long as the sills are of more or less uniform thickness. Usually they change in thickness gradually and appear to die out slowly. However, they necessarily cause considerable local change in dip and strike where they end abruptly without being cut off by faulting. An example of this is to be seen in the large sill above the glory-holes of the Sunnyside mines Nos. 2 and 3. This sill near the glory-hole has a thickness of 70 feet or over. Its outcrop extends from behind Sunnyside mine No. 2 to the northeast to end abruptly between Sunnyside mines Nos. 3 and 4 and no trace of it could be found on the surface any farther. Directly north of the outcrop of this sill, a fracture occurs which might account for its discontinuity by faulting. Several diamond drill holes have been put down just to the west and north of the north end of the outcrop. These show the sill to continue westward underground with a thickness of over 50 feet, but to end abruptly in a northerly direction along a line running northwesterly from the last outcrop, for there is only a small sill 5 to 10 feet thick which can represent the thick one. To the north, the sediments show no displacement which could carry the thick sill below the depth reached by the drill holes, instead they bend around, forming the northeast limb of an anticline to take the place occupied to the south by the sill. A large number of small crumples in the beds as they bend over the end of the sill suggests that these crumples may owe their origin to the intrusion of the sill.

The connexion between the gentle minor folds and the major fold is difficult to determine. Whereas the axis of the major fold strikes approximately north and south, the axes of the minor folds follow northwesterly directions. This fact suggests that they are not ordinary drag-folds. Their position and direction suggest that if they were formed by the same movement as the main fold, they may have been due to torsional stresses set up by different degrees of movement in the various parts of the larger fold. If this is the case, the general direction of the minor folds suggests that folding was more intense to the south than to the north, or that the strata to the northeast offered greater resistance to folding than did the beds to the southwest. The presence of the great wedge of volcanic rocks of the Red Mountain formation, which thickens abruptly north of Nickel Plate mountain to 1,200 feet, supports this explanation.[1]

The relative ages of the intrusion of the diorite-gabbro complex and the major and minor folding are difficult to establish. With regard to this matter, Camsell writes as follows.

"It has been very difficult to determine whether the tilting and deformation of the strata which are now seen in the sedimentary rocks happened before the intrusion of the diorite-gabbro complex, or whether it was later. The evidence at times might point to a time of tilting later than the diorite-gabbro intrusion, because, in a great many instances, the sheets of porphyry which emanated from the main masses and penetrated along the bedding planes of the sediments, have been included in the folding. This, however, might also have happened after the tilting, and the sheets may have simply followed the bedding planes of the strata as the lines of least resistance. Most probably the deformation of the strata and intrusion of the diorite are genetically connected with each other. In relation to the granodiorite, there is no doubt that the strata were tilted to their present altitude before the intrusion of this rock, so that we have a limit, at least in this direction, to the time in which the tilting might have occurred."[2]

Circumstantial evidence bearing on the question seems, however, to point in one direction. Nickel Plate mountain is a section of a large, steeply folded anticline and is composed in part of a large, stock-like body of the diorite-gabbro complex and in part of sedimentary strata of very different competency, yet no dislocation between these two has been noted either by Camsell or the writer. The great majority of the apophyses extend up the dip of the strata. These conditions suggest that the intrusion of the diorite-gabbro complex took place when the folding was nearing an end or afterwards.

In the Nickel Plate mine the strata form a gentle fold along which the ore deposit extends. This fold is intersected by a dyke which extends

[1]Ibid., p. 62.
[2]Ibid., p. 123.

to the surface. Throughout the mine are a number of sills of the same rock as the dyke and apparently extending from it. Whereas on each side of the dyke each sill follows with fair consistency a single horizon, only in a few cases does it appear possible for any of the sills to follow the same horizon on each side since the spacing of the sills in the sediments on the two sides is different. The dyke does not appear to have caused any distortion of the fold, but there is a slight displacement of the strata corresponding in amount to what would be produced by the opening of the fracture followed by the dyke so that the width of the dyke might be accommodated. The dyke shows no marked brecciation or fracturing which, if present, would probably have been rendered prominent by the metamorphic effects of ore deposition, the period of ore deposition being known to be later than that of the invasion of the dyke and sills. These facts seem to indicate that this gentle fold was formed before the intrusion of the dyke and sills.

It has already been pointed out that the sills conform to the folds and crumples of the sedimentary strata. The intrusives are of extremely hard rock and would be expected to fracture more than, or at least as much as, the sediments. Though the sills are cut by numerous joints and fractures, mineralization in them is found only in the very small fractures immediately adjoining the ore-bodies and in one group of the faults. Thus the sills do not appear to show the fracturing they might be expected to possess if after their consolidation they had been folded and crumpled with the sedimentary beds. The various lines of evidence though not conclusive strongly suggest that the gentle folds and crumples were formed at some time before the complete solidification of the sills.

Faults and Fractures

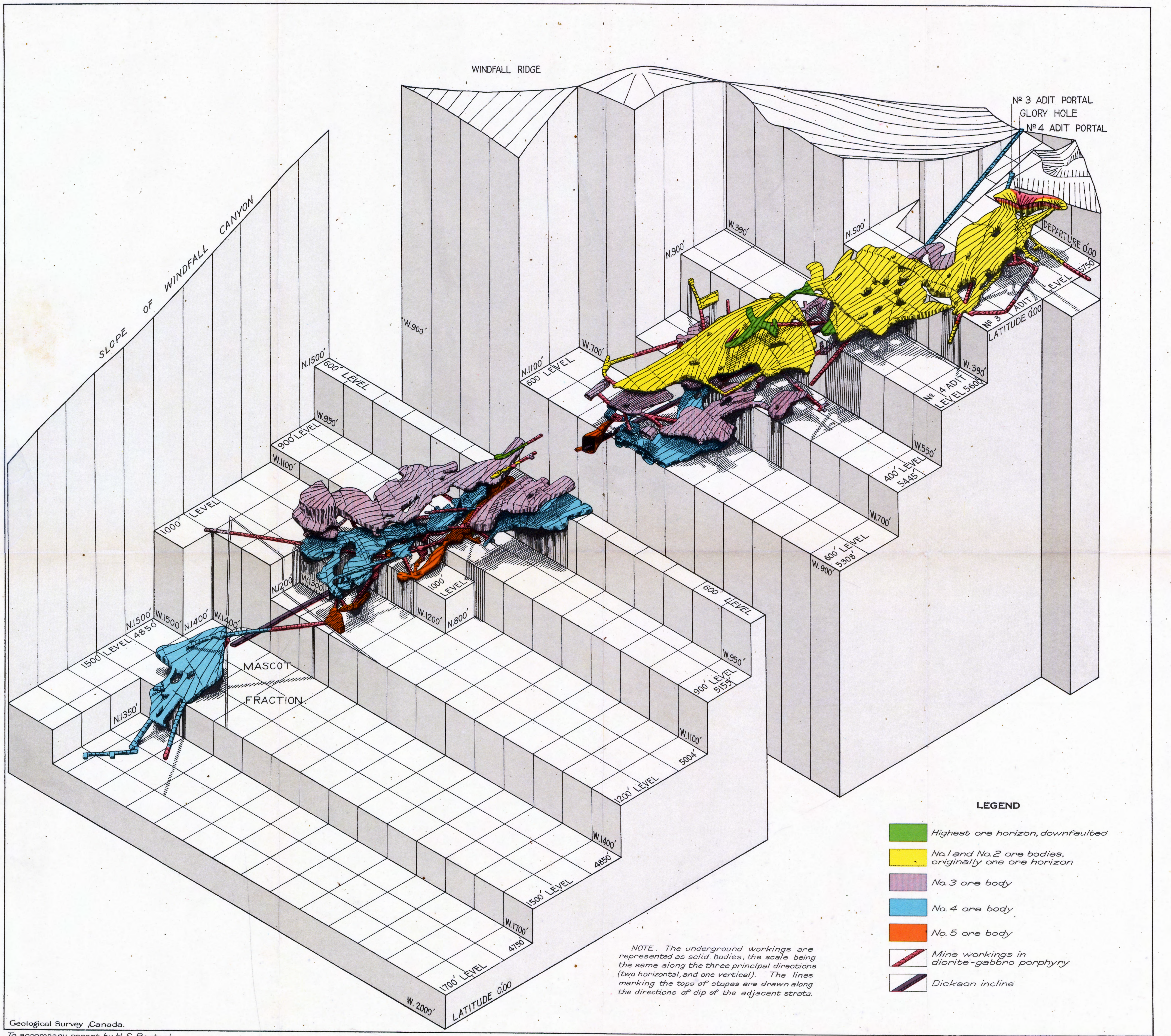
Within the area mapped the general continuity of the strata shows that no faults of very great displacement occur. In the case of the known faults, the displacement where it can be estimated is, in most instances, less than 60 feet and in no case is over 150 feet. The faults and fractures found on the surface and the great majority of those found underground have very steep or vertical dips, and all the faulting is of the normal type.

As a whole the fractures and faults exhibit a wide range of strike, but on the surface the majority of those found may be classified in two groups: one group consisting of faults striking north 65 degrees to 85 degrees west and having their downthrow on their north side as exemplified by the Nickel Plate fault; and the other group including faults striking north 20 degrees to 35 degrees west and having their downthrow on their southwest side, as in the cases of the Climax and Horsefly faults. Representatives of these two groups are apparent underground, but there a third group is the most prominent. This group consists of faults striking north 15 degrees to 35 degrees east approximately parallel to the Bradshaw fault, and having their downthrow on either their east or west side. In several cases the direction of movement is shown in the drag of the beds adjacent to the fault planes. Though in a few places underground breccia zones of loose material have been encountered these show only slight displacements and are not associated with the more marked faulting. Usually the faults are clean breaks without appreciable brecciation, and contain a few inches of gouge of carbonate vein material. In many cases they are attended on either side by several parallel or slightly divergent fractures or faults showing small displacements in sympathy with the main fault. As a result the fault and fracture lines on the surface are, as regards erosion, zones of weakness. Those running down the slope are most easily eroded and become the sites of depressions. Those paralleling the contours of the hill have little surface expression except a slight flattening of the slope which usually is covered with drift. As a consequence, the east slope of the mountain shows the topographical expression of east-west fractures best. Also, here, the contacts of the sills and strata are roughly parallel the contours, north and south, and, therefore, show displacement along fractures having east and west directions, to best advantage. Perhaps it is partly as a consequence of these conditions that the map shows a majority of faults having directions with these relations to the slopes where they occur.

The fault that appears to have the largest displacement is that shown directly northwest of Sunnyside No. 2. A thick sill which dips into the hill to the west is exposed at the top of the glory-hole several feet above the ore. A second thick sill outcrops farther up the hill with a parallel attitude, but no drill holes put down above it show more than one thick sill. A group of marked fractures are apparent in the glory-hole of Sunnyside No. 3 and fractures were reported in drill holes in the bottom of Sunnyside No. 2, all of which appear to occur and strike along the same line just below the outcrop of the upper sill. Also, close to this line the mining of part of the ore-body of Sunnyside No. 2 appears to end. All these facts appear to be good evidence of a fault. The downthrow in this case is approximately 150 feet on the southwest side. The dislocation of the minor folds suggests some lateral displacement also.

On the surface the fractures and faults exposed to examination show no sign of mineralization even where they cut the ore deposits. In a group of faults underground a consolidated vein filling is found containing the ore sulphides, arsenopyrite, chalcopyrite, and pyrrhotite. These sulphides are fragmental and may have been mechanically obtained from the adjacent ore-body. Subsequent to the formation of the vein filling a gouge was formed by later movement. The ore-bodies were unusually thick adjacent to this group of faults which suggests that the mineralization was influenced by the faults and that they began either during the mineralization or at an earlier date. The prevailing direction of the longer andesite dykes underground is approximately parallel to these particular fractures, but the dykes are unaffected by the metamorphism associated with mineralization and are definitely post-mineralization. In a few places dykes other than those of the diorite and gabbro porphyry types have been found following the planes of small faults and having a general strike a little north of west like that of the majority of the dykes on the surface.

Every fault found crossing the diorite and gabbro porphyries displaces them as well as the sediments. Where the faults cut later dykes no noticeable sign of displacement was found, but in every case the intersection was concealed.



To accompany report by H.S. Bostock, in Summary Report, Part A, 1929.

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Figure 16

ISOMETRIC DIAGRAM OF THE UNDERGROUND WORKINGS OF NICKEL PLATE MINE, (NEAR HEDLEY), BRITISH COLUMBIA.

These facts indicate that all the major faults are of later date than the intrusion of the diorite and gabbro porphyries, that one group of faults in the Nickel Plate mine is perhaps pre-mineralization, but that most are post-mineralization and that the intrusion of many of the dykes occurred during or slightly after the formation of the faults. They do not appear to show any relationship to the folding either by their direction or age.

ORE DEPOSITS

INTRODUCTION

The ore deposits that have yielded a profitable production in Hedley district are those that were found on the Nickel Plate and Sunnyside mineral claims. Their position is shown on the accompanying map (No. 2248) on the east slope of the Nickel Plate mountain. Of those that of the Nickel Plate mine which outcropped upon the mineral claim of that name has been the sole producer for the last twenty years. The ore deposits on the Sunnyside mineral claim have been abandoned and their workings allowed to fill with water. Only the glory-holes of these are accessible for examination and consequently the following account refers mainly to the Nickel Plate mine. The ore deposits on the Sunnyside mineral claim and many others in the surrounding district, which have not yet been thoroughly explored, are of the same general type, so that the features found in the Nickel Plate ore deposit may be regarded in general as typical of them all.

The Nickel Plate ore deposit belongs to that class generally described as the contact metamorphic type. The ore consists of gold-bearing arsenopyrite in a gangue of metamorphic silicates and occurs in a group of sedimentary rocks amongst which a nearly equal volume of igneous rock has been intruded in the form of sheets.

GENERAL FEATURES OF THE ORE DEPOSIT

The ore deposit occurs in a somewhat definite zone as shown on the accompanying map (No. 2248) and Figure 16. It may be regarded as the space enclosing all the known bodies of ore as well as the barren rock between them. In this light the ore deposit has an irregular elongated form 350 feet wide horizontally, 215 feet thick, and 2,000 feet long approximately. Within this the ore has been found in a series of five irregular sheet-like bodies, each of which plunges at approximately 24 degrees northwest along its longest axis and overlaps those below *en echelon.* This arrangement of the ore-bodies gives the axis of the whole deposit a plunge of 28 degrees to the northwest steeper than that of the individual ore-bodies. The ore-bodies are named consecutively downward, the top one which outcrops at the glory-hole being known as No. 1 ore-body, the next below as No. 2 ore-body, and so on to No. 5 ore-body. The forms of the ore-bodies and the distribution of the workings are shown in Figure 16.

The ore-bodies occur in the sedimentary strata referred to on a preceding page as the Nickel Plate productive beds. The general strike of the sediments is slightly east of north and the direction of the ore deposit is diagonal to this, north 50 degrees west, so that it plunges northwest more gently than the general dip of the sediments to the west. The five ore-bodies lie one above the other in these sediments, separated by zones of lower grade values in the sediments and by diorite-gabbro porphyry sills. Within the ore deposit the sediments make up approximately 60 per cent and the sill 40 per cent of the rock. With the exception of an insignificant quantity in the porphyry intrusives all the ore occurs in the sedimentary strata.

GENERAL DESCRIPTION OF THE ORE

Gold has always been the chief commercial product of the mine. In recent years a sale has been found for the arsenic as well, but the value of the ore is based on the gold content. Visible free gold occurred in considerable amounts at and near the surface. With depth, however, the gold is no longer visible either to the unaided eye or under the microscope. The values are almost exclusively associated with the arsenopyrite which is the most abundant sulphide. Chalcopyrite and pyrrhotite are common throughout many parts of the mine, but their presence does not raise the gold values and no copper is recovered. Very small amounts of sphalerite and pyrite are also found, but these are unusual. The great majority of the sulphides occur disseminated through the gangue and the amount occurring as filling fractures or as distinct veins is insignificant. The ore is associated with very intense metamorphism evidenced by garnet, epidote, and other lime silicates which form the gangue. The general colour of the ore is green. Some of the silicates are usually more concentrated in some bands than others and preserve the original banded character of the sediments, in many cases giving the ore a striped appearance in shades of brown and green. The arsenopyrite is usually irregularly scattered through the gangue, but it also is more concentrated in some bands than others. It clearly shows a marked preference for the beds of coarser silicates in contrast with those of finer and cherty texture and with those of pure limestone.

GENERAL FEATURES OF THE MINE WORKINGS

There are three openings into the workings of the ore deposit, the glory-hole, No. 3 adit, and No. 4 adit. Below No. 4 adit, which has an elevation of 5,600 feet, the ore-bodies are rendered accessible by an incline, known as the Dickson incline, which extends down under the northeast side of the ore deposit on a slope of 30 degrees to an elevation of 4,825 feet. Down the incline from No. 4 adit a series of levels have been spaced at vertical intervals of 50 feet approximately, though they are designated the 100-level, 200-level, etc., the 100-level being the first and only 50 feet below No. 4 adit level. They continue down to the 1,500-level at an elevation of 4,850 feet. At the levels crosscuts have been run from the incline to intersect the ore-bodies in the foot-walls as they extend down the slope from the levels above. The 1,300- and 1,400-levels have not been developed since the extensions of the ore-bodies at these levels would be in the Mascot fraction which is held by outside ownership. The two lowest levels of the mine, 1,600 and 1,700, are reached from the 1,500-level by a short incline on the foot-wall of No. 4 ore-body. The vertical extent of the workings is 1,150 feet from an elevation of 5,900 at the glory-hole to 4,750 feet on the 1,700-level.

In two places the mining operations have been completely interrupted across the whole ore deposit; at one place by the nearly vertical dyke striking east-west 1,000 feet northwest of the glory-hole; and at a second place by the wedge-shaped corner of the Mascot fraction which cuts across 1,500 feet from the glory-hole.

GENERAL FEATURES OF THE ORE-BODIES

Within the sediments as a general rule the changes in the degree of concentration of the gold values are not abrupt and the limits of the ore-bodies are determined by the value of commercial ore. Structural and contact relationships, however, frequently give the ore-bodies at least one well-defined wall. As a rule the highest values in the sediments occur adjacent to the top contracts of sills, the grade decreasing gradually in the sediments. This results in a sharply defined foot-wall, rather vague side-walls, and hanging-wall which are the usual conditions. Similarly where the ore is adjacent to the underside of a sill or to the large vertical dyke encountered in the mine workings these form definite walls. In a number of places faults also abruptly terminate the continuity of portions of the ore-bodies. In a few places the maximum values do not occur adjacent to sills, but along some particular bed, the grade decreasing above and below without sharp limits. The maximum thickness of any single ore-body is approximately 65 feet, except in the case of No. 3 ore-body which thickens abruptly to over 100 feet near its lower end. In several instances the ore-bodies have been mined continuously for 500 feet and more down their length. The general distribution and forms of the ore-bodies may be seen in the accompanying section and diagram, Figures 16 and 19.

MINERALOGY AND DESCRIPTION OF THE ORE AND GANGUE

The mineralogy of the mineral deposits of Hedley district as a whole, the major part of which is based on that of the Nickel Plate and Sunnyside ore deposits as they stood at the time, is given by Camsell.[1] The characteristics, relationships, and occurrence of each mineral found are described by him in detail. Here, however, only the minerals of particular interest in the Nickel Plate mine will be described and their relationships will be considered only so far as they bear on the origin of the mineralization.

The minerals found by Camsell in the Nickel Plate mine are given below and no additional ones have been noted by the writer. To this list, however, may be added native copper which has been reported by the management in an oxidized brecciated zone on the 1,700-level.

Gold	Chalcopyrite	Amphibole
Silver	Sphalerite	Garnet
Platinum	Pyrrhotite	Epidote
Cobalt	Quartz	Axinite
Tetradymite	Calcite	Erythrite
Pyrite	Feldspar	
Arsenopyrite	Pyroxene	

[1]Camsell, C.: Geol. Surv., Canada, Mem. 2, p. 135 (1910).

The broad characteristics of the ore as a whole have already been described, and here only the characteristics and relationships of the individual minerals will be given.

Arsenopyrite, except in small local patches, is the chief sulphide and in many places it occurs abundantly with only very small quantities of any other sulphide. Camsell describes its occurrence as follows.

"......Here it occurs as disseminated individuals in well-formed crystals, or else in more or less well-defined bands when the crystallization is less perfect. It appears to have been formed in this case simultaneously with the garnet, epidote, and other contact metamorphic minerals, and is associated generally with pyrrhotite, less frequently with chalcopyrite.... A later generation of arsenopyrite accompanies the crystallized arsenopyrite, and this appears in more or less well-defined lines roughly parallel to each other and showing a crystallization much less perfect than the above. ......There is a slight difference in colour between these two kinds, the crystallized variety being white in colour, while the massive form has a very slight bluish tinge. When crystallized, the arsenopyrite is very often twinned, the twinning lines appearing as striations on the faces of the crystal. The arsenopyrite is most important on account of its association with the gold. It has been definitely proved that gold, rarely, if ever, occurs in payable amounts, unless arsenopyrite is present in the ore in considerable quantity; but it has also been demonstrated that all deposits of arsenopyrite in this district need not necessarily contain gold in sufficient quantity to pay for working. The massive form is more often an indication of good gold values than the well crystallized form. On account, however, of the patchy nature of the distribution of the gold values, concentrates of pure arsenopyrite give very variable amounts of gold on assay. Absolutely clean arsenopyrite taken from a part of the ore-body which was known to be rich, gave results of 12·38 ounces of gold and 0·78 ounce in silver per ton, also 8·36 ounces in gold and 0·06 ounce in silver. Another assay of pure arsenopyrite which was taken from another part of the ore-body, also being mined as rich ore, gave only 0·30 ounce in gold and 0·30 ounce in silver. Experiments of this nature simply serve to confirm the findings of the mine operators that the gold values are in spots, and that it is impossible to tell, except from assay, what results arsenopyrite ore will give in gold values."[1]

The writer differs with Camsell as regards the relationships of the arsenopyrite with the gangue minerals. This matter will be discussed later.

For the most part arsenopyrite occurs disseminated in the sediments, but it is also present, though less abundantly, in the diorite-gabbro porphyry intrusives. It was not noted to occur in the pure limestones and occurs only in small quantities in the purer quartzites, the main quantity being in the impure calcareous sedimentary rocks. In the fine-grained, siliceous bands it is fine grained, though always in good crystal form. In the coarse, massive, silicate beds of uniform grain it is commonly in coarsely crystalline patches evenly distributed or forming knotted strings. In the well-banded beds it is more abundant in some bands than in others. It is in some cases concentrated in the coarser bands at the boundary where there is an abrupt change to finer, more siliceous, relatively barren bands. In many cases the arsenopyrite forms solid bands parallel to the bedding and up to one-half inch thick for several inches in length. In many places it forms small veinlets one-quarter inch or less wide cutting across the bedding in diverse directions. It is often in this form where present in quantity in the porphyry sills, though in these rocks a sparsely disseminated mode of occurrence is the more widespread. Where the veinlets are so narrow as to form only a film, the arsenopyrite in some instances forms the most beautiful silvery fern-like dendrites.

[1]Ibid., p. 139.

"In the Nickel Plate ore chalcopyrite generally accompanies arsenopyrite, and in that case is seen to lie along the borders of crystals of arsenopyrite, and may on that account be one of the later sulphides to be formed in the ores......"[1]

In the lower workings of the mine chalcopyrite is locally more plentiful and in a few places the ore has been found too high in chalcopyrite to be treated economically in the mill. The mineral is found in disseminated patches, but commonly shows a greater preference for some bands than for others. It was noted in several instances to form microscopic veinlets.

Pyrrhotite usually accompanies the chalcopyrite, but is often more abundant locally by itself. It occurs in the andesite dykes in which the other sulphides are lacking.

"....It is much less abundant in the Nickel Plate ore, where the gangue consists entirely of lime silicates, than in all the Sunnyside workings, where lime silicates are not so abundantly developed, and lime carbonates are in greater proportion...."[2]

This lack of pyrrhotite in the areas consisting predominantly of silicates without carbonate is true also within the Nickel Plate mine itself. Pyrrhotite is found to follow certain bands in preference to others.

Sphalerite is reported to occur occasionally in the Nickel Plate ore. It was noted in only one case by the writer and there was in very small, irregular patches with chalcopyrite and pyrrhotite.

Pyrite, besides occurring in veins along fault planes as already mentioned, is sometimes found in small cubes in the chalcopyrite, but only in very small quantities.

The gold has already been mentioned as the element of value of the ore deposits and as associated primarily with the arsenopyrite, below the surface zone no visible gold has been found.

"In the drift derived from the decomposition of the ore-bodies, gold is found in very fine grains, and this can be followed for a very short distance on the slope below the outcrop of the ore-bodies. It occurs in a dark red dirt, usually covered by other drift which completely conceals it.

In the ore-bodies themselves, gold is only visible in the rock in the surface zone. Below this, while the value of the ore may not have decreased much, gold can rarely be seen. In this surface zone free gold can frequently be seen in a gangue of sulphides and lime silicates. The particles are small, but can easily be detected without the aid of a lens. It is seen to be associated either with arsenopyrite or tetradymite. The latter is only sparingly disseminated through the gangue, but wherever it does occur, it is generally found to be associated with some free gold.

Gold is also known to occur with arsenopyrite. It becomes visible in the surface zone, where after oxidation of the arsenopyrite in which it was held, it remains as an insoluble residue, while the arsenopyrite was carried away. What the exact nature of the combination of the gold and arsenopyrite was in the primary ore is not known, but it does not appear to have occurred as a telluride. It is more likely that it may have been intimately mixed with the arsenopyrite, and in its cleavage planes, or else it is in actual solid solution in the arsenopyrite. The great difficulty met with in the recovery of the gold in the stamp mill, seems to point to the latter as being the actual combination of the gold with the arsenopyrite.

The surface ores lend themselves very readily to reduction by amalgamation, but in the ores below the influence of surface alteration the treatment becomes more difficult, and only a very small per cent of the total value is obtained on the amalgamating plates. Besides the arsenopyrite, gold to a limited amount is known to occur with the other sulphides of the ore-bodies. Attempts, however, to prove the relative amount associated with each sulphide were not successful. All that was ascertained

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[1]Ibid., p. 141.
[2]Ibid., p. 142.

from these tests was that the greatest amount of gold is with the arsenopyrite, and a much smaller proportion with the others. It was also determined that equal amounts of arsenopyrite do not carry uniform values, but that these values vary through hundreds of dollars to the ton."[1]

Calcite occurs in a few pure crystalline limestone beds in the mine. Elsewhere where it occurs it commonly forms coarsely crystalline patches in the ore with crystals of garnet and arsenopyrite projecting into it. Very small quantities are also commonly found in the interstices between the other minerals. The calcite of these two modes of occurrence is probably residual from that which was an original constitutent of the beds. Much of the ore, however, if formed of silicates and sulphides, appears, even on examination with a lens, entirely free from calcite, but its presence was always indicated by testing with acid and it appears to occur universally in very minute fractures in the other minerals under the microscope. It also occurs in all parts of the mine in vein fillings of later date than the formation of the silicates. Every occurrence of carbonate tested, including crystalline limestone beds, patches in the ore and veins, was found to be calcite.

Quartz is not a common constituent of the ore. In very fine-grained form it makes up a large proportion of the fine-grained, siliceous beds which are barren or only carry very low values. Very small quantities also occur in the calcite veins associated with the faults.

"As a secondary mineral, in the ore-bodies it occurs in irregular areas filling interstices or in small fractures with some calcite . . . As an alteration product it appears in the thin section as filling small fractures in some of the garnet of the Nickel Plate ore-body . . . ."[2]

The metamorphic silicates include garnet, epidote, pyroxene, and axinite. The garnet is brown and is a variety of andradite. It commonly occurs massively, making homogeneous, solid brown bands following the bedding plane. Where any quantity of the other silicates are abundant and also particularly where calcite is abundant, it asserts its crystal form.

". . . . It (garnet) is frequently intergrown with epidote, diopside, and arsenopyrite and sometimes holds these three minerals as inclusions. It is traversed by irregular cracks and these are often filled with calcite or quartz."[3]

Epidote is very abundant. It seldom has euhedral form in the ore except where it projects into calcite. Usually it forms fine-grained, massive bands following the bedding planes. It also occasionally occurs in small veinlets traversing the rock. The pyroxene is a pale to dark green variety and is also very abundant. It has been determined by Camsell as diopside. These silicate minerals are intimately intergrown and though any one may predominate in some beds, the other silicates are always intermingled in small quantities.

Axinite is not abundant, but occurs in very coarsely crystalline patches in a few places in the mine. It is important, however, as an indication of high temperature.

[1]Ibid., p. 136.
[2]Ibid., p. 143.
[3]Ibid., p. 147.

Camsell points out the presence of untwinned feldspar as follows:

"All of these plutonic rocks are also cut by small veinlets of pink acid feldspar. In the metamorphic rocks it is present as small, wedge-shaped crystals of unstriated feldspar, filling small fissures which traverse the rocks in the neighbourhood of the igneous intrusion. As a metasomatic mineral, it is found in a limited amount in the igneous and metamorphic rocks with which the ore-body of the Nickel Plate mine is associated. In large, clear, but undefined masses it replaces the constituents of the gabbro dykes forming the foot and hanging-walls of the ore-body. Also, in idiomorphic, well-crystallized individuals, clear and free from inclusions, it replaces the pyroxene phenocrysts of these dykes, either by projecting in from the outer edges or by developing in the interior of the pyroxene to form a mosaic of feldspar and pyroxene. There can be no doubt in these cases of the secondary origin of the feldspar, and the variety is very much like the adularia which is so common a product of metasomatism in the vicinity of ore deposits. If it is adularia, however, its presence is rather difficult to understand, when potash feldspars are so subordinate in quantity to the lime soda feldspars, and virtually unknown in the rocks immediately connected with the ore-bodies."[1]

The presence of veinlets of unstriated feldspar in the andesite dykes where they cut the ore deposits suggests that the feldspar is in no way connected with the diorite-gabbro intrusives, but of very much later age.

PARAGENESIS

The paragenesis of the chief ore and gangue minerals of the ore deposits of Hedley district, based largely on those of the Sunnyside and Nickel Plate mines, has been worked out by Camsell. Consequently the major part of his results are repeated here.

"In discussing this subject of paragenesis, a three-fold division suggests itself as the simplest form of treatment. These subdivisions are: (1) paragenesis of the ore minerals; (2) paragenesis of the gangue minerals; and (3) relations of ore to gangue minerals.

(1) Among the metallic sulphides of the district, arsenopyrite always has the best-developed crystal outlines, while pyrrhotite, chalcopyrite, and sphalerite rarely show any tendency to crystallographic form. Where arsenopyrite and chalcopyrite occur together, as they so generally do, arsenopyrite forms large, well-dveloped crystals, while the chalcopyrite lies in a thin streak around its outer edges. It does not appear as if the chalcopyrite were occupying a small fracture plane along the edge of the arsenopyrite, but rather as if in crystallizing from solution the chalcopyrite was forced to take that position by the greater crystallizing power of the arsenopyrite. They would, therefore, be of virtually contemporaneous origin. If the chalcopyrite were later, and filled a fracture, we should expect, where arsenopyrite is so abundant, that occasionally the fracture might cut across the arsenopyrite crystals, and the chalcopyrite be in this; but no such occurrence was ever noted, and we are forced to the conclusion that the two minerals formed simultaneously. In the same way, when arsenopyrite, pyrrhotite, chalcopyrite, and sphalerite occur together in the same section of a hand specimen, the arsenopyrite forms large crystals of regular outline, while the other three are intergrown together, and fill the interstices between the arsenopyrite crystals. No fracturing is apparent, but the pyrrhotite, chalcopyrite, and sphalerite appear to have formed from the same solution as the arsenopyrite, and were forced to a subordinate position in the interstices, by the greater crystallizing force of the arsenopyrite. All, however, are of the same age.

In the high-grade ore of the Nickel Plate mine, not far below the surface, it is highly probable that there are two generations of arsenopyrite. In thin sections of this ore, two kinds of arsenopyrite are apparent—the one the customary kind well crystallized and the other following well-defined lines, and without good crystallographic form. The latter is taken to be due to the same causes as the former, but of a

[1]Ibid., p. 145.

slightly later date, and fills cracks which formed on the cooling of the rock. In the same way, chalcopyrite is very occasionally seen filling minute fissures in the ore-body. The second generation of these two sulphides, however, is inconsiderable in proportion to the amount that is undoubtedly of primary origin.

(2) In the case of the gangue minerals, it is difficult to generalize, for the order of crystallization which holds in one case will not hold in another. Calcite in all cases was the original mineral where the ore-bodies now lie. In the immediate neighbourhood of the intrusives, however, the calcite has been entirely replaced, and one now remains. Where metamorphism has not been so extreme, as in some parts of the Sunnyside mine, much of it yet remains as an original constituent of those minerals, but the large crystals which are there formed are seen to be full of smaller crystals of garnet, grains of epidote and diopside, and the sulphide minerals. Quartz is also seen in the thin sections to be replacing the calcite. This kind of calcite, therefore, is of earlier formation than the lime silicates garnet, epidote, pyroxene, and hornblende, and also quartz and the sulphides. There is, however, another kind of calcite which is later than the above-mentioned minerals, and this is found in fissures, traversing the ore-bodies, and is probably due to circulating surface waters.

Where calcite has been completely replaced, and the lime silicates formed, no definite and uniform order of crystallization can be made out. An apparent sequence in one section will be completely reversed in another, so that it appears accidental which of the four—garnet, epidote, diopside, or tremolite—formed first.

Quartz is undoubtedly later than the calcite, and frequently replaces it, without replacing the garnet and epidote which formed in it. It appears to hold a fairly constant relation to all the other gangue minerals, and is one of the last minerals to have formed. It frequently fills small fissures in the ore-body, and often occupies cracks in the garnet crystals, so that it can only be of later origin."[1]

From the study of a number of polished surfaces and thin sections, the writer has formed a conception of the paragenesis of minerals that differs slightly from that expressed by Camsell. No new relationships have been discovered among the gangue minerals, but the relationships of the sulphides to the gangue minerals and of the sulphides among themselves appear to show a definite order of deposition.

Where the various silicates and sulphides occur together the garnets and the arsenopyrite almost invariably exhibit their own characteristic crystal forms in contrast with the other minerals, only a few of which occasionally show this feature. The garnets occur scattered among the other minerals without arrangement. The arsenopyrite, which appears to be scattered irregularly through the gangue, on examination frequently is found to form knotted strings of crystals traversing the rock as though its crystals had developed along minute fractures. Where the arsenopyrite crystals abut against those of garnet the latter maintain their crystal form and project into or are completely surrounded by those of arsenopyrite. No minute seams of arsenopyrite of microscopic size were found actually cutting across garnet crystals, though in a few instances arsenopyrite projects into them slightly. In addition to this in a few cases in thin sections the arsenopyrite was noted to follow round the edges of pyroxene crystals which have retained their crystal outline and in many cases, too, the arsenopyrite contains numerous, small, irregular pieces of the other silicates besides garnet. These relationships are interpreted as showing that the arsenopyrite is younger than the garnet and other silicates.

The gangue minerals are cut by small veins of arsenopyrite and calcite which distinctly follow fractures. Here the arsenopyrite most

[1]Ibid., p. 152.

probably belongs to the second generation mentioned by Camsell, since arsenopyrite disseminated in the rock adjacent to the veins, as well as that in the veins, does not show the same strength to assume the crystal form as the great majority of disseminated arsenopyrites which occurs in the ore away from the veins.[1] Some crystals of disseminated arsenopyrite were noted to show clear centres and numerous small inclusions of silicates in their outer borders. This suggests a second period of growth in the formation of these crystals, which may correspond to the deposition of the arsenopyrite in the veins, since that in the veins is taken to be of slightly later formation than that disseminated through the rock as already mentioned. Chalcopyrite, in minute veinlets, cuts both garnet and arsenopyrite crystals and it forms numerous small patches in the crystals of these minerals. These minerals present their own crystal outline to the chalcopyrite as a rule and it fills the spaces around them. In one case where a large arsenopyrite crystal has grown round the border of a garnet, chalcopyrite lies between them in an irregular border accentuating the indent in the arsenopyrite without destroying the outline of the garnet to the same extent. The relationships of the chalcopyrite to the veins of arsenopyrite were not discovered, except that small amounts of chalcopyrite and pyrrhotite were found to occur disseminated in the adjacent wall-rock without any evident relations to the veins as if they had been deposited before the fracturing. Where chalcopyrite and pyrrhotite are abundant they fill the spaces round the garnets and arsenopyrite that elsewhere are filled by gangue minerals. Pyrrhotite extends in large, irregular patches through the chalcopyrite and also cuts it in well-defined veins. Together also they form small veins in adjoining silicates. In no case was pyrrhotite found cutting the arsenopyrite and the arsenopyrite crystals preserve their crystal outlines where they are bordered by pyrrhotite. Sphalerite was found in very small quantities in chalcopyrite and pyrrhotite, but its relationships to these minerals could not be definitely determined.

These relationships of the chief ore and gangue minerals are interpreted as showing that the formation of the gangue silicates took place before that of the sulphides. Also that, omitting from consideration the vein arsenopyrite, the main part of the deposition of the three chief sulphides ended in the following order: arsenopyrite first, then chalcopyrite, and finally pyrrhotite. Chalcopyrite has replaced arsenopyrite to some extent, but has preferred the gangue minerals with the exception of garnet. Pyrrhotite in turn has replaced chalcopyrite and the gangue minerals with the exception of garnet. The almost universal presence of very small quantities of chalcopyrite and pyrrhotite with the arsenopyrite suggests that the deposition of these three sulphides was in part contemporaneous. After the fracturing of the garnet and arsenopyrite crystals, perhaps with reduction of temperature, the deposition of the main quantity of chalcopyrite and then pyrrhotite took place. The arsenopyrite that, associated with calcite, occurs in veins, is thought to be of slightly later deposition and to correspond to the later arsenopyrite mentioned by

[1]Ibid., p. 152.

Camsell with which it agrees in lack of crystal form, though the variation in colour mentioned by him[1] was not apparent to the writer.

Quartz was not determined among the minerals cut by the sulphide veinlets, except where it was an original constituent of the beds. Camsell, however, described the relationship of quartz as follows. "Quartz is the only one of the gangue minerals which is not included in the arsenopyrite, so that it is always later . . . . ."[2]

A great many veins containing various minerals cut rock containing the ore. Among the earliest are the small veins of arsenopyrite, chalcopyrite, and pyrrhotite mentioned. The mineralization of certain fault planes with arsenopyrite, chalcopyrite, and pyrrhotite, already described, possibly was associated with the formation of these small veins also. Later than these are veins of calcite, sometimes also containing quartz and pyrite. In addition, Camsell found feldspar which he mentioned as follows.

"In rare instances, some of these fractures contain clear, unstriated feldspar as a secondary mineral, but the amount is relatively small."[3]

Similar feldspar was found in veinlets cutting the andesite dykes where they cross the ore-bodies. These dykes are distinctly later than the ore-bodies, and the feldspar veinlets found by Camsell and the writer are of the same origin; then they are of considerably later formation than the other silicates and ore minerals and cannot be associated with the intrusion of the diorite-gabbro complex but are later than the granodiorite.

GEOLOGICAL RELATIONSHIPS TO SEDIMENTARY STRATA

The ore deposit, as a whole, occurs in the group of sedimentary beds which have been described under the heading of the Nickel Plate productive beds. So far as can be determined, ore has been formed somewhere in every horizon of these beds for a total thickness of approximately 175 feet, which includes all the ore-bodies in the mine. On the surface, though the limits are not sharply defined, the abundance of silicates characteristic of these beds extends over a thickness of approximately 200 feet. The actual distribution of the ore within this group of beds appears to have been more largely controlled by the sills and the structure than by variations in the composition of the individual beds, though the composition of the beds unquestionably played some part as the distribution of the arsenopyrite more thickly along some bands than others indicates. A short distance above and below the Nickel Plate productive beds where the upper and lower siliceous beds occur, and the sediments as a whole are of a more siliceous character, no persistent ore-bodies have been discovered even where the relations exhibited by structure and the intrusives are apparently the same as in the Nickel Plate ore deposit. Where the beds, however, again become more calcareous and somewhat similar to those of the Nickel Plate productive beds, as in the case of the Sunnyside productive beds, ore deposits have been discovered. These associations of the ore deposits with certain groups of strata suggest that the original composition of the strata

[1]Ibid., p. 154.
[2]Ibid., p. 154.
[3]Ibid., p. 154.

as a whole was a factor of primary importance in determining the location of the ore deposits, the impure limestones apparently having the most favourable composition for the precipitation of the mineralizing materials.

The sedimentary beds have been intensely metamorphosed and are now composed primarily of lime silicates, calcite, and the sulphides. The metamorphism has so completely obliterated the character of the sedimentary rocks that only the banding corresponding to the variations in original composition remains preserved. Usually these bands are from ½ inch to 3 or 4 inches thick and show up by the different proportions of the various silicate and sulphide minerals they contain. In addition, however, at a few horizons, massive beds of dark, uniform colour up to 3 feet in thickness also occur in the ore. Beds of very fine, cherty texture and thinly banded in shades of green from almost white to very dark, are particularly prominent in No. 3 ore-body and along the hanging-wall of No. 4. Beds of white, crystalline limestone from a few inches to a foot thick are also met with in some parts of the mine. The recurrence of these varieties of beds at several horizons and the intensity of metamorphism prevent the picking out of any well-defined band for a continuous horizon marker.

In the ore the grain is usually coarse enough to be readily visible. The crystal faces of garnets and arsenopyrite, and also the cleavage faces of other silicates, can be easily seen. In such cases the original texture of the sedimentary rock has been completely destroyed, so that very little can be learned of the original constituents and texture. Under the microscope no sign of the original grains of any kind remains, only an intergrowth of the various minerals is apparent, certain ones being more abundant in some bands than in others. In the very fine-grained, thinly banded siliceous beds, however, metamorphism has not been so complete. A thin section of this rock as it occurs near the top of the beds of No. 3 ore-body shows numerous, small quartz fragments retaining their original forms and embedded in a mass of very fine quartz intermingled with various quantities of epidote, pyroxene, carbonate, and secondary quartz. The general appearance of the structure and texture is identical with that of the thinly banded quartzites already described among the upper siliceous beds. In the bands of slightly coarser grain the metamorphic silicates have developed to the greatest extent around the quartz fragments and along rather indefinite vein-like zones cutting the bedding. Small euhedral crystals of arsenopyrite are very thinly disseminated through the rock and do not appear to be associated with any fractures or veins. Cutting the vein-like zones, just mentioned, of coarser silicate, are veinlets of carbonate, quartz, chlorite, and pyrrhotite and these in turn are cut by minute veinlets of material, which from its refractive index, birefringence, and colour may be silicates. Still later veinlets of carbonate cut these.

DIORITE-GABBRO PORPHYRY INTRUSIVES

The general features of these intrusives have already been mentioned. Other features exhibited in relation to the ore deposit are given below. The degree of regularity in form and position of the sills is indicated in the underground section (Figure 19). The sills tend to step up across the sedimentary beds as they extend up the dip, which makes their dip and the dip of the ore-bodies slightly steeper than that of the sedimentary beds. With the sills a large dyke of the same rock occurs, which is shown in Figure 19. As already mentioned it is taken to be the lower part of the dyke found on the surface almost directly over it and having the same general trend. The dyke strikes across the ore deposit east and west, but bends towards the southeast as it reaches the east side, becoming nearly parallel to the deposit. Where it cuts the ore-bodies, it is 30 feet wide, but to the east thickens to 60 feet. It ends before it intersects No. 4 adit. Its extension westward has not been traced. On the 400-level on the east side of the ore-bodies it dips 70 degrees to the north, but steepens with depth to vertical on the 700-level 200 feet below. On either side of the dyke the sills are differently distributed. Where the boundary between the dyke and sills is not marked by a fracture, the sills appear to be continuous with the dyke. From this it is inferred that the intrusion of the dyke and of the sills was contemporaneous or nearly so and that they are genetically related. Where the dyke crosses the ore deposit, it is accompanied by a number of conspicuous vertical fractures including the Nickel Plate fault. Throughout its length, several fractures parallel it and beyond its extremity a breccia and fracture zone continue in the same direction across No. 4 adit.

In detail a number of relationships are apparent between the Nickel Plate ore deposit and these intrusives. The intrusives have suffered metamorphism and mineralization like that which affected the sediments, but not to the same general extent. Though they have been intensely metamorphosed and mineralized in many places, particularly along their contacts with the ore-bodies, as described on a preceding page, throughout the ore deposit and elsewhere the greater part of the intrusives are relatively little altered compared with the adjacent sediments. However, it is evident that the metamorphism and mineralization of the intrusives are of the same origin as those of the sediments and ore deposits. It would then appear that the intrusives either contributed directly to the metamorphism and mineralization or were accompanied by them during their intrusion, or else that these phenomena took place after the intrusion. The general distribution of the ore-bodies along a definite zone, regardless of the extent of the individual sills or of the dyke, is evidence that the mineralization did not come directly out of the individual sheet during their solidification. The distribution of the arsenopyrite in veinlets and development of metamorphic silicates along fractures in the intrusives, shows that these phenomena took place after their solidification, and the distribution of the ore-bodies among the intrusives and not in them suggests that the intrusives were less permeable and less effective as precipitants to the mineralizing agents, referred to here as solutions, than the sedimentary rocks in which the ore-bodies developed. These facts indicate that mineralization took place later than the solidification of these intrusives and that the rôle played by them in the formation of the ore-bodies was not that of directly contributing mineralizing solutions, but of directing their localization. This rôle of localization has been played by them in two modes, namely the production of favourable zones in the bordering sediments for the ingression of mineralizing solutions, and the restricting of the course of these solutions in certain places.

The second mode, that of restriction of the passage of solutions, is evidenced by the general lack of mineralization in the intrusives themselves and the manner of distribution of the ore-bodies among the intrusives, particularly where they are adjacent to the dyke on the north side as will be described later.

The occurrence of the best values and the larger ore-bodies in the sediments adjoining the upper contacts of the sills, is the effect of the first mode. The development of these favourable zones for the influx of solutions may have been affected by the rupture of the strata with dilation as they were warped up to make room for the sills, or by fracturing resulting from the rapid heating and later contraction of the strata adjacent to the sills on their intrusion.

There are, also, broad relationships between the distribution of the productive ore deposits, those of the Sunnyside and Nickel Plate mines, and that of the gabbro and transitional porphyry phases of the diorite-gabbro intrusives. The ore deposits lie within the area in which these intrusives occur, but near its outer edge and among the bottom members of the series of sills of this type in their immediate locality. No outcrops of the intrusives were found on the slopes below the Sunnyside ore deposits or in the Nickel Plate. No. 4 adit, and the diamond drill holes under the ore deposit, show a marked decrease in the quantity of intrusives below the horizons of the ore-bodies. The ore deposits together are arranged roughly in the arc of a circle which has its centre in the neighbourhood of Climax bluff where the largest body of the gabbro intrusives outcrops and, occurring as the ore deposits do to the eastward of this body, they are up the dip of the sedimentary strata and sills from it. From these relationships it appears that the ore deposits have been formed at the outer edge of the area of the intrusion of the gabbro rocks where the most structural straining of the strata and the most marked changes in temperature would be present directly after the intrusion of the sills, making the locality of the ore deposits singularly favourable for the precipitation of mineralizing materials rising from a source at depth in the direction of the larger bodies of gabbro in the west side of the mountain.

DYKES

A number of dykes have been met with in the mine workings cutting through the diorite-gabbro intrusives and the ore-bodies. These are of the camptonite, keratophyre, and andesite types which have already been described earlier in the report. They are unaffected by the metamorphism and mineralization which the sediments and diorite-gabbro rocks have suffered and they are considered to belong to a later date. In one case an increase in the amount of pyrrhotite was noted in the sedimentary strata directly adjacent to a dyke of andesite which carried a considerable quantity of pyrrhotite, suggesting that some of the pyrrhotite in the adjacent sediments may have come from it. Elsewhere, throughout the ore deposit, however, with one exception the concentration of sulphides and the ore values are unaffected by the presence of these dykes. This exception occurs in the older part of the workings near the surface where Camsell noted that

"........Where the gabbro foot-wall came in contact with the crosscutting keratophyre dyke and the black dyke, forming a sort of V-shaped trough, there was found to be a remarkable concentration of the ore values.........."[1]

This he concludes was due to the dykes acting as dams here to the circulation of meteoric waters which produced enrichment of the ore.

The keratophyre referred to here has been mentioned as being in all probability older than the granodiorite and in this light sets the date of mineralization before the intrusion of the granodiorite.

Except for the andesite dykes the majority of the dykes, irrespective of their age, maintain a direction north of west approximately parallel to that of the diorite-gabbro porphyry which cuts across the Nickel Plate ore deposit. The concentration of dykes of all types in the zone about the Nickel Plate mine is significant in showing that this has been a persistent zone of weakness from the time of the intrusion of the diorite-gabbro dyke to that of the youngest intrusives, the andesites.

GRANODIORITE

Though the granodiorite does not outcrop directly about the Nickel Plate and Sunnyside ore deposits, in all probability it underlies the entire Nickel Plate mountain at depths of 2,000 to 3,000 feet from the surface. Camsell points out the general lack of metamorphism and mineralization in the rocks adjacent to its contact compared with that associated with the quartz diorite, diorite, and particularly the gabbro intrusives, in the surrounding district. Outside Hedley district, however, areas of metamorphic silicates and mineralization in the form of auriferous arsenopyrite, chalcopyrite, pyrrhotite, and other sulphides have been found in a number of places in the sedimentary rocks along the contacts of the large batholiths of similar granodiorite which occur in the surrounding country exhibiting the same geological relationships as those at Hedley. At the foot of the Nickel Plate mountain on the Sacramento mineral claim a vein carrying the three sulphides just named and gold values with a gangue of quartz cuts a small granodiorite dyke which cuts a portion of the diorite stock and was traced to the talus of the large dyke of this rock cutting across the mountain at Central station. The presence of the untwinned feldspar considered by Camsell to be potash feldspar which occurs in connexion with the Nickel Plate ore deposit might be more readily explained if the granodiorite were considered the source of mineralization. Further, Camsell points out that though arsenopyrite occurs in all the plutonic rocks of the district, "It was observed more abundantly in narrow cracks in the granodiorite, where it appears in a gangue of the white quartz, and it appears in the same way in the diorite."[2] The extensive metamorphism with which the ore deposits are associated suggests the introduction of silica and is of a type unusual with such a basic rock as the gabbro. The age of the mineralization is not conclusively proved in the light that it is based on the presence of dykes of later age than itself which are considered older than the granodiorite because none like them has been found cutting it. In

[1]Ibid., p. 192.
[2]Ibid., p. 139.

this light the evidence may be considered of a circumstantial nature. In view of this it is conceivable that the mineralization may have taken place as late as the granodiorite intrusion. In the absence, however, of other more definite evidence, that the origin of the mineralization of the Nickel Plate and Sunnyside ore deposits was associated with the granodiorite intrusion, the writer agrees with Camsell and holds that the great weight of evidence points to its association with the diorite gabbro intrusives and more explicitly the gabbro.

The features of the vein on the Sacramento mineral claim are considered with the other instances of auriferous arsenopyrite mineralization associated with granodiorite as indicating that the larger, later intrusions of granodiorite contained the same general association of mineralizing constituents as its forerunners of the diorite gabbro complex in the great post-Triassic invasions of igneous rocks which took place in this region.

PRESENT EROSION SURFACE

At and near the surface the Nickel Plate ore deposit contained abundant free gold and phenomenally high values in places, one particularly noteworthy instance being that in the trough-like structure formed between the keratophyre and andesite dykes and the foot-wall gabbro porphyry of No. 1 ore-body as already mentioned. With depth, however, the free gold has disappeared and the spotted abnormally high values also to a great extent. Though no regular assay charts have been kept, these features seem to be evidence of supergene enrichment taking place at and near the surface. This may appear remarkable in a locality so well within the sphere of continental glaciation. The outcrops of the Nickel Plate and Sunnyside ore deposits, however, occur between the 5,600 and 5,900 contours and probably did not have over 3,000 feet of ice over them at any time. Besides this the outcrops are on the southeast side of the mountain which was the lee-side with regard to the movement of the continental ice-sheets here. In this way the immediate locality of the outcrops of the deposits was unusually sheltered and probably suffered much less erosion from the ice than most of the surrounding country. In addition to this the altitude and sheltered position freed it from ice at an early date after the ice had begun to diminish and long before the recession of the ice in the valleys. In this way the processes of supergene enrichment have had an unusually long opportunity to make their influence felt on the particular locality of the outcrops, since the maximum glaciation and perhaps some remnant of the enrichment formed prior to the Pleistocene may still have remained.

METAMORPHISM

In the greater part of the map-area the sedimentary rocks are intensely altered to metamorphic silicates. The areas containing abundant sulphide mineralization always occur within those of metamorphic silicates and traces of sulphides are usually present with the silicates. Some of the areas, however, where the metamorphism is most marked, are practically free of sulphides and the sulphides are concentrated within certain zones inside the areas in which silicates have been developed. In turn, the gold values are restricted to the areas of sulphides and particularly the presence of arsenopyrite which is the most abundant and most widespread sulphide in the map-area. The concentration of gold, however, does not correspond to that of the sulphides as a whole and only approximately to the amount of arsenopyrite in the majority of places. Yet generally for practical purposes the abundance of arsenopyrite has proved a fair guide for the grade of the ore values.

The ore deposits occur near the northeast edge of the areas in which the metamorphic silicates occur. In the case of the Nickel Plate mine the beds beneath the ore deposit and on the northeast side show an increase in the degree of metamorphism as the ore-bodies are approached. A similar change was not noted on the southeast side. The change may be seen along No. 4 adit on entering the mine and in the No. 3 ore-beds on the 100-level in the upper part of the workings, but becomes more particularly noticeable in the lower horizons north of the dyke. On the 1,500-level, for example, at the landing from the Dickson incline, the beds show strikingly little alteration. They consist of the light and dark grey, banded quartzites with a very few, fine, fragmental beds. Going along the crosscut to the No. 4 ore-body at a higher horizon, four sills are crossed. Beginning next to the lower contact of the lowest sill alteration has taken place in patches, the sediments becoming lighter in colour and being mineralized with pyrrhotite. After crossing the third sill the whole rock has altered to silicates with thinly disseminated sulphides. In another case increasing alteration could be traced over a few feet distance along some beds from the relatively unaltered rock to where it is intensely metamorphosed and contains ore values. Here, the impure limestone bands were found in a distance of about 1 foot to become coarsely crystalline and impregnated with pyrrhotite and a little chalcopyrite. Beyond this over a length of approximately 3 feet the metamorphic silicates, particularly garnet and epidote, are distinguishable and arsenopyrite appears. In the siliceous, fine-grained bands the rock remains fine grained, and dark as a whole, but becomes lighter in colour and green is substituted for the dark grey along small fracture lines and in patches opposite where the silicates develop in the more calcareous bands. The associations of the metamorphism and mineralization given here, together with those of the paragenesis, indicate that these phenomena were very closely connected in origin. They appear to have been practically contemporaneous to a great extent, but the metamorphism as a whole took place more uniformly, over a more widespread area, and before the mineralization which developed more during the close of the metamorphic processes and became concentrated in certain favourable zones by conditions not affecting the metamorphism to the same extent.

STRUCTURE

Folding

The ore deposit, as already stated, appears to follow a minor fold. On the surface the gold is not conspicuous, but shows only as a gentle warp along the strike of the beds. Underground it gives the contours or level plans of each ore-body the form of gently curved " S " which is illustrated in Figure 17. Only in a few places do the ore-bodies spread continuously all across the fold, but they tend to favour certain definite parts more than others and these parts of the fold do not hold the same relative order of importance with relation to one another in all of the ore-bodies. For the deposit as a whole the greatest production and most continuous bodies of

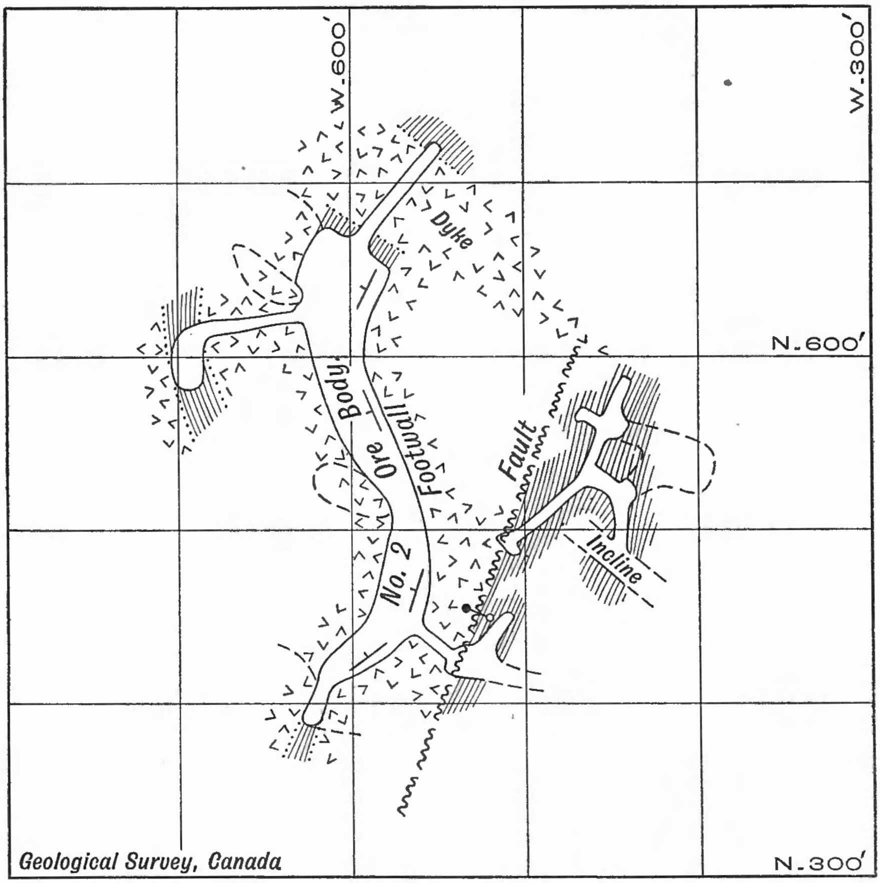

Figure 17. Plan of 100-level, Nickel Plate mine, near Hedley, Similkameen district, B.C. Elevation 5,560 feet. Diorite gabbro porphyry sills and dyke shown by angle pattern; sediments by line pattern. Pecked lines show workings extending above and below 100-level.

ore have been found on the southwest side of the crest of the anticline. Next to this, in consistency of production, comes the trough of the syncline and finally the least in consistency and importance is the limb between these two.[1] In this manner of distribution it is apparent that the ore-bodies formed in those parts of the fold in which the folding had produced the greatest porosity in the strata. In these relationships to the fold the ore-

[1]This relationship of the ore-bodies to the fold was first suggested by Mr. Paul Billingsley in 1927.

bodies are somewhat analogous to saddle reef veins. These features are exemplified by Figures 17 and 18 and the general form of the deposit as a whole is illustrated in Figure 16. Examination of the individual ore-bodies shows that this distribution of the ore applies more particularly for the upper ore-bodies. No. 1 and No. 2 ore-bodies are chiefly along the side of the anticline and No. 3, though still having its greater portion along the side of the anticline, has a considerable portion in the trough of the syncline,

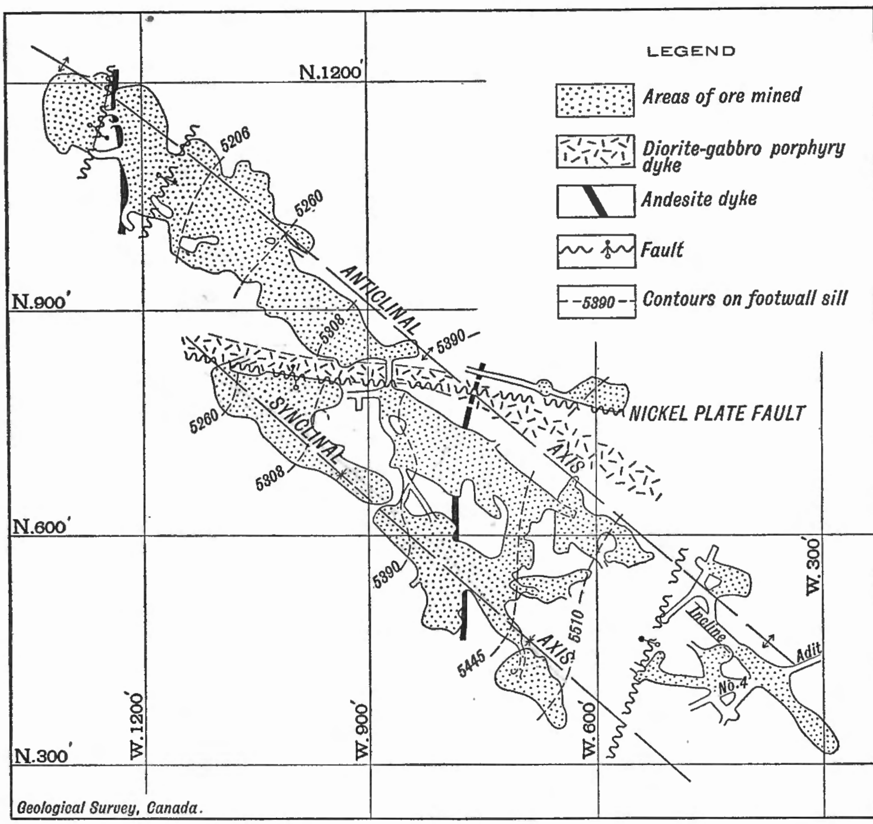

Figure 18. Horizontal projection of No. 3 ore-body, Nickel Plate mine, near Hedley, Similkameen district, B.C.

but in No. 4 ore-body the anticlinal and synclinal sections are approximately of equal importance and the greater part of No. 5 ore-body lies in the syncline. Thus, there is a general tendency for the ore as developed in successively lower ore-bodies to lie more and more largely in the syncline. Though these broad relationships of the ore-bodies to the general trend of the fold persist throughout the mine workings, they are frequently marred in perfection by local irregularities in the form of crumples in the strata and changes in the thicknesses of the sills.

The values are reported by the management to improve where the footwall steepens and this condition corresponds with the concentration of mining on the southeast slope of the crest of the anticline, rather than on the top of the crest itself.

Southeast of the Mascot fraction, the axial plane of the fold strikes north 50 degrees west. Northwest of this claim it appears to be bending farther to the west. In correspondence with the change in the strike of the axial plane on the northwest of the Mascot fraction, No. 4 ore-body there diverges slightly westward from the general alinement of the ore-bodies farther to the southeast. Similarly on the southeast of the claim in the lowest ore-body, No. 5, a bend in the strike of the axial plane of the fold is indicated to a more westerly direction than that exhibited by those above it. Between the dyke and this claim the same beds, those of No. 5 ore-body, show that the fold at this horizon lies farther southwest than at any horizon above it; this condition indicates a very steep southwesterly dip in the axial plane of the fold in this section of the workings.

In No. 4 ore-body a narrow stope extends east along the north side of the dyke. At the extreme east end of the stope the dips indicate the presence of another syncline northeast of the ore deposit. The presence of this second syncline is more clearly shown in the two detached stopes situated on the north side of the dyke and lying below one another in, respectively, No. 2 and No. 3 ore-bodies.

Fractures and Faults

A large number of fractures, some of which are faults, occur in the mine workings. The great majority of them are of no significance, but a small number of them are faults which have displacements of 10 feet or over along their planes. No fault, however, seriously dislocates the continuity of the ore deposit as a whole. The fractures underground strike in all directions and dip from 15 degrees to vertical. Over 80 per cent, however, of those mapped, including all of the faults of recognized importance, have dips over 80 degrees. The majority of the steep fractures belong to two groups striking very approximately, at right-angles with each other. By far the largest number belong to a group striking between north 20 degrees and 40 degrees east and which includes the fault at the lower end of No. 1 ore-body and the group of faults near the south boundary of the Mascot fraction, as well as a large number of small faults of insignificant displacement. The members of the other group strike between north 45 degrees and 75 degrees west and include the Nickel Plate fault. The significant faults mentioned here are represented on Figures 18 and 19.

Numerous fractures cutting the ore-bodies seem to show in the backs of the stopes a step down in the direction of dip, but whether this appearance is due to displacement along the fractures or to the necessity of breaking along the fractures in mining is often difficult to tell. Those fractures which do show some small displacement, do so in sympathy with the nearest significant faults. Thus, south of the dyke, where the downthrow is on the north side, these inverted steps usually give a true impression of the direction of displacement.

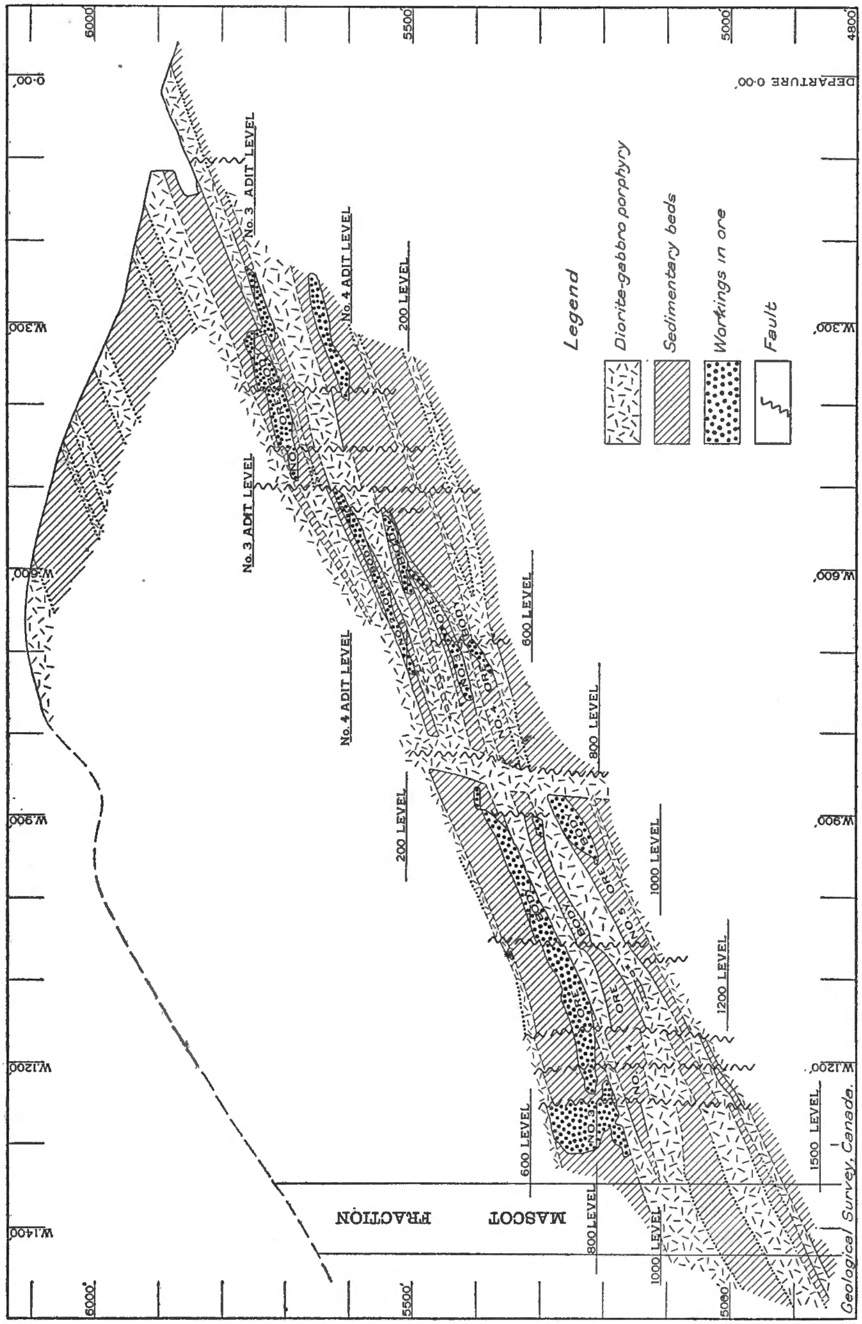

Figure 19. Vertical section along Dickson incline, Nickel Plate mine, near Hedley, Similkameen district, B.C.

The first fault of importance encountered in mining and that having the greatest determined movement is that at the lower end of the main stope in No. 1 ore-body. At its lower end this stope is cut by a group of very marked vertical fractures which may be picked up in all the workings directly below and strike approximately north 20 degrees east. At these fractures No. 1 ore-body is abruptly reduced in thickness and though sedimentary beds continue down the trend, the ore values cease, except in the small stope on No. 4 adit level. On the southwest side of the same fractures and approximately 50 feet below, No. 2 ore-body opens up with equal suddenness. From this it appears more than probable that No. 2 ore-body is the continuation of No. 1 and that the narrow band of beds which appear to be the continuation of No. 1 ore-body belong to the next horizon above it and have been faulted down into their present position (*See* Figures 16 and 19). The fault is accompanied by parallel faults on either side with much smaller downthrows, but in all cases on the same, western side. Between this fault and the dyke no break of importance occurs in the deposit. The dyke, wherever it has been encountered, is accompanied by marked fractures, veins of gouge, calcite, and pyrite, and sometimes by brecciation. This fracturing, in the form of a wide breccia zone, extends southeast across No. 4 adit beyond the southeast limit of the dyke. No mineralization, however, has been found along it other than veins of calcite containing a little pyrite. A very marked fracture belonging to this zone of fracturing striking east and west and cutting across the dyke where it bends, is probably the chief fault of this zone and has been named here the Nickel Plate fault (*See* Figure 19 and sections on 2248). The accurate determination of the movement which took place along the Nickel Plate fault or along the zone of fractures is impossible owing to the lack of a positively identifiable horizon marker. However, by matching the ore-bodies on either side of the fracture zone, there appears to be a downthrow on the north in the neighbourhood of 20 feet.

North of the dyke the ore-bodies continue northwesterly without serious interruption for 350 feet to where they are cut by a fault striking north 20 degrees east and having a dip from 85 degrees east to vertical. This fracture shows a downthrow on the east side of 15 to 25 feet. Northwest of it, across a width of 150 feet, it is accompanied by a large number of parallel fractures which have displacements in the same direction. The result of this series of fractures is to produce a general flattening out of the ore bodies and sills where they occur, by the faulting along them. The three more prominent of them are shown on Figures 16, 18, and 19 and have displacements of approximately the same magnitude. Directly on the north side of the northernmost of these three prominent faults, the No. 3 ore beds on the anticline have been mined for over 100 feet vertically. This is by far the greatest vertical thickness of continuous ore in the mine. Between the same group of faults, the No. 4 ore-body tends also to thicken, but to a less extent and the increase is in the syncline.

These faults are accompanied by gouge and in some cases, vein matter, which consists mainly of finely crystalline calcite, but contains also pyrrhotite, arsenopyrite, pyrite, and chalcopyrite. All these minerals show a granulated structure and distinct signs of movement having affected them after their deposition in the vein. The gouge accompanying the vein cuts the vein matter and is of later date. In one case a small vein, associated with these fractures, was found to contain a mass of arsenopyrite, crushed in such a way as to produce a mass of elongated parallel fragments separated by minute veinlets of calcite, giving the appearance of a gneissic structure in the arsenopyrite. These veins are unlike those found in fractures elsewhere, in that they contain all the four sulphides mentioned and not only pyrite. It might be that this group of fractures existed prior to the main period of mineralization and that they afforded easier lines of passage than elsewhere, thus, perhaps, accounting for the unusual thickness displayed in No. 3 ore-body at this place. The sill which appears on the northeast side of the workings in the No. 4 ore-body wedges out very rapidly to the southwest and accounts for the unusually great, continuous thickness of beds between the hanging and foot-wall sills of No. 4 ore-body. There may also be some relationship between the unusual irregularity of the sills in this section and the unusual thickness of the ore.

In the Mascot fraction a number of marked fractures occur along the crosscut on the 1,200-level, but their significance is difficult to judge. No. 4 ore-body and the sill beneath it appear to continue on the north side of the fraction without dislocation.

Ore has been mined down to the 1,600-level. On the 1,700-level, the values in No. 4 ore-body have decreased and a breccia zone has been encountered. This zone occurs in the crosscut on the west of the 1,500 level (*See* Figure 16). Where it cuts the sills a coarse breccia has been formed of angular fragments between which a filling of carbonate has been deposited and amongst which open spaces commonly occur. In the sediments the fragments are small and red-brown; oxidized, clay-like material is found between them, but no mineralization appears to be associated with it. Drill holes show the foot-wall sill No. 4 ore-body to continue beyond the breccia zone without appreciable displacement. The ore values, however, do not appear to continue in this direction in depth, but their extension may be in a westerly direction as will be discussed below.

DISTRIBUTION OF THE ORE-BODIES

The mode and direction from which mineralization was introduced are of primary importance in considering the origin and extension of the ore deposit beyond its known limits. A number of features of the deposit suggest that mineralization took place from agents, referred to here as solutions, which percolated upward among the rocks of the ore deposits, taking advantage of the more permeable zones. The ore-bodies show a general tendency to occur in those sections of the strata within the ore deposit in which the greatest permeability had been produced by structure. The ore-bodies extend over each other, the upper ones usually farther in the direction up the dip than the others. They are deflected out of the general direction of the fold where they come up the dip against the dyke. The ore-bodies do not appear to have been mineralized by a single stream of solution migrating from the bottom to the top of the whole ore deposit, since this would necessitate passage through the dyke which cuts completely across the ore deposit. The deflexion of the ore-bodies along the side of the dyke, impermeable character of the rock of which it is composed, the lack of evidence of the passage of the solutions, and the lack of correspondence of the positions of the ore-bodies on the south side with those of the ore-bodies on the north side, all point against the passage of the solutions from the lower north side of the dyke to the south side. These features suggest that the dyke divides the ore deposits into two separate ore-shoots that were mineralized from two independent streams of solutions. The downward extension of the ore deposit towards the source of the solutions in this case would be in two different places, one in each ore-shoot. There is no very definite evidence pointing to particular points in the two ore-shoots from which the solutions entered, but the general manner of distribution of the ore-bodies within the ore-shoots seems to indicate certain parts as the most probable.

In the case of the upper ore-shoot, that on the southeast side of the dyke, the ore-bodies appear to spread upward from the lowest part of this shoot at the northwest end in the syncline adjacent to the dyke. Here, No. 3 and No. 4 ore-bodies contained an unusual thickness of ore and they spread out up the trend of the deposit with No. 2 and No. 1 ore-bodies continuing above them.

In the lower or northwestern ore-shoot at its lower end below the 1,600-level in No. 4 ore-body mineralization does not appear to extend farther downward and no continuation of the ore in the beds of No. 5 ore-body has been found on the north side of the Mascot fraction. From this it seems probable that the mineralization of this shoot did not take place by the solutions rising from the lower end. The possibility of the solutions coming up the side of the dyke and spreading downward does not seem any more feasible since the ore-bodies show no general relationship to the dyke and are only adjacent to it for a small part at their upper ends. In this ore-shoot, however, the ore-bodies show a marked *en echelon* arrangement east and west up the dip, suggesting that the solutions rose and spread up the ore-shoot from the west side in the neighbourhood of the lower end of No. 5 ore-body.

The view expressed here that the mineralization took place by solutions spreading upward from particular parts of ore-shoots suggests that the downward extensions of the shoots are most likely to be found below the points from where they appear to start. But their positions will be influenced by the folding, the composition of the strata, the distribution of the intrusives, and the manner of arrangement of the ore-bodies up the dip of the strata as found in the ore-shoots so far as they are now known. These factors suggest that the downward extension of the ore-shoots will probably be found in a structural zone similar to the fold along which the present ore-bodies have been found and in strata in this fold of generally favourable composition. The downward extension of the upper or southeast ore-shoot thus may be expected under No. 4 ore-body in the syncline of the known fold and in the next fold to the west. In the lower ore-shoot the extension may be expected below No. 5 ore-body in the syncline and in the next fold to the west as in the case of the upper ore-shoot. The fact that these views suggest that the extension of the ore deposit lies in lower horizons where the proportion of fine-grained, siliceous beds is higher than in the Nickel Plate productive beds, is an unfavourable point, but since ore does occur in such beds in places in the mine and since the limits and proportion of unfavourable beds are uncertain, this factor loses significance when the others may be expected to be favourable. The downward extension of the ore deposit to the west as suggested here does not prohibit the presence of other ore-shoots farther northwest along the trend of the present ore deposit.

Considering the possibilities of the upward extension of the ore deposit in the same light the ground over the northeast side of the known ore-bodies appears to be the most promising. In many places this has already been tested by diamond drilling, but one likely and relatively unexplored section still remains. This consists of sedimentary beds above those of No. 1 ore-body. It is considered that No. 2 ore-body is the down-faulted, lower end of No. 1 ore-body and the body of ore known as the lower end of No. 1 ore-body is a down-faulted section of the beds above No. 1 ore-body. From this it seems logical that the upper end of this small body of ore still lies untouched over the No. 1 ore-body.

GENERAL FEATURES ASSOCIATED WITH THE ORE DEPOSITS

The outstanding features which appear to have bearing upon the location of the Nickel Plate ore deposit are briefly repeated below in view of their value in the search for other ore deposits. Considering the whole district in the vicinity of Hedley it appears that although auriferous arsenopyrite mineralization has accompanied the intrusions of both the diorite-gabbro complex and the granodiorite, to the present that associated with the diorite-gabbro complex has been found to be productive and more marked than that with the granodiorite. Of the phases of the diorite-gabbro complex, the later gabbro phases appear to have had the greatest mineralization associated with it. The ore deposits occur in the intruded sedimentary rocks close to the contacts and particularly where an abundance of apophyses occur. They are found to favour beds of certain composition, particularly impure limestones. The ore deposits occur within areas in which metamorphic silicates have been developed. On Nickel Plate mountain the ore deposits have been found near the edge of the area in which numerous gabbro porphyry apophyses occur. In greater detail the location of the Nickel Plate ore-bodies appears to be due to permeability produced in the strata by a small fold and the intrusion of sill apophyses. The anticline has proved to be the most productive part of the fold and the upper contact the most productive side of the sill apophyses. In other localities, although these factors may have different significances and others may be present of greater importance it is probable that the majority of the significant factors will be the same or similar to those associated with the Nickel Plate ore deposit.

GENESIS OF THE NICKEL PLATE ORE DEPOSITS

The evidence leading to the writer's conception of the genesis of the ore in the Nickel Plate mine has already been given in the preceding sections. To avoid repetition, only a summary of the features leading up to the formation of the ore will be given here.

It has been shown that after their deposition, the Mesozoic sediments were uplifted and intruded by the rocks of the diorite gabbro complex in the form of stocks, dykes, and sills. These intrusives are now accompanied by important contact metamorphism in the sediments adjacent to them. This is particularly true of the gabbro, the later phase of the complex.

In some places the gabbro porphyry intrusives are also accompanied by valuable mineralization as well as metamorphism, as in the case of the Nickel Plate mine. There the metamorphic silicates are mainly garnet, epidote, pyroxene, and amphibole. With these are found quartz and calcite. Among these minerals arsenopyrite, chalcopyrite, and pyrrhotite, with smaller amounts of gold, sphalerite, and pyrite, occur, as well as axinite and untwinned feldspar.

There is no conclusive evidence of the proportions of materials forming the metamorphic silicates which were obtained from the original constituents of the beds and which were obtained by introduction from solutions or other agents during the process of metamorphism. It is certain, however, that although the original constituents were of primary importance in determining the relative abundance of the individual silicate minerals in certain beds and contained much of their constituents, some materials were also introduced with the formation of the silicates. The preservation of the bedding by the silicates, coupled with the marked change in density which the development of these minerals has brought about, suggests the introduction of a considerable proportion of their constituents, particularly silica and iron. Sulphur, arsenic, iron, copper, zinc, and gold were introduced subsequently with the formation of the sulphides, and finally quartz, calcite, and feldspar were introduced.

The distribution of the metamorphic silicates corresponds closely to that of the gabbro porphyry phases and their origin is probably directly connected with these intrusives. The paragenesis, however, and the form of the ore deposits show the mineralization to have been independent of the individual sills except in their influence in guiding and localizing the mineralizing agents and in forming zones favourable for deposition. The distribution of the ore-shoots indicates that the solutions introducing the ore minerals rose from a source at depth to the west of the ore deposit after the solidification of the gabbro porphyry intrusives. The relation of the ore deposit to certain other dyke rocks shows that its formation took place before the intrusion of these dykes and as the first event in the immediate vicinity after the intrusion of the gabbro porphyry intrusives and formation of the metamorphic silicates. The Nickel Plate and Sunnyside ore deposits show a relationship in distribution, age, and other phenomena already pointed out, that suggests that their origin was closely connected with the end of this intrusion.

To this must be added the secondary enrichment found near the surface, the origin of which Camsell described as follows:

"Finally, the gold values have been later concentrated by downward moving surface waters, not only on the foot-wall side of the ore-body, but in impervious troughs that have been forced by the conjunction of a crosscutting dyke with the foot-wall. In certain cases, the highest grade of ore ever mined in the district has been recovered from such a trough, at a distance of 200 feet below the surface."[1]

[1]Ibid., p. 174.

MINING AND MILLING

Mining has been carried out with remarkably little development. Diamond drilling has been held extensively for exploration underground. The ore was first extracted through the glory-hole and later by means of Nos. 3 and 4 adits. With the continuation of the ore-bodies below the level of No. 4 adit, the Dickson incline was sunk for the purpose of bringing the ore up to this level. The ore is mined in the stopes by mining up the slope of the ore-bodies from the levels. No timbering has been necessary, the backs of the stopes standing completely unsupported across wide spans. Mucking and tramming on the levels is done by hand. The ore is dumped into pockets above the Dickson incline. The ore is hoisted in 2-ton skips on 36-inch gauge in balance or otherwise, by air, and dumped into ore pockets above No. 4 adit. These pockets supply the trains that carry the ore out of the adit and south to the tipple bin at the head of the incline. The tramway is of the trolley type and the trains consist of twelve 2-ton cars. From the tipple the ore is lowered 3,500 feet to the ore bin above the mill at Hedley by means of two 5-ton skips in balance. Air is supplied to the mine from the compressor plant in Hedley.

Power is obtained from hydro-electric plants belonging to the Hedley Gold Mining Company. The sources of water being Hedley (Twentymile) creek and Similkameen river, and during low water an auxiliary steam plant is used.

In the mill the ore is crushed by a series of Blake crushers and fine ground in cyanide solution by means of stamps and tube mills. The mixture is agitated and the solids are separated from the cyanide solution. The gold is removed from the solution on the premises. A sulphide concentrate is made from the solids and shipped to the American Smelting and Refining Company smelter at Tacoma, Washington. One ton of concentrates is made from about 20 to 25 tons of ore. From 200 to 250 tons of ore are treated a day, but with a more consistent supply of power this tonnage could be increased. The concentrates contain about 25 per cent arsenic, 2 to 2½ ounces of gold, and 1 ounce of silver per ton. The arsenic is unusually free from harmful impurities and since 1917 a sale has been found for it.

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MINERAL DEVELOPMENTS IN SALMO MAP-AREA, BRITISH COLUMBIA

By J. F. Walker

CONTENTS

INTRODUCTION

The east half of Salmo map-area, described in this report, lies between longitudes 117° and 117° 15′ and latitudes 49° and 49° 15′. The area includes the southwesterly part of Nelson range and is drained by Hidden, Sheep, and Lost creeks, all of which flow westerly to join the south-flowing Salmo river.

Salmo, the nearest point for supplies, is situated on the Great Northern railway just west of this part of the map-area. The International highway between Nelson and Spokane passes through Salmo and parallels and lies just west of the area. Branch roads lead up Hidden, Sheep, and Lost creeks for 3½, 7, and 6 miles respectively. Two mine roads leave the Sheep Creek road and climb steeply into the basins of Deer and Fawn creeks. Another branch road leaves the highway at Sheep Creek crossing and climbs southerly to the Emerald mine. Trails extend from the ends of Sheep and Lost Creek roads across the summit of Nelson range to Kootenay lake. With the exception of the northeast and southeast corners the area is easily accessible.

Earlier geological work in the district includes that of Brock and McConnell on the West Kootenay sheet, Daly along the International Boundary, and LeRoy on the Sheep Creek gold camp. The reports of the British Columbia Minister of Mines contain much information on the district, which has been freely used in this report and for which recognition is here made.

A new topographic base on a scale of 1 mile to 1 inch with 100-foot contour intervals is in course of preparation and the geological work is being laid down on this base. When the work is completed a full report accompanied by a geological map will be published. The present report deals briefly with some of the more important economic features of the map-area; is of a preliminary nature and subject to revision upon completion of field and laboratory work. Parts of the season of 1928 and the season of 1929 were spent in mapping in detail an area of 120 square miles and in detailed examination of the various properties and prospects. Messrs. E. H. Lovitt, Roy Graham, Vere McDowall, and W. J. Kocker rendered efficient assistance in the field. The writer is indebted to many residents of the district, to mine managers and owners' representatives, for courtesies extended to him in carrying out his work.

Topographic relief within the map-area ranges from 2,000 to 7,800 feet above sea-level; the valley bottoms averaging from 2,500 to 4,000 to 4,500 feet above sea-level and the ridges from 6,000 to 7,000 feet. The whole area has been heavily wooded, but about half of it has been burned over. Large areas are masked by timber and overburden and outcrops in them are few. These areas are underlain by the softer rocks.

GENERAL GEOLOGY

The greater part of the area is underlain by sedimentary rocks which are intruded by large and small masses of the Nelson batholith. The sedimentary rocks include the Summit and Pend-d' Oreille series of Daly[1] which are the same rocks mapped as Lower Selkirk and Niskonlith by Brock and McConnell.[2] No correlation has yet been made by the writer, but the succession corresponds very closely with that worked out on Kootenay lake[3] including the upper part of the Horsethief and Hammil series, the Badshot formation, and the Lardeau series. The whole sedimentary succession is folded into a series of anticlines and synclines, with northerly strikes, exposing the lower part of the series in the eastern side of the map-area and the upper part to the west. A shallow syncline striking about 15 degrees east of north lies close to the east side of the map-area and is followed to the west by a shallow anticline striking roughly along the summit of Nelson range. These two folds expose the grits and quartzites of the lower part of the series. West of this anticline lies a deep syncline exposing the schists of the upper part of the series. This deep syncline is followed toward the west by a closely folded anticline, overturned in part toward the west, exposing the quartzites of the lower part of the series. The axis of this anticline strikes through Stag Leap mountain, mount Vernon, and to the east of Reno mountain. It pitches steeply to the south at Stag Leap mountain. West of this anticline is a broad syncline followed by a broken anticline, both structures exposing the upper schists. The axis of the anticline strikes through the Emerald and H.B. properties and, south of the Emerald, exposes the quartzites across Lost creek.

MINERAL DEPOSITS

The mineral deposits are of two distinct types and are found in well-defined belts. Zinc and zinc-lead replacements in limestone are found along the westerly anticline and gold fissure-veins are found along the central quartzite anticline. Some gold deposits lie to the east of this anticline and to the west between it and the zinc belt are some sulphide deposits carrying gold.

The junction of Wolf with Sheep creek may be considered to be the heart of the gold camp and is distant 10 miles by motor road from Salmo.

[1]Daly, R. A.: Geol. Surv., Canada, Mem. 38.
[2]West Kootenay sheet.
[3]Geol. Surv., Canada, Sum. Rept. 1928, pt. A, pp. 124-126.

Development started in 1899 on the Yellowstone and other properties soon came into being. Production reached its peak in 1913 and declined suddenly in 1916 due in part to the fixed price of gold and high war costs of production and in part to the working out of the richer and more easily mined parts of the ore-shoots. Of recent years interest has been renewed in the district, but production has been on a very small scale, with little or no development other than that done in the actual mining of ore.

Three mills are in existence in the camp—the original Yellowstone mill which has been in operation off and on for thirty years; the Motherlode mill, erected in 1911 and operated for four years; and the Reno mill constructed in 1929 and now in operation.

The gold deposits occur as fissure-veins, cutting quartzites and schists. The sediments strike north to 15 degrees east of north and dip from 50 degrees east to vertical and steeply west. The fissures strike 60 degrees east of north to east and the dips are generally high to the south to vertical.

Displacement on the fissures varies from a few feet to about 200 feet and in all cases observed the south wall has moved west in relation to the north wall. The fissures are in part filled with quartz and crushed country rock and vary from almost nothing to some 20 feet in width, the average being generally less than stoping width. Pyrite and a little galena and sphalerite occur sparingly in the quartz. Kidneys of tungsten minerals have been reported from the Kootenay Belle vein.[1] In the upper part of the vein, the pyrite has ordinarily been oxidized and the gold set free. With the exception of the Queen vein the primary ore has been found of too low grade to mine, which may be accounted for in part in that the average vein is narrower than stoping width and dilution enters into the problem. The result is that most of the mine workings have been confined to the oxidized zones which vary in depth from a few feet to as much as 500 feet.

The ore-shoots appear to be confined to the quartzites and harder argillaceous rocks, the fissures being tight with little vein matter where they cut the schists. The ore-shoots tend to rake with the dip of the sediments, but are very irregular and the rake is not always evident.

QUEEN MINES

The Queen mine, situated on Wolf creek just above its junction with Sheep creek, has been the chief producer in the district. The Queen property now includes the Queen, Yellowstone, Hide Away, and Alexandra groups consisting of fifteen claims.

The Yellowstone before coming under control of the Queen produced in 1900 and 1901, 16,987 tons of ore yielding 5,912 ounces of gold and 4,354 ounces silver. It is reported that this represented only about 50 per cent recovery of the content of the ore, considerable gold being lost in the pyrite. No further production is recorded from the Yellowstone, though the intermediate level was reconditioned a few years ago and some work done.

The Yellowstone vein, outcropping low down on the ridge southeast of the junction of Sheep and Wolf creeks, has been opened by three levels.

[1]Sketch map of Sheep Creek mining assays. Marginal notes.

The lowest level, elevation 3,195 feet, was driven from the Wolf Creek slope at creek level and just behind the Queen office. It is completely caved and no information concerning it is available.

The intermediate level, elevation 3,394 feet, starts as a crosscut from a point on the Sheep Creek slope above the old Yellowstone mill and is driven 140 feet through drift and heavy ground to intersect the vein which it then follows easterly for 520 feet. The vein, as it is followed easterly from the point of intersection by the adit, is tight, splits at 30 feet, and the southerly or main fracture splits again at 100 feet. For 150 feet the northerly splits closely parallel the main fracture. At the end of this distance they rejoin and with the main fracture curve southerly and at the same time depart from it by a breadth of about 4 feet to 12 feet. The northerly split gives off several small branch fractures curving toward the northeast. After curving southerly the vein curves easterly again and the northerly split joins at 420 feet. The main fracture, along the curved area, sends out two fractures to the west and south. The area between the north split, main fracture, and southerly splits is largely composed of fractured country rock and vein matter, but does not appear to have carried commercial values. This area has been formed by movement along a curved fracture, the south wall moving west about 150 feet in relation to the north wall and opening up the ground along the curve. The ore-shoot starts on the most southerly split, continues easterly along it and the main break to about 12 feet beyond the junction of the north split and main break. The length of the ore-shoot on this level is about 120 feet.

Quartzites form the greater part of the north wall and argillaceous rocks the south wall of the ore-shoot. At 14 feet east of the stoping on the ore-shoot, the quartzites give place to argillaceous rocks which continue to the face. The ore-shoot has been stoped to the upper level 111 feet above. A winze has been sunk from the intermediate level, but no information is available.

The upper level was driven on the outcrop and stoped to the surface, about 100 feet above the level at the highest point.

The Yellowstone vein has been cut by the McCune adit about 300 feet east of the most easterly Yellowstone working and drifted on for 200 feet, showing a well-defined but narrow fissure. A small adit just off the Kootenay Belle trail above the McCune adit cuts a small, tight fracture which appears to be the Yellowstone vein.

The possible eastward extension of the Yellowstone vein would follow along the side hill of Sheep Creek valley fairly low down, thus limiting the depth of possible oxidation and enrichment to a rather shallow zone. The possible westward extension would be in low ground with no possibility of an enriched zone. Any future which this vein may have will depend largely on the gold content of the primary ore.

The Queen vein, outcropping on the west side of Wolf creek, is parallel to, and about 900 feet south from, the Yellowstone vein. This vein, first opened in 1900, made its first shipment in 1902 and produced steadily until 1916 with a record of 116,076 tons yielding a recovery in gold and silver of $1,188,326, an average of $10.20 to the ton. This is reported to have represented about a 65 per cent recovery.

The Queen vein has been opened by three adit levels on the west side of Wolf creek and by one adit level on the east side. No. 3 level on the west side is 20 feet above Wolf creek and Nos. 2 and 1 are 81 and 117 feet respectively above No. 3. Two ore-shoots were stoped from No. 3 level to the surface and a third and westerly shoot to a height of 50 feet. The greatest height above No. 1 level was about 75 feet. A shaft was sunk from a point 580 feet in on No. 3 level to a depth of 540 feet and Nos. 4, 5, 6, and 7 levels opened from it. The easterly ore-shoots were mined to No. 4 level and the westerly shoot, which widened with depth so as to extend under the upper middle shoot, was mined out to No. 6 level. Some stoping was done on No. 7 level, but values are reported to have been too low to warrant continuing operations. No. 3 level was driven about 330 feet beyond the shaft, but apparently did not open up any new ore. These workings are now inaccessible except No. 3 level as far in as the shaft. The floor sill is out beyond the shaft and the lower workings are full of water.

An adit was driven 1,100 feet easterly on the vein from the east side of Wolf creek and 14 feet in elevation above No. 3 level west. The top of an ore-shoot was cut about 135 feet from the portal and it opened out to about 300 feet in length below the level and continued down to No. 6 level. This shoot has been stoped out and also some ground below it on No. 7 level. Five, 6, and 7 levels extend under Wolf creek connecting the easterly and westerly workings. With the exception of No. 3 level east these workings are full of water. No. 3 level east enters softer rocks east from the ore-shoot and the fracture is tight and unpromising.

Displacement on the Queen vein is about 70 feet, the south wall having moved west relatively to the north wall. The vein has been cut by two faults along which mica dykes have been intruded. The displacement is small and in the same direction as the earlier movement. The country rock in the westerly workings is chiefly quartzite as far in as the shaft. In the east workings it is quartzite for about 240 feet from the portal and then argillaceous quartzites and argillites with a few bands of limestone.

The McCune adit cuts the Queen fracture 270 feet east of, and about 100 feet lower in elevation than, the face of No. 3 level east. The fracture is very small and tight. A small, tight fracture at the portal of No. 2 level of the Kootenay Belle is very probably the eastward extension of the Queen fracture. It is apparent that the Queen vein so far as it has been developed has been largely mined out. The easterly extension of the vein does not look promising and the writer has been unable to examine the westerly extension beyond the shaft.

The Alexandra vein outcrops on the east side of Wolf creek about 1,600 feet south of the Queen vein. It has been opened by three adit levels. The lowest at an elevation of 3,594 feet is just above Wolf creek and the upper levels are at elevations of 3,827 and 3,949 feet, respectively.

The lowest level was driven 240 feet without, in that distance, cutting the vein. Crosscuts were driven south and north and the vein cut in the north crosscut at 24 feet. Continuing the adit the vein was again cut at 90 feet beyond the crosscuts and followed for 30 feet, then lost in the south wall for about 78 feet to where it was again intersected and followed to a distance of 630 feet from the portal. The vein is small, the greater part being little more than a fracture. Near the face galena and pyrite appear in the quartz. Apparently values and widths on this level have not warranted mining, for no stoping has been done.

No. 2 level intersected the vein at 33 feet and followed it for 360 feet opening up two small ore-shoots 45 and 12 feet long, respectively. During the seasons of 1927 and 1928 a small tonnage was taken from the larger shoot and put through the old Yellowstone mill.

No. 1 level was driven 235 feet and two small shoots about 21 feet in length opened up and stoped. A winze from this level is reported to be 48 feet in depth. Should the ore rake with the dip of the quartzites the westerly shoot on No. 1 level would join the easterly shoot on No. 2 level. The stope on the westerly shoot on No. 2 level is coming up to the west of the westerly shoot on No. 1 level. The vein is small and the upper levels do not give promise of much tonnage. The vein is oxidized in the upper workings, but this oxidation dies out before No. 3 level is reached.

No. 3 level would have to be driven 120 feet to get under the westerly ore-shoot of No. 2 level and should the ore rake to the east with the dip of the quartzites, as it appears to do, then another 100 feet would have to be driven. The amount of raising to reach the oxidized zone is unknown, so that unless values near the face of No. 3 level are such that mining could be carried on provided the vein opened out to 12 inches to 18 inches in width, development on this level is hardly warranted.

The Hideaway vein is a small fracture in quartzites and has been opened for 60 feet. It outcrops on the east side of Wolf creek between the Queen and Alexandra veins. A mica dyke follows the fracture throughout most of the length exposed in the adit and a quartz porphyry dyke outcrops just at the portal. This appears to be one of the numerous small fractures occurring in the area which generally carry small values or a trace of gold but which seldom warrant development.

KOOTENAY BELLE MINE

This property, comprising the Yosemite, Yosemite fraction, Rio Tinto, Rio Tinto fraction, Pasadena, and Sultana claims, is situated on the south side of Sheep creek about a quarter of a mile above the junction of Wolf creek.

The property is developed by three adits, the lowest of which is connected to the ore bins on the Sheep Creek road by a light aerial tram having a vertical drop of about 700 feet. The valley side is very steep with slopes of 40 degrees and greater.

Two veins, No. 1 the north and No. 2 the south, strike along the hillside and dip into it. Four ore-shoots outcropped, two on each vein. The easterly ore-shoot on No. 2 vein lies directly in line with the easterly ore-shoot on No. 1 vein, but the westerly ore-shoot on No. 2 vein lies to the west of the westerly ore-shoot on No. 1 vein. Originally these ore-shoots were mined by shafts. "C" adit was driven to cut the westerly ore-shoot on No. 2 vein and a small block of ground stoped to the surface.

No. 1 adit, a crosscut, was driven to cut the downward extension of the easterly ore-shoots of both veins and these ore-shoots have been stoped to the surface. The portal of No. 1 adit is 38 feet lower in elevation and 270 feet northeasterly from the portal of " C " adit. No. 1 adit cut No. 1 vein at 112 feet and No. 2 vein at 211 feet from the portal. No. 1 vein was drifted on for 96 feet and No. 2 vein for 189 feet. The ore-shoot on No. 1 vein was 70 feet long on the surface, but shortened on its dip of 80 feet to No. 1 level. This shoot was also narrow but of high grade. The ore-shoot on No. 2 vein lengthened from 70 feet on the surface to about 140 feet and then shortened and partly played out before reaching No. 1 level 140 feet below the outcrop on the dip of the vein. This ore-shoot showed a greater width but lower values than No. 1 vein. Good ore is reported from a shallow winze on No. 2 vein below No. 1 level.

No. 2 adit was next driven to crosscut the veins below the westerly surface showing on No. 1 vein. The portal is 195 feet lower in elevation and to the west and north of No. 1 level portal. It cut No. 1 vein at 327 feet and No. 2 vein at 501 feet from the portal.

No. 1 vein was drifted on westerly for 75 feet and the downward extension of the ore-shoot opened for a length of 30 feet. Some 80 feet of stoping has been done above this level, leaving about 80 feet of backs to the bottom of the surface stope. The vein was drifted on for 145 feet in an easterly direction when broken ground was encountered and the drift turned to the south of the vein, encountering it 87 feet farther to the east and following it for 65 feet. This broken ground is a feature associated with minor folding of the quartzites and is of a local nature. Values were reported where the vein entered the broken ground and as this point is under the easterly ore-shoot it is of considerable interest. Raising on the vein to the west of the broken ground and then drifting to the east would probably avoid it.

No. 2 vein was drifted on easterly for 233 feet. At 150 feet the vein split, the southerly split forming the south wall of the drift to the face and the northerly or main fracture forming the north wall of the drift to within 20 feet of the face where it disappeared into the wall of the drift. Some information may have been missed by not breaking into this northerly fracture. The ore-body opened on the surface and on No. 1 level has not been found in this drift.

The westerly drift on the vein opened a small ore-shoot 30 feet long which has been stoped for a few feet. This shoot, which is on line with the westerly shoot on No. 1 vein, does not outcrop and with the small amount of raising but little is known about it. The drift followed the vein for 100 feet when it split and became rather ill-defined. The southerly split was followed into broken ground and lost when the drift was turned northerly to intersect the north split which followed more closely the strike of the vein. This work was discontinued within a few feet of the projected strike of the north split. This drift was driven to tap the possible downward extension of the westerly ore-shoot on No. 2 vein exposed at the surface and opened by " C " adit. Theoretically the ore-shoot should rake to the east with the dip of the sediments and the present face of the westerly drift on No. 2 vein on No. 2 level should be close to this projected downward continuation of the ore-shoot.

Nos. 1 and 2 veins are supposed to unite to the east of the surface workings. No. 1 vein was not followed around the steep hillside, but it would appear to join No. 2 vein about 320 feet east of the easterly surface working on No. 2 vein. The intersection of the veins at depth would be much farther to the east due to the angle of convergence and difference in dip. No. 2 vein has been traced for over 1,500 feet on the surface and probably extends farther east than it was followed. With the exception of the two ore-shoots mentioned and a slight swelling to the east of the presumed intersection with No. 1 vein, it is tight and unpromising. Blind ore-shoots may exist but the search for them by costly underground development is not justified. West of the workings the veins enter argillaceous rocks and the chances of finding ore-shoots are less than in the quartzites. What is presumably the Queen vein outcrops at the portal of No. 2 level as a small, tight fracture. There is just a possibility that it might open out in the quartzite to the east. The Yellowstone vein should outcrop about halfway between the bottom of Sheep creek and No. 2 level. This fracture does not make ore in either the McCune adit or in a small adit off the trail from the compressor to the Kootenay Belle workings, but there is a possibility that in the quartzite it might open out.

Oxidation extends to No. 2 level on both veins and should the old water table have conformed in any way with the present slope of the hillside then oxidation can be expected for at least 60 feet on No. 1 vein below No. 2 level. How deep oxidation may extend on No. 2 vein, is, however, unknown, but oxidation on No. 1 vein can be expected to extend below the level reached on No. 2 vein.

NUGGET-MOTHERLODE

The Motherlode mine is situated on the north side of Sheep creek, one mile east of the junction of Wolf creek, between elevations of 5,400 and 5,900 feet above sea-level or 1,900 to 2,400 feet above Sheep creek.

The Motherlode made its first shipment in 1906 and was a fairly steady producer until the autumn of 1915. In 1911 a 100-ton stamp-cyanide mill was built on Sheep creek and connected with the low-level adit by a 3,600-foot tram having a vertical drop of 1,900 feet. A 7-mile flume and pipe-line with a head of 700 feet supplied water-power to the mill and mine. In 1919 the Motherlode and Nugget properties combined and the workings were connected by a long crosscut and raise from the low level adit of the Motherlode.

The Motherlode vein has been exposed in cuts and by stripping for over 1,500 feet. Two ore-shoots were exposed, one on the Independence claim and one on the Motherlode and they are known by the claim names.

The Independence, or westerly, ore-shoot has been opened by four adit levels and two sub-levels to a depth of 630 feet. The Motherlode ore-shoot has been opened by three adit levels and a sub-level to a depth of 480 feet. Nos. 3 and 5 levels have been extended from the Independence to the Motherlode ore-shoot which are separated by about 550 feet in which one very small ore-shoot occurs.

No. 1 level, elevation 5,808 feet, starting on the Independence outcrop, has been driven about 580 feet westerly on the vein and some stoping carried to the surface. It is in an unsafe condition. The lower levels are crosscuts to the vein which they meet about vertically under the portal of No. 1. No. 2 level, elevation 5,728 feet, with 500 feet of drifting westerly on the vein and 200 feet easterly, is in poor condition and was only partly examined. The Independence ore-shoot averaging 300 feet in length between Nos. 2 and 1 levels has been stoped out. This level has been extended to a small, parallel fracture 135 feet north of the main vein and 315 feet of drifting has been done on it, part of which was examined.

No. 3 level, elevation 5,629 feet, intersected the vein 306 feet from the portal and it has been drifted on for 600 feet to the west and 1,065 feet to the east. At 90 feet from the eastern face a crosscut was driven 51 feet north to the parallel fracture or split and it was drifted on for 60 feet to the west and 570 feet to the east. All of this level was examined with the exception of the extreme east and west ends. It opens up both the Independence and Motherlode ore-shoots as well as the small intermediate one. The Independence ore-shoot has been stoped out over a length of 380 feet between this level and No. 2. The intermediate ore-shoot has been stoped out over a length of 100 feet and to a height of 20 to 40 feet.

No. 5 level, elevation 5,400 feet, intersects the vein 690 feet from the portal and it has been drifted on for 390 feet to the west and 960 feet to the east. The Independence ore-shoot, 200 feet long on No. 5 level and expanding to about 400 feet in length between No. 5 and No. 3 levels, has been stoped out. A small block of ground has been stoped out in the intermediate ore-shoot above this level. The 1,280-foot crosscut to the Nugget vein starts 720 feet east of the point at which the vein was intersected. At 855 feet on the east drift a 30-foot crosscut to the north intersects the small, parallel fracture or split which has been drifted on for 150 feet. All of this level was examined.

A shaft has been sunk from No. 5 level at the point where the crosscut to the vein intersected it to a depth of 170 feet. No. 6 level, 100 feet below No. 5, represents 230 feet of westerly, and 420 feet of easterly, drifting on the vein. Fifty-five feet below No. 6 is a short level with 90 feet of westerly, and 25 feet of easterly, drifting on the vein. A small block of ore has been mined out between No. 6 and No. 5 levels. The shaft was full of water at the time of the writer's visit.

No. 1 level, elevation 5,890 feet, on the Motherlode ore-shoot, now caved, intersected the vein 75 feet from the portal and followed it easterly for 75 feet. No. 2 level, elevation 5,736 feet, intersected the vein 290 feet from the portal and the vein was drifted on for 75 feet to the west and 300 feet to the east. This level is caving badly and was only examined in to the intersection with the vein. The Motherlode ore-shoot has been stoped out over a length of 300 feet on this level and the stoping has been carried to the surface. No. 3 level, previously mentioned, extends through this ore-shoot which has been stoped out over a length of 250 to 300 feet between No. 3 and No. 2 levels. No. 5 level also extends from the Independence through this ore-shoot which has been stoped out over a length of 70 feet and to a height of about 80 feet. No. 4, a sub-level, 130 feet above No. 5, has opened the vein for 340 feet and a block of ground 240 feet in length but shortening upwards, has been stoped out to No. 3 level. This sub-level was not examined.

Two long surface cuts have been made up the hillside above the outcrop of the vein. They are now partly sloughed in. Apparently they did not expose any parallel veins. No parallel veins were discovered in the crosscut from the Motherlode to the Nugget on No. 5 level.

The Motherlode vein cuts a series of quartzites, fine to coarse in grain and white to grey in colour and containing some beds of argillite and schist. The most westerly workings are close to the west side of this series, beyond which the country rock is more argillaceous and less favourable in nature. To the east of the most easterly workings there is a considerable thickness of quartzitic rocks which make more favourable ground. The slope of the hill in this direction reduces the possible backs and so far development in this direction has been unsuccessful in opening up new ore-shoots.

The ore-shoots have seldom exceeded 3 feet in width, the average being considerably less. The depth of oxidation and enrichment is unknown to the writer, but it would appear that No. 5 level has about bottomed it.

The Nugget mine is situated between elevations of 6,100 and 6,500 feet above sea-level on the east side of Fawn Creek basin north and across the ridge above the Motherlode.

The Nugget made its first shipment in 1907 and continued to produce until October, 1911. The property was equipped in 1908 with a small mill of four stamps and two Frue vanners. The tailing loss is reported to have been about $5 a ton.

In 1919 the Nugget and Motherlode enterprises were united and the workings connected.

The Nugget vein has been opened by four levels. No. 1 level, elevation 6,357 feet, 125 feet in length, is now caved, as also is No. 2 level, elevation 6,298 feet, with some 690 feet of workings. No. 3 level, elevation 6,205 feet, with 1,400 feet of workings, of which 930 feet consists of drifting on the vein and 290 feet on a split, is caving and only a small part was examined. No. 4 level, elevation 6,050 feet, with 1,230 feet of drifting on the vein, 210 feet on the main split and 70 feet on a minor split as well as 610 feet of drifting on a parallel vein to the north, is practically all open and fit for examination, though the crosscut to the vein is beginning to cave.

The Nugget vein, as exposed in No. 4 level, cuts quartzites east from the point at which the veins were intersected and for about 150 feet west. From this point to the end of the west drift the vein cuts quartzose schists, quartzites, and massive argillaceous rocks which latter have been mistaken for a dyke. The vein is small and tight throughout the westerly drift, becoming little more than a joint near the face Along the east drift the vein opens out in the hard quartzites. It splits at 230 feet along the east drift and again at 560 feet which is near the extreme east end of the level. These splits have been drifted on as previously noted. An ore-shoot about 400 feet long has been stoped out between No. 3 and No. 2 levels. Above No. 2 level the shoot appears to have been very irregular and to have died out. Below No. 3 level the west end of the ore-shoot has been stoped out to No. 4 level and a small block of ground has been stoped from No. 4 level under the east end.

The Nugget vein has been opened at depth by the crosscut from the Motherlode and by the raise to the Nugget workings. A sublevel was driven 200 feet above the crosscut level and some ore mined between the crosscut and this level and a little above it. Values are reported to have been too low to meet mining and milling costs. This work has, however, proved a depth of 1,000 feet on the vein and the presence of values throughout. As the ore-shoots are not always of stoping width low values cannot be mined and stoping has been confined largely to the oxidized and enriched ground near the surface. The ore-shoots are irregular in outline in both enriched and primary zones.

Reno Gold Mines, Limited

The property of Reno Gold Mines, Limited, consisting of sixteen Crown-granted claims and three claims held on location, is situated at the head of Fawn creek, a tributary of Sheep creek. A branch road leaves the Sheep Creek road at an elevation of 3,100 feet and in 5·8 miles climbs to the mine buildings at an elevation of 6,240 feet above sea-level. The total distance to Salmo is approximately 15 miles. This property, prospected in 1914, was brought into active development in 1928 and into production in the autumn of 1929. It is equipped with a 25-ton cyanide plant.

Two veins occur on Reno ground, but so far prospecting and development work has proved but one vein, namely the Reno, to carry commercial values. This vein was originally exposed by surface stripping and by four short adits. The two lower adits have been advanced, the upper, No. 3, being the present working level. The lower, No. 4 level, is connected to the mill by a short aerial tram and by a raise to No. 3 level.

No. 4 level, elevation 6,400 feet, has been driven easterly for 495 feet. The vein is first seen about 95 feet from the portal where it is very tight and ill-defined but can be followed for 60 feet when it splits, the north split entering the north wall of the workings 15 feet from the split and the south split following the south wall for 27 feet to a small fault. The adit does not expose the vein for the next 60 feet or to a point 225 feet from the portal. It is then exposed for 21 feet along the north wall between two small cross slips or faults. For 20 feet the vein is again lost when it reappears in the north wall. It is possible that to this point the vein exposed is not the main fracture but a southerly split and that the main vein now appears for the first time. From this point it has been drifted on to the face and is seen to be a small fracture pinching and swelling. At 370 feet from the portal a raise connects with No. 3 level. Beside the raise galena appears in the iron-stained quartz gangue, an indication that although the bottom of the oxidized zone has not been reached a change is taking place and primary ore may be expected at any depth.

A crosscut has been driven 300 feet south, from a point 315 feet from the portal, without disclosing any parallel fractures.

No. 3 level is 138 feet vertically above No. 4 and the portal is 220 feet easterly from No. 4 portal. At the time of the writer's visit in August, 1929, it had been driven 732 feet. The vein was intersected 96 feet from the portal and kept in the north wall of the drift for 111 feet, then lost for 30 feet, again opened and kept in the north wall for 60 feet to a small slip with about 5 feet displacement carrying the vein to the south wall of the drift. Twenty-four feet from the slip the vein splits and the workings followed the southerly split which soon died out. A crosscut to the north shows the main fracture crossing it. For 235 feet the adit is to the south of the vein which it again encountered and followed for 160 feet to the face. A crosscut located the vein 45 feet back or 205 feet from the face. Two ore-shoots occur in this level, the first starting where the vein was first cut at 96 feet from the portal and the second where the vein was intersected 160 feet from the face. Considerable stoping has been done since the writer's visit, at which time production was just about ready to start.

No. 2 level is 178 feet vertically above No. 3 and 330 feet east and north from the portal of No. 3. It is a short prospect adit 70 feet long exposing the vein in the south wall for the last 30 feet.

No. 1 level 123 feet above No. 2 is 162 feet east from it. It is a short adit splitting at 30 feet with a 39-foot branch to the northeast and an 84-foot branch to the east. A vein shows in the last 12 feet of the northeast branch which appears to be the main fracture. A minor fracture shows along the east drift.

Surface stripping has shown the vein to continue easterly to the top of the hill 510 feet from the portal of No. 1 adit and 230 feet above it in elevation.

The Reno vein cuts a series of quartzites, argillaceous quartzites, and siliceous argillites which come at the top of the series of quartzites and form a transition between it and the highly argillaceous series higher in the section. The argillaceous series starts just west of No. 4 portal and continues westerly. The series which the Reno vein cuts is about 1,600 feet thick and below it or to the east in the section is about 900 feet of calcareous and argillaceous schist and limestone and then the main quartzite series.

The face of No. 3 level is about 300 feet west of a point vertically under the crest of the ridge. The distance from the face easterly to the contact with the schists and limestones is about 550 feet. From about 125 feet from the face the vein should cut uniformly harder rocks than have so far been encountered. Whether oxidation will reach the depth of No. 3 level farther into the hill and whether ore-shoots will be found only development can prove. There is, however, favourable ground, so far as the rock formations are concerned, ahead of the present face for some 500 feet on No. 3 level.

Iron Cap

The Iron Cap is situated on the east side of Fawn creek at an elevation of 4,500 feet above sea-level and 200 feet above the creek.

The mineral occurrence is in limestone near the easterly contact of a mass of granite exposed on the Reno road from Sheep creek.

Attempts to expose the bedrock, heavily covered with overburden, by hydraulicking, have not met with much success. The dumps of two caved adits consisted of surface material and a few blocks of limestone. A shallow shaft 20 feet deep had 8 feet of water in it. It is sunk in a grey, banded limestone and shows disseminated galena and sphalerite with branches of galena across 6½ feet on the north side. The south side of the shaft shows no mineralization nor could any be found in a cut immediately to the south of it. The mineralization occurs as a small pocket. A cut 265 feet to the north and another 210 feet to the northeast show very little mineralization. Between the latter cut and the shaft are some exposures of limestone, but no mineralization. Three hundred and seventy feet southerly is a second shaft 30 feet deep sunk on an iron capping derived from the oxidation of a little pyrrhotite in silicified limestone. It is traceable northerly for 18 feet, then covered for 12 feet, and again exposed for 6 feet. One hundred and sixty feet along the strike a similar exposure is shown in a surface cut. An adit reported to be located to the south of the shaft and lower down the hillside was not examined.

Salmo Consolidated Mines, Limited

The Salmo Consolidated property is situated on the east side of Elk creek at an elevation of 5,200 feet above sea-level and 11 miles by road from Salmo. The property consists of four claims and two fractions.

Mineralization occurs in irregular veins in hornblende granite and with one exception these are small and unimportant. The hornblende granite outcrop is triangular in shape with the apex to the northeast and it is roughly 2,000 feet by 4,000 feet. The workings are near the middle of the western side of the granite.

The workings consist of an old shaft, some old surface cuts, three new adits, and some twenty surface cuts. The upper and greater part of the shaft, which is 116 feet in depth, has an easterly slope of 67 degrees and the lower part a slope of 52 degrees. The vein, which has an average dip of 56 degrees to 58 degrees, shows in the upper part of the shaft and in two crosscuts, one from the bottom of the shaft and one 20 feet up. It varies in width from 1 to 6 feet and shows a low-grade mineralization of sphalerite, galena, and pyrite in a quartz and calcite gangue.

The road level adit is on a level with the collar of the shaft and 25 feet north of it. The vein turns more easterly just within the portal and also flattens in dip to 40 degrees and less. It pinches and swells, the best showing having a length of about 35 feet and a greatest width of 3 feet, and dies out in 125 feet. Near the face of the adit a little galena and pyrite show above a joint in the granite and a little mineral can be seen in a crosscut close to the face. A crosscut to the south at 38 feet from the portal is barren.

One hundred and seventy-five feet southerly and 45 feet lower in elevation is a 75-foot adit opening up a small vein which has been drifted on for 23 feet. This vein, a few inches in width, is composed of milky quartz with some galena and pyrite and dips 59 degrees east. It is the downward continuation of a small showing exposed on the edge of the road immediately above and 85 feet south of the shaft. This little vein appears to be different from the one in the shaft, but considering its irregular trend it is possible that it is the southerly continuation.

A low level adit has been driven from a point 275 feet westerly and 160 feet lower in elevation than the road level adit. It intersects the vein at 360 feet from the portal at a point approximately 70 feet down the dip from the bottom of the shaft. The vein has been drifted on for 100 feet to the north and 150 feet to the south. As exposed in the north drift the vein is very irregular, really being lenses of vein matter in the granite. The greatest width shows 4 feet of vein matter with fine-grained galena, sphalerite, and pyrite, and 2 feet of vein matter and granite over a length of about 50 feet. A 30-foot raise shows the lens to pinch out 25 feet above the floor of the level. Another lens extending from the north drift into the south drift is about 60 feet long with a greatest width of 6 feet of vein matter and granite with lenses of sulphides. To the south is another short lens of vein matter and granite pinching and opening into another lens which is deflected easterly by a cross fracture. From the fracture to the face, a distance of 35 feet, the vein averages 1 foot to 18 inches in width and is composed of quartz, pyrite, and galena.

Out of nineteen surface cuts just above the road level adit but two show a little mineralization. Higher up the hill and east of these surface cuts is an old inclined working sunk on a quartz vein 1·3 feet wide carrying galena and striking 80 degrees east of north and dipping 45 degrees to the south. A small outcrop of quartz is exposed 60 feet north of the last showing with a strike of 80 degrees east of north and flat southerly dip. A long surface cut to the north is barren. Easterly from this cut at the summit of the ridge is a small cut showing a narrow quartz vein in granite with a strike of 70 degrees east of north and a high southerly dip. There is a little pile of mineralized quartz similar to that at the old incline, but none could be found in place. Some trenching has been done on the summit of the ridge but no bedrock is exposed.

Salmo-Malartic Mines, Limited

The Aspen property is situated near the head of Deer creek about 2½ miles by road beyond the H.B. group. The workings are located between elevations of 4,525 and 4,850 feet above sea-level. This property is first mentioned in the report of the British Columbia Minister of Mines for 1912 and again in the reports for 1913, 1917, 1918, and 1926 to 1928. It consists of six Crown-granted claims and five claims held on location. The property has been under the control of Salmo-Malartic Mines, Limited, of Toronto, since the autumn of 1927.

The property is located close to the easterly contact of a large area of granite exposed along the east side of Salmon valley south from Hidden creek. The granite forms an irregular contact with limestone and argillaceous rocks, many dykes and sills extending out from the main mass. The purer limestone in contact with these granitic tongues is ordinarily coarsely crystalline, but where the limestone contains argillaceous impurities it is altered to a hard, rusty rock. Mineralization occurs in some small slips in the limestone and in some places as sparsely disseminated specks. One small replacement has been exposed in development operations.

The most northerly working examined is an old prospect adit 57 feet in length, driven across a granite contact with limestone. The limestone is brecciated and shows evidence of oxidation above the contact, with a little pyrite and sphalerite mineralization near it. Two hundred and fifty feet southeasterly from this working a little galena, sphalerite, and pyrite occurring in small fractures and disseminated in a bed of limestone, have been exposed in a surface cut. One hundred and sixty feet southeasterly from this cut is an old inclined working the lower part of which is flooded. At the mouth of this incline is a small slip, strike 88 degrees, dip 60 degrees south, cutting across limestone striking approximately 335 degrees and dipping to the northeast. A little fine-grained sphalerite and galena can be seen in the limestone immediately below the slip. A small pile of ore indicates that a pocket occurred somewhere in this working.

Two hundred feet southeasterly from this working in No. 1 adit, a cut to the south of the portal shows a slip in limestone. About the slip, mineralization consisting of sphalerite and a little galena has a width of 2 feet, but does not go down and has no apparent length. The adit, 97 feet in length, cuts a little pyrite, sphalerite, and galena at 43 feet from the portal. A raise from this point to the surface could not be examined. An adit 61½ feet below No. 1 had been driven 210 feet at the time of the writer's visit in August, 1929. A raise connects it with No. 1 adit at the point of mineralization. A little pyrite, pyrrhotite, and galena occur as specks in the limestone near the face of this lower adit. A little mineralization was seen in the raise near the bottom and also about 50 feet up. Eleven open-cuts extending for 600 feet south of No. 1 adit were examined. No mineral could be seen in seven of these cuts. One cut exposed a small quartz vein with pyrite and specks of sphalerite.

A long adit has been driven 220 feet below No. 1 and about 500 feet south of it. It is 550 feet in length and has a crosscut 130 feet northwesterly at a point 50 feet from the face. This adit extends into the hill 300 feet beyond a point vertically below the open-cuts. A few specks of sphalerite were seen 285 feet from the portal. A little mineralization, chiefly pyrrhotite and pyrite, was seen in the first part of the crosscut.

Eight hundred feet southerly and 100 feet lower in elevation is "H" adit, an irregular working, in the form of a distorted letter H, with two portals. This working explores a belt of limestone between two masses of granite. A small lens of galena and sphalerite was encountered in this working and completely explored. It is almost flat-lying and fades out rapidly in all directions as exposed in the workings. Close to the north portal of this working is a small cut in limestone showing a brittle, metallic, grey mineral occurring in small seams. This mineral has not been definitely identified, but is one of the less common lead sulphantimonides. Some diamond drilling has been done up the hill from "H" adit following a Radiore survey, but the results have not been divulged to the writer.

It is evident from the foregoing that while the upper surface showings appear to have some alinement, no definite lead can be found and no continuity determined, the mineral occurrences being but small, detached mineralized slips.

Howard Mines, Limited

The Howard mine, formerly known as the Union Jack, is situated at an elevation of about 5,600 feet above sea-level on the east side of the south fork of Porcupine creek. The mine is reached by road from Ymir to the old compressor, a distance of 7 miles (5½ miles from railroad), and thence by trail a distance of 1·8 miles.

The property is developed by three levels at elevations of 5,467, 5,592, and 5,700 feet above sea-level. Some old workings higher up on the hill are partly open. North and west are an old adit and shaft on two quartz veins in granite.

No. 1 level, elevation 5,700 feet, is driven along a fracture or fault in hard, massive quartzites intruded near the portal by granite. This fracture is known as the Queen vein. The adit follows it for 315 feet and then turns southerly cutting at a distance of 45 feet a rock of dioritic nature which it passes through for 11 feet then cuts 15 feet of limestone, again turning easterly for 48 feet through the dioritic rock and limestone. This limestone has not been encountered elsewhere in the workings. Had the working followed the Queen fracture it is probable that information throwing some light on the displacement might have been gained. At 150 feet from the portal ore was opened on the north side of the Queen fracture and drifted on for 270 feet. The first 105 feet was through quartzite, then a 10-foot tongue of granite, again quartzite for 38 feet, with 20 feet of granite showing in the east wall, then 18 feet of either quartzite or silicified granite, and finally granite for 90 feet to the face with one or two small remnants of quartzite. It is evident that this drift has been driven northerly across a southerly dipping and very irregular granite contact with quartzites. Mineralization dies out very quickly within the granite. It occurs along a fissure strike approximately 16 degrees east of north and dip 40 degrees to 45 degrees west, cutting across the granite-quartzite contact. In the face this fissure is very narrow, containing a little pyrite and tourmaline and showing alteration of the granite. Coming southerly along the fissure toward the quartzite contact mineralization becomes more pronounced and the granite shows intense silicification. Under the microscope it shows a complete alteration from granite to a siliceous rock in which all trace of the original constituents has disappeared. This intense silicification has accompanied or immediately preceded mineralization and has taken place after complete crystallization and fracturing of the granite and is found only along fissuring. Mineralization, accompanied or preceded by silicification, has replaced the wall-rock, forming a replacement fissure vein. Mineralization consists of pyrrhotite, pyrite, sphalerite, and galena, with gold values.

The manner in which the granite is exposed in this drift for 90 feet south of the main contact indicates that it underlies the quartzites at shallow depths. From the manner in which the mineralization dies out in the granite it is not to be expected that it will extend to any depth in this area. There is, however, a possibility of backs in this area. With the fissure dipping 40 degrees west and the hillside having a slope of 30 degrees in the same direction, and allowing for 40 feet of surface material, it is possible to obtain 120 feet or more of backs. No raising, however, has been done to prove the continuity of the mineralization up the fissure in this area. The 105 feet of mineralization from the most southerly granite exposure to the Queen fracture has possibilities of some depth which has been proved for 40 feet at the south end. A few feet of stoping has been done in this section, but not sufficient to prove the backs which have possibilities comparable to the last section described. The mineralization appears to show a drag at the Queen fracture indicating that the north side moved west. No mineralization has so far been found to the south of the Queen fracture indicating a continuation of the mineralization across it. The problem offers two explanations: (1) that the southerly dipping Queen fracture is pre-mineral, that the north-south fissure tended to die out away from the granite toward the Queen fracture and that mineralizing solutions rising along the north-south fissure managed to work their way along the fissure through replacement as far as the Queen fracture but found it an impassable barrier, thus being confined to the north or under side; and (2) that the Queen fracture is post-mineral and that there has been considerable displacement along it. The quartzites exposed in the workings do not display any characteristics by which displacement can be estimated. The manner in which the granite is cut off in No. 2 level does indicate displacement.

The Queen fracture shows little mineralization in No. 1 level, but stronger mineralization in surface workings above this level occurs in what is undoubtedly the Queen fracture.

No. 2 level, 107 feet vertically below No. 1 level, is a very irregular working. The Queen fracture was encountered after driving through 105 feet of wash and granite. At 70 feet from the portal a crosscut to the south intersected the Queen fracture which was opened up for a length of 20 feet, showing some quartz and mineralization. The Queen fracture at this point represents a faulted contact between quartzites to the south and granite to the north. Commencing again at 105 feet from the portal the Queen fracture was followed to 240 feet from the portal with granite on the north wall to 156 feet and quartzites elsewhere. About 135 feet from the portal quartz and mineralization appeared in the fracture and a small stope was made. At 240 feet from the portal the fracture is indistinct, turns abruptly south and then east as exposed in a crosscut to the south at this point. The main working was turned north at 240 feet from the portal and encountering mineralization followed it for 60 feet where it was cut off by a fault closely paralleled by a mica dyke. This fault cuts the mineralization at a small angle and has a more westerly trend. About 12 feet of granite shows in the west wall of the working south of the fault. A small stope was made on the mineralization just south of the fault which it came up against. The working was continued north of the fault for 45 feet and then turned westerly for 18 feet without results. The working was next driven easterly from the fault, showing granite for 30 feet in the north wall and quartzites in the south wall, and then quartzites in both walls for 60 feet, then granite for 36 feet. At 60 feet from the fault a small fracture showing specks of mineralization was encountered and drifted on for 18 feet northerly when granite was exposed, and for 15 feet southerly. This fracture strikes 35 degrees east of north and dips 70 degrees to the northwest and occurs at a point where the downward extension of No. 1 level ore-body would appear in this level provided its average dip was maintained. The main working was continued south-westerly from the last mentioned point for 90 feet in granite to a point underneath and to the east of the mineralization on No. 1 level. From a point directly underneath the mineralization on No. 1 level a working was turned southerly for 95 feet, passing out of granite into quartzite at 17 feet, entering granite again at 35 feet, and again quartzites at 53 feet. At 36 feet a raise with 70-degree slope to the west was put up encountering mineralization at 80 feet on the slope, then turned easterly following the dip of mineralization to a point on No. 1 level at the south end of the mineralization. A sub-level 54 feet vertically above No. 2 level was driven southerly for 50 feet. Continuing again on No. 2 level the working was turned westerly for 100 feet in quartzites except for a 12-foot tongue of granite at 9 feet. Mica lamprophyre dykes, striking 347 degrees, dipping high to the northeast, and accompanied by gouge and crushing of the country rock, were cut at 65 and 74 feet. Another lamprophyre, striking 320 degrees and dipping 75 degrees to the northeast, was cut at 83 feet. No sign of the Queen fracture has been found in this part of the working, which was driven southerly to find it, unless the shearing associated with the lamprophyres should prove to be the Queen fracture bending northerly at the point exposed. It is evident that the first dyke and fault encountered in this level connect with the lamprophyres and shearing just mentioned, in which case the fault cutting off the mineralization might be a split from the Queen fracture occurring north of the last mentioned exposure. If such has been the case then it is apparent that movement had first been along the main Queen fracture, the north wall moving west relatively to the south wall, and then movement in the same direction along the Queen fracture and the northerly split. An alternative is that the faulting associated with the lamprophyres has cut the Queen fracture, causing the west wall to move north relatively to the east wall. According to the first hypothesis the mineralization on No. 2 level would have no relation to that on No. 1 level, but would be an entirely separate occurrence. According to the second hypothesis the mineralization on No. 2 level would in all probability be the downward continuation of that on No. 1 level.

No. 3 level, 125 feet vertically below No. 2 level, had been driven, at the time of the writer's visit in August, 1929, a distance of 337 feet. The first 135 feet is driven southeasterly through quartzites and one granite tongue, then northwesterly for 60 feet through granite, a little mineralization showing along 40 feet, then southeasterly for 150 feet in granite. This level is apparently south of the Queen fracture.

H.B. Mine

The H.B. mine, owned by the Consolidated Mining and Smelting Company of Canada, is situated on the west side of Deer creek between elevations of 3,250 and 4,200 feet above sea-level and distant about 8½ miles by road from Salmo. This property (which includes the Zincton), first mentioned in the report of the British Columbia Minister of Mines for 1911, has been developed and mined by various interests up until 1927, a total of some 17,000 tons of zinc and lead carbonate ores being shipped to the smelter.

The property has been developed by two main adit levels, two sub-levels, two minor adits, several shafts, and a long low-level adit.

No. 2 level, elevation 3,920 feet above sea-level, is a 600-foot crosscut with drifts north and south for 480 and 400 feet respectively from points 416 and 400 feet from the portal. The last 240 feet of the north drift has caved and the ground is caving toward the main crosscut. This level has developed an oxidized ore-body which appears to have been a disseminated replacement in limestone. This oxidized replacement is fairly regular, has a greatest width of about 60 feet in the south workings, splitting and narrowing toward the north. Stoping indicates that 16 feet was about the greatest width of commercial ore when mining operations were being carried on. No. 2 level was connected by shafts with Nos. 1 and 3 sub-levels from a point 220 feet south of the main crosscut. These workings are now caved. No. 3 sub-level, 100 (?) feet below No. 2, apparently explored the ground beneath the southerly drift on No. 2 and is reported to have been in oxidized ore. Most of the stoping has been done between No. 2 level and the surface, a large part of the ground apparently having been stoped out.

No. 4 level, 300 feet vertically below No. 2, is a 1,132-foot crosscut with some 3,000 feet of irregular workings extending 500 feet north and south from a point 776 feet from the portal. This level has fully explored the ground below No. 2 level and has exposed irregular sulphide mineralization of low grade, chiefly pyrite, sphalerite, and galena; 60 feet at the extreme north end is in oxidized ground.

No. 7 level, 280 feet vertically below No. 4, has been driven from creek level a distance of 1,945 feet to a point vertically below and about 80 feet south of the face of No. 4 level main crosscut. Some diamond drilling has been done from this level. The whole working is practically barren of any sign of mineralization.

The regularity displayed in No. 2 level is lacking in No. 4 and mineralization is practically absent in No. 7. The deduction is that the upper working exposed the oxidation in place, with some enrichment, of an ore-body which may be described as having been a disseminated replacement in limestone, and that the irregularity of sulphide mineralization exposed in No. 4 level and its absence in No. 7 indicate a feathering out of this ore-body in the vicinity of the No. 4 level. The depth of oxidation is unknown, except that No. 3 sub-level is reported to have been in oxidized ore and that a small area of oxidized ground appears in the north end of No. 4 level. Oxidation appears, therefore, to die out somewhere between 260 and 450 feet from the surface. The chief value in both oxide and sulphide ore is in zinc. Some lead oxides as well as mixed oxides have been mined, but so far as the writer can ascertain lead values were mostly near the surface and decreased with depth. Surface cuts in parallel bands of limestone above and to the west of the H.B. outcrops show a little sphalerite. Tracing these limestone bands south into Sheep creek, surface cuts on the Black Jack and Legal Tender properties show low-grade zinc mineralization extending sporadically over a vertical depth of about 1,200 feet in a southerly direction. The southerly exposures of the H.B. limestones on the Sheep Creek slope are barren of mineralization wherever the writer has examined them. For nearly a mile and a half north of the H.B. workings to the granite contact, exposed on the surface, the ground is heavily covered with but a few outcrops of dykes and metamorphosed argillaceous sediments, the limestones being completely masked in this direction.

On the south side of Sheep creek opposite the Black Jack and Legal Tender is the Lucky Boy property. Several surface cuts and small workings expose low-grade zinc mineralization in limestone similar to that on the north side of the creek.

Two miles farther south is the Emerald mine, a bedded lead-zinc replacement in limestone. All of these properties are located on a broken anticlinal structure.

Emerald Mine

The Emerald mine is situated at an elevation of 4,400 feet above sea-level on the ridge between Sheep and Lost creeks, overlooking Salmon valley and distant almost 8 miles by road from Salmo. The grade from the main highway at Sheep creek to the mine is very heavy.

This property, first mentioned in the report of the British Columbia Minister of Mines for 1907, was a steady producer, in a small way, of lead ore until 1925. Exploratory work and diamond-drilling were done in 1926, after which the property was closed down. A Radiore survey was carried out in 1929, the results of which are unknown to the writer.

The main level of the Emerald, elevation 4,420 feet, is a crosscut to the east of 584 feet and thence a drift to the south for about 1,000 feet, with four short crosscuts east from it.

The south drift located the downward extension of the mineralization developed in the upper workings about 150 feet south of the main crosscut. It is a bedded replacement in limestone of sphalerite, galena, and pyrite, occurring along this drift as lenses of 1 to 2 feet in thickness. The first three easterly crosscuts have exposed a parallel mineralization which has been stoped out to the north of the first crosscut.

A sub-level, 45 feet above the main level, has a length of 750 feet, of which 120 feet is to the north of the main crosscut and the remainder to the south. Most of the commercial ore has been mined out between this and the main level. Another sub-level 79 feet above the last one has a length of 360 feet to the north of the main crosscut and is now open for 150 feet south. The ground between this and the last sub-level has been largely mined out. Mineralization in the north end of the level becomes less massive, more banded, and lower in grade. Another sub-level 47 feet above the last one extends 360 feet north of the main crosscut. The extent to the south is not known to the writer. From this level to the surface, following the ore, is 86 feet on a 24 degrees slope. Most of the ground between this and the last level and the surface has been mined out.

Mineralization dips easterly with the dip of the limestone becoming steeper from the surface down the dip, but showing small rolls throughout the workings. The sulphides have been partly oxidized near the surface and oxidation gradually dies out until there is little evidence of it on the main level.

From an examination of the old stopes and the different levels it is apparent that mineralization is fading out with depth and also that the proportion of zinc tends to rise. It is also apparent that nearly all of the commercial ore developed has been mined out. The property is equipped with camp buildings and a 50-ton mill erected in 1919, also a small sawmill, both run with steam power.

Molly Molybdenite

The Molly Molybdenite property is situated on the south side of Lost creek at an elevation of 3,600 feet, 600 feet above the creek, and about 3 miles from the International highway. The distance to Salmo is a little over 12 miles.

This property was developed during the war and over 200 tons of ore treated at different plants, including the Department of Mines, Ottawa, The International Molybdenum Company, Renfrew, Ont., and Henry E. Wood Ore Testing Company, Denver, Colorado. The Consolidated Mining and Smelting Company of Canada acquired the property in 1926.

The property has been partly developed by open-cuts, diamond drilling, and a short adit and raise. The property is located on the west end of a large area of granite outcropping for 4 miles along Lost creek and averaging a mile in width. This granite area is only part of a large mass that outcrops again to the south and north. The contact at the Molly runs a little east of south up the hill to an elevation of 4,000 feet, when it turns east for a little over 1,500 feet and again turns south. To the west of the Molly the sediments outcrop for about 1,200 feet, when granite outcrops westerly for about 1,100 feet and up the hill to elevations of 3,600 to 3,700 feet.

The granite is jointed or sheeted more or less parallel to its surface contact with the sediments. The molybdenite occurs in the granite close to the contact and particularly so in a sheeted zone having a maximum observed width of 10 feet. The best ore appears to be at a point on the contact where it begins to flatten toward the top of the granite.

The northerly extension of the best mineralization appears to have been eroded away as the contact strikes down the hillside. The most favourable ground not yet exposed would appear to be south along the contact into the hill about the level of the open-cuts. Some diamond drilling has been done in this direction, but the results are unknown to the writer.

CLEARWATER LAKE AREA, BRITISH COLUMBIA

By N. F. G. Davis

CONTENTS

INTRODUCTION

Clearwater Lake area is part of a wide belt of unexplored territory in the northwest corner of Kamloops mining division in north latitude 52° 10′ to 52° 40′ and west longitude 119° 40′ to 120° 20′. It lies near the border between the Columbia system of mountain ranges and the region of Interior plateaux and is drained by the headwaters of North Thompson river and its tributary the Clearwater. Trappers entering the district in search of furs returned to prospect and latterly the staking of claims on Hobson creek and near the head of Azure river aroused interest.

The area can be approached from three directions.

(1) A trail leaves the Canadian National railways at the junction of Albreda and North Thompson rivers approximately 3 miles north of Lempriere station. This trail follows the north bank of North Thompson river for approximately 25 miles, then crosses a divide between North Thompson and Azure waters and leads to some mineral claims near the head of Azure river. It is 40 miles long, has many steep grades, and hazardous mud-holes. (2) From Clearwater station on the Canadian National railways, a wagon road follows a high bench on the east side of Clearwater river for 12 miles, thence a good pack trail continues up Clearwater valley for approximately 35 miles to the south end of Clearwater lake. From the south end of Clearwater lake travel is by boat or canoe. (3) The district may also be entered from the west by way of Quesnel lake. A trail approximately 7 miles long connects the east end of Quesnel lake with Hobson lake.

During the summers of 1927 and 1928 geological and topographical reconnaissance surveys were carried out in this area, the work being under the charge of J. R. Marshall to whom the writer acted as assistant. In 1927 the area was approached by the valley of North Thompson river and an area mapped near the head of Azure river. In 1928 the district was entered by Clearwater River valley and a considerable area was surveyed.

It was not possible to join this survey with the survey of the preceding summer because of the nature of the intervening country. The accompanying maps (Figures 20 and 21) are by J. R. Marshall, chief of the party.

No previous geological investigations of this area or any immediately adjacent areas have been made. The earliest and nearest approach to the area was made by A. R. C. Selwyn who in 1871 made a traverse up North Thompson River valley from Kamloops to Tête Jaune.[1] More recent work has been carried on by the Geological Survey in areas more or less distant, but geologically similar. W. L. Uglow worked in North Thompson Valley map-area which lies 60 miles to the south.[2] W. A. Johnston and W. L. Uglow surveyed Barkerville area which lies 60 miles to the northwest.[3] In 1923 the area was visited by A. W. Davis, Resident Mining Engineer for the central district, who gives a brief description of the claims with suggestions as to improved communications.[4] In 1927 it was again visited by the present Resident Engineer, H. G. Nichols, who gives some notes on the geology of the claims.[5] J. R. Marshall has given a brief account of the results obtained during the 1927 field season.[6]

Grateful acknowledgment is made to Angus Horne, G. W. Stewart, Adolf Anderson, Norman Anderson, R. Buchanan, of Blue River; W. E. Noble, Forestry Officer, Birch Island; W. S. Drewry, F. C. Green, of Victoria, and H. G. Nichols, Resident Mining Engineer, Kamloops, B.C., for much helpful advice and courtesies extended. Sincere thanks are tendered to Mr. Marshall and to A. H. Lang, O. Richmond, W. A. S. Fraser, H. M. Thomas, and N. F. G. Brooks, assistants to Mr. Marshall, for help rendered. Laboratory work was done by the writer at Princeton University and grateful thanks are extended to the faculty and graduate students of the Department of Geology, particularly Professors E. Sampson and A. F. Buddington, under whose direct supervision the work was done.

GENERAL CHARACTER OF THE AREA

CLIMATE, FLORA, AND FAUNA

The area lies in a belt of heavy precipitation. During the summer of 1927 rain fell almost continually in North Thompson and Azure Rivers valleys, from the beginning of June to the middle of July, and from August 25 to September 20, when work was discontinued for the season. In 1928 in Clearwater valley there were frequent rains of three and four day periods during June and July. The dense foliage and underbrush in the valley bottoms suggest heavy annual precipitation. Trappers and prospectors familiar with the district report that July and August are as a rule dry and warm. The snowfall in the winter months is heavy, as much as 14 feet in the valley bottoms.

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[1] Selwyn, A. R. C.: Geol. Surv., Canada, Rept. of Prog. 1871-72.
[2] Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 72.
[3] Johnston, W. A., and Uglow, W. L.: "Placer and Vein Gold Deposits of Barkerville, Cariboo District, British Columbia"; Geol. Surv., Canada, Mem. 149 (1926).
[4] Ann. Rept., Minister of Mines, B.C., 1923, pt. A, pp. 155-59.
[5] Ann. Rept., Minister of Mines, B.C., 1927, pt. C, pp. 192-195.
[6] Sum. Rept. 1927, pt. A, pp. 42-46.

Timber-line is at 6,500 to 7,000 feet altitude. North Thompson River valley and the region of the lakes is densely timbered, but timber is sparse at the head of Azure river. The timber is not uniform and as a rule not of commercial value with the exception of cedar in North Thompson valley. Devastation by intermittent fires is noticeable and parts have been burned off almost completely.

Near timber-line common juniper, mountain pine, and spruce exist. In the lower valleys red cedar, spruce, hemlock, and fir grow to considerable size. Poplar, cottonwood, birch, willow, and alder occur along the stream courses. On dry, sandy flats, jackpine grows. In swampy hollows devil's club and skunk cabbage make traverse uncomfortable. Huckleberry and blueberry bushes are plentiful on sunny slopes and particularly along the west shore of Clearwater lake.

Of the larger game animals caribou are the most plentiful. Herds of thirty individuals have been seen on the large snowfields. These animals summer in the alpine meadows near the snow and winter near the lakes. Deer are found particularly on the low flats west of Clearwater lake. Goats are common on the high ridges and steep, grassy slopes. Bears, both black and grizzly, are present but not commonly seen. Coyotes are heard frequently. Of the smaller animals, whistling marmots are abundant on the rocky summits, porcupines, skunks, squirrels, chipmunks, and bush rats are common. The trap-lines yield beaver, marten, fisher, lynx, weasel, and an occasional wolverine. Of the game birds blue, willow, and Franklin grouse are common and ptarmigan are seen on the rocky summits. Rainbow and cut-throat trout are abundant in Azure and Clearwater lakes.

TOPOGRAPHY

Clearwater Lake area is in the southern part of Cariboo Mountain area in the transitional zone between the main range and the country to the west. It is bordered on the north and east by mountain masses. To the south it ends in low ridges running down Clearwater River valley. On the west it is bounded by the valleys of Clearwater and Hobson lakes, beyond which lie irregular mountain groups and the plateau country.

The area is deeply dissected. In the northern part, North Thompson River valley where its floor stands at 4,000 feet altitude, is bordered on both sides by peaks which rise to heights of from 9,000 to 11,000 feet. The lakes making the west boundary stand at altitudes of 2,200 and 2,800 feet and peaks east of the lakes rise to altitudes of 8,000 and 9,000 feet. The central part of the area stands at general altitudes of from 7,000 to 9,000 feet. Some deep canyons enter this part, but in most of the central part ice-fields lie between the peaks and ridges.

The area is divided into blocks of upland surface by large, deep valleys such as those of North Thompson river and Clearwater lakes. Where the large valleys cut into the area, a distinct topographic unconformity is seen in places between the upland surface and the steep valley walls. In most places, however, this break is indistinct being masked by an ice edge or the effect of active glaciers. The break is found near the 7,000-foot level above which the peaks and ridges rise to altitudes of 8,000 and 9,000 feet. In the northern and central parts of the area the upland surface is less cut

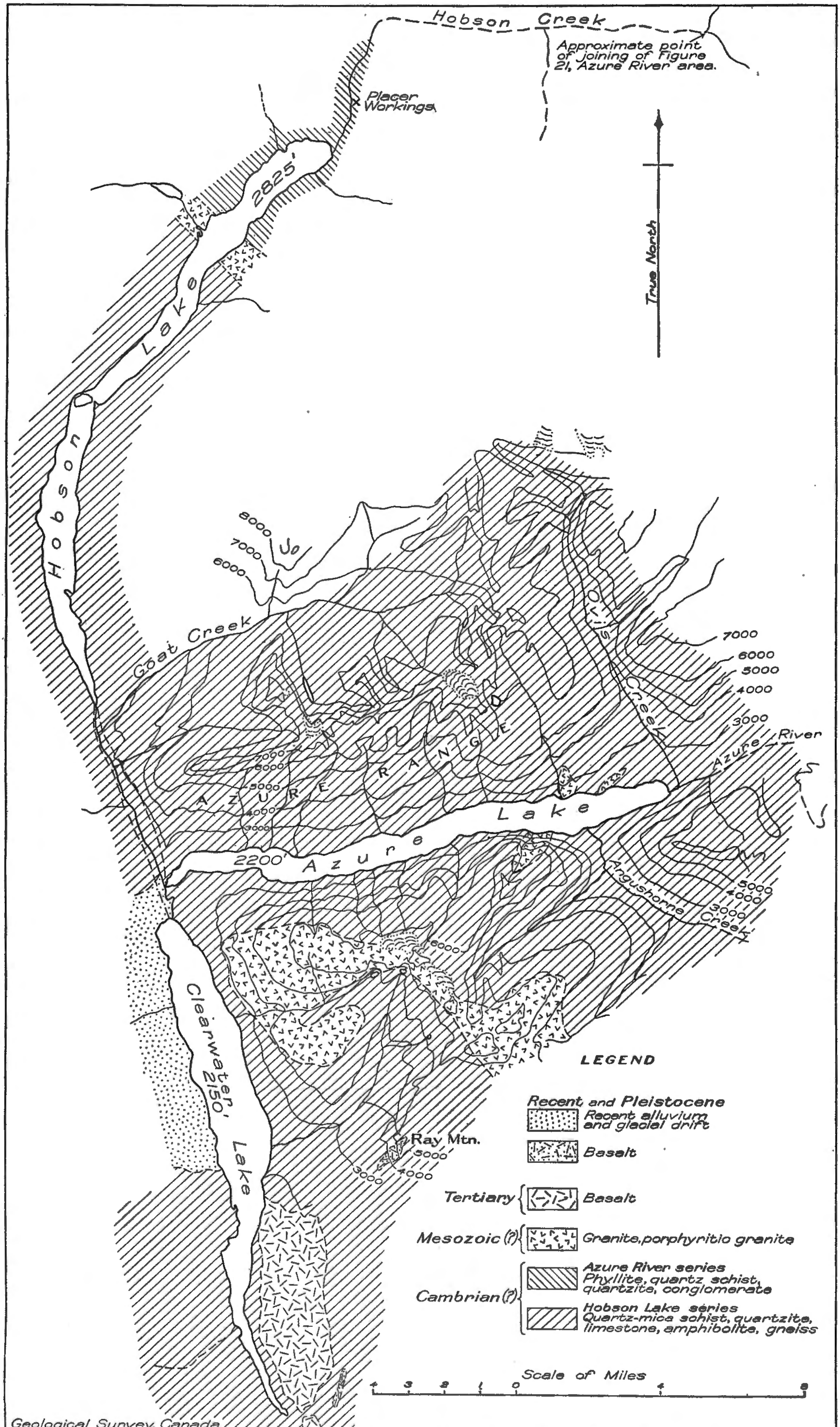

Figure 20. Azure Lake area, Kamloops district, B.C.

into by large valleys, the general altitude is slightly higher than in the south, and more extensive ice-fields exist. In the southern part a short range which parallels Azure lake on the north side stands out as a fairly definite topographic feature. It is about 12 miles long and the average summit level is 8,000 feet. At its west end a spur extends north and culminates in a peak over 9,000 feet in altitude.

South of Azure lake the peaks and ridges are irregular and deeply incised and still farther south there is an abrupt change, the surface dropping to the level of Tertiary lava flats and of low ridges which continue south on down Clearwater River valley.

The upland surface gives no indication of accordance of summit level suggestive of an uplifted plain. It appears, rather, to be a tract in which structure and character of the underlying formations have exerted a great influence on the configuration of the present surface. Possibly the intensity of active mountain glaciation precludes the recognition of any previously formed surface.

North Thompson river drains the northeastern part of the area. Its source is in ice-fields from which it flows southeast for 3 miles, then turns and flows more directly east for 30 miles to where it is joined by Albreda river from the north. Peaks on whose sides rest the glaciers that feed the headwaters of the river, rise to altitudes of over 11,000 feet. The tributary streams at its head drop abruptly into the valley whose floor within 2 miles of the ice stands at 4,000 feet altitude. From here to the mouth of Albreda river the average drop of the stream is 40 feet to the mile. The valley floor is wide in places containing swamps and low ridges of glacial material. In other places, small rock canyons are cut in the floor of the valley.

North Thompson River valley shows the effects of glaciation in that it is roughly U-shaped, projecting spurs are truncated, and till occurs in the bottom and along the sides. Rough terraces have been cut in the glacial filling and some tributaries come in through small gorges in the glacial gravels. The valley is large in proportion to the size of the stream it contains and is even more out of proportion compared with the valleys of its tributaries, many of which are hanging.

Clearwater river is one of the main tributaries of the North Thompson. It drains the lakes that lie on the west side of the area and that receive most of the drainage from the central, southern, and western parts of the area. It flows from the south end of Clearwater lake directly south for about 50 miles to join North Thompson river. The average drop a mile for the 50 miles is 18 feet. The river has some long, quiet stretches, but there are numerous rapids and canyons. The northern part of the valley is from 5 to 6 miles wide, but the valley narrows where it joins the North Thompson to a mile in width. In the northern part low ridges stand out in the valley floor. The valley is bordered to the west by the plateau country, above which rise some higher ridges.

Along the lower two-thirds of Clearwater river precipitous cliffs of Tertiary volcanic rock form the valley walls, producing a distinct inner and outer valley. Above the lava surface the valley sides rise much more gradually to the bordering ridges. Tributary streams come in over waterfalls entirely cut in lava. The greatest of these is Helmcken falls on Murtle river, a stream that enters the Clearwater about 25 miles from its mouth. These falls are reported to be 465 feet high. The topographic unconformity between the upper slopes of the valley and the lava surface is noticeable. Underneath the lavas are beds of conglomerate of Middle or Upper Eocene age, so that the surface underneath the lavas is that of an Eocene or still older valley.

Azure river has its source in the northern part of the area and flows south and then southwest into the east end of Azure lake. The valley at its head is a glacially scoured through-valley in which the divide separates the Azure River waters from streams that flow into Raush river. This valley at the divide is U-shaped and floored by grassy meadows about one-

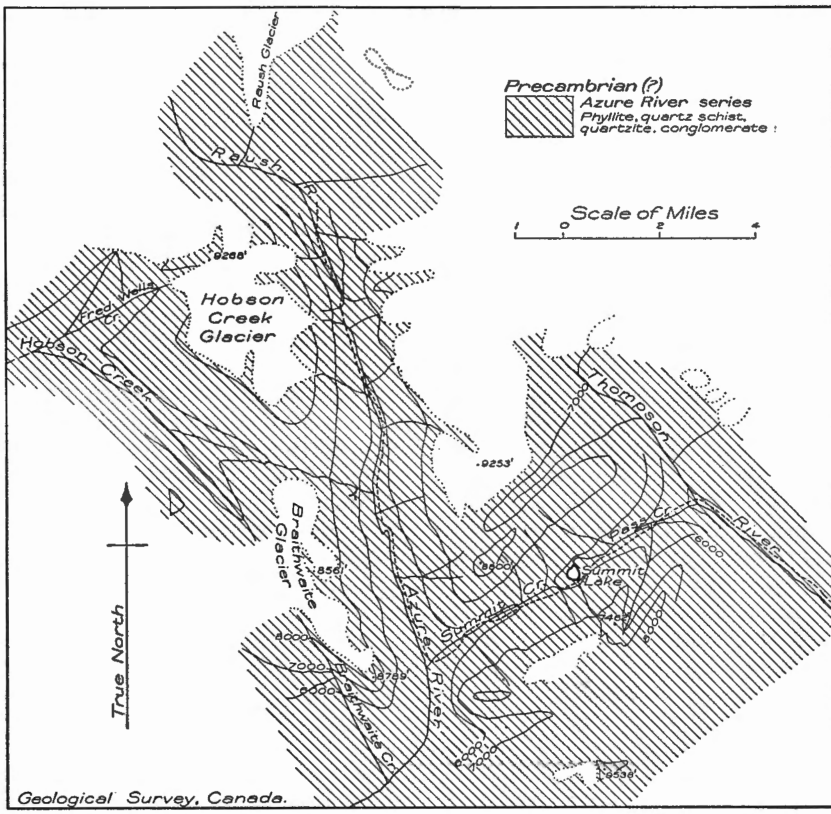

Figure 21. Azure River headwaters area, Kamloops district, B.C.

half a mile wide, which stand at an altitude of 6,100 feet. The average drop a mile for the length of Azure river is approximately 150 feet. Approximately 8 miles from the head, the main stream turns southwest into a rock canyon and within the mile to the point where it is joined by Braithwaite creek, it drops 1,000 feet. The valley of Braithwaite creek is deeper than that of the present main stream which is hanging with respect to Braithwaite Creek valley. From the mouth of Braithwaite creek to within a few miles of Azure lake the valley is wide and steep-walled and the stream is reported to flow in a deep canyon in the valley floor. For 5 miles above the lake the valley is a mile or so wide with a flat bottom covered with gravel and silt. The stream is continually shifting its course over this flat and building the material out into the lake.

Other main valleys in the area are those of Raush and Angushorne rivers and Hobson creek. Baush river has its main source in the large Raush glacier lying north of the meadows at the head of Azure river. Some of the waters from these meadows flow north, dropping down a series of cataracts in a deep canyon and joining the main stream from the Raush glacier about 3 miles from the meadows. In the 3 miles the stream drops 2,000 feet. The main river then flows northwest for about 3 miles in a wide, flat, swampy-bottomed valley. It then turns north and flows approximately 40 miles to join Fraser river, Angushorne river rises in Angushorne lake and flows northwesterly into the east end of Azure lake which it enters over a series of waterfalls. The valley is wide, steep-walled, and the river occupies a deep canyon in the floor. The valley is densely timbered. Hobson creek flows west from the glaciers on the ridge west of the head of Azure river for 9 miles, then turns southwest into the north end of Hobson lake. The valley contains glacial till to a depth of 150 feet in places and the stream occupies a gorge cut in this material and has in many places just cut down to bedrock. The creek is building a large delta out into the lake. Two other large creeks are contributing to this delta, with the result that the north end of the lake is being filled in and the lake water is turbid for over a mile from the north shore.

Hobson lake is the most northerly of the Clearwater Lake group. It is about 18 miles long and averages 1 mile in width, varying from 2 miles in the widest part to a few hundred yards at the south end. The northern half trends southwest. It then turns, where it is greatly narrowed by an island near the west shore, and stretches south for the rest of its length. The shore line of the northern part is abrupt, cliffs rising from the water except where large creeks enter. The shoreline of the southern part is less abrupt and sand and boulder beaches are revealed when the lake level is low. The ridges surrounding the southern part of the lake are lower and their slopes less steep than those to the north. A river drains the lake from the south end and flows south for 7 miles into the north end of Clearwater lake. In this length it drops 600 feet. About one mile above its mouth a short river, 500 feet long, enters from the west end of Azure lake. The river is navigable between Clearwater and Azure lakes, but no farther.

Azure lake is the only east-west trending lake of the group. Its west end is only one-quarter of a mile north of the north end of Clearwater lake. It is about 15 miles long and averages a mile in width. There are few beaches and most of the shoreline is made by steep slopes or cliffs, some of which rise vertically from 150 to 200 feet above the water's edge. Only at the east end and along the north shore near the west end, are sizable beaches being formed from material brought in by streams. The lake lies in a rock basin which has evidently been greatly overdeepened by the action of a valley glacier. Most streams enter the lake over waterfalls, the largest of which are Angushorne falls near the east end, and Rainbow falls about half-way along the south shore. Where deltas are being formed the bedrock is seen to drop off abruptly. All the tributary streams have hanging valleys with respect to the bottom of the lake.

Clearwater lake is the southernmost lake of the group. It is 16 miles long, has an average width of 1½ miles in the northern half but narrows to less than a mile in the southern half and a few hundred yards at the south end. Its northern half occupies the east side of a wide valley whose floor is partly covered by glacial and stream deposits. The east shore is made by steep rock slopes. The west shore is of unconsolidated glacial and stream deposits. It rises steeply for 400 feet, beyond which a flat, occupied by small lakes, stretches west for 6 to 8 miles to a group of high mountains. Streams coming into the lake from the west cut deep gorges in the unconsolidated material. Streams coming in from the east occupy hanging valleys. The shoreline of the southern half is entirely in bedrock and the form of the valley and bordering ridges shows alinement and modification by ice-action. At the foot of the lake is a waterfall with a 10-foot drop where the water spills over a flow of Recent lava.

Along the west side of the lake a small terrace, about 10 feet above the lake level, is cut in the loose, unconsolidated material. There is no corresponding terrace on the steep rock banks of the east side. The river flowing from the south end of the lake occupies a channel along the east side of a narrow valley, leaving, on the west side, a narrow flat of Recent volcanics standing about 10 feet above lake-level. This flat surface in places shows current marks, and at its south end an abandoned waterfall. It appears that the Recent lavas dammed back the lake waters, raising the level about 10 feet above the present level.

GLACIATION

The most striking features of the upland in the area are those produced by active mountain glaciation, whereas the deeper valleys show the erosional and depositional effects of a much more extensive glaciation. Much of the upland surface is covered by ice-fields and large glaciers descend to as low as 4,000 feet altitude. Pyramidal-shaped peaks rise above the ice in places and long ridges lead away from them in all directions. One particularly fine, spire-like peak rises well over 9,000 feet altitude to the north of the ridge west of the head of Azure river. Both sides of the short range north of Azure lake are dissected by cirques. The difference in development of cirques on the north and south slopes is noticeable. On the north slope the cirques are deep, steep-walled, most of them contain tarns, and glaciers exist at their heads. Those on the south slope are shallower, contain no ice, as grassy slopes rise as high as 7,000 feet. Cols on the north slope are steep and knife-edged, whereas those on the south are low and rounded. The arrêtés between the heads of the cirques fall off vertically to the north, but slope gradually to the south.

Many large glaciers descend from the extensive ice-fields at the heads of North Thompson and Azure rivers. They are retreating and only small remnants are left in the southern part of the area. The Raush glacier at the head of Raush river is the most magnificent one in the area. It is a hanging glacier with a great ice-fall at the lower end bringing the ice down to an altitude of 4,100 feet. The glacier is receding and cutting down into its old ground moraine, leaving cut-banks from 100 to 150 feet high along the sides of the valley immediately ahead of the present ice-front. The glacier at the head of Hobson creek has retreated to its rock basin. A deeply grooved and polished rock pavement lies in front of the ice. On the sides irregular moraines are forming. Many of the glaciers peripheral to the ice-fields in the central part of the area descend in deep canyons to low altitudes, some below 4,000 feet.

The greater extent of a former glaciation is shown by U-shaped valleys, hanging valleys, faceted spurs, overdeepening of lake basins, glaciated ridges, and glacial fill and moraines on the valley floors. The valleys of the main drainage channels of the area are all U-shaped. Many of the valleys tributary to them and most of the smaller valleys tributary to the lakes are hanging. Spurs projecting into the main valleys are truncated. Particularly good examples of faceted spurs are those in the valley of Goat creek. None of the lakes show a drowned coast, which they would if an ordinary valley were flooded by damming. Many of the streams enter Azure lake over waterfalls. All the streams have hanging valleys with respect to the bottom of the lake. Where deltas are forming the bedrock falls off steeply. Low, rounded ridges, particularly in Clearwater valley, stand out on the valley floor and trend parallel to the valley walls. The valleys of North Thompson, Raush, and Clearwater rivers, and Hobson creek are filled with till to considerable depths. In North Thompson valley morainal ridges flank the sides, terraces are cut in the till, and many tributaries enter through gorges in the glacial gravels. In Hobson Creek valley the present stream shows cut-banks from 100 to 150 feet high in glacial material. The wide valley at the head of the Clearwater, north of the Tertiary lava limit, is filled with glacial and stream deposits to a depth of over 300 feet. Farther south in the valley small ridges of morainal material parallel the general direction of the valley and erractics of metamorphic rock are found many miles south of its main outcropping.

The character and structure of the underlying formations have noticeably affected the configuration of the present surface. On the upland surface where underlain by the metamorphic series the peaks are sharp and the ridges continuous, where underlain by granite the peaks are more massive and rounded and the ridges irregular or radiating from a central mass. The ridges on the east side of Azure river follow along the axis of an anticline; where composed of hard quartzite the ridges are sharp, where composed of phyllites they are rounded. The short range paralleling the north side of Azure lake follows the axis of another anticline. North of this lies the central part of the area which was not studied in detail, but the long ridges that project above the ice seem to bear some relation to structure. South of Azure lake the peaks are rounded and the ridges irregular in direction and not continuous, showing the effect of the underlying granite batholith. The flats in Clearwater valley are the surface of lava flows.

North Thompson river from within 3 miles of its head to the mouth of Albreda river, flows generally along the strike of the rocks. Raush river from Raush glacier flows 3 miles along the strike of the rocks, then turns rather abruptly. Tributary streams coming into the meadows at the head of Azure river are cutting at right angles across the strike of the beds along cross-fractures. Many of the small streams in the area show this right-angle relationship, some flowing along the strike, others in the direction of the cross-fracturing.

GENERAL GEOLOGY

The oldest rocks found in the area are sediments of, presumably, Precambrian age. They were originally a conformable series of quartzose, clayey, and limy sediments which have been metamorphosed to quartzites, phyllities, schists, and gneisses. This series is intruded by granitic rocks probably of Mesozoic age. The Precambrian (?) series and the granitic rocks make up by far the greater part of the rocks outcropping in the area. The only sedimentary rock younger than the Precambrian (?) series is a conglomerate containing fragments of the old schists and the intrusives. From its position in Clearwater River valley it is thought to be of the same age as the Eocene conglomerate found farther south. Unconformably overlying this conglomerate are lava flows which can be correlated with flows to the south considered to be Miocene. Unconsolidated glacial drift is found in the valleys and on the mountain slopes as the result of Pleistocene glaciation. Recent volcanic flows rest on this till.

Table of Formations

Quaternary	Recent.................	....	Lava River gravels, sand Delta silts
	Pleistocene.............	....	Morainic accumulation. Stratified sand, gravel, and bouldery deposits
	Unconformity		
Tertiary	Miocene................	....	Olivine basalts
	Unconformity		
	Eocene (Middle or Upper)	....	Conglomerate............
	Unconformity		
Mesozoic	Jurassic.................	....	Batholith, stocks, sills, and dykes of granite, pegmatite, and aplite
	Intrusive contract		
Precambrian (?)		Azure River series	Schistose quartz pebble conglomerate, schistose quartzite Quartz chlorite schist phyllite, limestone
		Hobson Lake series	Amphibolite Composite gneiss Quartz mica schist Quartzite Limestone, marble

PRECAMBRIAN (?) SEDIMENTARY ROCKS

Precambrian (?) series consists of a conformable series of sedimentary beds which were originally sandstones, shales, and limestones, but which have been metamorphosed to quartzites, quartz schists, phyllites, amphibolites, gneisses, and marbles. They underlie practically all the area surrounding the three Clearwater lakes and their surface outcrop is only broken where intruded bodies have been uncovered by erosion or where they are concealed by lava flows and glacial and stream deposits.

No definite information regarding the age of this series was obtainable. However, a very suggestive lithological similarity exists between this series and the Cariboo series in Barkerville area[1] and the Barrière series in North Thompson Valley area.[2]

[1]Johnston, W. A., and Uglow, W. L.: Geol. Surv., Canada, Mem. 149 (1926).
[2]Uglow, W. L.: "Geology of the North Thompson Valley Map-Area"; Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 72-106.

For the purpose of areal mapping the Precambrian (?) series has been divided into a lower Hobson Lake series and an upper Azure River series. But this division is purely arbitrary and not well established structurally.

Hobson Lake Series

This formation underlies most of the area around the three Clearwater lakes. It outcrops along both sides of the south half of Clearwater lake and extends as low ridges down Clearwater River valley. It also makes most of the northeast shore of the lake. The shoreline of Azure lake is formed by this formation, except in a few places where igneous masses intrude. Most of the shoreline of Hobson lake is in this formation except the north part. It extends northeast and southeast of Azure lake.

The strike of the beds is generally north 70 degrees west, but there is considerable local variation near the intrusive masses. The beds are folded into broad anticlines and synclines with dips up to 60 degrees, but usually about 30 degrees.

The series consists of sedimentary schists and gneisses, quartzites, and altered limestones. Igneous material from the intruding batholith has permeated some of the beds to a considerable degree and injection gneisses and composite gneisses have been formed. Quartz-mica schists, quartzites, and limestones make the upper beds of the formation. The lower beds, which are those in immediate contact with igneous masses, are highly metamorphosed and consist of banded amphibolites, and composite gneisses, the result of injection metamorphism, and granulose metasomatic gneisses, some of which are the result of pneumatolytic metamorphism.[1] The schistosity is in all observed cases parallel to the bedding which is shown by the persistence of contacts between the different types of beds.

The extreme types of granulose metamorphic rocks are found on the peaks and slopes south of Azure lake. One of these, a coarse-grained, dark rusty-coloured gneiss, is composed chiefly of scapolite and pyroxene with minor amounts of plagioclase, titanite, and apatite. Another type is a massive, green, pink, and white speckled rock composed of plagioclase, diopside, and garnet, with some quartz and titanite. Another granulose gneiss consists chiefly of feldspar, pyroxene, and quartz, epidote, zoisite, and calcite, with accessory titanite and apatite.

Most of the highly metamorphosed sediments are amphibolites varying from a dark green almost pure hornblende rock to lighter coloured types in which hornblende is still plentiful but more feldspar and quartz are present. The amphibolites consist essentially of hornblende, plagioclase, and quartz, but in the various types pyroxene, epidote, and garnet are plentiful and in some types biotite and much secondary chlorite are found. Titanite is the most abundant accessory and together with it are found apatite and magnetite.

The amphibolite is banded in places, particularly along the shore of Azure lake, by the injection of granitic material. The dark bands are almost entirely hornblende and epidote and the light bands, feldspar and quartz. A red garnet is abundant all through the rock. In some places

[1]Tyrrell, G. W.: "The Principles of Petrology" (1926); pp. 324-26-31.

granite material has penetrated the beds so completely that a gneiss is formed consisting mainly of quartz and feldspar with residual masses of hornblende, partly altered to chlorite, and some epidote, garnet, and titanite.

Some of the beds are more thinly foliated and consist of dark biotite schists with layers of quartz parallel to the schistosity giving the rock a banded appearance. The principal constituents are biotite and quartz with some muscovite, sillimanite, garnet, and magnetite.

Very quartzose beds have been changed to a coarse, rough-weathering quartzite composed almost entirely of quartz, with locally some large masses of green pyroxene, and hornblende, garnet, apatite, and titanite. Other gneisses are composed chiefly of quartz and feldspar with some biotite and muscovite, garnet, and apatite. Some types are fine and medium-grained, grey gneisses in which the foliation is brought out by the alinement of scattered biotite flakes. In this type the biotite is in places accompanied by small zircon grains. Other types are medium-grained, brownish gneisses in which the biotite and muscovite flakes occur in bunches alined along definite planes of foliation.

In the upper parts of the formation are massive, light-brownish quartzites, which show only a slight alinement of micas, and green and greenish grey, lustrous garnetiferous quartz-mica schists. The schists consist mainly of a mass of interlocking quartz grains, alined flakes of muscovite and biotite, some of which is altered to chlorite, garnet, and magnetite. Garnet occurs as large, shattered masses with secondary quartz between the fragments. In most of the specimens all that remains of the macroscopic garnets are masses of alteration products about ¼ inch across.

On the shores of the north end of Hobson lake a very pure, slaty limestone is found. The rock is dark grey and dense near its contact with a granite sill. The only impurities in the rock are a few small quartz grains and pyrite cubes, but right at the contact there is an alinement of recrystallized calcite grains. In the mountain range north of Azure lake, a similar, dark grey limestone occurs. Where it has been subjected to great pressures along the axis of the range it is recrystallized to marble. In places the limestone is full of zoisite nodules up to an inch in diameter. Quartz, feldspar, and scapolite are also found. The zoisite nodules stand out conspicuously on the weathered surface. Some types of metamorphosed limestone bands in the Azure range consist of crystalline calcite with considerable phlogopite.

A band of altered, impure limestone outcrops along the south shore, near and at the mouth of Azure lake. The rocks are dense and brownish grey and are cut by stringers from a pegmatite dyke. The rocks are composed chiefly of calcite with some quartz and feldspar as impurities. Among the contact minerals developed are zoisite, epidote, green pyroxene, biotite, garnet, titanite, and scapolite.

Azure River Series

The rocks of this series underlie the regions at the heads of North Thompson, Raush, and Azure rivers, and Hobson creek. Their general trend is north 70 degrees west and they are folded into broad anticlines and synclines. The best exposures, though only of partial sections, are on the slopes of the mountains and ridges above timber-line. Good sections are exposed on the north and south slopes of the valley of Pass and Summit creeks, on the east and west slopes of the upper part of Azure river, and at the head of Hobson creek. This formation also outcrops at the north end of Hobson lake where Hobson creek enters and for approximately 1½ miles south on the west shore.

The main rock types are quartz pebble conglomerates, massive and schistose quartzites, quartz schist, quartz-chlorite schist, and phyllite. In the lowest exposed parts of the formation grey, green, and reddish brown quartzites and somewhat metamorphosed quartz pebble conglomerates or grits are the dominant types. These are interbedded with fine-grained, green, chloritic schists. In places along their contact lenses and stringers of schist are squeezed along cracks and joints into the more massive beds. In the upper parts of the formation fine-grained schists and phyllites are dominant.

The section at the head of Hobson creek contains good examples of the coarse quartzose sediments. Here massive beds of grey, green, and reddish brown quartzite are interbedded with green chloritic schists. The quartzite breaks up into large, rectangular blocks on the mountain tops and the schist makes fine, slippery talus slopes. The quartzites are mainly massive. An arkosic quartz pebble conglomerate has a matrix of quartz grains with sericite flakes that fold around the large fragments; the feldspar fragments are usually much altered and considerable secondary calcite is developed; iron oxide, tourmaline, and zircon occur in the matrix. In the quartzites a similar mineral assemblage is found, but the quartz fragments are of more uniform size. Finer grained beds are represented by a dark green, chloritic quartz schist in which elongated quartz grains are surrounded by sericite and chlorite flakes with some grains of iron oxide and tourmaline. A brown-spotted quartz sericite schist consists of a matte of elongated quartz grains and sericite flakes that bend around masses of iron oxide that make the brown spots of the rock. All these beds are crosscut by many quartz veins from a few inches to a foot or two in width.

On the north and south slopes of the valley of Summit and Pass creeks, the middle and upper parts of the series are well exposed. The coarsest grained rock is a dark green, schistose quartz pebble conglomerate. The quartz pebbles are elongated, show undulose extinction, and are granulated on the ends to some extent. A matte of sericite and chlorite flakes bends around them. A similar but finer grained rock is a dark green, schistose quartzite. The quartz grains are smaller and there is more recrystallized quartz in the matrix. There are more feldspar fragments and some show patchy twinning. Biotite as well as sericite and chlorite is present and also some calcite and epidote from the breaking down of the feldspar. Other types are lighter in colour and occur in more massive beds, but show foliation under the microscope. These types weather with a smooth white surface. They are purer quartz rocks and contain proportionally less biotite, sericite, and chlorite. Tourmaline is present in all of them. One type is composed mainly of quartz, but large crystals of biotite, muscovite, and chlorite are developed and garnet, calcite, and a little apatite are also present.

In the upper parts of the formation finer grained schists are found. Some are grey and brownish grey, spotted quartz schists made up mainly of very fine-grained quartz with sericite and some calcite. The spots are aggregates of chlorite. The brownish tinge is due to iron oxide. Other types are dark green quartz-chlorite schists in which tourmaline is always present and pyrite cubes are common. All these rocks contain some garnet, apatite, and iron oxide.

The finest grained types are crinkled and crenulated dense phyllites varying from dark green and black to light green and pearly white. Their foliation is at an angle of 15 degrees to 20 degrees with the bedding. Some break in thin plates along the plane of foliation and reveal crenulations on a lustrous surface. On some types only a very fine puckering or crinkling is seen. The phyllites are composed of very fine-grained quartz with considerable chlorite and some sericite. Tourmaline is prevalent and in places small grains of garnet. Magnetite or some iron oxide is always present and some varieties weather to a rusty surface. Some very dark, dense types contain metacrysts of staurolite and usually some pyrite cubes. Greatly strained bands of quartz are developed bending around the pyrite cubes. Some are thin-bedded rocks consisting of argillaceous and quartzose layers. The quartzose layers are mainly recrystallized quartz with some biotite and muscovite. The argillaceous layers are very dense and are masked by magnetite dust, locally very minor amounts of sillimanite are developed. In the quartzose layers the elongation of the quartz grains parallels the bedding, whereas the planes of cleavage in the less competent argillaceous layers is at an angle of 20 degrees to the bedding. The fine-grained beds are shot through with quartz veins varying in thickness from a few inches to 4 to 5 feet. In the very fine, dense rocks some large, lenticular masses of quartz are found.

Limestone beds occur in the middle and upper parts of the series, but are insignificant in amount and extent. North of the Summit Group mineral claims are two bands of greatly crushed, buff-coloured, siliceous limestone, each from 50 to 100 feet thick. These beds can be traced westerly for a mile. To the east they cross Azure river and outcrop on the summit and north slope of the ridge west of Summit creek where they have a platy structure and slaty cleavage. These beds are freely impregnated with quartz and there has been replacement by quartz along the bedding planes. In the upper part of the series a band of thin-bedded, dark and light grey limestone contains many stringers of quartz 2 to 3 inches thick. Another thin band of dolomitic limestone outcrops on the slope south of Summit creek.

MESOZOIC GRANITE

The Precambrian (?) series has been intruded by a granite batholith with associated minor outlying bodies. The main mass of granitic material is exposed on the peaks south of Azure lake, but many inclusions of the sediments make it difficult to trace the boundary. The outline of the contact suggests that the granite mass is the northwest end of a much larger mass which lies to the southeast in the vicinity of Murtle lake. Dykes, sills, and stocks from the main mass are exposed along the shores of Azure lake and in Azure range north of the lake. Near the north end of Hobson lake a large, granitic sill is exposed on both sides of the lake. It lies between beds of phyllite above and limestone below. The rocks exposed in and near the main granite mass are light coloured, almost white, coarse to fine-grained pegmatites and aplites. The coarse-grained pegmatities are composed of quartz and feldspar, with minor amounts of muscovite. Microscopically the quartz is always very glassy and much darker in colour than the feldspar which is white to flesh-colour and occurs as tabular crystals 2 to 3 inches long; muscovite is transparent to translucent and occurs in thick booklets and flakes up to 3 inches in length and also as veinlets a fraction of an inch in width. Near contacts with the sediments garnet, hornblende, zoisite, and sillimanite have developed. Under the microscope the main feldspar is seen to be orthoclase; perthitic intergrowth of albite and microcline and graphic intergrowth of quartz and orthoclase are common; oligoclase with very fine twinning lamellæ is present. Muscovite occurs as large flakes and in small veinlets traversing the large crystals. The medium-grained types are similar mineralogically, but contain more muscovite and accessory apatite and garnet. In some a little biotite is also found. Microcline and an intergrowth of vermicular quartz and oligoclase replacing orthoclase, are common. The white, fine-grained types consist mainly of quartz, orthoclase, and oligoclase. The feldspars are cloudy from alteration to sericite, some calcite also being produced. Flakes of chlorite have been developed from biotite and small zircon grains are with them. Garnet is common. These very fine-grained types have in places intruded the schists in a lit-par-lit manner.

The Hobson Lake sill in its central portion is a medium-grained, grey, biotite granite. It consists of quartz, orthoclase, oligoclase-andesine, large tabular flakes of biotite, some muscovite, abundant epidote, and accessory apatite. There is a slight tendency to gneissic structure in the arrangement of the large biotite flakes in the coarser grained varieties. Towards the edges of the sill the rock becomes very fine grained and darker grey in colour, weathering to a smooth, greenish surface. The mineral assemblage remains the same, but considerable chlorite has developed from the biotite. The sill has caused very little alteration of the surrounding sediments. On the upper edge the phyllite is somewhat indurated and pyrite is developed. The limestone on the lower contact is also indurated and the recrystallized calcite is layered, but very few silicates were formed. The granitic rocks are younger than the Precambrian (?) series and older than the Tertiary. Pebbles of the intrusive rock are found in the Tertiary conglomerate in Clearwater River valley. The lack of foliation, the general fresh appearance, and their mineralogical characters suggest that the granitic rocks are to be correlated with those intrusive bodies to the south which Uglow considered to be of Jurassic age.[1]

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[1]Uglow, W. L.; Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 82.

TERTIARY CONGLOMERATE

Approximately 20 miles south along the trail from the foot of Clearwater lake at a locality 2 miles south of where the trail crosses Hemp creek, are two outcrops of conglomerate, the larger of which is only 20 feet wide and 200 to 300 feet long. The beds strike northwest along the direction of the valley and dip from 10 degrees to 30 degrees to the southwest.

The rock is composed of rounded pebbles of granite and quartz and of angular fragments of schist in a cement of silica. Flat, angular fragments of schist similar to the fine-grained schists of the Azure River series make up over 60 per cent of the rock and give it a general greenish colour.

The rock is lithologically similar to the basal conglomerate of the Chu Chua formation of North Thompson Valley map-area which is Middle or Upper Eocene.[1] It is overlain by Miocene lavas and the outcrop is interpreted as a small body of the Chu Chua formation which survived pre-Miocene erosion and being on the side of a schist ridge in the valley when it was flooded by lava is now just being uncovered by erosion of the lava.

MIOCENE VOLCANICS

Miocene volcanics occur in the lower part of Clearwater River valley as benches along the valley walls, 900 feet above the present river bottom which in places has been cut down through them to the schists below. They, therefore, flooded the valley to a minimum depth of about 1,000 feet. The volcanics outcrop along the east shore of Clearwater lake for a mile south of the large creek which enters near the centre of the east shore of the lake. Here they rise abruptly from the lake-level for 300 to 400 feet to form the surface of a swampy flat that continues south for 8 or 9 miles to where it reaches the ridges near the south end of the lake. East of the south end of the lake they form a ridge which rises 600 feet above the lake-level. Other ridges continue to the south down Clearwater River valley. The greatest development is in this valley. Tributary streams have cut deep canyons in the volcanics and enter the main river over great waterfalls. In few places have the streams exposed the base of the volcanic rocks. The volcanics are very dark and weather to a brownish surface. Columnar jointing is well developed along canyon walls. The rocks are predominantly olivine basalts. There are two main types; a dark, fine-grained, massive, blocky-weathering type; and a vesicular porphyritic type. The porphyritic type is composed of small phenocrysts of labradorite in a groundmass of smaller labradorite laths and grains of augite, olivine, and magnetite. There are, also, a few phenocrysts of olivine and of augite. The finer grained type is composed of a groundmass of labradorite laths and grains of augite, olivine, and magnetite in which there are a few phenocrysts of augite and olivine.

The lava flows of North Thompson Valley map-area, described by Uglow as the Skull Hill formation, can be traced up Clearwater River valley to the south end of Clearwater lake.[2]

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 82.
[2]Uglow, W. L.: op. cit., p. 90.

They unconformably overlie the Eocene Chu Chua formation of North Thompson Valley map-area. The same relations are seen between the lavas and conglomerate in Clearwater valley. As stated by Uglow: "No sediments older than the Pleistocene and overlying the lavas were found within the sheet. The Skull Hill formation is, therefore, only provisionally referred to the Miocene." [1]

RECENT VOLCANICS

Volcanics considered to be of Recent age were observed at different points in the southern part of the area. The source of these volcanics is Ray mountain, a strikingly red peak 6,200 feet above sea-level, which stands out prominently at the south end of a long, glaciated ridge and is approximately 8 miles from the south end and 4 miles east of the shore of Clearwater lake. From this peak a stream of lava averaging about a quarter of a mile in width flowed more than 8 miles southwest to the foot of Clearwater lake and extended approximately 1½ miles down Clearwater valley.

The thickest section of the volcanics is at the peak. The material seems to have been extruded through a fissure which extends for a mile or more south along the ridge crest, but whose edges are concealed by the flows. Only one small fissure 5 feet wide and filled with olivine basalt has been uncovered by erosion. This fissure extends to the west from the main mass of volcanics at the peak. On the west side of the ridge, at about 5,300 feet altitude, the lowest exposed and earliest part of the main mass makes a cliff 150 feet high. Below the foot of the cliff are Precambrian (?) schists. Here the volcanic rock is a dark, blocky-weathering olivine basalt with a dense, compact groundmass dotted with crystals of olivine and augite. The groundmass consists of feldspar, mainly incipient crystals, some augite, and much magnetite. The augite crystals are dotted with magnetite grains, whereas the olivine crystals are clear. This material continues to an altitude of 6,000 feet and is the predominating material of the flows.

Above the blocky-weathering basalt lies reddish, scoriaceous material which gives the red colour to the peak. This weathers to a fine red dust. This material has a bedded appearance and interbedded with it is a brownish, crumbly-weathering bed which contains some tachylite. In the scoriaceous material a few small crystals of olivine, augite, and feldspar have formed and in the brownish opaque material which makes up most of the rock seen in section, a few faint outlines of incipient feldspar crystals can be seen.

The material that makes the flows that run southwest to the foot of the lake is the dark, compact olivine basalt. It is very vesicular in places and particularly at the foot of the lake a flow banding and elongation of the vesicles are noticeable. Typical ropy or "pahoehoe" lava is seen in places on the surface.

From the peak the flow descends to a flat, along which it follows an old watercourse which, by means of a canyon, joins Clearwater river a few hundred yards below the south end of Clearwater lake. The canyon is less than a mile long and the elevation of the flat where the stream enters the canyon is 300 feet above the lake-level. At that point the flow is from

[1] Op. cit., p. 88.

20 to 30 feet thick. Above the head of the canyon the most recent flow (it did not reach the canyon) presents an edge about 10 feet thick. The surface of this flow is very rough and the lava highly vesicular. At the foot of the lake and down the river valley for 1½ miles the maximum thickness of the flow is from 15 to 20 feet. The flow originally probably filled the canyon to a greater depth than at present.

The small flow of lava in the canyon joining Clearwater river a short distance below Clearwater lake can be seen to overlie glacial drift at a point 200 yards up the canyon and again at the head of the canyon about 1 mile from Clearwater river. Bay mountain, composed of these volcanics, is unglaciated. The surface of the flow at the foot of Clearwater lake is generally flat but rough and ungrooved with no erratics on it, and in marked contrast with the glacial ridge to the west upon which the lava overlaps. The surface of the most recent flow, 1½ miles east of the south end of the lake, is very strikingly fresh. The surface is covered with blocks of very vesicular and ropy lava. Only small birch and poplar are growing on it and no grass whatever. A few charred stumps of larger trees witness the devastation of a recent fire, but it does not appear likely that the rough, black surface was ever covered with a matte of soil and grass.

PLEISTOCENE AND RECENT

Unconsolidated deposits of recent alluvium and glacial drift are widespread. The recent deposits are much less conspicuous topographically and areally than the drift deposits. Glacial drift is abundant and in places reaches a depth of 300 feet in the valley bottoms. It also mantles the sides of the valleys to altitudes of more than 5,000 feet.

The most extensive glacial deposits make the north half of the west shore of Clearwater lake. These consist of stratified and unconsolidated gravels, coarse and fine sands, and boulder clay through which are scattered boulders up to 4 feet in diameter. The deposits rise 400 feet above the lake level in less than ½ mile from the shore. The surface is rough and uneven with pot-holes and small hollows and ridges with no consistent general trend. The surface is poorly drained and 3 or 4 miles west of Clearwater lake there are many small lakes on it. Some of the hollows that trend east towards the lake are occupied by small streams which reach the lake, but many have no visible outlet and the drainage seeps through the unconsolidated gravels.

On the north bank of Moose creek, one mile from its mouth, is a cut-bank 300 feet high in glacial material. The lowest exposed part is coarse gravel with many boulders. This gravel grades up to a coarse sand with gravelly lenses, which becomes finer towards the top of the section. The finer sand at the top is covered with 2 feet of soil. All levels are boulders a foot or two in diameter. Along Hobson creek thick deposits of drift are exposed in cut-banks 150 feet high. The lowest exposed parts of these sections are composed of large boulders and boulder clay. This is overlain in succession by gravel and coarse sand, fine sand, and at the top a thin film of soil. Morainal ridges occur at the south end of Clearwater lake. Thick drift deposits are found in North Thompson River valley and seem to be thickest at the mouths of tributaries.

Recent deposits have been formed by streams eroding glacial drift and bedrock. They consist of gravels, sands, silts, and muck, deposited in the beds, flood-plains, and the mouths of streams. At the front of active glaciers large terminal moraines are forming and the streams from the glaciers are carrying the fine material to deposit it in the valley bottoms. In this way the wide flat at the head of Azure river is being formed.

The most conspicuous Recent deposits are the deltas being formed at the heads of Hobson and Azure lakes. The main material of these deposits is a very fine silt glistening with small mica flakes. The very finest material is carried into the lake and remains suspended for some time, making the water cloudy for some distance from the head of the lake. This distance is only 50 feet in Azure lake where only one stream enters, but in Hobson lake where three streams are contributing to the delta the lake waters are cloudy for 1½ miles from the head of the lake. Floods bring coarser material down and the delta is cut into, revealing the interbedding of coarse gravels with silt. The deposit at the head of Hobson lake is being formed for about 3 miles along the shore and averages about ¼ mile in width.

GEOLOGICAL STRUCTURE

The Precambrian (?) series has been folded into broad anticlines and synclines which trend generally north 70 degrees west and pitch very slightly to the southeast. The dips on the limbs of anticlines vary from 25 degrees to almost vertical, but dips between 60 degrees and 70 degrees are common. The competent beds are massive quartzites and quartz pebble conglomerates of the Azure River series. They outcrop along the crests of the anticlines and are characterized by open structures and regularity of strike and dip. The incompetent parts of the structures are the schists and phyllites which have been drag-folded and possibly strike-faulted, causing a considerable thickening of their outcrops, which makes the estimation of thickness difficult.

On the southwest side of the peak at the head of Hobson creek about 1,000 feet below the summit is the apex of an anticline which can be followed on the ridges and peaks for many miles to the northwest. Its axis strikes north 64 degrees west. It is followed to the southwest by a syncline whose centre was found at about 6,800 feet altitude on the east side of Azure valley near the head of Azure river. This is followed by another anticline crest to the southwest, on the north arm of which there is considerable drag-folding and thickening of the beds of the incompetent members.

In the region of the lakes similar structures were observed. On the west side of Clearwater lake the apex of an anticline can be seen in the schists. The beds on the northeast arm dip into the lake. From here to the short range north of Azure lake is, apparently, a broad syncline. Along the shore of Azure lake beds on the northeast arm of the syncline dip gently to the southwest, 20 degrees to 30 degrees. The dips steepen on the south slope of the range to the north and then flatten to the northeast along the crest of a broad anticline. To the northwest, as seen on Hobson lake, thick beds of slaty limestone have acted as competent beds, but along the range bordering Azure lake where dykes and stocks of pegmatite and aplite have been intruded, the limestone beds are marmorized and squeezed into large, lenticular masses between the more competent beds of gneiss. The main igneous mass has apparently been intruded along the bulge of an anticline and is uncovered chiefly along the southwest arm. It would appear then that the batholith has concordant relations with the broad structures of the rocks, but at the same time crosscutting relations are seen along the contacts of some of the minor igneous bodies.

ECONOMIC GEOLOGY

The country is underlain almost wholly by the metamorphosed Precambrian (?) sediments and it is only in connexion with veins and large, lenticular masses of quartz in the series that any mineralization has been observed. All types of beds in the series are in places cut by quartz veins and masses, varying from networks of thin veins a few inches thick to large, lenticular masses 300 feet across. The thinner veins are most commonly found in competent beds, such as quartzites, whereas the larger masses are more commonly found in incompetent beds of quartz schists and phyllites. None of the veins or masses is very persistent, a linear extent on the surface of 300 to 400 feet being unusual. The veins are usually barren of metallic mineral or mineralized sparsely with pyrite, but in places the quartz is accompanied by siderite and the pyrite by galena, sphalerite, and chalcopyrite. The quartz is in many places greatly pitted due to the leaching of pyrite cubes, giving a honeycomb appearance on the surface. As few outcrops have been staked and little work has been done on them, it is impossible to make generalizations concerning the structural relations of the quartz masses, with any degree of accuracy. But the veins and masses may be divided into two groups: (1) those that lie, in general, along the strike of the beds; and (2) those that cut across the strike of the beds.

The veins and masses of quartz, following the strike of the beds, constitute a conspicuous feature of the slopes and summits of many of the ridges, particularly of the ridges of the incompetent quartz schists and phyllites, on which they often stand out in bold relief. They are in places 10 to 15 feet thick, but do not exceed 300 feet in length. The quartz is creamy white and greatly cross-fractured, so that it tends to break in tabular sheets. These masses are usually barren of metallic mineral or sparsely mineralized by grains and cubes of pyrite.

The veins which cut across the strike of the rocks are generally smaller and of a more regular vein type, but large, lenticular masses also occur. The veins and masses generally strike northeast, but there is considerable variation in their angle of crosscutting. The quartz in them is less fractured and often has a bluish appearance. In this type of deposit the quartz is commonly accompanied by siderite and pyrite, galena, sphalerite, and chalcopyrite.

In the southern part of the area, near the north end of Hobson lake, are igneous intrusions and there are some quartz veins connected with them, but in no place were sulphides seen in the quartz. The metamorphosed sediments near the contact with the intrusive igneous rocks are practically unexplored. Where they have been examined no sulphide mineralization was seen, but this does not mean that none exists, for very little of the contact has been examined in any great detail and sulphide deposition may have taken place farther away from the batholith than any of the places examined.

DESCRIPTION OF PROPERTIES

Lode Deposits[1]

"*Summit Group*. This group consists of nine claims on the ridge between Azure river and Hobson creek, and approximately 4½ miles south of the head of Azure river. The claims are owned by Angus Horne and G. W. Stewart of Blue River.

On the west side of Azure River valley, 600 feet above the valley bottom, a tunnel has been driven north 40 feet on claim No. 3 of the group. At the portal the rock is a thinly foliated, rusty-weathering, quartz-sericite schist striking east and dipping 70 degrees north; the schistosity strikes north 80 degrees east. The face of the tunnel is in dark green and grey quartz-sericite schists with thin bands of sheared quartzite. The tunnel crosses an irregular quartz lens visible at the surface. The quartz in the tunnel is milky white, massive, and without apparent cross fractures. In the tunnel the lens is 25 feet wide, strikes north 55 degrees east across the strike of the schists, and dips 70 degrees north. Massive and granular pyrite is freely distributed across the full width of the lens and is also sparingly disseminated in the schists for a distance of 1 foot from the walls of the quartz body. A channel sample taken across the full width of the quartz mass in the tunnel assayed $2 per ton in gold. A sample taken by H. G. Nichols, resident mining engineer for Kamloops district, gave gold values of $4 per ton.[2]

Five hundred feet northwest of the tunnel a small lens of milky white quartz is exposed in an open pit. The weathered surface is coated with iron oxide, some of which was crushed and panned, but failed to show any colours. The interior of the quartz is honeycombed as the result of the leaching.

Approximately 1,000 feet northwest of the tunnel, three irregular quartz masses outcrop within 200 feet of one another. The largest is 250 feet long, 20 feet wide, and strikes north 40 degrees east. Granular pyrite is sparingly disseminated at intervals through these masses. In the largest mass is a lenticular seam of pyrite 1 foot wide and 30 feet long paralleling the trend of the mass. A sample taken along the full length of this seam assayed $31 in gold and $3 in silver.

Approximately 1½ miles northwest of the tunnel an irregular quartz lens, 30 feet by 20 feet, and trending north 15 degrees west, outcrops in the bed of a small creek. One hundred feet west of this mass is a second lens 100 feet long and 15 feet wide striking north 20 degrees west. Quartz sericite schists striking south 80 degrees east, dipping 70 degrees northeast, form the country rock. Pyrite is very sparingly disseminated through the quartz.

War Colt Group. This group of six claims, owned by Adolf Anderson and Lewis Knutson of Albreda, is on the east side of Azure river 4 miles from its source.

On the east bank of the river a tunnel driven north 30 degrees east for 20 feet, intersects two quartz veins. At the portal of the tunnel is a vein of blue quartz 8 feet wide striking south 60 degrees east and dipping 60 degrees northeast. This vein can be traced for 50 feet along the strike. Pyrite, chalcopyrite, sphalerite, and galena are disseminated across the full width of the vein. A sample taken across the vein assayed gold $1.50 per ton, silver $1 per ton.

In the face of the tunnel the foot-wall of a second vein is exposed. The trend of this vein is about 35 degrees east. It is sparingly mineralized with pyrite, chalcopyrite, and galena. A sample assayed: gold trace, silver trace. Two hundred feet east of, and 400 feet above, the tunnel is an irregular mass of bluish white quartz

[1]Marshall, J. R.: Geol. Surv., Canada, Sum. Rept. 1927, pt. A, pp. 45-6.
[2]H. G. Nichols—personal communication.

measuring 60 feet by 25 feet. It is sparingly mineralized with pyrite, chalcopyrite, and galena. In all three veins considerable siderite accompanies the quartz as gangue.

Hobson Creek. Near the head of Hobson creek large blocks of white quartz occur in the glacial debris. Many of these blocks consist of 40 per cent pyrite and 60 per cent quartz, and do not appear to have been transported far.

At the foot of the glacier, quartz veins, from 4 inches to 3 feet wide, occur in a shear zone 50 feet wide. Quartz-sericite schist with interbeds of coarse, reddish brown sandstone form the country rock. These strike east and stand on edge. The veins are confined to the schists, and follow the bedding planes. They can be traced, as lenses 30 feet long, for 200 feet to the east. There are also in this zone numerous, small, lenticular quartz veins not exceeding 15 feet in length and up to 6 inches wide and striking northeast. Pyrite is sparingly present in both types of veins, and also is sparingly disseminated in the schists."

Placer Deposits

The only located placer claims are on Hobson creek which flows into the north end of Hobson lake. In the " Report of the Minister of Mines, B.C., 1902," mention is made of the operations on Hobson creek. The following quotation from the report for 1913 shows the activity at that time.

" The Westenhiser Company has made considerable progress towards opening up its property on Hemlock (Hobson) creek at the head of Clearwater (Hobson) lake. A force of men were engaged all summer on the construction of a sleigh-road across the portage between Quesnel and Clearwater (Hobson) lakes to permit the hauling of the pipe and other mine equipment which was landed at the head of Quesnel lake."

The old placer claims are located approximately 2 miles up Hobson creek from its mouth and 250 feet above the lake-level. In the canyon at that point are the remains of a dam, sluice boxes along the east side of the creek below the dam, and pipe leading in from the gravel bank on the east side of the creek. The gravel bank rises from 100 to 150 feet above the present creek-level. The lower part of the bank is made up of large boulders and boulder clay with gravels above and finer sand making the top. The country rock at the workings is the phyllite of the Azure River formation and the gravels rest directly on it. The gravels are glacial filling of the narrow valley and owe their origin to the valley glacier at the head of the creek. They do not appear to be reconcentrated older gravels.

SPRINGS

Some samples were taken of a spring located near J. B. Ray's farm, on the trail between Clearwater station on the Canadian National railways and Clearwater lake, approximately 40 miles from the railroad and 10 miles south of the lake. Another similar spring, ¼ mile north along the trail from the farm, was not sampled.

The following analysis was submitted by the Division of Chemistry, Mines Branch:

"As received, the sample contained a small quantity of rust-stained colloidal matter in suspension, which was removable by filtration. On opening, the containers were under slight pressure.

Its analysis showed it to contain:

	Parts per million
Sodium (Na)	157·69
Potassium (K)	none
Lithium (Li)	none
Calcium (Ca)	243·00
Magnesium (Mg)	86·00
Iron (Fe)	2·20
Aluminium (Al)	0·53
Bicarbonic acid (HCO_3)	1,499·73
Sulphuric acid (SO_4)	37·32
Chlorine (Cl)	27·90
Iodine (I)	none
Silica (SiO_2)	1·00
Oxygen for aluminium	0·47
	2,055·84
Carbonic anhydrite free (CO_2)	594·00

Hypothetical combination:

	Parts per million
Sodium bicarbonate ($NaHCO_3$)	444·14
Calcium bicarbonate ($Ca(HCO_3)_2$)	984·15
Magnesium bicarbonate ($Mg(HCO_3)_2$)	517·38
Iron bicarbonate ($Fe(HCO_3)_2$)	6·99
Sodium sulphate (Na_2SO_4)	55·20
Sodium chloride (NaCl)	45·98
Silica (SiO_2)	1·00
Alumina (Al_2O_3)	1·00
	2,055·84
Carbonic anhydrite free (CO_2)	594·00

The analyses of the rust-stained material:

	Parts per million
CaO	40·02
Fe_2O_3	13·01
Al_2O_3	1·00

DEEP BORINGS IN BRITISH COLUMBIA

By D. C. Maddox

The Borings Division, Geological Survey, Canada, has for its object the collecting of samples and records from borings put down for oil and gas, water, non-metallic minerals, and coal, and special forms and log books are provided for this purpose, as well as bags for the taking of samples.

The staff of the Borings Division is too small to permit of much field work being carried on and it is, therefore, earnestly hoped that all owners or drillers of water wells will co-operate in the collection of information of this nature. Delay in the receipt of information of this kind is especially dangerous as the memory loses much of its reliability with the lapse of time and it is essential that samples be taken as the well is being put down. The mass of records accumulated during the twenty-one years since the work was first started are carefully filed and become available as a basis for replies to inquiries by prospective well drillers. Provision is made for the work of sample examination by the use of a laboratory specially equipped for the purpose, with limited facilities for certain lines of research, notably the heavy mineral content of the sediments. Mr. F. J. Fraser is in charge of this work.

During the year samples from two wells, which had been received several years back, were examined. The fact that these samples were still available illustrates the value of collecting and storing samples, since in many cases, many years elapse before sufficient interest is taken in the area from which the samples were obtained, to warrant their detailed examination. The two wells from which samples were examined are: the Okanagan Coal, Oil, and Gas Company's well situated about 2 miles north of Armstrong, 400 feet deep; and the Armstrong Oil Company's well also in Okanagan area, 250 feet deep. The results of the examination seem to show that the Armstrong Oil Company's well was still in the silt and fine sands of the surface deposits at 250 feet, and that the Okanagan Coal, Oil, and Gas Company's well passed out of the surface deposits into rock at about 280 feet.

In Yukon territory no drilling for oil and gas has been recorded during 1929.

Drilling for oil and gas in British Columbia during 1929 was limited to Sage Creek area, Flathead district, in the southeastern part of the province. In this area the Crow's Nest Oil and Gas Company deepened to 3,260 feet the well that has been drilled intermittently for several years, and the British Columbia Oil and Gas Company's No. 1 well was carried down to about 1,600 feet. No further drilling for oil and gas seemed to have been done in Fraser Delta area or elsewhere in the province.

Some drilling for water was done in 1928 in Telkwa area and samples were examined from the well put down at Telkwa to a depth of 350 feet by Mr. Scott for Mr. C. J. Keller. Information as to water conditions at Smithers was obtained from well data supplied by Mr. W. G. Scott.

The C. J. Keller well, the log of which is here given, is located in Telkwa River area, lot 879, township A, range 5, southwest of McClure lake on old Hazelton road and on the site of the old Telegraph station.

C. J. Keller Well, Telkwa, B.C.

Depth (in feet)	—	Notes
0—10	Peaty, dark brown............	
10—190	Mud or silt, medium grey.....	A little coarse sand
190—205	Sand, medium grey...........	Coarse grained, angular. Some dark shale present
205—215	" "	Medium grained. Some dark shale present
220	Shale, dark grey..............	A little medium-grained sand present
230	Sandstone, light grey..........	Medium grained
240	" "	"
250—320	" "	"
330	" "	" slightly calcareous
340—350	" "	" "
	Summary: Base of drift presumed around 200 feet. The light grey sandstone is mainly composed of subangular grains of quartz and subordinate feldspar, a few dark grains, with occasional but persistent green grains suggesting glauconite.	

OTHER FIELD WORK

Geological

W. E. Cockfield. Mr. Cockfield topographically and geologically surveyed the southwest third of Laberge quadrangle (latitudes 61°-62°, longitudes 134°-136°), Yukon. This work will be continued in 1930.

George Hanson. Mr. Hanson continued the geological mapping and study of an area of about 200 square miles in the vicinity of Alice Arm, British Columbia. This work will be continued in 1930.

C. E. Cairnes. Mr. Cairnes commenced a geological survey of Trinity quadrangle (latitudes 50°15′-50°30′, longitudes 118°30′-119°00′), B.C. This work will be continued in 1930.

H. S. Bostock. Mr. Bostock continued the geological survey of three quadrangles in southern British Columbia bounded by respectively: latitudes 49°00′-49°15′, longitudes 119°30′-120°00′; latitudes 49°15′-49°30′, longitudes 119°30′-120°00′; and latitudes 49°15′-49°30′, longitudes 120°00′-120°30′. This work will be continued in 1930.

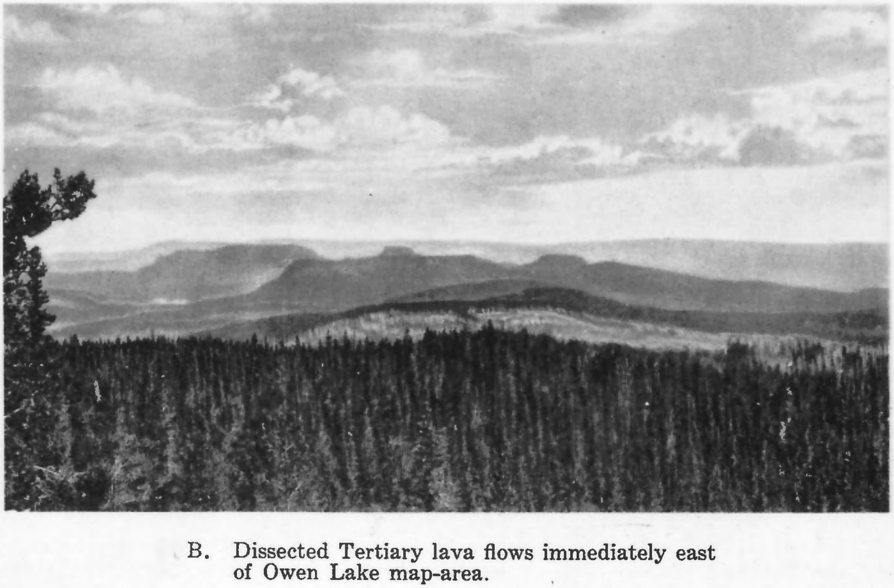
Topographical

R. Bartlett. Mr. Bartlett completed topographical mapping of an area of about 200 square miles in the vicinity of Alice Arm, British Columbia.

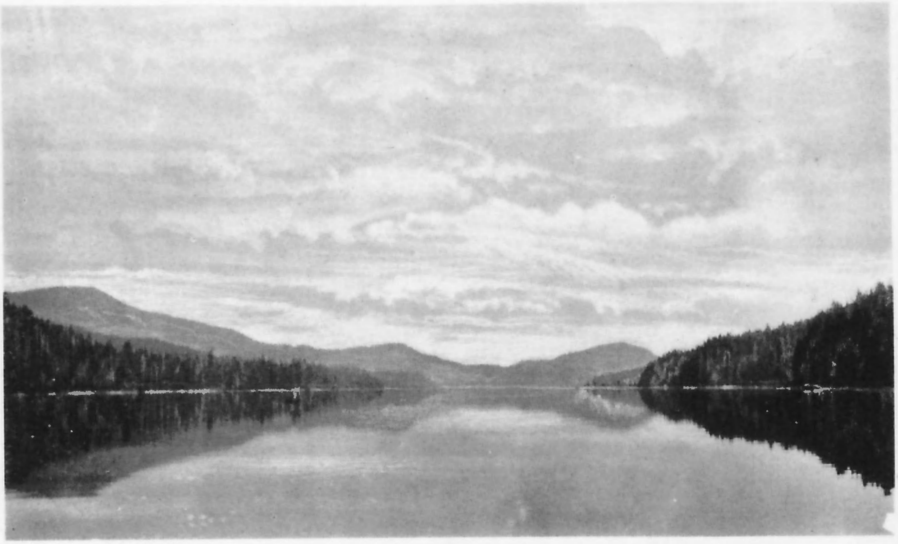
S. M. Steeves. Mr. Steeves continued topographical mapping of Salmo quadrangle (latitudes 49°00′-49°15′, longitudes 117°00′-117°30′), British Columbia.

J. V. Butterworth. Mr. Butterworth continued topographical mapping of the east half of Cranbrook quadrangle (latitudes 49°30′-49°45′, longitudes 115°30′-116°00′), British Columbia.

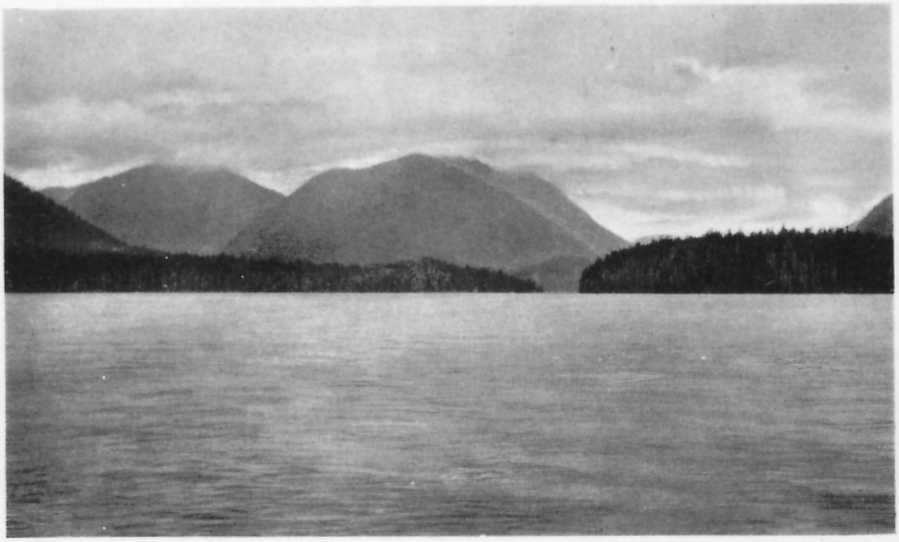
A. Southeastern side of mount Nadina. Owen lake and Taylor ridge in foreground.



B. Dissected Tertiary lava flows immediately east of Owen Lake map-area.



A. Looking north on Alice lake.



B. Looking south on Victoria lake.

A. Looking southwest across Elk lake at Coast Copper hill. Portal of main adit just to left of picture.

B. Open-cut, Yreka mine, showing unreplaced remnants of limestone (white) in zone of contact metamorphic silicates and sulphides. Note banding in silicates after bedding in limestone.

A. Aurum mine camp, Coquihalla area, Yale district, B.C.

B. Camp of Peer River Placer Company, Sowaqua creek, Coquihalla area, Yale district, B.C.

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NOTE. All place-names and claims are in British Columbia unless otherwise designated.

The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.