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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1930, Part A

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F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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THE MINING INDUSTRY IN YUKON AND PARTS OF NORTHERN BRITISH COLUMBIA IN 1930

By W. E. Cockfield

About half of the field season of 1930 was devoted to visiting some of the mining camps in Yukon and northern British Columbia.

The year 1930 was a difficult one for the mining industry of the north as early in the year the decline in metal prices made it apparent that some of the enterprises could be carried on only with great difficulty. This decline, owing to the remoteness of the main producing camp in Yukon and to the fact that ore shipped during any season is largely hauled to the river before the spring break-up, is not reflected in the shipments for 1930. The Mayo camp shipped 10,000 tons of ore and concentrates and, although accurate figures are not available, this may be estimated to contain roughly 5,000,000 ounces of silver and 5,000 tons of lead. These figures constitute a record for the camp.

Actual figures for the production of placer gold are not available and estimates from different sources show considerable differences. The production may show a slight falling off as compared with 1929, but as all estimates were made prior to the close of the season they are subject to correction according to the amount of gold recovered by operations in the autumn.

PLACER MINING

In Klondike district, Yukon Consolidated Gold Company had four dredges in operation. Two of these were boats of the larger type and were worked on the Klondike flats between the mouths of Bonanza and Hunker creeks. The other two were working on Dominion creek, one at Cariboo and the other near Granville. In addition the company operated its hydraulic plants at Jackson gulch on Klondike river, and at Lovett gulch on Bonanza creek. It is reported that the hydraulics did not operate to capacity owing to lack of rainfall and also owing to the interruptions caused by breaks in the ditch.

A number of individuals are, also, working claims in Klondike district. These account for about eight properties being worked on Hunker creek and its tributaries and approximately the same number on Bonanza creek. On the Dominion slope there are six properties being worked on Quartz creek, three on Sulphur, one on Gold-run, and several on Upper Dominion creek. It is estimated that the production will not exceed $50,000.

In Sixtymile area a dredge which was put into operation in 1929 is at work on the concession between the mouths of Bog Gold and Miller creeks. No data are at hand with regard to the success of this operation. It is reported that on Thistle creek the operations carried on by Manley have been closed down. A small amount of work is being carried out on numerous other creeks in the territory.

Towards the close of the season a strike was made on Lake creek which enters Big Salmon river 2 miles below Livingstone creek and this strike has revived interest in a district long neglected. The discoverer, Mr. T. Kerruish, reports finding what appears to be a preglacial channel, on the right limit of the creek. The gravel contained in this is reported to be fine compared with the heavy wash in the bed of the creek. The paystreak has a width of 40 feet, with a depth to bedrock of 12 feet, but as the discovery was made late in the season, its linear extent is not known. The grade of the creek is steep; water is not abundant, but there is a sufficient supply to permit of sluicing for some hours each day. The gold obtained is high in value, assaying $18.50 an ounce; and is prevailingly coarse, by far the larger amount consisting of nuggets. There is no fine gold. The gold brought in to the bank yielded $2,360; Mr. Kerruish estimates that this was recovered from 546 cubic yards of the paystreak. An additional 50 ounces had been obtained, but not delivered at the bank at the close of navigation. The gold is believed to be scattered through the paystreak and not confined to within a short distance from bedrock. A placer lease of a mile has been staked on the creek, and 600 feet of pipe and a 4-inch monitor installed. It is probable that this discovery will stimulate more interest in Salmon area and that considerable prospecting will be carried out there this winter and next summer.

In Atlin district, northern British Columbia, there were three placer operations of considerable size, as well as work by a number of individual miners.

On Otter creek the Compagnie Francaise des Mines d'Or du Canada, of Paris, while running a cut from Surprise lake with the object of reaching bedrock on the creek, encountered fine gold on top of a slightly consolidated boulder clay. This deposit lies on the southern side of Surprise lake near its western end and is only slightly above the lake in elevation. The extent of the deposit had not been determined at the time of the writer's visit. The gold is fine and somewhat troublesome to save, but it appeared to be yielding sufficient returns to meet expenses of the operation. It is not known whether this represents a slough from the main paystreak of Otter lake, and, consequently, whether by following it up the main paystreak will be reached, or whether it is a concentration from other sources.

On Boulder creek, Consolidated Mining and Smelting Company is driving a cut from the northern side of Surprise lake in order to reach bedrock on the creek. On account of the difficulties encountered this work has progressed somewhat more slowly than was expected. A slightly consolidated boulder clay, similar to that found on the other side of the lake, was encountered. This, however, did not have gold on top. This deposit had to be blasted before it could be removed by sluicing; and this, added to the fact that for part of the season the amount of water available is limited, slowed down the work so that bedrock on the creek was not reached during the season.

The third company placer operation was the Pine Creek development by Engineer Mines, Limited. This company was engaged in running a cut parallel to the general course of Pine creek in order to reach pay reported from older workings, to lie above. Before the close of the season the company became involved in financial difficulties which have since been reported settled, and the company was transferred to stronger hands. It is

reported that the company is adequately financed to carry out its program and that work will be resumed next season. In addition drilling will be undertaken, so that the paystreak may be definitely located and thus prevent the driving of the workings blindly.

LODE MINING

Mayo district has furnished the only production from lode mining during the year. As already pointed out, the decline in metal prices did not cause a reduction in shipments during 1930. Present plans, however, call for a drastic reduction in tonnage to be shipped in 1931; these plans call for a shipment of 4,000 tons. The reduction in silver output will not, however, be as great as indicated by the tonnage figures, for the concentrates to be shipped in 1931 will be much higher in silver than those shipped in 1930, and but little crude ore will be shipped. Recent advices from Mayo are to the effect that the tonnage may be increased to 6,000; but of this there is no confirmation.

The decline in silver prices has undoubtedly brought about a large reduction in ore reserves. An ore that was profitable a year ago can no longer be considered as ore; the minimum content of silver necessary for profitable operations has nearly doubled. Consequently, material that falls under the minimum for profitable operations must be left in place, and will not likely become available during the lives of the enterprises unless silver speedily reverses its recent price trend. The type of ore must also be carefully scrutinized. An ore may contain the minimum of silver necessary for profitable mining, but if the silver cannot be concentrated to the point where shipping is profitable, the ore cannot be mined at a profit. The ratio of ounces of silver to unit of lead thus becomes of extreme importance. In the early days of the camp an ore with 200 ounces of silver and 60 per cent lead was shipped without concentration. Such an ore or concentrate is no longer profitable. The reduction in ore reserves brought about by these considerations has been quite severe. Although definite statements of the tonnages of ore in sight are not available for the full time the camp has been working, it may be stated that in 1929 the ore in sight was very nearly as great as at any time during the development of the camp. At the close of 1930 Treadwell-Yukon Company, Limited, announced that the ore in sight in its properties was sufficient to last two and a half years.

The individual operator is the hardest hit. In most cases he cannot produce at all and is forced either to close down or to content himself with development work or with merely doing the necessary assessment work to hold his ground in good standing. Some few individuals are fortunate enough to possess small bodies of ore that can be hand-sorted for shipment even at present prices, but on the whole the production from these sources will be very small. The company, on the other hand, can by concentration raise its ores to the point where shipping becomes profitable.

Along with the decline in silver prices there has been a slowing down of development. In 1929, Treadwell-Yukon Company, Limited, had four properties under option with development work proceeding on these and

prospects seemed bright for a second mill in the camp. It seems likely that the course to be followed will be to exhaust the ore in the property now being mined and then to move the present mill to a point where it can serve the other properties.

With regard to the ore deposits themselves, certain facts stand out from the developments that have taken place in the past few years and these have considerable bearing on the future development of the camp. In the first place, the ore-shoots that have been developed do not extend to any great depths. The Sadie ore-shoot proved to be the largest found to date and furnished 110,000 tons of ore. It did not extend below the fourth level, 400 feet from the surface, and the same has proved to be the general rule for the ore-shoots of the camp, which have been fully developed. In some cases the veins continue downward almost undiminished in size, with a siderite gangue, but ore has not been found to a depth of more than 600 feet in any deposit. However, on only one deposit, namely, the Ladue where considerable drifting was done on the 6th level, has development taken place at this depth.

It may be that ore deposition in any one vein was for some reason confined within very sharply defined vertical limits, or it may be that ore-shoots do occur at different elevations within the same veins. If the first view be accepted and if ore deposition was due to a temperature gradient, it would have to be assumed that the present surface is essentially the same as though deeper than the surface at the time of ore deposition, for ore-shoots outcrop at many different elevations on the hill and there is no evidence that ore-shoots on the top of the hill extend deeper than those found at lower elevations. The view that the ore-shoots are prevailingly shallow has much to support it, as five of the more promising deposits have been bottomed at relatively shallow depths. On the other hand, the second view, namely, that other deeper ore-shoots may occur in the same veins cannot be said to have been disproved, particularly in those cases where the veins are known to continue below the known ore-shoots.

A second feature which stands out is the existence of a number of northwesterly trending faults. The prevailing trend of the mineral veins is northeast. The northwest faults cut and offset them and in some cases the connexion between the northwest faults and the positions of ore-shoots is striking. The view may be held that the northwest faults are post-mineral and that their apparent connexion with the ore-shoots is accidental, or, at most, brought about by such shoots being located in weaker parts of the strata through which such faults would naturally trend. On the other hand, the faults may be regarded as being pre-mineral fissures at whose intersections with the northeast fissures ore deposition took place, movement continuing along the faults after the conclusion of ore deposition. If this had been the case, the faults would, possibly, have been the main circulating channels and have given rise to the ore-shoots in the northeast fissures, thus accounting for the localization of ore-shoots near the northwest faults. Against this explanation may be urged the lack of mineralization in the northwest faults. So far as known they do not contain ore other than that which might be considered as having been dragged into the fault zones. Whatever view is accepted, the occurrence of ore-shoots at or near the intersections of the

two types of fissures is striking and though there are probably not enough examples to prove that as a general rule they are so localized, yet the available evidence supports such a rule which is important as possibly limiting the areas that must be intensively prospected. Unfortunately, owing to overburden, the courses of the faults cannot be traced for considerable distances and, in many cases, their presence can only be inferred from the offsetting of one part of a vein with respect to another.

COMPANY OPERATIONS

Treadwell-Yukon Company, Limited, had in 1929 four properties under option or purchased and was developing these in addition to mining the Sadie property. The ore on the Sadie, which was worked under lease from Keno Hill, Limited, was exhausted early in 1930 and the Sadie and the adjoining Ladue property, owned by Treadwell-Yukon Company, Limited, were closed down and mining operations transferred to the Lucky Queen situated about a mile from Ladue camp.

Lucky Queen Group

The shaft on this property has been sunk a short distance below 300 feet and drifts have been run on the 50, 100, 200, and 300-foot levels. All these drifts are to the southwest of the shaft and are 300, 1,300, 1,100, and 650 feet long. A number of crosscuts and subsidiary drifts run on different levels explore the ore-body thoroughly. There are two main ore-shoots, the first being 170 feet long on the 100-foot level and 280 feet long on the 200-foot level. The second is about 240 feet long. The width of the ore varies considerably from point to point. The mineralization is freibergite, galena, and zinc blende in a siderite gangue. Ruby silver and native silver are somewhat common on and below the 200-foot level and oxidized ore is common from the 100-foot level up. The ore-shoots have not been fully explored on the 300-foot level. Two main faults cut the ore-bodies, one of which has been tentatively correlated with a similar fault in the Sadie workings. The Treadwell-Yukon interim report, published at the close of 1930, gives the ore reserves in the Lucky Queen as sufficient to last about a year. There is still the chance of finding more ore in this property as mining progresses.

The company's option on the Arctic and Mastiff group on Galena hill has been abandoned. The company put down a 200-foot shaft in the foot-wall of the vein and crosscut to the vein at the 200-foot level. A second shaft was put down on a faulted segment of the vein lying southwest of the main workings. This is reported to be 50 feet deep. These workings were full of water and consequently could not be examined. Since the option was abandoned the owners have found another faulted segment of the vein to the northeast of the main workings.

Breifalt Property

Development work on this property was partly completed and the property closed to await the moving of the mill from the Ladue property. This property is developed by three crosscut tunnels at elevations of 3,320, 3,240, and 3,070 feet. The highest of these is 210 feet long; the inter-

mediate is 380 feet with a drift to the northeast of 130 feet and a drift to the southwest of 1,100 feet. The lower adit is 1,020 feet long and hits a small stringer at 660 feet and a quartz vein at 980 feet. This vein has a reverse dip to that of the main vein and lies on a greenstone contact. It varies in width from 1 to 2 feet. It joins the main vein 90 feet from the adit. Drifts have been run from the adit 440 feet to the southwest and 520 feet to the northeast with a crosscut 160 feet long situated 320 feet from the adit along this drift.

The northeast drift of the intermediate level terminates in a fault zone and the vein has not been picked up beyond. Some development work remains to be done on this property to the northeast of the fault zone, and also to find the course of the ore between the intermediate and lower levels. Otherwise the tonnage available is known with a fair degree of certainty.

Silver King Property

This property was the first producer of silver-lead ore in Mayo district. After working out a single shoot of ore the owners closed the property and although numerous attempts were made to trace the vein and to locate other ore-shoots, it was not until 1929 that the continuation of the vein to the northeast was found and a promising shoot of ore located on this and the adjoining claim, the Webfoot. Both properties were optioned to the Treadwell-Yukon Company, Limited. Development and the erection of a camp were started in 1929. A shaft has been sunk to 200 feet and levels driven at 100 feet and 200 feet. At the time of the writer's visit the south drift on the 200-foot level had been driven 120 feet. The width of the ore was 5 feet and it was very high in zinc. On the 100-foot level the north drift was 100 feet long and above it the material has been largely stoped out. The south drift on this level is 420 feet long with the material above largely stoped out. The maximum width of the vein is 8 feet and the mineralization is galena, zinc blende, and freibergite in a siderite gangue. Ruby silver is plentiful in the upper workings.

Keno Hill, Limited

This company recently started development on an ore discovery made on the Porcupine claim in the course of assessment work in 1929. It is the intention of the company to sink a prospect shaft on this showing and to drift from the bottom of the shaft should the results obtained be favourable.

The company has abandoned the option which it held on the Nabob claim and several others in the vicinity of its original group.

Reserve Mining Company

The property of this company has lain idle throughout the year.

Nabob Claim

The owner, L. Beauvet, has put in several open-cuts, tracing one of the main northeast veins of the vicinity from the holdings of Keno Hill, Limited, part way across this claim. These cuts are close to the shaft

which had been sunk on this vein and some ore of milling grade has been found in them. The vein has also been traced farther to the east by a series of cuts, but no new development has been added to this group of workings during the year.

Stone Claim

The owner, Mat Butyer, is engaged in driving a long tunnel to cut, at a lower elevation, the vein found in the older workings. This tunnel is now 240 feet long and is still in overburden. About 100 feet from the portal the tunnel passed through a reef of schist, but after passing this once more entered gravel. The gravel contains boulders of ore material such as siderite with galena and grey copper, and also pyrite and chalcopyrite. The pyritic material carries high gold values. The gravel in which this material was found is quite evidently of glacial origin as it carries pebbles and boulders of granite, a rock which does not outcrop on Keno hill. Consequently the finding of the ore material in it cannot be looked upon as indicating with any certainty the occurrence of veins close at hand. This tunnel is 460 feet below and 1,400 feet distant from the older workings.

Shamrock Group

Work at this property had been suspended at the time of the writer's visit. It is reported that the lessees of this group shipped 500 tons of ore in 1930, but that no attempt will be made to ship ore during 1931.

Silver Basin Group

This property is owned by R. Rasmussen and occupies part of the steep northeasterly slope of Silver Basin gulch. A large amount of work has been done on the property at different times, but the entrances to nearly all the adits have caved, thus making an examination unsatisfactory as it is difficult to secure the relations of one showing to another. The property is one on which it is difficult to keep the various cuts and adits open owing to the heavy overburden and steepness of the slope. Some of the mineral showings may still be observed in the open pits. It would appear that there are two main veins cutting diagonally across the steep slope and that there are a number of cross fractures in connexion with these, some of which carry mineralization. The lower vein where exposed has a width varying from 2 to 7 feet and strikes north 77 degrees east with a dip of 70 degrees to the southeast. The upper vein is approximately 4 feet wide. Both are quartz-arsenopyrite veins carrying galena, freibergite, and zinc blende in places. Gold values of $10.50 a ton are reported from a shipment of 12 tons.

Some of the cross veins carry mineralization, but details with regard to them cannot be supplied.

Dorothy Claim

This property is being worked by E. Corp and J. Ryan. A siderite vein 4 feet wide has been traced for nearly 200 feet on the surface by means of two shafts and an open-cut. One shaft is 55 feet deep and is terminated

by a drift 35 feet long to the southwest. The second shaft is 45 feet to the northeast of the first. Both were filled with water. Several open-cuts beyond these workings have not picked up the vein. No ore minerals were encountered in the workings other than a few specks of grey copper. One block of galena was encountered on the surface near the outcrop. The vein is probably cut off to the northeast by a fault, but there are so few exposures that this could not be definitely determined.

GALENA HILL

No Cash Claim

This claim is owned by Breifalt and Tolmie and worked under lease by E. Bjonnes. There is a shaft 50 feet deep with two drifts, one slightly higher than the other, at the bottom. These drifts are connected by cross-cuts. One drift is on the foot-wall and the other on the hanging-wall side of the vein. The hanging-wall drift is 60 feet long, it extends 15 feet to the north and 45 feet to the south of the shaft. The foot-wall drift is 22 feet long on either side of the shaft. The hanging-wall of the vein shows a dip of 55 degrees and the foot-wall varies from 60 to 75 degrees. Between the two drifts there is a streak of low-grade ore. The ore on the hanging-wall is 5 feet wide and is fairly high grade; the lean ore between the two drifts is 3½ feet wide; and the foot-wall streak is well mineralized and about 3 feet wide. Very high assays have been secured from the ore as hand-sorted for shipment. The lessee shipped 21 tons during 1930, but the actual returns for this were not available. Mr. Bjonnes states that a channel sample cut across the whole width of the deposit assayed 75 ounces.

Tyee Claim

This claim is owned by H. E. Formo who has also an option on the adjoining claim, the Rocket. These claims are situated on the northern slope of Galena hill near the mouth of Christal creek. A considerable amount of work has been done improving the trail to the property. The workings consist of an incline shaft 80 feet deep; the dip of the vein is somewhat flatter than normal, being about 35 degrees, and the strike is north 17 degrees east. There is a drift to the south at the bottom of the shaft and another drift to the south at 60 feet with a raise connecting the two. Both these drifts are 15 feet long. At the bottom of the shaft there is a 15-foot drift to the north. The ore is 20 to 28 inches wide in a vein which shows a maximum width of 4 feet in the shaft. In the bottom of the shaft the ore increases to 36 inches, but is of much lower grade, containing much pyrite and zinc blende. In the north drift the vein is cut off by a northwesterly trending fault and no attempt has been made to pick it up beyond this fault. The best ore was found 25 to 30 feet down in the shaft and 40 tons of this were sorted and shipped. The smelter returns on this shipment were not available, but assays of the ore made before shipment indicated a content of between 225 and 250 ounces of silver and 60 per cent lead.

BUNKER HILL

Homestake Group

Only one property was visited on Bunker hill, which lies to the south of Keno hill. This property, the Homestake group, is operated under lease by J. Carpenter and J. McLean. The workings consist of two shafts close to one another, a crosscut and a number of open-cuts. Owing to sloughing the vein cannot be seen in the open-cuts or crosscut and the shafts are full of water. The original shaft is reported to be 32 feet deep and the second shaft 42 feet deep with a drift 15 feet to the south and a drift of 7 feet to the north. Three hundred and fifty feet to the north of the shafts, the vein was reported to have been found in an open-cut, but this cut was also sloughed and consequently the showing could not be examined. A streak of galena 2½ feet wide was reported as occurring in the second shaft.

KLONDIKE DISTRICT

Lone Star Property

A hurried visit was paid to the Lone Star property near Dawson. As this has already been described[1] there is no need to repeat the details with regard to the property. The object of the work being done at present was to crosscut the mineral zone and then drift along it to a point below a shaft sunk some years ago and connect with the shaft by means of a raise, thus draining some of the older workings. The crosscut was driven 196 feet and from the point where it intersected the mineral zone a drift was started towards the shaft. Considerable quartz with pyrite and galena, also specimens of free gold, were encountered in the drift.

A survey of the data obtainable with regard to this deposit shows them to be contradictory. Assays from channel samples have shown almost uniformly low results and with the exception of occasional high assays, are, if these results are to be accepted, sufficient to condemn the property. On the other hand the management has assayed numerous grab samples, most of which show good values. The tendency would be to discard the results of these assays were it not for the fact that mill tests have shown a rather uniform recovery of $3 a ton, or slightly better. The management states that approximately 8,000 tons of rock from the open-cut was milled and the gold recovered was approximately $24,000. At that time, it is claimed, the mill was not equipped to recover the values contained in the sulphides and it was felt that the loss on this account was high. Consequently, 1,860 pounds of hand-sorted ore was shipped to a smelter and the return from this shipment was $2,200. These statements are given added weight by the publication of certain of the mill tests by MacLean who sampled the property. The mill tests for 1912 as summarized by MacLean are as follows.

Ore milled	Recovery	Average
2,495 tons.....	$9,467.58	$3.79 per ton

[1]Cockfield, W. E.: Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 2–4.
MacLean, T. A.: Lode Mining in Yukon, Mines Branch, Dept. of Mines, Ottawa, 1914, pp. 20–31.

The workings from which this ore came were sampled at the time the mill tests were being run and the weighted average of the samples is only 77 cents a ton. It is not to be inferred that MacLean's sampling was poorly done. Many others, including the writer, have since sampled the property with results closely checking those of MacLean. The writer took eleven samples from different parts of the property and on assaying these all proved blank. The details are as follows.

No.	Location	Character	Width
			Feet
1	North end of open-cut	Schist	10
2	" "	Yellow oxides, quartz and schist	3½
3	Wall of open-cut at top of shaft	Schist, very little quartz	9
4	East wall of open-cut 50 feet from shaft	Yellow oxide and quartz	5
5	Face of drift	Quartz	2
6	35 feet from face	Schist with quartz	4½
7	50 feet from face	Quartz vein	2
8	110 feet from face	Pyritized dyke	2
9	Mineral zone west of drift at junction of crosscut	Schist with quartz stringers	20
10	Mineral zone east of drift at junction of crosscut	Schist with quartz stringers	25
11	Hanging-wall (?) of mineral zone	Schist	10

Gold specimens may be obtained from the workings from which the last seven samples were obtained. In addition a grab sample was assayed showing some pyrite and galena, but no free gold. This yielded $40 to the ton.

The possibility with regard to the property lies in the fact that if the mill tests are to be accepted there may be a very large tonnage of rock of this grade. There is no apparent reason why mining should be restricted to the widths that it has, as there is no apparent difference between wall-rock and ore. There is thus the possibility of a zone of very considerable width carrying $3 values. Although $3 rock is not attractive in the Klondike if the deposit is limited, it does become attractive if there is exceedingly large tonnage in view. Unfortunately, to ascertain the value of the deposit will mean the expenditure of a considerable amount of money. Ordinary sampling does not give results at all comparable with the mill tests and it would consequently appear likely that the only way to adequately test the property would be to remodel the existing mill and put through it sufficient tonnage from different parts of the hill to test the content. If one of these zones in the Klondike becomes proved there are similar zones in other parts that might prove equally attractive.

WHEATON DISTRICT

Only two properties were visited in Wheaton district; these were the Export group (formerly the Union and Nevada mines) and the Cariboo group. Both properties are situated on Idaho hill near Annie lake.

The Export group of eight claims is situated on the southern, eastern, and northern slopes of Idaho hill and is owned by C. McConnell. In

addition there are two claims owned by Mrs. C. McConnell. The country rock consists of greywackes and argillites of the Laberge series. The ore-bodies are veins and replacements in those rocks. The property is in part a re-staking of the Union and Nevada mines[1] and there are a number of mineral showings of which the two upper are the most important. These are situated at elevations of 3,625 and 3,500 feet, respectively, and appear to represent two zones with somewhat similar dips and strikes cutting diagonally across the face of the hill. The upper showing is 27 feet wide and consists of a quartz and calcite gangue with pyrite, arsenopyrite, galena, and zinc blende. The better mineralized part consists of a streak 2 feet wide about 7 feet above the foot-wall, but there is some mineral throughout. The lower of these two showings is 22 feet wide and has an approximate strike of 80 degrees with a dip of 50 degrees to the south. There are three streaks from 1½ to 2 feet wide with heavier sulphide mineralization; the balance of the showing is somewhat sparsely mineralized.

Coming down the hill towards Schnabel creek from these showings there are a number of cuts all of which show mineralization and which are supposed to represent the traces of these veins descending the hill. This is, however, uncertain. Several of the cuts show narrow bodies of galena carrying high values in silver. On Schnabel creek are some of the older workings of Union mines, which include two tunnels, one driven 25 feet on a flat-lying quartz vein about 5 feet wide and carrying heavy pyrite mineralization, and the other being caved and inaccessible. There are also a number of narrow veins visible in the canyon of Schnabel creek. The majority of the galena veins are narrow, ranging from 4 to 12 inches. Assays of material picked from these show values ranging as high as 127 ounces of silver, 49 per cent lead, and 6 per cent zinc. A considerable amount of work is necessary in order to prove the relationships of the various showings.

The Cariboo group of three claims, owned by T. Brooks, is about 1½ miles up Schnabel creek from the Export group. There are four open-cuts, the lower two of which indicate a vein striking 35 degrees and dipping 60 degrees to the northwest. In the lower cut this shows a width of 7 feet and in the upper cut of 3 feet with a 2-foot streak of copper-stained rock on the hanging-wall. In the third cut there is a vein approximately parallel to the first and about 10 feet higher up the hill. This appears to be about 8 feet wide, but is not well exposed. The fourth cut was not into solid rock at the time of the writer's visit. The values reported are quite low.

ATLIN DISTRICT

Engineer Mine

The Engineer mine is situated on Tagish lake approximately 12 miles south of Golden Gate where the route to Atlin turns to the east. This property has been known for a long time and has frequently aroused interest on account of its spectacular gold showings. There has, however, been comparatively little written with regard to the geology of the property in recent years. The earlier developments are described by Cairnes[2] and descriptions of the property have also been given in the Annual Reports

[1]Cairnes, D. D.: Geol. Surv., Canada, Mem. 31, pp. 129–139 (1912).
[2]Cairnes, D. D.: Geol. Surv., Canada, Mem. 37, pp. 73–89.

of the B.C. Minister of Mines. A few years ago the first attempt was made to mine this property on a large scale and a great deal of money was spent on the development of the mine and in improvements to the camp, but the veins containing the high-grade ore did not furnish sufficient tonnage to justify operations on the scale attempted and the venture ended in failure. Since that time a small crew has been working to explore certain possibilities of developing a large tonnage of low-grade ore which has been indicated by some of the development carried out on the high-grade veins. Lately the property has been closed down due to financial troubles, but it is anticipated that it will re-open at an early date.

The country rock in the vicinity of the Engineer mine consists of Jurassic argillites, greywackes, etc., belonging to the Laberge series. These are pierced some distance back of the property by a stock of granodiorite which forms Engineer mountain. On the property itself and towards its southern end are two small outcrops of granodiorite, apparently part of the same stock which has been barely deroofed.

The vein system is intricate and it is largely because of the amount of development work that has been done by Engineer Mines, Limited, that the relations show as clearly as they do. In the central part of the property are two hubs of quartz; one of these is 200 feet east from the shore of the lake and the other about 1,400 feet east of the first. These are known as hubs "A" and "B" respectively. Hub "A" is the larger and is approximately 240 feet long by 160 feet wide, and is composed of a number of veins of quartz with replacements of country rock and included country rock; the whole forming a stockwork. Hub "B" is approximately 120 feet long by 80 feet wide and is similar in character to hub "A". These zones have been extensively tested, but so far have not been proved to carry commercial values.

There are also a number of veins which were originally thought to radiate out from these hubs, but more recent work tends to throw some doubt on this theory. The principal veins are the Double Decker, Engineer, Jersey Lilly, Boulder, Andy, and Blue veins. In addition there are a numbers of others which have been more or less neglected in the recent developments.

Running from the granodiorite outcrops near the south end of the property towards hub "A" there is a shear zone which is marked on the surface by a pronounced topographic depression and is well shown in the underground workings. Instead of the veins radiating out from the hubs of quartz previously mentioned it would appear that they are connected with this zone of shearing from which they appear to be given off at different angles. This shear zone divides the veins into two groups—the Double Decker, Engineer, and Jersey Lilly veins lying to the west, and the Boulder, Andy, and Blue veins lying to the east of this zone. Its relation to the veins is not quite apparent; none of the veins has been traced into the shear or across it. They all apparently start a short distance from this zone.

There are two sets of dykes on the property. One of these is roughly parallel to the direction of the shear zone and the other roughly parallel to the Engineer and Double Decker veins. These dykes are believed to be satellitic to the granite and the two sets are believed to be essentially contemporaneous. On account of the lack of outcrops near their points

of intersection this could not be definitely determined, but neither set of dykes apparently offsets the other. Both sets of dykes are older than the vein system. This is easily seen from the underground workings where the dykes are cut and offset by the veins. In places the dykes are heavily impregnated with pyrite.

The veins are characteristically narrow and range from mere stringers up to 2 feet or more in thickness. The better mineralized parts of the veins are in many cases only 6 inches to 8 inches thick. Most of the veins are filled with quartz. The Engineer vein, however, has a calcite-mariposite filling.

The workings above the fifth level are largely stoped out and were not visited. The main workings at the present time consist of the fifth, sixth, seventh, and eighth levels. The fifth level forms the main entry to the mine. This level has been driven from a point somewhat over 100 feet above the lake-level, and at the time of the writer's visit was 1,450 feet long. This adit encounters the Double Decker vein at 625 feet and the Engineer vein at 1,185 feet and was being continued to intersect the shear zone. From the point where the adit encounters the Double Decker vein a drift has been run on this vein 640 feet in a southwesterly direction and 360 feet in a northeasterly direction, and is continued in this direction to crosscut the shear zone. Throughout this distance the vein varies from a narrow stringer to about 2 feet and consists of quartz carrying values in free gold. Occasional spectacular values are encountered. The gold apparently follows cracks and crevices in the quartz.

The Engineer vein has been drifted on 1,100 feet southwest from the adit and 220 feet northeast. This latter drift is continued as a crosscut through the Jersey Lilly vein, the shear zone, and to the Andy, Boulder, and Blue veins, with a considerable total of drifting on the latter three veins. From the southwest drift a shaft has been sunk to the 800-foot level with intermediate levels at 600 and 700 feet.

The Engineer vein ranges in width from a seam to nearly 2 feet. It differs from the other veins of the property in being mineralized with calcite, mariposite (chrome-bearing mica), allemontite (a compound of native arsenic and native antimony), and free gold. The gold is associated with the mariposite.

The Boulder vein where cut by the 500-foot level is 4 feet wide and has been drifted on for 600 feet. It maintains this width over a considerable part of this distance. It consists of quartz with included fragments of country rock and carries in spots high values in gold. It lies on the eastern side of the fault zone and trends away from it at an angle of 30 degrees.

The Andy and Blue veins are somewhat similar to the Double Decker vein. The latter has an indicated length on the surface of 400 feet, but was not visited in the underground workings owing to ventilation difficulties. These veins do not, so far as is known, contain the spectacular values found in some of the other veins.

The Jersey Lilly vein from surface and underground workings has an indicated length of 1,400 feet, but it has not been traced continuously over this distance. It is inclined to the fault zone at 30 degrees towards the southwest. It also does not, so far as is known, contain spectacular values in gold.

The workings below the 500-foot level were full of water and consequently could not be examined. The following information, however, kindly made available by Mr. Hershman, gives an outline of the work done.

On the 600-foot level the Engineer vein has been drifted on for 160 feet southwest from the shaft and for 80 feet northeast from the shaft.

On the 700-foot level the Engineer vein has been drifted on for 260 feet southwest from the shaft and 320 feet northeast.

On the 800-foot level the Engineer vein has been drifted on 320 feet southwest from the shaft and for 280 feet northeast from the shaft. In these workings this vein shows essentially the same characteristics as to width and mineralization as in the upper levels.

On the 800-foot level there is a crosscut 320 feet long to the Jersey Lilly vein and a crosscut 380 feet long to the Double Decker vein with a drift on the latter 400 feet long—the greater part of this distance lying to the northeast of the crosscut. The Double Decker vein shows a definite widening on the 800-foot level where it has an average width of 2 feet and a maximum width of about 4 feet. This drift continues until it cuts the shear zone and from it the shear zone has been drifted on for 330 feet to the northwest and for 500 feet to the southeast, the drift being only partly in the shear zone and largely in the dyke that accompanies it.

The shear zone is one of the most important features of the property. As indicated by the topography it is quite persistent and underground it has been opened at several points. On the 500-foot level it is crossed by the Double Decker and Engineer drifts and on the 800-foot level by the Double Decker drift. At each point where cut by the underground workings it is well mineralized with quartz heavily impregnated with pyrite and carries values in gold. The width of this zone varies; but including the dyke, which in many cases accompanies it, it is as much as 65 feet wide. Of this 20 to 28 feet is well mineralized with quartz and pyrite. Good values have been indicated over widths of 6 to 14 feet, with lower values over the whole zone.

The property has interesting possibilities. Although it may be definitely stated that there is not sufficient ore in the vein system to maintain a large operation, yet there is sufficient to permit the property to be worked in a small way. The definite widening of the Double Decker vein on the 800-foot level and the widening of the Boulder vein on the 500-foot level indicate that there may be a possibility of the veins increasing in width with depth. The increases in width so noted have not been accompanied by a definite trend toward lower values. Further, the Double Decker and Engineer veins are inclined, so that if this attitude be continued they will intersect.

The most interesting possibility, however, is the chance that within the shear zone a concentration of workable grade and width of ore will be encountered. A large part of this shear zone has not been explored. It has an indicated length of about 4,000 feet and may be much longer, and as this shear zone was likely the main circulating channel for the mineralizing solutions there is a possibility of concentrations of ore along it which might supply the necessary tonnage to make the property a success. The values indicated in place are encouraging and further work on this zone is justified by the results already obtained.

Any further work which is done on this property will be watched with interest, for it is unlikely that such shear zones would occur singly. As there are several properties in the vicinity which exhibit seams of high-grade gold ores there is the possibility that these occur in connexion with similar zones of shearing. If the zone on the Engineer can be proved to carry ore-bodies of commercial size and grade much more work would be justified on these outlying deposits than has been the case in the past.

Ruffner Property [1]

The Ruffner property, or Atlin Silver Lead Mines, was being operated by a group closely allied with Engineer Mines, under name of the Atlin Ruffner Mines. The property was operated under agreement with Atlin Silver Lead Mines under which stock is transferred to Atlin Ruffner Mines in return for the development of the property. This agreement will place control of the stock of Atlin Silver Lead Mines in the hands of Atlin Ruffner Mines.

The property is situated on Leonard mountain in the vicinity of Fourth of July creek about 14 miles by road from Atlin.

Leonard mountain is underlain by granite intrusives. These are light grey, coarsely-textured rocks with a granitic habit, and are identical in appearance with the rocks of the Coast Range batholith. This intrusive has been invaded by dense, finely-textured dykes of hornblende or mica, feldspar, and augite. These dyke rocks are typical hornblende lamprophyres and may be regarded as basic differentiates of the granitic intrusives. The dykes that mining development has attempted to trace have proved quite persistent, one of them having been traced at intervals along the surface for over 5,000 feet. They vary somewhat in thickness, but do not generally exceed 30 feet.

The ore-bodies occur in fissures in the dykes. So far as is known the fissuring which gave rise to the ore-bodies is confined to the dykes and does not pass into the granitic rocks. The fractures are not simple fissures, but rather zones along which the dyke rock has been more or less shattered. The ore minerals filled fissures and also replaced the brecciated dyke material itself. The mineralization does not usually exceed a width of 6 feet and is in most cases somewhat narrower than the figure given. The mineralization is galena, arsenopyrite, and zinc blende associated with pyrite and chalcopyrite. Ruby silver has been reported from one of the workings. The gangue minerals are quartz, calcite, and ankerite. Values are in gold, silver, lead, and zinc.

Two main dykes have been identified. There are several others that are much narrower. The two important dykes are known as Nos. 2 and 4. On the No. 2 dyke the workings in order from the top of the hill downward are the 2B, 2A, 2X, and 2D. On the No. 4 dyke there are three sets of workings known as Nos. 4AA, 4A, and 4E. In addition

[1] Cockfield, W. E.: Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 17–22. *See also* Reports of the B.C. Minister of Mines, 1919–1927.

there are a number of prospect pits. The difference in elevation between the 2D and 2B workings is 1,500 feet and the horizontal distance 5,000 feet.

Work during the past summer was confined to the 2D workings. On the 2X adit the dyke had been explored for a length of 700 feet and had shown two ore-shoots with a combined length of 485 feet and an average width of 3½ feet carrying average values of commercial grade. A winze had been sunk 60 feet on this shoot.

The 2D tunnel which was a crosscut to the dyke 200 feet below the level of the 2X, was worked during the summer. The drift from this tunnel was not in good shape, so work was started in both directions along the dyke to pick up, along one direction, the ore under the winze from the 2X, and along the other the faulted component of the dyke beyond a fault which had been encountered in the work. The ore encountered in these workings was much lower in grade than that found on the 2X, but the possibility of striking the richer ore in these workings had not been entirely exhausted. This work had not been definitely completed when the company became involved in financial difficulties. These were, however, rapidly straightened out and work is once more under way. A development campaign has been laid out to rapidly test the possibilities of the property in depth.

The other workings referred to have been driven on ore showings, but as these have been described in a previous report it is unnecessary to repeat their descriptions here.

The work to date has not progressed to the point of proving the property to contain ore-shoots of sufficient size and grade to be commercial. On the other hand the results so far obtained are distinctly encouraging. Two shoots of ore of a very good grade are indicated and there are also possibilities in the upper workings. Lower grade sulphides have been found below the shoots of ore mentioned. Much more work remains to be done, but it appears that the present development campaign will furnish much more data with regard to the size, distribution, and values of the ore-shoots.

SOME OF THE MINERAL PROPERTIES OF TAKU DISTRICT, BRITISH COLUMBIA

By F. A. Kerr

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INTRODUCTION

During the summer of 1930 a few weeks were spent in Taku district examining some of the mining claims and it has been deemed advisable to publish some of the information gained. The work was greatly facilitated by the assistance and co-operation of the officials of the Alaska Juneau Gold Mining Company, of the United Transportation Company, and the Taku Trading Company. The writer is also indebted to Chas. G. Warner, T. A. M. Haney, Corp. Barber, Leo Ostermann, and many others, for assistance and advice in the field. R. B. McConnell and J. A. Mitchell rendered valuable aid as field assistants.

A general description of the district has been given in a former report[1] and the present report constitutes merely a supplement. The general characteristics of the district and some features of the general geology are described in the succeeding report in this volume and some further information is contained in the following articles by the present writer: "Northwestern British Columbia during 1930 and 1931," Can. Min. Jour., March 13, 1931, and "Defining the Mineral Zones of Northern British Columbia," Can. Inst. of Min. and Met., August 1931.

The great activity which it had been anticipated would take place in this district during the summer of 1930 did not materialize. Extensive operations by the Alaska Juneau Gold Mining Company had been carried on throughout the winter of 1929-30 on the newly discovered Manville property. These were continued until about the middle of August, 1930, when work was stopped and the property abandoned. The same company did considerable work in testing the Banker and Potlatch groups of claims, and in prospecting along the east side of Talsekwe valley and in other parts of the area. Some work was done on a number of other discoveries made the previous year and prospecting by a small number of men was carried on throughout the season. A few discoveries were made, but none was reported to be outstanding.

[1] "Taku River District, British Columbia"; Geol. Surv., Canada, Sum. Rept. 1929, pt. A.

GENERAL GEOLOGY

The non-intrusive rocks of the district appear to consist of Palæozoic, non-calcareous sediments capped by limestone and overlain by Mesozoic volcanics. The valley of the lower Talsekwe appears to be flanked largely with massive and poorly bedded green volcanics. The upper Talsekwe, on the other hand, is largely in altered, non-calcareous sediments. Rocks suggestive of these materials appear from distant observations to occur on the mountain northeast of the Tulsequah Chief workings and on the mountains west of the Whitewater. Limestone which appears to lie between the sediments and volcanics occurs on the mountain northwest of the junction of the Talsekwe and Taku and sediments were observed on its west side. Furthermore, on the Tulsequah Chief property near the old camp north of the trail at about 150 feet above the river, on the Talsekwe about a mile below the Tulsequah Chief warehouse, and in the vicinity of the Banker and Potlatch workings, there are limited outcrops of limestone and other sediments amid the volcanics. The limestone in the vicinity of the Banker and Potlatch workings is said by those in charge of prospecting there, to occur in a series of *en échelon* bands, trending southeast from the workings. Observation of structural features and a study of the distribution of these rocks strongly suggest that the limestone and other sediments in the lower part of the valley are brought to the surface on the crests of minor, sharply folded anticlines. If all the limestone belongs, as seems reasonable, to the same series, there is a further suggestion in the general distribution of the limestone that Talsekwe valley occupies a synclinorium made up of very close folds. All this suggests that the extent of volcanics below the surface may not be nearly as great as it might appear to be. They may very well occur in a relatively thin shell which thickens only in the minor synclines and becomes thin to absent on the anticlines. Toward the south, however, there is less evidence of the sediments, and the volcanics appear to become more widespread and probably extend to greater depth.

Although the data gained so far by no means indicates definitely that these features do exist, it is sufficiently suggestive to deserve serious consideration by those prospecting in the area. It is, of course, possible that the sediments observed do not correlate and that some of them may be interbedded with the volcanics.

ECONOMIC GEOLOGY

Practically all the observed deposits, including the Tulsequah Chief, Manville, Whitewater, Potlach, Banker, and a number of others of lesser importance, are of the same general type. All are in the main replacement deposits and, with the exception of some of the Potlatch-Banker group that occur in limestone, are in volcanics. All those in the volcanics are characterized by much the same megascopic appearance: the normal dark grey or green rocks have been altered to a light grey and have been pyritized in zones within which sulphides carrying some gold and silver are concentrated in comparatively small, irregular masses.

In general there is a large area of volcanics along the Talsekwe and south fork of the Taku which shows considerable evidence of this type of mineralization and in which most of the discoveries have been made. It lies several miles east of the main contact of the batholith and about the same distance west of a series of large, intrusive masses believed to be related in origin to the main batholithic body, but to be quite different in age. In this area along the south fork for about 8 miles from the Taku, there is a series of small satellites believed to be associates of a phase represented in the main batholith. It seems probable that these, together with others not exposed at the surface, are the source of the mineralization. Solutions rising from them penetrated the overlying rocks. The non-calcareous sediments appear to have been the least favourable for precipitation of the minerals, so that wherever possible the solutions migrated beyond them. However, in some places, as was observed at one property in Alaska, deposition did take place within them. Passing beyond, the solutions would reach limestone in a narrow band, or volcanics. The limestone was favourable for replacement as is illustrated by the Potlatch-Banker deposits and the volcanics also favoured precipitation as shown by the many deposits in them throughout the area. It seems very likely and, indeed, the contention is supported in many places, that the solutions on reaching the limestone or volcanics migrated along the contact between these rocks and the non-calcareous sediments, so that the deposits now lie between the non-calcareous sediments and unaltered volcanics. In such cases, owing to the deformation of the contacts, the altered zone and likewise the concentrations of sulphides within it are similarly irregular. In other places the solutions entered broken or sheared parts of the volcanics and moving along these parts altered the rock and deposited in concentrations or disseminations the sulphides and other important minerals.

Alteration zones have been observed throughout the area indicated. As a rule they are easily discernible by reason of their rusty, weathered surfaces. The unweathered rock is usually grey and impregnated with pyrite. The size of the zones varies greatly; many are clearly small and lenticular in shape. Others extend for considerable distances with irregular outlines, and many are discontinuous. None was observed to maintain uniformity in size and shape for any great distance. The trend of the individual zones is not as a rule very definite and they show no very systematic arrangement. There is, however, a greater tendency toward north-south trends and it is to be expected that well-developed zones will be most commonly found trending in this direction, which is that of the general structural lines. However, the direction of zones may very well be controlled by local structural features which may show trends considerably at variance with these. In Talsekwe valley the direction of minor folds, schistosity, and other structural lines observed is as a rule nearly parallel to the valley.

Within some of the altered zones there have been found important concentrations of sulphides. The size or position of these has not yet been found to bear any systematic relationship to the size or shape of the containing zone. They are essentially in the form of lenses which tend to lie in one plane of the zone, though there may be subsidiary series. Where the deposits are large the lenses may be intergrown and more or

less continuous for considerable distances. In some cases beyond these lenses the zones, besides the usual pyrite content, carry in restricted sections disseminations of other sulphides.

Microscopic examination of a large number of specimens, mainly from the Tulsequah Chief and Manville properties, has contributed much information about the nature of the volcanics and their alteration. However, it has not afforded an entirely clear conception of their original nature nor of the development of the altered zones. In the field, though there were differences in appearance of the volcanics, it was not considered feasible to make any subdivision other than on the basis of extent of alteration and pyritization. In the vicinity of the deposits it was not possible, except in rare cases, to distinguish with certainty flow, dyke, and pyroclastic rocks. Microscopic examination contributed little toward a solution of the problem. It has not yet been possible to determine whether the volcanics in the vicinity of each altered zone that was studied are all of the same type or what types are included, since the original characteristics are as a rule largely destroyed. Evidence gained throughout the area suggests that there is a series including flows and pyroclastics with associated intrusives, all considerably folded and altered. The composition and other characters of the rocks near and within the altered zones have been found to vary widely, thus indicating the possibility of differences in the original rock. However, as gradations between extremes both in field observations and under the microscope are fairly complete and as most of the changes can be attributed to alteration, the preponderance of evidence suggests similarity. Study of the geology of the volcanics beyond the immediate vicinity of the deposits, which has not yet been undertaken, will, of course, throw much light on this question.

In view of the apparent similarity of the mineralization in most of the examined deposits in Taku district a study of a representative of the type may be of considerable value and serve a more useful purpose than a limited study of many. Therefore, the general characteristics of the Tulsequah Chief deposit, offering the best opportunity for observation, will be described in detail.

In order to gain some conception of the rocks involved a large number of specimens were taken from the light grey, altered zones and from the adjacent dark grey and green material. No specimen taken, though some were procured as far as 400 feet from the light grey zones, is entirely free from alteration produced by the mineralizing solutions. Three specimens, one of which is from a locality beyond the Tulsequah Chief claims, suggest that these rocks were originally andesitic. Apart from the effect of the mineralizing solutions, two of these specimens are made up in the main of considerably altered oligoclase and secondary minerals, mainly epidote, chlorite, zoisite, and calcite. Textures in these and other specimens suggest intrusives or extrusives and there is sufficient evidence in thin sections examined to suggest that all the rocks were originally of andesitic composition.

The dark-coloured rocks adjacent to the lighter zones show characteristics that are attributed to the effects of the mineralizing solutions. In places they grade to a soft, green rock which under the microscope is found to be entirely chlorite. One specimen in part is entirely chlorite, but other parts exhibit knots and impregnations of pyrite and albite, the latter being

in general much fresher than the main mass of the rock. Another specimen shows well-defined replacement veinlets, knots, and impregnations of albite and quartz, with, in places, a centre filling of calcite. These are cut by calcite veinlets. Some quartz in the original groundmass may not be the result of the mineralizing solutions. One dark specimen has in places a

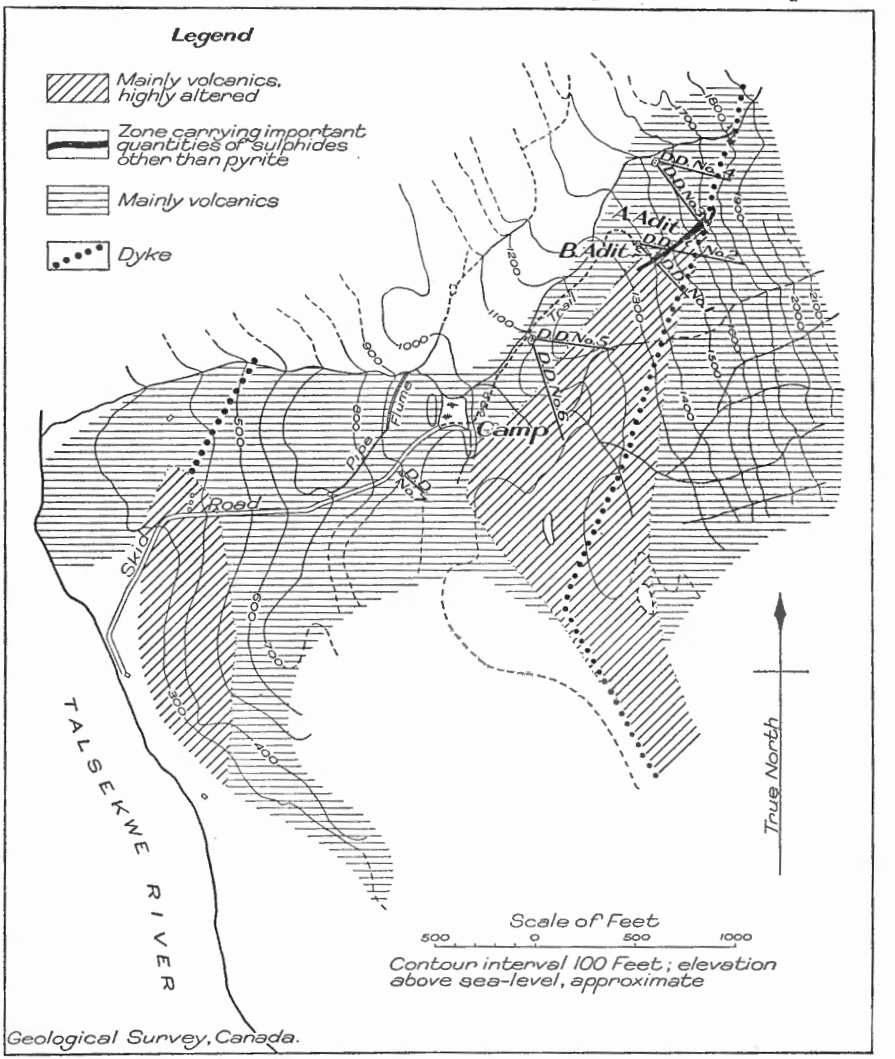

Figure 1. Area adjacent to Tulsequah Chief workings, Cassiar district, B.C.

texture suggestive of breccia. Under the microscope there is also a suggestion of a fragmental character. The rock is largely chlorite with considerable white mica (paragonite) and some quartz scattered throughout. Calcite is not present. A specimen of the dark rock, though it is closer to the altered zone, appears fresher than those so far described. Its

groundmass is difficult to determine, but appears to be largely albite (or oligoclase) and quartz with some well-defined laths of the former. Chlorite, epidote, magnetite, and calcite are fairly abundant. Unlike any of the other specimens described there are large masses of albite which in some cases have definite phenocryst-like forms. They are in the main fresh, with only a few scattered shreds of white mica and there is a suggestion that they have grown by recrystallization or replacement. This rock may originally have had a composition quite different from those of the several rocks already described, but there are many suggestions that its present composition is largely secondary, the result of alteration by mineralizing solutions.

A specimen of dark rock from the west side of the zone is dark green, breccia-like, and is schistose. It is largely chlorite and white mica with fragments of quartz, scattered throughout. Magnetite and a small quantity of calcite were noted. The white mica in places occurs in forms suggestive of the alteration of larger individuals of plagioclase which might have been phenocrysts or perhaps secondarily developed. The quartz masses are comparable in size with the phenocryst-like masses of feldspar and have, as a rule, distinct crystal outlines. Though in places vaguely cracked into small, irregular pieces and in places cut by small veins of the groundmass, each has practically uniform extinction. A number of features suggest that these masses, like some of those of plagioclase, have grown in place. Another specimen holds albite (or oligoclase) in large masses like phenocrysts and has quartz masses similar to those of the last described specimen. They, with irregular grains of quartz, occur in a finer grained matrix of mica, chlorite, quartz, and possibly feldspar. The large, phenocryst-like masses of albite are partly or completely altered to white mica. Another specimen holds large quartz masses and areas of white mica in a groundmass largely of quartz, white mica, and chlorite. The thin section shows sharp, angular contacts between areas and suggests a breccia, as does also the weathered surface. There are also present some replacement stringers and masses very similar to albite-quartz stringers of some other specimens, but composed of quartz alone; it is not unusual in other specimens for one of the minerals to be entirely absent in a veinlet for the whole length of a thin section or a large part of it.

From these descriptions of the dark grey and green country rock it is clear that it is not yet possible to say how many different types of rocks are involved. However, there are good reasons for believing that all were probably andesitic. The quantity of ferromagnesian minerals may have varied considerably. It is thought that practically all the albite and quartz, which vary greatly in amount, are secondary. It follows then that some of the dark rocks are wholly of secondary minerals, though all these minerals may not be due to the effects of the mineralizing solutions. Field observations supported by microscopic examinations lead to the conclusion that few of the dark-coloured volcanics on the hillside in the area represented by Figure 1, do not show some effects of the mineralizing solutions. The chlorite in these rocks is largely responsible for their colour and by its masking effect makes all rocks, despite great differences in composition, appear very similar megascopically. Magnetite is usually present in the least altered sections. Secondary pyrite is abundant to absent. In some

places it is very abundant in rocks not greatly altered. This is particularly true of the southern part of the upper altered zone of Figure 1, where the rock, though it has not the usual light grey colour, has been included in the altered zone.

In general the light-coloured volcanics represent more complete alteration by the mineralizing solutions. The light colour is borne by a variety of rocks and is brought about mainly through the bleaching or removal of the chlorite. Magnetite and epidote are of very minor importance. Almost entirely chlorite rocks grade to light green and white through bleaching of the chlorite. Light-coloured rocks of this type occur at various points, mainly near the edge of the altered zones. In places they appear to be fairly extensive.

A light grey specimen, and a somewhat darker specimen, both from the altered zone near the camp, are almost entirely quartz, white mica, and pyrite. The darker specimen owes its darker colour to a small chlorite content. Much of the quartz appears to have been introduced with the pyrite. It markedly increases in abundance near the pyrite, whereas the white mica shows a corresponding decrease, though some other specimens consisting mainly of white mica contain much pyrite. Parts of the darker specimen in texture and composition are very like the dark rocks which carry large masses of albite and quartz in a finer grained groundmass. Another specimen is a light grey, hard rock taken from near the dyke and so resembles it that in hand specimens the two cannot be readily differentiated. It has a fine-grained groundmass largely of quartz and white mica with possibly some chlorite. Within this are small fragments of quartz and the whole is cut by irregular replacement stringers or masses of quartz and albite with some pyrite. The feldspars of these are fresh, the quartz is little broken, and the veinlets have not been distorted since formation. A specimen from the lower altered zone is light grey and under the microscope is similar in most respects to the specimen just described. Some of the quartz fragments have crystal outlines. The rock shows a somewhat schistose structure and the veinlets tend to follow these lines. Specimens from the very soft, usually highly sheared sections of the altered zone are, as a rule, almost entirely white mica; those from harder zones exhibit a higher quartz and (or) albite content.

The light grey rock of the altered zone is not greatly different from much of the dark grey material. It is made up mainly of quartz and white mica. Plagioclase feldspar is found in varying amounts, much of it being a product of mineralization. Green chlorite is rare to absent, but bleached chlorite is abundant in certain localities near the edge of the altered zone. It is due largely to the lesser amount of chlorite that these rocks are light grey instead of dark. Pyrite impregnations are found throughout the light grey zones and vary from almost insignificant quantities to massive lenses. The occurrence of other sulphides will be described later.

Associated with the altered zones, in some cases within and in some cases beyond, are light grey dyke-like masses. In the upper workings the dyke-like mass, as a rule, shows a sharp contact with the adjacent rock. The outcrop cuts across the altered zone, truncating laminations. It also cuts through a corner of the small exposure of the altered zone on the creek north of the mine workings and continues into the dark, less altered

rock beyond with all the characteristics of a dyke. Beyond the lower altered zone, material like the dyke at the workings appears to occur in a wedge-shaped mass. Its continuation south of the trail into the zone was not identified, but within the altered zone many outcrops exhibit a rock somewhat similar to that of the dyke. Similarly in the upper workings there are many places where the rock has an appearance identical with that of the dyke. Conversely, in some places in the zone the presence of the dyke is hardly discernible and not identifiable with assurance. In many places the dyke is beautifully banded parallel to its walls by dark lines and breaks into smooth, even-surfaced laminæ along these lines. This characteristic, when present, seems to identify the dyke.

Under the microscope the dyke rock in many ways markedly resembles some of the light grey and also some of the dark grey rocks. However, the dyke rock varies much and there are as great differences in character between specimens of dyke rock as between dyke and other materials. One specimen of the dyke resembles both the dark and the light grey quartz-albite rocks, except that large masses of albite are well-defined phenocrysts and have sharp crystal edges. The groundmass is fine-grained, largely white mica, quartz, and possibly feldspar with somewhat larger, irregular grains of quartz. Calcite is present and pyrite occurs in isolated cubes and along the lines of lamination. These two minerals appear to contribute mainly to the darker colour. The dyke is sheared and the planes of schistosity bend around the phenocrysts of albite, which are in some cases slightly broken. There are indications of replacement stringers of quartz (and albite) such as are noted in so many other rocks. The phenocrysts are partly altered to white mica. A specimen from the lower dyke shows a similar rock, but without phenocrysts. One specimen believed to represent the centre of the upper dyke is almost entirely quartz and albite. It shows some fairly large masses of somewhat spherulitic albite with small angular crystals and irregular inclusions of feldspar or quartz. There are some scattered feldspar laths with irregular borders. Some white mica occurs in the feldspars. Schistosity is not readily apparent. Only a few phenocrysts are present and these have irregular, as if corroded, edges, unlike the sharp borders of the specimen previously described. A specimen from a point believed to be fairly well within a thick part of the lower dyke shows some similarity to the last described. It is, however, much finer grained and has no very large masses of albite. It, however, has similar, small, corroded laths of plagioclase. These two specimens are much like—not only in composition but in texture—light grey and dark grey materials beyond the dykes.

Two specimens from the contact of the dyke in the upper workings show textures not previously noted. The groundmass contains innumerable spherulites believed to be of quartz. Some other specimens showed a texture somewhat similar in the main, but true spherulites were not noted. In the spherulitic specimens there are definite phenocrysts of albite with sharp crystal outlines. The rocks are largely quartz, albite, and white mica. The contact here, both megascopically and microscopically, is fairly sharp and marked by a difference in colour—the country rock being somewhat darker. The spherulites in the dyke become smaller toward the contact and along the edge there is a narrow coalesced band of them. Small stringers from the dyke lose the spherulitic character on becoming

narrow and resemble the contact band. The country rock is not spherulitic, but otherwise it is not greatly different. The dyke, however, contains only a few isolated grains of pyrite, whereas this mineral is abundant in the country rock. An irregular replacement vein cuts both; in the dyke section it contains calcite and quartz and quickly pinches out; in the country rock it also holds fluorite and flaky chlorite. Galena appears in the vein for a short distance into the dyke. Chalcopyrite was observed elsewhere similarly located, but in this specimen occurs only in the country rock. At other points in the dyke similar masses of chlorite and calcite without sulphide were noted; these probably constitute the dark spots that occur in some parts.

In the case of the dyke rock it is to be noted that only two well-defined features were observed which were not seen in the other rocks; these are the sharply defined phenocrysts of albite and the spherulitic groundmass. Even these features are not universal. In the main the dyke rock exhibits a saccharoidal texture somewhat different from similar phases in the altered zone, but the differences are not clearly enough defined or sufficiently persistent to be of much significance. The dyke rock is mainly albite and quartz, the former in places being altered largely to white mica. In the groundmass, which is usually fine grained, there are somewhat larger, irregular masses or spherulites of quartz. Pyrite is rare, occurring in fairly large cubes in the lower dyke and in tiny crystals in the upper one. In places the dyke is well sheared. Rare replacement stringers of sulphides and associated minerals penetrate the edges for short distances. Whether the country rock was altered to the feldspar-epidote-chlorite state before, during, or since the development of the altered zone is not apparent. The dykes are clearly different from the rocks, unaffected (or least affected) by the mineralizing solutions, but are so much like some of the altered phases that it seems necessary to consider that much the same alteration processes affected both.

Close to the edges of the altered zones, the dark rocks show two main types of alteration due to mineralizing solutions; in one case the product is entirely chlorite with its usual green colour and soft soapy texture and in the other hard, siliceous rocks made up mainly of plagioclase, quartz, and chlorite. There are gradations from the one type to the other and from these to the original rock. Calcite occurs in most of the dark rocks of the second type and some white mica is present. Magnetite is well distributed in the original feldspar-epidote-chlorite rock and in most of the slightly altered phases, but disappears with considerable alteration. Secondary pyrite, occurring only locally in the dark-coloured rocks, does not necessarily bear a direct ratio to the extent of alteration.

The altered zone is characterized by the light grey colour (excepting the highly pyritized dark phases). The dark, chloritic rocks, by bleaching of the chlorite, or by loss of this constituent and epidote through replacements by albite, quartz, and white mica, have become lighter in colour. Textural and compositional changes have been brought about by recrystallization of albite and quartz, alteration of secondary albite, and other factors of minor importance. Pyrite, though occurring with a pure quartz gangue in places, is as a rule least abundant in the hard, dyke-like siliceous sections. In places its abundance is relative to that of quartz;

elsewhere it is absent where quartz is dominant. Likewise it may be abundant to rare in highly sheared, largely mica matrices. The dykes show in places the sharp, well-defined contact, as well as other features characteristic of fracture filling, but lack of these and pronounced similarity to sections of the zone point almost equally definitely to a replacement origin for other sections.

Within the upper zone development work has shown up shoots of mixed sulphides. They are clearly replacement deposits. The sulphides, chalcopyrite, sphalerite, galena, pyrite, and others in minor quantities, have replaced the rock minerals. Where the sulphides are scattered the ordinary rock constituents form the gangue. Locally in the massive sections and nearby there are veinlets and some scattered masses of fluorite, calcite, flaky chlorite, and barite. There may, also, be associated veinlets of quartz and albite.

The genetic relationships to be deduced from the various features exhibited are not entirely clear. From the data gained, however, a number of stages in the development of these features can be distinguished fairly definitely. The order in which they are stated below is not necessarily correct, but is believed to be so in a general way.

(1) Alteration of a rock originally almost quartz-free and bearing a large percentage of albite-oligoclase, to in part, chlorite, epidote, and calcite.

(2) Alteration of parts of the altered rock of stage 1 (or a different rock) to chlorite.

(3) Alteration of the altered rock of stage 1 (or different rock still holding feldspar) to a chlorite-epidote-calcite-quartz-white mica rock of dark colour and by further loss of the first two constituents and gain of the last two, to a light grey rock in which either quartz or white mica may be dominant almost to the exclusion of the other.

(4) Bleaching of chlorite, a process which took place without change in mineral content.

(5) Introduction in disseminated grains and massive shoots of pyrite. White mica and quartz contents, generally the latter, appear to be greater in the immediate vicinity of pyrite. Quartz undoubtedly accompanied the pyrite in places; albite possibly did the same; fluorite and other gangue minerals developed in minor quantities. It is notable that the amount of pyrite is not directly proportional to the extent of alteration; for instance it is found locally in dark rocks in greater abundance than in some of the light rocks which have been subjected to much greater change.

(6) Replacement in places, of constituents, mainly the pyrite, by chalcopyrite, zinc blende, galena, and gangue minerals.

(7) Injection of albite-quartz dyke-like masses; alteration of these in part to white mica and quartz and their shearing parallel to their trend.

(8) Formation of chalcopyrite and galena stringers and replacement masses cutting sulphide shoots and edges of dykes. Possibly, also, other sulphides were introduced in the same way. Formation of calcite-chlorite-fluorite-quartz-barite veinlets which in part form the gangue of the above sulphides, in part form the continuation of sulphide-bearing veins, or may be entirely separate from them.

(9) Injection of replacement veins, knots, and masses of quartz and (or) albite.

The following features, though not proven, are strongly suggested and are believed to have taken place.

(1) Recrystallization of quartz to form large phenocryst-like masses in the chlorite-calcite-white mica-quartz-albite (albite-oligoclase) rock.

(2) Building of albite phenocryst-like masses in similar rock.

(3) The breaking down of albite or albite-oligoclase into quartz and white mica and the building up of albite masses by recrystallization or replacement alternated.

(4) Shearing of the rock in parts of the now altered zone before penetration by mineralizing solutions and continuation of shearing during the early stages of penetration by the solutions. Undoubtedly considerable shearing of the volcanics took place, but at what time is not clear. The massive sulphides do not show any definite evidence of shearing, though there appears to be a slight tendency to bending of lines of schistosity around grains of pyrite. The mineralization is banded corresponding to the shearing planes. The dyke truncated the shearing of the rocks and the banding of the mineral deposits. Shearing of the character occurring in the dyke is not apparent beyond it and is thought to be peculiar to the dyke. Small sulphide stringers in the dyke cut across the shearing.

From the foregoing statement of facts and inferences the following hypothesis is offered. The volcanics were subjected to shearing during a considerable period of time, in the latter part of which circulation of hydrothermal solutions began. These, in general, deposited infinitely more silicates than metallics, as is well exemplified not only by the relatively extensive areas of highly altered, light grey rock, but also by the limited alteration extending far beyond these. The circulation of the solutions continued for a considerable period of time, during which changes in composition and probably in temperature took place. At times these solutions produced mesothermal pyrite impregnations throughout a broad zone and in concentrations some of which constitute the body of the main sulphide shoots. The location of these, probably, was along lines of major circulation represented by much sheared or broken sections. Accompanying the deposition of pyrite there was most probably an increase of quartz and white mica. At other times, in general later, the solutions carried sphalerite, chalcopyrite, galena, and minor quantities of other sulphides and gangue minerals which replaced mainly the pyrite and thus seem to owe their presence in the shoots chiefly to the abundance of the pyrite there and to its more ready replacement. The minor gangue minerals such as fluorite, calcite, barite, and flaky chlorite, accompanied in the main the later sulphides. They occur also as stringers without sulphides, cutting the shoots and in places extending beyond. With the introduction of the later sulphides there were probably changes in the wall-rock similar to those effected at the time of introduction of pyrite. There may also have been some albite associated with some of the sulphides. In the lower altered zone no appreciable quantities of the later sulphides were noted. In the main the solutions seem to have been of a nature somewhat between the ordinary hydrothermal mineralizing solutions and those producing aplites; in mineral composition they seem to have resembled aplites, but as regards penetration of the wall-rock they seem to have been more like ordinary hydrothermal solutions. At one time, as evidenced

by the dykes, the injected material seems to have been still more in the nature of an igneous intrusive. The dyke rock in some of its characteristics, notably the well-defined phenocrysts present in some sections, is more in the nature of a quartz keratophyre than an aplite. It is probable that the dykes assume in places the characteristics of quartz keratophyres and elsewhere those of albitite (albite-quartz aplite). The dyke materials were somewhat less tenuous and though following in the main the established circulation channels, forced open cracks and penetrated in some cases far beyond the limits affected by slower moving solutions. It is notable that these dykes are reported to be fairly abundant on the hillside between the Tulsequah Chief and Manville properties and as a rule carry appreciable quantities of pyrite. Malachite stain in places in the dykes on the former property suggests a possible chalcopyrite content other than the fine stringers introduced along the edge.

The order of succession of the various kinds of injected materials is not entirely clear. The age relationship of the sulphides is that commonly found in the so-called pyrite deposits of this type. The age of the dykes in relation to the mineral deposits has not been definitely established, but it seems reasonable to conclude that the dykes were injected after the ore-shoots had largely formed, and that some mineralization, notably some chalcopyrite and galena, was later. It may be significant that according to the assays made, galena is in appreciable quantities only on the east side of the dyke. It is possible that the dykes which are so well defined in places may not in other places be recognizable.

The solutions responsible for the deposition of quartz and albite seem to have been effective at different times as the products are seen in various stages of development, alteration, and shearing. It seems possible that conditions tending to build up feldspar alternated with those effective in breaking it down. In many places stringers containing albite remain unaltered, unsheared, and unbroken in materials badly sheared and altered to white mica. These characteristics suggest that the stringers were among the last developments. The change from conditions suitable for deposition of feldspar to those that would alter it to white mica might not be very great as the two minerals are not greatly different in composition.

By the various processes outlined there have been developed great zones of alteration in which there are fairly large pyritized sections with relatively small concentrations of this and other sulphides. The Tulsequah Chief zones probably owe their location to the shearing so evident in various sections. Because of the nature of the volcanics, the shearing and consequent development of the zone have been very irregular. Many peculiarities brought about by varying degrees of alteration are attributable to corresponding degrees of shearing. Hence, irregularity is not only a matter of shape and size but of practically everything concerning these zones. Another factor that may contribute to the shape, size, and distribution of the altered zones is the presence of rocks not susceptible to replacement. Sedimentary rocks occur at the northern end of the lower altered zone on the Tulsequah Chief property and seem to be present on top of the mountain. These may have had some bearing on the distribution of the altered zones here.

The distribution of pyrite within the altered zones does not appear to conform to any clearly defined rules. There is, however, a tendency for it to be most abundant and concentrated along or near the zones of maximum shearing or fracturing, which in turn probably were those of maximum circulation of solutions. Relative to other sulphides it appears to be more abundant at depth, but this may be largely the result of these having displaced it in the upper sections. The later sulphides for the most part seem to have followed the pyrite. There are some suggestions that the upper parts of the zones have been favoured. Association with narrow parts may also have some significance other than that already noted.

The foregoing descriptions pertaining to the Tulsequah Chief claims, indicate the irregularity and variations that occur even within one deposit. Between different deposits even greater differences occur, but as a rule there are sufficient similarities to identify clearly each with the group. The extent of the altered zone varies considerably with each deposit and in some cases is relatively insignificant compared with those at the Tulsequah Chief. Many small zones do not appear to be accompanied by any mineral deposit. The valuable minerals in different deposits show some variation, but those most abundant in the property described are the most common so far discovered. Other minerals observed in fairly large quantities in the properties examined will be noted under property descriptions.

TULSEQUAH CHIEF

The upper, highly altered zone on the property trends in the main a little east of north. Its top is visible at two points near its north end and there dips south at the rate of about 50 feet in 400 feet, but this is not a very satisfactory criterion of what may have been the average rate of dip. It is not improbable, however, that to the south the top of the zone maintained an attitude not far from this, so that farther south, in the draw extending southeast from the camp, where the top has been eroded, the zone may have been cut down 400 to 700 feet.

The zone in the workings and where penetrated by drill holes has a steep northwest dip and this may be maintained to the south. It is noteworthy that the dip of structures observed and postulated for the area is also northwestward. The dips of both walls are about the same, but owing to great irregularities the walls are not parallel. In the section in the northern part of the zone above the projection of drill hole No. 4, the zone has a width of about 40 feet at A level, narrows to 10 feet on B level 200 feet below, and is again about 40 feet in the drill hole more than 100 feet lower. The pinching and swelling thus exhibited vertically, also take place laterally, the zone widening southward on the surface to a possible 900 feet. This is believed to be due mainly to a widening laterally, though it may in part be due to a widening at depth. The zone in general appears to be lenticular in shape.

Offshoots and subsidiary zones are numerous. The main zone divides or links up with others either at depth or laterally. Towards the north end, in drill holes Nos. 3 and 4, a subsidiary zone is shown to lie more than 150 feet to the northwest and about parallel to the main zone. The presence of two sulphide shoots with considerable dark-coloured rock intervening is shown farther south in both drill holes Nos. 1 and 2. From

this it is believed that the wide part of the altered zone represents the merging of two separate zones. In drill hole 5, still farther south, a band of about 100 feet of dark-coloured rock is cut at the bottom. This band may correspond to the band lying between the sulphide schists cut by holes Nos. 1 and 2 to the north. In drill hole No. 5 west of the dark rock is a zone of about 200 feet of rock, on the whole not as highly altered as in the workings, but probably corresponding to that section. On the other hand, drill hole No. 6 (directed more to the south than No. 5) cuts more than 300 feet of largely highly altered rock.

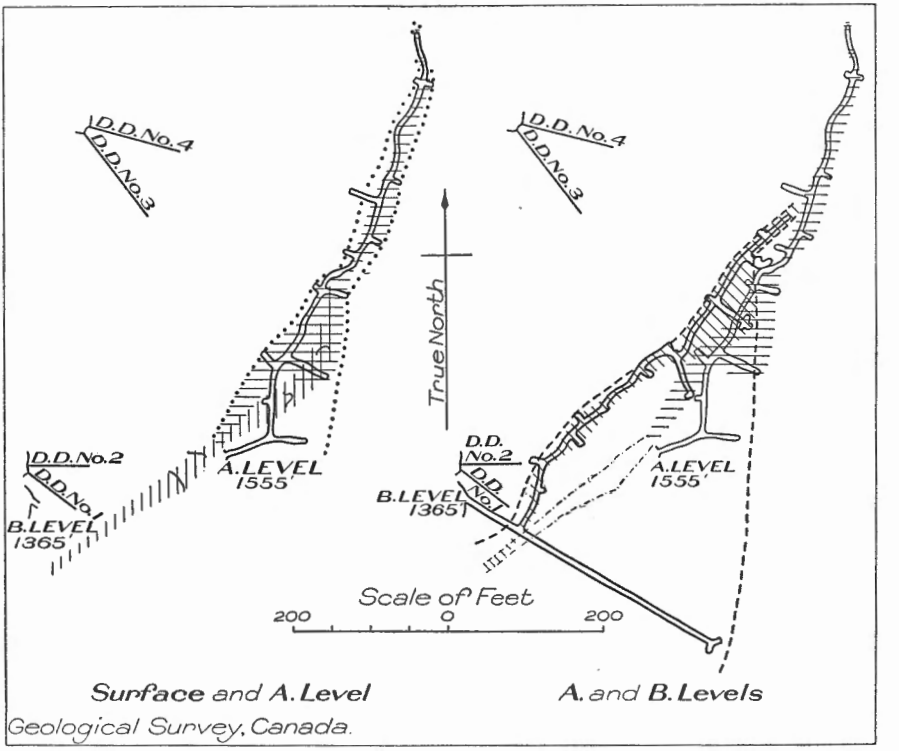

Figure 2. Workings of the Tulsequah Chief showing approximate extent of altered zone carrying important quantities of sulphides other than pyrite. (Zone on surface represented by pattern of vertical lines, on A level by pattern of horizontal lines, on B level by pattern of inclined lines: assumed limit of altered zone on A level by dotted line, on B level by pecked line; the dyke is not represented.)

Drill holes Nos. 1, 2, 3, and 4 cut mineralized sections thought to correspond to the sulphide concentrations in the mine workings above. In No. 4 the band high in sulphides is of about the same width and character as the band in the workings above. This is also true of No. 3 where the dyke lies in the zone of concentration. In No. 2 the proportion of pyrite to other sulphides appears to be greater than in B level. This may also be true in drill hole No. 1 where the massive mixed sulphide zone is only 6 feet wide on the west side of a well-pyritized zone of over 50 feet.

The evidence from these four drill holes, however, suggests that the shoot maintains about the same width and character for more than 100 feet below B level. Drill holes 5 and 6, cutting what appears to be the corresponding section of the altered zone at 500 feet lower than B level and, respectively, 500 and 800 feet, southwest of its portal, show well-pyritized sections, but no shoots corresponding in character to those of the other holes were noted. A number of open-cuts and outcrops near the camp and southeast of it show much well-pyritized rock. Prospectors working on the southern extension of this zone during the summer of 1930 also reported finding highly pyritized rock. The attitudes of the shoots of the workings in the main conform with the attitude of the altered zone. They dip steeply northwest, though below the southern part of B level there is an easterly dip.

Drill holes 1 and 2 also show a highly pyritized section over 100 feet in width lying more than 100 feet east of the main shoot. There appear to be small quantities of other sulphides scattered throughout and at one place in No. 1 there is a concentration zone of about 8 feet similar to the main shoot. Near the end of the long crosscut of B level there is a highly pyritized zone said to carry in places other sulphides. This may be the upper extension of the easterly shoot. Much evidence suggests that this shoot is separate from the main shoot and not directly connected with any part in the section explored.

It is clear from the evidence gained that much of the main shoot has been carried away by erosion. It may well be that the exposed part of the altered zone near the camp may represent the roots or lower part of the deposit.

The altered zone near the river has about the same general trend as that higher on the hill. To the north it appears to terminate somewhat abruptly, though a dyke continues for some distance farther. The apparent abrupt termination of the zone may be the result of a change in character of the rocks, for in a direct continuation of the strike of the mass on the creek there is a series containing much sedimentary material. The vaguely suggested structure is that of a badly crumpled syncline plunging to the south. The continuation of the dyke beyond the zone may indicate the position of the solution channel beyond suitable replacement rock.

This zone is highly pyritized in many sections and may carry minor quantities of other sulphides. Its outcrops are generally badly weathered and the sulphides have been removed by solution. Though some concentrations of pyrite seem to be indicated nothing in the outcrops suggests the presence of a shoot similar to that of the upper workings. However, the outcropping there, in places, is an equally poor indicator of what lies below. No important development work has been done on this zone.

MANVILLE

During the latter half of 1929 and the first half of 1930 the mineralized zone on the Manville property was drifted on for over 1,950 feet and a number of crosscuts were run on either side. Also a large amount of diamond drilling was done. Work was stopped later in August, and the property was abandoned by the Alaska Juneau Gold Mining Company which had been working it under purchase agreement with the original owners.

On this property the country rock is like that on the Tulsequah Chief, but shows more variety. Dark green, massive volcanics are the most common and exhibit the features already noted at other points. In places

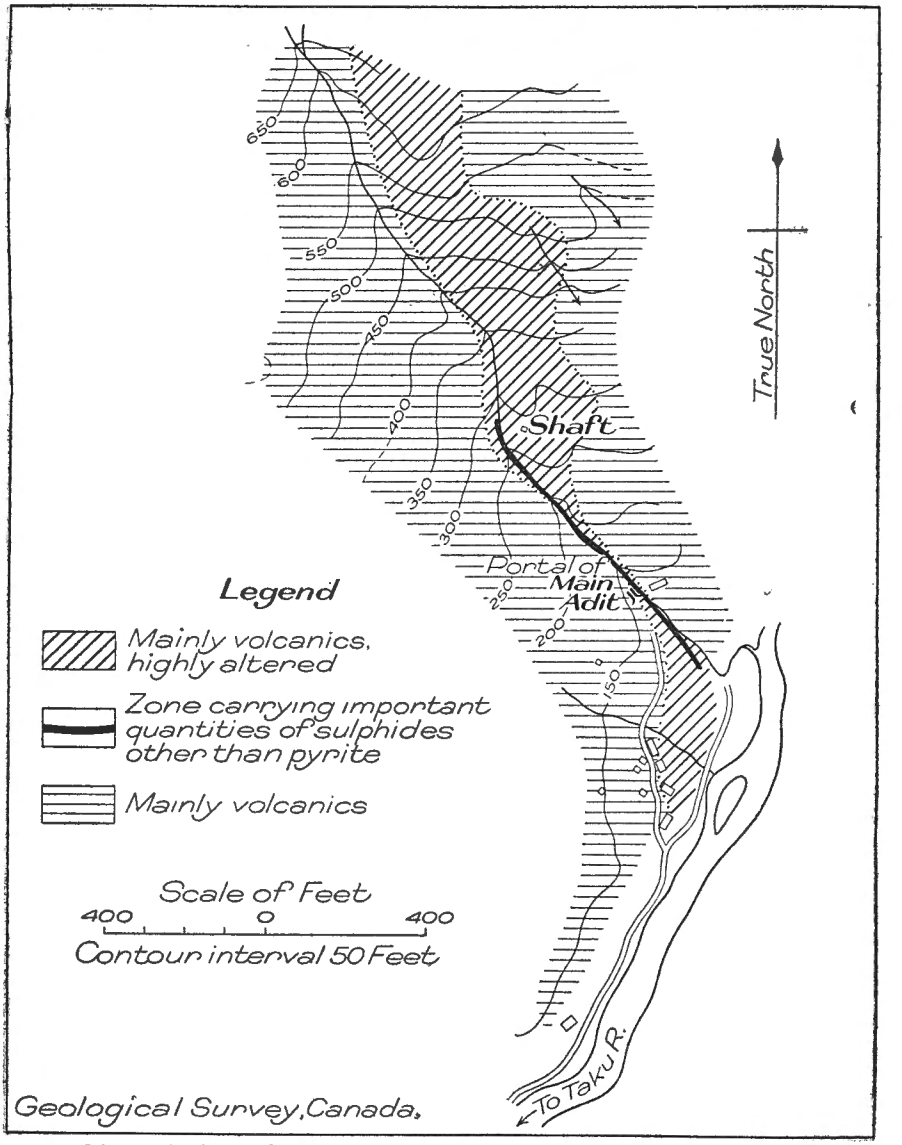

Figure 3. Area adjacent to Manville workings, Cassiar district, B.C.

they carry considerable magnetite which in part occurs in irregular masses several inches across. Alteration of the magnetite to hematite in many sections has produced much jasper-like rock. In other places there are veins of jasper which probably have derived the hematite colouring from

much the same source. About 400 feet northwest of the shaft, red and grey schists are fairly abundant and associated with these are some well-banded rocks suggestive of sediments and it is stated by those prospecting in the vicinity that the sedimentary series of the Potlatch-Banker groups trends irregularly toward the Manville. Thus, a series of sediments may lie west of Manville creek and, if so, probably underlies the volcanics at no very great depth. If sediments are present, they may represent the top of the thick Palæozoic series or they may form only relatively limited lenses. Near the altered zone both at the surface and in the underground workings, the rocks are the green volcanics. In places they have a massive appearance; elsewhere they are distinctly schistose. Specimens from the massive-looking phases, examined in thin section under the microscope, were found to be greatly sheared. Apparently much more shearing has taken place than on the Tulsequah Chief property and it seems that a fairly broad section west of the altered zone, as well as the major part of the zone, has been so affected. Though there is considerable irregularity, the strike of the schistosity in general is northwesterly, parallel the creek, and it dips from vertical to 45 degrees west. The schistosity also tends to parallel the boundary of the altered zone in the nearby sections.

Three specimens of the dark grey rock beyond the altered zone were examined under the microscope. All are so greatly sheared as to offer little clue as to their original characters. One, however, showed broken and corroded masses of albite-oligoclase which suggested remnants of phenocrysts. The groundmass of the three specimens is a fine-grained aggregate of white mica, chlorite, epidote, albite-oligoclase, magnetite, and quartz. The quartz is rare in two specimens, but in the third is moderately abundant and in it appears to occur in part as replacement veinlets with calcite.

The altered zone trends slightly west of north. In the central part for a length of about 300 feet it is very narrow, but both northwards and southwards it widens abruptly to 200-300 feet. The western boundary, both at the surface and underground, is for the most part fairly sharply defined. The eastern boundary is also fairly definite for short distances where the zone is narrow, but elsewhere is for the most part poorly defined. In many places where the boundary is sharp it owes this character to small faults which show no systematic arrangement. Within the zone the character of the rock varies as at the Tulsequah Chief. Underground the northward widening of the zone is due primarily to a splitting of the altered zone by a large mass of dark green volcanics, and in the wide part to the north there are short sections of similar material, much of which is not as highly altered as in the narrow sections. Traversing the length of the zone is a narrow, highly sheared section containing in most places a few inches of black gouge. This is suggestive of a fault. In places it seems to have acted as a barrier to the circulation of solutions.

Microscopic examination of specimens of the softer part of the altered zone shows that white mica is dominant with lesser quantities of quartz. It is not known if the hard zones are of quartz and albite as on the Tulsequah Chief. There is no dyke such as occurs on the Tulsequah Chief, but otherwise megascopic examinations suggest a marked similarity between the rocks on this property and the Tulsequah Chief.

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Pyritization occurs throughout the light grey rocks and in some places beyond in the dark rocks. On the whole, pyrite seems less abundant than in the Tulsequah Chief zones. Within the zone there are massive lenses and sections of disseminated mixed sulphides. Pyrite, sphalerite, chalcopyrite, and galena appear to be the most abundant. In two open-cuts west of the shaft such lenses are well exposed. The upper cut displays a lens of massive sulphide about 40 feet long and 6 feet wide parallel to the zone. About 6 feet from this to the east another is partly exposed. The lower cut exposes massive sulphides for over 100 feet along the zone. At the north end the lens is 18 feet wide and may extend beyond for as much as 20 feet to a point 20 feet from the lens of the upper cut. With some re-entrant angles it possibly widens to 30 feet at the centre of the mass and narrows to the south where dark green rocks on either side are much closer than 30 feet. The exposures suggest a lens the dimensions of which do not greatly exceed 100 feet in length and 30 feet in maximum width. The material between the lenses is the altered light grey rock which may carry some mixed sulphides.

Mandy's map[1] shows eight cuts at fairly regular intervals over a total distance of 1,000 feet or more from just above the river flat up the creek and the ore-body is represented as being continuous for about 1,000 feet. Many of the cuts were partly filled at the time the present writer examined the property, but the limited observations possible, together with descriptions given by mine officials, lead the writer to concur with the belief that the sulphide concentrations on the surface are practically continuous between the original cuts with, of course, such gaps as are indicated in the larger exposures already described. In the underground workings the lensy character of the shoots is well exemplified. The underground workings consist of a drift about 1,950 feet long mainly close to or along the west edge of the highly altered zone. At intervals crosscuts explore the ground on either side of the drift. Three crosscuts from the southern part of the drift indicate that in this section there may be a fairly continuous shoot about 500 feet long, but much narrower than at the surface. One mass at the northern end of this stretch is clearly lenticular, for though its southern limit is not visible the body towards the south end is at least constricted to less than a foot in width and to the north pinches out against the gouge. The mass is about 70 feet long with a maximum thickness of about 7 feet. A slightly wider shoot is shown in a crosscut near the portal of the drift, but it appears that this must be cut off in a very short distance to the north. At other points underground, as a rule not far from the gouge line, there are tiny lenses. Some relatively limited sections were observed in which mixed sulphides are finely disseminated. Most of the mineralization by mixed sulphides occurs in the first 700 feet of the workings. Beyond this very little was noted.

The workings seem to have demonstrated that the sulphide bodies pinch out quickly at depth and that their extent is very limited on the level of the adit. It is, of course, possible that the shoots widen at greater depth or between the crosscuts, but there is nothing to suggest that this is the case. It would appear that the masses represent the roots of the deposit. It is not implied, however, that erosion has removed any very large quantity of sulphides; on the contrary there is no suggestion that the original deposit was other than relatively small.

[1]Ann. Rept., Minister of Mines, B.C., 1929, pt. C, p. 130.

Dykes that cut the altered zone do not appear to be related to it. They probably were originally andesitic in composition, but are now considerably altered and are mainly plagioclase, epidote, and chlorite with some quartz. They are not sheared and, therefore, appear to be younger than the formation of the zone.

WHITEWATER

The Whitewater group of claims lies on the west side of Talsekwe valley a short distance downstream from the Tulsequah Chief. The showings are on a small stream, about one mile from the river, at an elevation of approximately 750 feet. A fairly good trail has been cut from the river. Development work consists of a number of open-cuts in which the surface debris has been cleared away and a little rock has been removed, but not sufficient to penetrate below the rusty surface zone. The rusty rock was originally exposed along the wall of the creek which has cut a sharp, V-shaped valley 50 feet to 100 feet deep; otherwise most of the rock is obscured by overburden and timber.

The country rock is in the main massive, green volcanics similar megascopically and microscopically to those at the Tulsequah Chief. Banding in places suggests bedding; elsewhere it is due to shearing. The strike of the banding is generally between 20 and 45 degrees east of north and the dip is 60 to 80 degrees southeast.

The rusty showings, which are, in the main, zones of altered volcanics, are confined to the south side of the stream which cuts across the rock at right angles to the strike of the banding. Outcrops are not as continuous on the north as on the south side of the stream and it is possible that the gaps between outcrops on the north side may be occupied by altered zones, but it is clear that such zones are at least not nearly as extensive as on the south side. There are some indications that the stream occupies a fault; if this is the case it might mean that the altered zones had been displaced.

So far as can be judged by the limited exposures the altered zones have an attitude about the same as the structural lines: that is, they trend a little east of north and dip steeply southeast. At the upper limit there is a considerable display of dark volcanics beyond which outcrops were not noted. Going east, down along the stream and across the apparent strike, the dark volcanics are followed by a very narrow band of altered rock, to which succeeds 15 feet of dark volcanics, 1 to 2 feet of altered rock, 15 feet of dark volcanics, and 6 feet (revealed in an open-cut) of somewhat altered volcanics with 2 to 3 feet in the centre of dark volcanics. East from the open-cut for 30 feet across the strike, the rocks are partly obscured, but are largely dark volcanics. To these succeed about 15 feet of altered rock, exposed in the main open-cut, beyond which is a gap of 30 feet unexposed, followed by 10 feet of green volcanics which appear to be bedded. Just beyond these at 30 feet vertically below the main cut, is a smaller opening in an altered zone about 8 feet wide, but which appears to pinch out upward. East of this are exposures of massive green volcanics for some distance, to another indefinite rusty showing. Two open-cuts south of the creek bank indicate that one of the western altered zones continues southward along the suggested strike for at least 50 feet. Otherwise no work has been done which gives further information about extension to the south along the strike.

The altered zones have undoubtedly originated in much the same way as those at the Tulsequah Chief and Manville properties. The volcanics have been penetrated by mineralizing solutions, altered in places to light grey materials, or completely replaced by irregular to vein-like masses of quartz and sulphides. Some of these sections which are largely quartz are very resistant to erosion and as a consequence stand out prominently. Other sections suggest the softer quartz-mica sections of the Tulsequah Chief zones; still others are fissile and rusty, as are some of the badly sheared dark sections at the Manville. The exposures are so badly weathered and rusted as to afford only a very poor idea of the nature of the zones. However, it appears that on the whole there is less alteration to light grey materials and relatively more pyritization (or impregnation by whatever sulphide is responsible for the widespread rustiness) than was noted at the other properties. The softer parts of the zones, which are dominant, are most affected by weathering, but their present character does not in general suggest a high sulphide content. The hard masses scattered among the softer are for the most part irregular. They owe their hardness to the quartz present and carry a fairly high sulphide content, which is in the main scattered to massive pyrite and (or) stibnite. Assays of the sulphide-bearing sections are reported to show a high gold and antimony content with little else. The manner in which the gold occurs and other details have not yet been determined.

It is reported that three or more similar zones occur about 800 feet to the west, but these were not visited.

Sufficient work has not yet been done on the showings described to afford a satisfactory conception of the size or importance of the mineral zones. The way some of the zones pinch out upward suggests that the exposures represent about the tops of these zones. There is also evidence in the creek wall and open-cuts that the zones continue along the strike for 100 feet or more south of the creek, but despite fair exposures there is no definite suggestion of a continuation to the north. For the most part the western zones are narrow and not heavily mineralized. The main zone, however, since there is much obscured rock, may be of much greater width than is indicated in the open-cut. In this cut and in that east of it there are displayed fair widths of altered rock within which there is considerable mineralization in irregular bands, but until these zones are definitely cut across their strike in reasonably fresh rock it will not be possible to know much about their true worth.

POTLATCH-BANKER

The main showings on the Potlatch-Banker groups lie just above the valley flat on the east side of the Talsekwe, 3 to 4 miles above its mouth. They are located on a limited outcrop which is surrounded by a largely drift-covered area. Development work consists of a number of fairly deep trenches and several diamond drill holes.

The deposits are in bedded and massive limestone which in places is well silicified. Bedding and shearing strike in the main 30 to 60 degrees east of south and dip 80 degrees southwest to 60 degrees northeast. Directly southeast along the strike is one small outcrop of bedded argillites and quartzites with a southeasterly dip. These appear to grade to a peculiar

rock suggestive of volcanic material with a brecciated texture. Beyond a narrow gap to the northeast is a wall of massive green volcanics similar to those found elsewhere. The features observed suggest that there is a series made up of a fairly thick limestone member overlain by light grey, silicified limestone or quartzite, then a thin series of dark grey quartzitic and argillitic material, then volcanics. Such a succession is characteristic of many of the limestone volcanic contacts observed elsewhere. The rocks appear to be closely folded and the deposits seem to occur on the crest of an anticlinorium of minor folds, plunging to the southeast, and it is believed that along this direction the limestone passes under the sedimentary volcanics series. The massive green volcanics to the northeast probably dip northeast on the northeast limb of the anticline and may be represented on the west side by a band of such rocks indicated in one of the drill holes. To the northwest they strike toward the river. In the main the limestone outcrops in a relatively small, triangular area. It is reported that to the east limestone has been observed in bands lying successively farther southeast and, across the strike, farther northeast. This suggests a series of southeast-plunging anticlines and synclines. The records of three short drill holes seem to indicate the presence of a narrow mass of limestone lying along the axis of an anticline and bounded on the northeast and southwest by volcanics which dip at angles that are not less than 45 degrees and probably exceed 60 degrees. The fold may be overturned, if so, most probably to the northeast. At 300 feet below the surface the breadth of limestone probably does not greatly exceed 400 feet. At the surface the limestone, with one wall obscured, is exposed, though not continuously, across a breadth of more than 200 feet.

In the trenches are exposed several long masses of green rock which may be dykes or masses of volcanics included in minor synclines. No similar bands are reported in the drill hole which cuts directly under these.

Within the limestone, as revealed by a series of trenches across the strike, is a considerable amount of mineralization occurring for the most part in irregular replacement lenses scattered about without system except that they are in general oriented, where length exceeds breadth, parallel to the strike and dip. One lens has a width of 8 feet, of which 4 feet are well mineralized, but as a rule the well-mineralized sections are narrower than this and laterally they are not well maintained even for moderate lengths. In places the sulphides form small veins as though occupying minor faults. Mineralization occurs intermittently for a breadth, across the strike, of more than 70 feet and occurs again beyond a gap of over 80 feet, though somewhat more sparsely. The best showings appear to be toward the southeast. Mineralization was noted over an area 300 to 400 feet long and over 200 feet wide. Diamond drill holes penetrating the limestone below the showings furnished little evidence of mineralization and even in the trenches, which reach a depth generally less than 10 feet, the mineralization tends to decrease with depth.

The most abundant sulphides are pyrite, sphalerite, and galena. They occur in varying proportions in different deposits and different sections of the same deposit. In places beautiful specimens of individual or mixed, massive sulphides can be obtained; in others the grains are well disseminated. In the richer sections quartz is the chief gangue and occurs commonly as exceptionally well-formed crystals. Vugs are common.

Other minerals, including chalcopyrite, tetrahedrite, jamesonite, and magnetite, occur in various parts of the mineralized section. Carbonates form part of the gangue in practically all parts and in some are very abundant. Malachite stains the rock in places. The sulphides as a rule are coarsely crystallized and in many places they occur as vug filling. Sampling of these deposits, unless very extensive, would not give a satisfactory idea of their true value. It is worthy of note, however, that assays which appear to represent the well-mineralized sections show in some cases well over 100 ounces of silver to the ton and small quantities of gold.

The mineralization is irregular and apparently confined to the limestone which, seemingly, occurs on the crest of an anticline plunging southeastward. The mineralized zone seems to be shallow. To the northwest the valley wall falls rather steeply and, therefore, and because of the southeastward plunge of the anticline, it seems probable that any original extension of the mineralization in this direction has been carried away by erosion. To the southeast a small valley cuts across the strike and the rock surface there may be below the mineralized zone. It is, however, in this direction, to the southeast, that any extension of the mineralized zone seems most likely to occur. Within a short distance along this direction the limestone passes beneath other materials and the mineralized zone, if it continues, is probably intact, for it seems likely that the siliceous rocks above the limestone would act as a barrier to further progress of the migrating solutions.

The original thickness of the mineralized zone is unknown. The trenches show that it was at least 6 feet thick, but there the upper part has been eroded away, and the best concentrations probably occurred there if the once overlying siliceous rocks did act as a barrier to the migrating solutions. To exhaust the possibilities it would seem to be necessary to explore the limestone at some point where its upper part has been preserved, that is, to the southeast either at the edge or under the cover of overlying volcanics.

Anticlinal deposits of the type postulated are usually confined to the crest of folds. In the case of a fold with very steep sides such as is suggested to exist here it is most likely that mineralization would be restricted to the crest. One side of the fold is exposed over a very limited extent and the other side has been explored by a drill hole. Neither side shows definite evidence of a continuation of mineralization downward. The distances to which mineralization extends along the axes of anticlinal deposits, depend to a large extent on the rate of plunge of the fold. If a fold plunges in both directions from the deposits, mineralization may be limited to the dome; on the other hand, if the plunge, character of the fold, and relationships are maintained for some distance in both directions, the deposit may also continue. The structure here suggests narrow, parallel folds extending deeply and it is possible that the plunge may be maintained without marked change for some distance.

As mineralization is widespread throughout this district, limestone on the crests of other anticlines would also seem to be a very favourable place for the occurrence of mineral deposits. Where Palæozoic non-calcareous sediments and Mesozoic volcanics occur in anticlines, and assuming that the non-calcareous sediments are not as suitable a media for replacement as the volcanics, mineralization of the general type described

might very well be expected to occur similarly on the crests of anticlines in the volcanics above the non-calcareous sediments. Deposits of this type have been noted in Iskut River area and it is not unlikely that they also occur in Taku district.

Several showings on the Potlatch group occur about one mile farther north along the Talsekwe trail. These have been opened by a number of shallow trenches and open-cuts. The rocks are in the main volcanics and they and the mineralization are somewhat like those occurring on the Tulsequah Chief and Manville properties. The northernmost cut is about 18 feet long across an altered zone which strikes a little east of north. The mineralization occurs in a shear zone about 18 feet broad. The shearing tends to parallel the direction of the altered zone, swinging from 30 degrees east of north to 15 degrees east of north toward the south. The sides of the altered zone are fairly sharply defined by walls of dark, more or less massive, unrusted volcanics. Across the altered zone there are some sections of the volcanics which have been altered to the typical light grey material, but in the main alteration is not very great and there are sections that are little different from the rock beyond the zone. In places, the altered sections carry disseminated sulphides, probably largely pyrite, which make the whole rusty. More or less parallel to the shearing are narrow, vein-like masses up to 6 inches broad, rarely more, of quartz, etc., carrying sulphides. Pyrite occurs in definite stringers.

Seventy-five feet east of this cut, which is on the bank of a creek, there are exposed volcanics that show some alteration. Northward there are few exposures and no further development work. About 90 feet south of the cut the altered zone is crosscut by a trench. The section exposed, beginning at the west, is: 3 feet of altered, silicified volcanics carrying pyrite and in places other sulphides; 10 feet of dyke paralleling the shearing and similar megascopically to the dyke of the Tulsequah Chief (the dyke was not found to the north either in the open-cut or for some distance to the west of it); 12 feet of mineralized volcanics, some altered to soft material and some silicified and carrying galena, sphalerite, pyrite, and chalcopyrite, mainly in two zones 2 and 3 feet wide, with 5 feet in between of soft, rotten material; 12 feet of dark, unaltered volcanics; 2 feet of rusty volcanics; 6 feet of unaltered volcanics; and then slightly altered material. The dyke has a sharp contact, carries pyrite, and is cut by barren quartz stringers. There are present some fissure veins of coarsely crystalline sulphides and quartz, the latter in places lining the walls with well-developed crystals.

About 190 feet to the southeast a second short trench exposes volcanics carrying augite-like crystals without much evidence of mineralization. This cut, however, may not extend far enough west to intersect the altered zone. Two hundred feet farther southeast, another long trench extends eastward. This shows sections of somewhat altered and rusty volcanics with one section near the creek to the east, much altered and carrying quartz and pyrite. The strike of the shearing and of the main altered zone as exhibited in the two first described cuts would carry these features well to the west of the second and third trench. The creek valley being parallel to the strike of structural lines and evidence of alteration occurring at two points near it, suggests that an altered zone may lie along it.

No sampling was done of the mineralized sections, but in the main cut there are several narrow bands which appear to have a sulphide content, mainly sphalerite, comparable with that of the Tulsequah Chief. These are separated by sections that are probably of much lower value or valueless. It is notable that there is an improvement toward the south in the 90 feet between the two points where the zone has been crosscut. The strike of the zone is clearly close to north and its southward extension should not be difficult to locate. As at the Whitewater there is less alteration of the volcanics in comparison with mineralization than at the Tulsequah Chief and Manville properties. The presence of the dyke here again suggests a close association between these intrusive bodies and the mineralization.

EXPLORATIONS BETWEEN STIKINE AND TAKU RIVERS, B.C.

By F. A. Kerr

CONTENTS

Illustration

INTRODUCTION

Stikine and Taku rivers, rising in the interior of northern British Columbia, cut through the range of mountains along the coast to enter the Pacific. In their course they flow through the narrow strip of Alaska which here lies between the axis of the range and the coast. Though these rivers form the chief mode of entry into northwestern British Columbia, yet, since within the Coast range only relatively small areas adjacent to the main streams are reasonably accessible, the intervening spaces have remained largely unknown.

The field season of 1930 was mainly spent in exploratory work in the region between the two rivers, the purpose of this undertaking being to locate the eastern contact of the Coast Range batholith, and to obtain some definite information about a little known and largely unexplored area comprising about 10,000 square miles.

The part of the area covered lies immediately northeast of the International Boundary, and between Patmore creek and Stikine river on the south and Taku river on the north. Work was confined largely to the Coast range and most of the information gained relates to a strip of country about 120 miles long and 25 to 50 miles wide.

The area was penetrated from the north by an overland trip to the headwaters of King Salmon creek and the south fork of the Taku, and by a river trip up the Taku and Inklin to the mouth of the Sutlahine. Farther south, the area was entered from the west by Whiting river and was explored for some distance north and south of this stream. From the south the area was penetrated by Chutine (Clearwater) river. These penetrations fell considerably short of overlap, but observations from advantageously situated high mountains made it possible to study in a cursory manner all parts of the area and to sketch in the main topographical and geological features.

R. B. McConnell and J. A. Mitchell rendered valuable assistance in the field. The co-operation and assistance of B. D. Stewart, Federal Mine Inspector of Juneau, Alaska, were greatly appreciated. In 1929 Mr. Stewart made a flight over the area between the Whiting and Taku and fixed approximately the eastern contact of the batholith. A copy of his unpublished map was used to verify the location of the contact between mounts Brundage and Fremont Morse.

PREVIOUS WORK

In 1925 W. E. Cockfield made a reconnaissance survey of the area adjacent to the telegraph trail between Atlin and Telegraph Creek.[1] Stikine river between Telegraph Creek and the International Boundary has already been mapped[2] and some preliminary work has been done in Taku district.[3] The work of B. D. Stewart has already been mentioned. Bulletin 800 of the U.S. Geological Survey, "Geology and Mineral Deposits of Southeastern Alaska," by A. F. Buddington and Theodore Chapin, gives a comprehensive outline of the geology along the coast of Alaska. The area adjacent to the International Boundary in British Columbia and the mainland of Alaska was mapped topographically by the International Boundary survey and the results published in a series of 4-mile sheets.

ACCESSIBILITY OF VARIOUS SECTIONS

Geographically the region falls into four sections: the Stikine-Chutine, represented mainly by the drainage basin of the latter river; the Whiting, including the area drained by this river; the Taku, comprising the basin of this river exclusive of the area drained by its two main tributaries, the Nakina and Inklin; and the Inklin-Sheslay-Tahltan section, which includes the northeastern part of the whole area.

The Stikine-Chutine section, except for a relatively small part in the northeast, lies wholly within the Coast range. It is reached via Stikine river where a good boat service is maintained during the summer.[4] Chutine lake can be reached by small river boats. Equipped with high-powered outboard motors and lifting devices, and manned by skilled rivermen, such boats can make the journey from the Stikine to within about one mile of the lake—without much resort to man power—in less than fifteen hours running time. The river in its upper reaches is swift, bars and snags are numerous, and there are bad rapids. For over one mile immediately below the lake, boulders are so numerous that it is doubtful if motors can be used to advantage even during the highest stages of water, and at low stages it is difficult to work a boat up by man power. For those travelling beyond the lake, a boat on the lake is a great asset, for travel on foot along its shores is impossible on the east side and very difficult on the west. The lake affords a good landing site for airplanes, though on very rare occasions icebergs might seriously menace a landing. The

[1]Cockfield, W. E.: Geol. Surv., Canada, Sum. Rept. 1925, pt. A.
[2]Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1926, pt. A; 1928, pt. A.
[3]Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1929, pt. A.
[4]Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1926, pt. A; 1928, pt. A.

north bank of Chutine river offers a fairly good overland route, as does also the trail to Barrington river from Shakes creek on the Stikine, thence up Barrington river to a low divide at its headwaters, and down the north wall of a tributary valley to a point on upper Chutine river a mile above the lake. At present, however, both of these routes are very poor substitutes for the air or water routes as there are trails for only short parts of the total distances.

The area south of Chutine river and drained by it can be reached best by travel along the valleys of the three large tributaries. There are no trails, and canyon sections on all of these cause serious difficulties. The ridges separating the three tributaries and the ridge between the most easterly and the Stikine present no low passes that are likely to afford better alternative routes.

The headwaters of Chutine river can be reached best by travel up the valley from the lake. On the east side this would seem to present no very serious difficulties. The upper part of Barrington river, as previously noted, can be reached by trail from Shakes creek. The valley is said to be easily travelled, though for a short section it may be filled with a glacier from the south. Above this, fairly well up on the south side, travel should be fairly good to the low divide at its head which, as mentioned before, can be reached from the west as well.

The central part of the Whiting River drainage basin is reasonably accessible only by way of the river. From Whiting point, which is somewhat east of the first shoals, to the International Boundary, is a distance of 20 miles. For the first 8 miles of this stretch, navigation is not unduly difficult for small river boats with modern equipment. Above this, however, conditions become increasingly worse, the current maintains a speed of from 6 to 8 miles an hour, the river is badly split up and is continually changing its course, and snags are numerous. With fair luck the journey to the boundary can be accomplished in less than ten hours running time. Above the boundary the river is navigable with power for about 10 miles to the junction of the South (or main) and North Whiting. The current maintains a speed of from 8 to 12 miles an hour and in the upper reaches the fall is at the rate of nearly 50 feet to the mile. The water spreads out in many channels over a wide gravel slope and is continually and rapidly changing its course. Bad riffles and obstructions are numerous and navigation is such that only two boats are known to have made the journey without more or less continuous resort to hand power to supplement the engines. On the North Whiting, boats have been manhandled as far as the first east fork. The use of an engine is hardly feasible except for very short distances. The character of the river is much the same as below the junction. The South Whiting for 8 miles above the main junction occupies such a narrow valley that at least near-canyon conditions are maintained for the whole of this distance. The first mile was navigated without serious difficulty, but owing to sharp turns, numerous reefs and boulders, and the high speed of the current the danger was very great. Progress was barred by a whirl and boiler which could have been surmounted by hand power with difficulty. From distant observations, which afforded views of practically the whole channel, it is believed that it may be possible to work a boat through this section at favourable (medium) water stages. The swiftness of the water, which makes it almost impossible

for a man to hold even a small, empty boat against the current without assistance, and the nature of the channel would seem to make such a venture too hazardous for any ordinary undertaking. The southwest fork of the South Whiting flows in a valley with a wider base. When observed it was extensively flooded above its first large tributary. Many standing trees were partly submerged and it had the appearance of having been dammed within recent years by the alluvial fan of the tributary. It seems likely that the east fork of the South Whiting occupies a canyon or near-canyon channel for some distance above the junction. Crescent lake, just north of Whiting river and west of the boundary, affords a way of reaching the district by plane. A rough trail follows the north bank of the river nearly to the head of the North Whiting. The flooded area of the southwest fork of the South Whiting or the lake[1] somewhat higher up, above the distributary from Sawyer glacier, may also afford landing sites for planes.

Travel on foot within Whiting district is difficult. The valley of the Whiting and its north branch is the only wide one which offers fair routes of travel. Most tributary streams of the system, like the South Whiting, occupy narrow valleys for long stretches with canyons in their lower reaches, and are, therefore, very difficult to travel. Sawyer glacier and its distributary, which flows east, offer a 16-mile ice route to the upper South Whiting. For those familiar with ice travel this might be a fairly easy route.

Taku district is easy of access by the river route.[2] The whole 40 miles of this river can be navigated by small river boat in less than nine hours running time. The section above Tulsequah, though swift, badly split up in places, and beset with numerous snags, does not offer any unusual difficulties. Talsekwe river on the north is readily navigable during the summer for about 8 miles. At a fairly high stage it was navigated with difficulty for another 5 miles to within about 1½ miles of the glacier. A boat could be taken up to the glacier by man power. Planes land readily at Tulsequah, and have landed on the Taku above this, but the danger was found to be so great that pilots are likely to be unwilling to attempt it again.

Trails have now been cut out along the Taku below Tulsequah, along the Talsekwe, South fork, Niagara (between South fork and King Salmon), and King Salmon, so that much of the district is readily accessible. The drainage basin of the Sutlahine can be reached by the last three of these routes.

Inklin river can be navigated from its junction with the Nakina to the Sutlahine in less than ten hours running time. The river is confined to one channel for the lower 12 miles, the upper 4 of which are in a deep and narrow canyon which presents considerable difficulty and danger. Above this the river, though not confined to one channel, is not badly split up. However, it is swift and snags are numerous. It is said that the Inklin can be navigated as far as the Sheslay, and the Sutlahine for several miles. By these rivers access can be gained to a very large area.

[1]This lake was in existence in 1909, having been observed and photographed by members of the International Boundary survey at that time. As it may have been the result of damming by the glaciers its existence now is problematical. Prospectors who reached Whiting valley a few years ago over the ice fields from the Chutine describe a lake 5 miles long, so that it is altogether likely that there is at least one large lake on the southeast fork of the South Whiting.

[2]Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1929, pt. A.

The valley of the Sutlahine should not be difficult to travel to the glacier at its head. A low pass of about 3,000 feet leads from this valley to the head of the North Whiting and may form a fairly easy route between these drainage basins. Other than this all passes between these sections are high and filled with ice for considerable distances and, therefore, are likely to be very difficult to travel. The character of the upper Sutlahine valley is such that it may contain a lake, possibly the one of considerable size reported by aviators to be at the head of the Whiting. From the lower 20 miles of the Sutlahine, travel north or south, either along the valleys or over the mountains, should be fairly easy as most of this area lies beyond the rugged section of the range. Southeast of the junction of the Inklin and the Sutlahine is an area of relatively low, rolling hills which can be travelled without difficulty. One or two large streams parallel to the Sutlahine drain this area. It is said that, by way of these, fairly easy, though long, routes lead to the headwaters of the east forks of the North Whiting. There are low divides at the heads of the main streams of both the first and second east forks and possibly also of the large southerly tributary of the former. However, these divides are well within a very rugged mountainous area and the valleys are relatively narrow. Lakes are numerous in the area beyond the range between Taku and Sheslay rivers, and probably a number afford good landing sites for planes. At least one large lake occurs at the head of King Salmon creek. Southeast of the lower Sutlahine many are reported and one 16 miles long, as already mentioned, is vaguely indicated to lie at the head of the Whiting. Trappers state that Tahltan lake is 8 miles long and 2 miles wide. Its elevation is probably about 3,000 feet.

The telegraph trail between Atlin and Telegraph Creek affords a means of reaching all of the area east of the Inklin and probably some of that to the west above the Sutlahine. From this trail, also, the headwaters of Sheslay and Tahltan rivers can be reached.

Between Sheslay and South Whiting rivers lies a large area of high, rugged mountains up to 8,000 or 9,000 feet. It is reported that there are usable passes from the east to the west side of the watershed, but that it is difficult to travel far down the valleys to the west. It seems altogether unlikely that any very satisfactory routes penetrate far into this section, though prospectors have travelled from the reported 5-mile lake on the upper South Whiting to the Sheslay. Between the Whiting and main Chutine drainage basins there are probably no passes that are not high and filled with ice for many miles. The area farther east between upper Barrington river and the headwaters of the Sheslay is also rugged, with high mountains throughout, so that between these four rivers there is a section of about a thousand square miles which is very difficult to reach and still more so to travel. To the southeast this grades off to a relatively low, easily travelled area drained by Tahltan river, by a tributary of Barrington river, and Shakes creek. Trails penetrate this area by way of the first and last streams mentioned.

CLIMATE, VEGETATION, AND GAME

The Coast range is a wet belt throughout. Prevailing winds, heavily laden with moisture, sweeping in from the Pacific ocean, begin to lose this moisture on striking the high mountains along the coast and throughout the western part of the range and for 10 to 20 miles east of its axis, precipitation is very heavy. There are few clear days, snowfall in winter is very great, and rain is abundant throughout the summer. Eastward from the first high mountains of the coast there is a general decrease in precipitation, but this hardly becomes perceptible until some distance beyond the axis when the change in climatic conditions is readily noticeable. At certain points, especially with an abrupt decrease in the height of peaks, it becomes phenomenally sudden. On Taku river at mount Lester Jones, where peaks of 7,000-8,000 feet give way to rolling hills of 3,500-4,500 feet, this is well demonstrated. Day after day, throughout the mountains to the west, a heavy cloud bank, often accompanied by rain, is abruptly replaced, to the east, by a clear sky and bright sunshine. On the Whiting near the International Boundary where there is no marked change in the elevation of peaks the same abrupt change was noted. Here, however, the edge of the cloud bank shifts back and forth more, according to the intensity of the storm on the coast. On the Stikine, at Little canyon, on many days, the cloud bank completely overlying the western mountains splits and a V of clear sky can be observed, broadening to the east until few clouds remain. As these cloud banks change, so do general climatic conditions: the wet belt grades gradually or rapidly to the dry belt of the interior.

From the coast inland mean winter temperatures become lower and mean summer temperatures higher. The coastal areas have a relatively small, daily, monthly, and yearly range, whereas the interior is subjected to much greater changes.

The character of the topography within the range likewise has a marked influence on the climate. The main valleys are sufficiently wide to affect considerably the formation of clouds and precipitation. This characteristic is well exemplified by a comparison of Whiting and Chutine valleys. Winds sweep directly up the former from the coast and pass beyond the axis, still retaining much moisture. As a consequence, precipitation is much heavier and climatic conditions more severe than on the upper Chutine which is protected from the coast by a high snow and ice-covered ridge. The valleys of northeasterly flowing streams, such as the Sutlahine, introduce a wedge of dry belt conditions into the range, whereas the rivers flowing westerly cause wet belt conditions to extend farther east.

Vegetation throughout the area shows marked variations according to the nature of the climate, topography, and geology. In the central part of the range vegetation is more luxuriant than toward the east, but is not so widespread owing to the heavy snow accumulation and ruggedness. The areas of granitic rock are in general less favourable for growth than others, since this rock maintains its polished, glaciated surface longer and is less easily broken up by weathering.

The upper Chutine valley, despite its location largely in granitic rocks and near the axis of the range, is unusually favourable for vegetation. The lower flats support a growth more characteristic of a semi-arid region: jackpines which are usually absent to rare near the axis are abundant. Timber extends farther up the slopes and scrub trees were noted almost as high as 5,000 feet, which is unusual even in the more favoured eastern part of the range. Likewise game (mainly moose and bear) is unusually abundant considering the rugged character and location of the area. On the other hand, the Whiting is a most desolate section. Timber is relatively scarce, rarely extending above 4,000 feet and in many places even the lower slopes are clothed entirely with alders and other bushes. No signs of moose were observed in this section, though there is a fair abundance of bear and goat. Taku valley, which is wide and deep, is comparatively well timbered throughout its entire length, as are also some of the larger tributary valleys. In the central mountains, however, timber rarely extends above 3,500 feet and many slopes are largely covered with bushes. Higher up the river timber extends to 4,500 feet.

East of the range in the area covered by this report timber is abundant everywhere and there are few places that are too dry to support a substantial though relatively open growth. Timber extends to about 4,500 feet, though in some favoured places it is found up to 5,000 feet. Throughout this area game (moose, goat, sheep, and bear) is abundant.

PHYSIOGRAPHY

The Coast range occupies a strip along the Pacific coast with a breadth of from 60 to 75 miles. It is rugged throughout and attains a relief of over 10,000 feet. In many places along the major valleys the slopes on either side rise 6,000 to 8,000 feet within less than 2 miles. Along the axis of the range, except where it is cut through by the great valleys of the Taku, Whiting, and Stikine, there is a vast ice and snow field 10 to 25 miles wide and of 5,000 to 7,000 feet altitude. Trending away from this to the northeast and southwest, except where the range is broken down, are innumerable glaciers. On the western slope many of these are of great size and extend to the ocean. Toward the east, because of reduced precipitation and in most cases more limited drainage basins, the glaciers are appreciably smaller. Most of them, however, attain a length of from 5 to 15 miles and in a few cases are nearly 25 miles long.

Eastward from the axis of the range there is in general a decrease in elevation, in ruggedness, and in the amount of snow and ice. There are, however, scattered promiscuously between the great valleys, isolated groups of high peaks which take on an aspect very much like the zone adjacent to the central axis, and in some cases because of greater immediate relief they display even more ruggedness. These features, which owe their development to a very irregular drainage system, give to the eastern part of the range an aspect much different from that of the western side where a fairly regular dendritic drainage from the axis to the coast is combined with a more consistent decrease in general elevation.

In the central part of the area described in this report is a section of over 1,000 square miles which is practically isolated from the main mountain system by the great valleys of the Sutlahine, North and South Whiting, Chutine, and Barrington rivers. This block is in itself a mountain range with a high, central axis in general paralleling the main axis and directly away from which drainage trends. Peaks in this section attain elevations of from 8,000 to 9,000 feet, exceeding those in the corresponding section of the main range, and because of less snow and ice filling the hollows ruggedness and relief are at least as great. Between Barrington and Chutine rivers is another much smaller, isolated mountain group, but one in which ruggedness and relief are very great. One peak attains a height but little below the highest in the northern British Columbia section of the range. Between Pendant and Stikine rivers is a similar, somewhat less isolated mass and on the outskirts of the range between Shakes creek and the Stikine still another. In the vicinity of the Taku there is also a tendency toward this characteristic.

The drainage of the area, as has already been intimated, is very irregular. South of Chutine river and in the Sutlahine basin it is normal in that dendritic drainage trends directly away from the axis of the range. At the headwaters of each main stream a series of glaciers from the axis join to form one large one which provides the chief water supply. Smaller streams and glaciers drain ridges intervening between the main streams. Barrington river also tends to be normal, but it falls short of reaching the axis of the range by 20 miles. When glaciers were thicker than now by 3,000 feet and more, it probably did derive part of its feed from the axis, but then only by stealing the overflow from the Chutine. There is a possibility that at one time it drained the upper Chutine basin, but this is unlikely, since with this larger drainage basin it should have been able to maintain its channel at as low a level as the main river, which it has not done by over 3,000 feet.

The upper Chutine for 25 miles flows parallel to the axis of the range and along what would seem to have been originally one of the highest parts, and even now is only 6 to 8 miles from the axis. As a consequence it is fed from the west by a series of small glaciers and streams. From the east it gains comparatively little drainage. There is a marked suggestion in the shape of the valley that it has shifted from the west toward the east.

Whiting river presents another peculiar drainage system which in some ways resembles the upper Chutine. Both the North and South Whiting trend for many miles parallel to the main axis of the range or rather in a trough between the main range and its subsidiary to the east already described. It is somewhat farther east of the main axis and is unlike the upper Chutine in having many large tributaries, mostly from the east. These, in general, flow at right angles to the direction of the axes and the main valleys.

The Whiting River system presents some interesting peculiarities. The valley of the Whiting and its North branch is wide and extensively gravel-filled, but that of the lower South Whiting is narrow and for part of its length cuts rock on both sides. The South Whiting, however, carries from two to five times as much water as the North branch. The first and second east fork and the west fork of the North Whiting all contribute

from narrower valleys at least as much water as is in the main channel at their junctions. In other words, the largest valley carries an amount of water altogether out of proportion to its size. Between the north branch and the Sutlahine is a low pass, probably of about 3,000 feet. This was neither visited nor viewed directly from a distance, nor was the base of upper Sutlahine valley visible from any observation point. The size of the streams flowing to the Whiting and to the Sutlahine strongly suggests that the drainage of the large area to the west feeds the latter. However, when the ice in Sutlahine valley was thicker a large part of it must have overflowed into the Whiting, thus giving the North Whiting a much greater volume of ice and water than at present. This is believed to be the explanation of the great discrepancy in size of valleys of the Whiting system. It is also possible that the Sutlahine robbed the Whiting of this drainage, but in view of the fact that the latter presents a far shorter route to the sea this is somewhat unlikely.

The Taku drainage presents some features similar to the Whiting. By its two large north and south tributaries, the Talsekwe and South fork, it has created a valley similar to that of the Whiting which separates the range into two sections. The development here is not as pronounced, but considered with those farther south there is presented a remarkable almost continuous trench along the range for a distance of about 100 miles.

East of the Coast range most of the drainage is gathered from streams flowing directly from it, by the Inklin-Sheslay river which flows northwest, mainly along the edge of the mountains. A relatively small amount to the south is picked up by the southeast flowing Tahltan river which occupies a similar position.

GENERAL GEOLOGY

From the cursory examination made of the area between Stikine and Taku rivers it would seem that the geology is very similar to that of Stikine district which has been examined in more detail.[1] The area is essentially a strip along the contact of the Coast Range batholith and as such the western part is naturally made up largely of rocks of this mass, whereas in the eastern part series of altered sediments and volcanics predominate. Accordingly, the rocks are classified into two groups: the Coast Range intrusives including only rocks whose reference to the batholith is easily discernible; and non-intrusives, comprising altered sediments and volcanics, but including some intrusives which cannot be easily dissociated from the flows and pyroclastics.

Of the non-intrusives, a series of schists, slates, argillites, and quartzites resembles and is believed to correlate with the Palæozoic sediments of the Stikine. Stratigraphically above, in the Chutine section, is the Permo-Carboniferous limestone, persistent throughout the areas mapped to the south. Limestone with similar relationships occurs in the western part of Taku district and to the east other extensive masses were observed, the relationships of which are not yet known. Stratigraphically above the

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

limestone of which the relations have been established is a thick series, dominantly volcanics, but including throughout some sediments and intrusives with, at some horizons, series largely of sediments. These correspond to the Mesozoic rocks (Triassic to Lower Cretaceous) of Stikine district. Probably throughout the southwestern part of the area the volcanics are largely Triassic. In the valley of the stream west of mount Lester Jones, there is in the volcanics a series largely of well-bedded argillites and conglomerates which is believed to be about the same as a similar late Triassic-Jurassic series of the Stikine and of the areas to the east and north.

NON-CALCAREOUS SEDIMENTS

In all sections along the range there were observed series of highly altered, well-laminated sediments. These for the most part are metamorphosed, highly argillaceous and quartzitic materials. Schists predominate; quartzites, gneisses, argillites, and slates are abundant. Many of the rocks suggest a pyroclastic content and there may be some altered flows, but owing to the abundance of dykes and stills, and to the high degree of metamorphism and deformation usually present, it was not possible to establish definitely the presence of igneous rocks in the series. Other than the overlying limestone band or bands which are usually rather sharply differentiated, there is rarely an appreciable calcium-carbonate content. The dominant colour is grey of various shades. Green is common, especially as a just appreciable tint. The rocks are usually well laminated, which in most cases is believed to be due largely to original bedding. Schistose and gneissic banding appear as a rule to conform with this and to further accentuate it. Quartz and dark-coloured mica are the most abundant mineral constituents. These rocks in many places carry a fairly large impregnation of pyrite which on weathering produces the bright rusty brown surface seen in many sections of the district. It is believed that, in some places, schists and gneisses of the type described have also been developed from rocks of the volcanic series.

Metamorphism in these rocks has been great everywhere, though there is a fairly marked difference according to relationships. Near the boundary on the Whiting, close to and within the batholith, granitic texture has been developed in a number of fairly large masses. The alteration to gneisses, coarse crystalline schists, and beyond to granitic rocks appears to result largely from the effects of intrusion. Regional deformation, which has been intense in all sections, is believed to be responsible for that part of the metamorphism that is common to all of these rocks.

Schist series have been observed along the Chutine and its second south fork in a band about 2 miles wide. They are believed to be exposed on the axis of a sharp double anticline overturned somewhat to the northwest. On either side of Chutine lake they have been cut into by the valley for a depth of 2,000 to 5,000 feet. Other masses probably occur south of the lower Chutine and north of the lake. On Whiting river just below the boundary for about 8 miles is an area in which numerous small masses are intermixed with intrusives. The four roof pendants along this river above the boundary, the top of mount Brundage, and much of the rock north of this are believed to be of the schist series and other small masses probably

occur farther east. West of Sittakanay and lower Talsekwe valleys and on both sides of the upper Talsekwe much of this type of rock is exposed. East of these sections there are probably a number of smaller areas within the volcanics. In general these older rocks are found most abundantly near the batholith.

Lithologically and as regards general relationships, these rocks are somewhat alike throughout the area and, therefore, it is suggested that they are all of about the same age. In the south their continuity with similar rocks in Stikine district bespeaks a correlation and thus suggests pre-Permian age.

LIMESTONE

Light grey limestone in narrow bands, probably at the maximum not exceeding 500 feet in thickness, was observed to lie at the top of the series of sediments. The rock is usually crystalline, contains much chert in irregular masses or beds, and as a rule is wellbedded. In places it is largely silicified, which makes it very resistant and causes it to stand up prominently on the tops of high peaks.

Limestone of this general type can be seen in a band a few hundred feet thick for several miles along the east side of the second south fork of the Chutine and in smaller bands and irregular masses north of the junction of this tributary with the main river, and west of Chutine lake. These masses in their stratigraphic and structural relationships appear to be correlatives of the more extensive masses of limestone along the lower Chutine in Stikine map-area. As such they are probably of Permo-Carboniferous age.

On the mountain northwest of the Talsekwe-Taku junction there is a fairly wide band of similar limestone trending parallel to the former river. Limestone occurs again near the mineral claims along the east bank of the Talsekwe and is reported from the Sittakanay in direct continuation of the band to the north first mentioned. Other masses are believed to occur throughout this general area. All those noted appear to have the same relationships, and in this respect are like the masses to the south and may well be of about the same age. Limestone was observed on the mountain southeast of Tulsequah and in a very extensive area crossing the upper Taku with a northwest-southeast trend. This mass appears to terminate to the south, just north of the small stream and joins the Inklin below the Sutlahine, as if in a north-plunging syncline. A number of small areas of limestone were also noted between the upper Taku and Atlin lake. Nothing definite is known about the relationships or the age of any of these masses. Throughout the area of the Sutlahine and Whiting no large masses of rock thought to be limestone were observed. A few bands of highly altered, calcareous material were noted in the sediments along the Whiting, but these were thought to belong in that series rather than above.

VOLCANICS

By far the greatest extent of rocks included under the heading of non-intrusives are volcanics and they form a great series of rocks dominantly extrusives. It includes throughout some sediments, in places considerable series largely of these materials, and also considerable quantities

of intrusive material associated with and not readily separated from the others. The volcanics along the Stikine include Triassic, Jurassic, and possibly Lower Cretaceous groups; probably the same is true of volcanics to the north.

The volcanics are dominantly massive, and dark grey and green. Bedding is common though not always readily detected. Red and various colours intermediate between this and green are to be noted in most sections. The rock is most commonly dense, though there are all gradations from this to coarse-grained, igneous rocks on the one hand and breccias and agglomerates on the other. In the field, unless bedding is well defined, it is not as a rule possible to distinguish between pyroclastics, flows, and intrusives. Sediments are intermixed with, and in many cases grade into, the volcanics. Dark grey and green argillites and quartzites are most common. A calcareous content was not noted to be nearly as prevalent as in Stikine district, though some lenses of limestone were observed.

The volcanic series in all sections is somewhat altered, but rarely shows the complete change to schists or gneisses which is common in the older sediments. As a rule it appears to be much deformed, though in some localities a simple structure was noted. The volcanics are abundant along the Chutine and are believed to occupy most of the area north and east of this river, east of the North and South Whiting, and between the Sutlahine and the Taku.

The part of this series which carries an unusually high proportion of sediments, as already noted, was observed south of Taku river on either side of the valley west of mount Lester Jones. This formation, which is fairly thick, is well bedded throughout and usually brown on the weathered surface. Argillites were observed to be very abundant, and quartzites and conglomerate containing granitic boulders were common. These rocks bear a marked resemblance to a Triassic-Jurassic series of Stikine district and also to the Laberge-Tantalus series found to the northeast, and are believed to correlate with both.

Most of the volcanics in the area under discussion are thought to lie stratigraphically below these and to be of Triassic age. They rest unconformably on the assumed Permo-Carboniferous limestone and pre-Permian sediments.

COAST RANGE INTRUSIVES

The Coast Range batholith in the area examined maintains the composite character noted along Stikine river to the south. The subdivision of the intrusives into two major groups was carried throughout. In the field this is done largely on the basis of colour which, of course, reflects the composition. One group of phases, found largely along the axis of the range, consists of grey rocks, whereas the second, occurring in the east, and occupying the greater part of the large lobes and satellites, shows brown, buff, or pink. Within each of these groups subdivisions have been noted, but it has not been feasible to maintain them throughout any very large area.

Practically all rocks of the Coast Range intrusives are granitic. Light grey, green, brown, and pink are the predominating colours. A coarse-grained, more or less uniform texture is most common, though a

great many variations are to be found. The grey phases in many places grade more or less imperceptibly to volcanics or materials so similar to these that it is difficult to differentiate the two types. There is thus exhibited a great variety of fine-grained phases. Though, as a rule, these are closely associated with contacts, in some places the dimensions of the masses which are extremely heterogeneous, appear to measure at least thousands of feet in all directions. Masses of this type occur rather abundantly in the vicinity of the headwaters of the first and second south forks of the Chutine, and in sections of Whiting district. Owing to the difficulty of distinguishing such rocks from the volcanics it has not been possible with accuracy to place the main contact or to locate masses beyond.

The brown phases of intrusive also include fine-grained types. These are in general similar throughout the area and present the appearance of felsites or aplites with a brown to pink colour. They do not occur continuously along the contact of the coarser rock. They are absent from many places, but in others they occupy rather extensive areas.

On the whole the brown phases are exceptionally fresh. Rarely, and then generally near the contact, is there any gneissic texture. Shearing and crushing have been noted along some well-defined zones, but not over any very great area. The grey phases, on the other hand, exhibit extensive areas that are much sheared and gneissic, but in other areas they are as unaltered as the brown. West of Chutine lake the former characteristic is well developed, apparently throughout an area of many square miles. Here normal, fresh rock can be observed grading to gneiss with a fine banding or to schist with large, phenocryst-like knots of feldspar. Porphyritic textures are relatively rare, though a slight tendency toward this is fairly common. Northeast of Chutine lake, however, along the contact of the brown-phase satellite, a coarse porphyry is fairly abundant. No large masses entirely of porphyry were noted.

The composition of the rocks of each phase appears, from field observation, to be fairly regular throughout the area. The most common types probably vary from granodiorite to granite. Diorite, gabbro, syenite, and rocks of intermediate composition occur locally in relatively small amounts. The brown phases are probably the most acidic, averaging quartz monzonite, and are younger than the grey, which probably average granodiorite.

Much further evidence was collected to support the belief gained in Stikine district that the batholith was the result of a series of intrusions which took place over a fairly long time, probably throughout the greater part of the Mesozoic era. This broader work has also brought to light a more or less systematic arrangement of at least the two major groups of intrusives; the so-called brown and grey phases. These appear as separate batholiths, the grey phase occupying in the main the core of the range and having a boundary that may be comparatively straight or, at least, lacks major indentations in the area under discussion. There are also satellites beyond the main mass. The brown phase is represented by a series of discontinuous masses. From the Whiting to the Chutine these masses overlap the older phase; to the north and south in the area mapped they trend away from it.

ECONOMIC GEOLOGY

The economic geology of the contact zone of the Coast Range batholith in Stikine,[1] Iskut,[2] and Taku[3] districts has already been discussed.

Except in Stikine and Taku districts, no deposits are known to have been staked in the whole region. Whiting River district has long been known as a land of mystery, and there is probably no section of northern British Columbia about which there have been more stories and rumours with less real information. Many men have set out for the district, and it has been penetrated from various directions. There have been reports of discoveries and great possibilities, but in most cases the actual results appear to have been discouraging.

So far as geological conditions govern, the whole area is rather sharply divided by the main contact of the batholith. To the west of this the rocks are largely intrusives, but because of the composite character of the batholiths, they are not as barren of mineralization as is normally expected of such rocks. Important mineral deposits are known to occur in granitic rocks elsewhere in northern British Columbia and in all sections visited some mineralization of the intrusives was noted. The possibilities of mineral wealth in the intrusive areas should not be overlooked, though at present these areas must be considered as by far the least attractive for prospecting. Within the batholithic areas there are isolated masses of non-intrusive materials and these constitute more promising prospecting ground.

The whole contact zone from the main batholithic mass eastward is favourable for the occurrence of mineral deposits. The eastern limit of this zone is roughly represented by a line following the Tahltan, Sheslay, and Inklin to the Sutlahine, thence northwest passing to the east of Atlin lake. It may be found, however, that between Chutine and Sutlahine rivers the favourable zone is much narrower. Little is known about the western part of the Sheslay drainage basin and, therefore, nothing as yet points to this area as being definitely favourable. Of the whole zone thus indicated, present information suggests that the western part holds the greatest potentialities. The areas of intrusives, especially of the brown phase, offer by far the least favourable prospecting sections, whereas the non-intrusives in the vicinity of contacts are the most promising. However, in the case of the brown phases it has not yet been demonstrated that these were productive of important mineralization.

In upper Chutine River district there is not a great deal to attract the prospector. Extending south of the river along Triumph river and far beyond its headwaters, and largely very difficult of access, is an extensive roof pendant from which the glaciers and streams bring pieces of mineralized rock. The limited part of this mass, which lies near the Chutine, was not observed to be as well mineralized as seems to be indicated in other sections. Between Chutine lake and Dirst river all the rock is granitic. From the lake another mass of non-intrusive extends northward. This in places is somewhat mineralized and showings are reported west of the lake, but this mass, also, is difficult of access. The area adjacent to upper

[1]Sum. Rept. 1928, pt. A.
[2], [3]Sum. Rept. 1929, pt. A.

Barrington river, though still more inaccessible, should also be favourable for mineralization. Northward from these areas to the Whiting is an extensive area likely to be mineralized, but provided with no reasonable means of access. The route by Sawyer glacier previously mentioned is not likely to be sufficiently practicable to warrant consideration except by the most venturesome.

Whiting River district, because of the extreme difficulty of navigating the river and the presence of a large eastward protrusion of the batholith, made up largely of the brown phases, offers little to encourage prospectors. The body of non-intrusives at the boundary was prospected last summer and though showing much rustiness is understood to have yielded nothing of much merit. The small roof pendant east of this exhibits some rusty streaks, but those examined were of no value. The roof pendants south and east of the South Whiting were not examined, but exhibit in places considerable rustiness. Casual observations of the small masses around the main junction did not yield anything of importance. East of the batholith, especially near the second and third east forks of the North Whiting, are a number of rusty zones. From Taku river south along the south fork is a series of small satellites of a grey intrusive. It is suggested that these satellites and probably others not exposed, both on this side of the Taku and to the north, are close associates of the mineral deposits of this section. Mineral deposits, and rusty zones likely to carry mineral deposits, were observed in a fairly large area including, mainly, the drainage area of the lower Talsekwe and the lower south fork. To the east, in part, the zone of prospective value is cut off by two large masses of brown intrusives, one of which lies north of Taku river. Toward the headwaters of the south fork the evidences of mineralization were not observed to be as abundant. This area is largely volcanics, though sediments fringe it to the southwest and northwest. The volcanics appear to be more favourable for mineralization, but the sediments also contain mineral deposits.

In an airplane flight over the section between Taku river and Atlin lake a number of well-defined, rusty zones were noted which suggest possibilities for this section. The area immediately south of the upper Taku has been so casually examined that no definite conclusions can be reached as to its possibilities.

BUTTLE LAKE MAP-AREA, VANCOUVER ISLAND

By H. C. Gunning

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Illustrations

INTRODUCTION

During the summer of 1930 a geological reconnaissance of Buttle Lake map-area was made and mineral deposits, other than coal, were examined. This work forms part of an extensive program of investigation of the geology of Vancouver island, commenced in 1929; the primary object being to cover as much as possible of the unmapped part of the island in a reconnaissance manner and from the knowledge thus obtained to delimit smaller areas which merit more detailed studies at a later date. Buttle Lake map-area is bounded by latitudes 49° 30′ and 50° 00′ and longitudes 125° 00′ and 126° 00′ and extends from Georgia strait on the east to within 2 miles of the head of Muchalat arm, a deep inlet on the west coast. As the work was of a reconnaissance nature there are many geological details that require further study. In this report all that is attempted is to present the more important, broad features of the general geology and to draw attention to the mineral possibilities of the area. Previous geological work[1] has been limited almost entirely to the strip of Upper Cretaceous coal-bearing rock along the east coast[2] and to the examination of a few magnetite deposits.[3] Dolmage[4] has studied the geology along the coast immediately west of the area and the various annual reports of the British Columbia Minister of Mines contain numerous valuable references to the properties. J. D. MacKenzie had practically completed his study of the coal-bearing rocks along the east coast, but unfortunately, due to his untimely death in 1922, neither maps nor a final report have been published.

[1] *See* Map 196A "Vancouver Sheet"; Geol. Surv., Canada, 1928.

[2] Richardson, J.: Geol. Surv., Canada, Rept. of Prog. 1871–72; 1872–73; 1876–77.
Dawson, G. M.: Geol. Surv., Canada, Ann. Rept. pt. B (1886).
Am. Jour. Sci., 3rd series, vol. 39 (1890).
Clapp, C. H.: Geol. Surv., Canada, Sum. Rept. 1911, p. 106.
MacKenzie, J. D.: "Coal Measures of Cumberland and Vicinity, Vancouver Island"; Trans. Can. Inst. Min. and Met., vol. XXV (1922).

[3] Young, G. A., and Uglow, W. L.: "Iron Ores of Canada, vol. I, B.C. and Yukon"; Geol. Surv., Canada, Ec. Geol. Series No. 3, pp. 71–79.

[4] Geol. Surv., Canada, Sum. Rept. 1920, pp. 12–22.

His manuscript maps, however, were available and from them and his notebooks much valuable information has been obtained. The writer was ably assisted in the field by Norman G. Freshwater, and is indebted to many residents and to the management and staff of Comox Logging and Railway Company, Elk River Timber Company, and Bloedell, Stewart, and Welch for information, assistance, and hospitality. Maps supplied by the logging companies and by Canadian Collieries (Dunsmuir), Limited, greatly facilitated the field work.

NATURE OF THE DISTRICT

The topography of the map-area varies greatly. The strip along the east coast underlain by Cretaceous sediments is relatively flat—a coastal plain—and rises but a few hundred feet above sea-level. It contains some fine farming land and at one time was heavily timbered with fir, cedar, and hemlock now largely logged off, the most important timber reserves being between Oyster and Campbell rivers and well removed from the coast. Logging operations are of prime importance in the district, and centre particularly in the vicinity of Bevan, and Comox lake, along the upper Oyster river, and adjoining Campbell and Quinsam rivers. Cumberland is a coal mining town, headquarters for Canadian Collieries (Dunsmuir), Limited. Courtenay, northern terminus of the Esquimault and Nanaimo railway, is a thriving and attractive centre. Campbell River, Royston, Union Bay, Comox, Bevan, Headquarters, Merville, and Oyster River are smaller settlements. Mixed farming is carried on principally in the vicinity of Courtenay, Comox, and Headquarters.

Mountains, 4,000 to 7,000 feet high, rise abruptly to the west along a front coinciding approximately with the western limit of the Upper Cretaceous sediments from the south edge of the district northwestward as far as Browns river. North of Browns river the Cretaceous sediments overlap more extensively on the mountains west of the coastal plain and the mountains become lower towards Quinsam and Campbell rivers, breaking up into a number of long, low ridges and rocky knolls covered with a luxuriant growth of timber and brush. The highest and roughest ground is on the southern half of the eastern part of the map-area and in a second area west of Buttle lake and Upper Campbell river. The latter area is within Strathcona park and is very rugged, peaks rising to 6,000 and 7,000 feet separated by deep, narrow valleys abounding in canyons and waterfalls. Buttle lake, 725 feet above sea-level, occupies a deep valley with high mountains rising abruptly from it on the east, south, and west. The lake and its surroundings constitute one of the finest natural playgrounds on the island. There are many excellent beaches and camp-sites, the water is ideal for boating or swimming, there is good fishing, and the adjoining valleys and mountains offer a wealth of variety for hikers and mountaineers. Deer and bear are plentiful.

Around the headwaters of Cruikshank, Oyster, and Browns rivers there is an area of fine mountain upland, 3,500 to 7,000 feet above sea-level, known locally as Forbidden plateau, that is fast becoming popular as a winter and summer resort under the active development of residents of Courtenay and vicinity. South of this there is a rugged, snow and ice-capped area between Comox and Buttle lakes.

A number of roads, trails, and logging railway grades render most of the coastal plain quite accessible. Auto stages run over the main island highway as far as Campbell River and Forbes Landing. There are boats on Comox lake and a trail leads from the south end of the lake to Alberni. There are two trails to Forbidden plateau, one proceeding a little north of west from Bevan and another following the drainage of Dove creek and Browns river from Ward's ranch, 3 miles south of Headquarters. The latter trail, 15 miles long, is used by packhorses, available in Courtenay, and leads directly to a summer camp. There is an old trail from Headquarters to Wolf lake. The country north and northwest of Headquarters, towards Oyster river and Quinsam lake, is well opened up by logging grades. From Forbes Landing to Upper Campbell lake there is a road, the last 5 miles of which are passable but hardly attractive for automobiles. From the west end of Upper Campbell lake a good packtrail follows the east side of Campbell river to the outlet of Buttle lake, a distance of 9 miles. Upper Quinsam lake is reached by a 5-mile trail from the Campbell River road 4 miles east of Upper Campbell lake. Two old trails, now badly overgrown in many places, follow up Elk river from Campbell river. The only trail in the vicinity of Buttle lake is 2½ miles long and leads to mining claims up Myra creek. An old trail up Price creek is very difficult to follow now. Away from trails and roads the district is not an easy one in which to travel, though on the summits there is much open and fairly level ground, abounding in lakes. The valleys, however, are deep and generally abound in canyons; they are heavily timbered on the lower slopes; and the ridges leading to the summits are as a rule excessively steep and rugged. The north side of Myra creek affords the best, and, indeed, almost the only reasonably easy, approach to the uplands in the heart of Strathcona park.

The climate is generally very agreeable between June and September. The snowfall at the higher elevations is heavy, corresponding to an abundant rainfall at sea-level, and prohibits much geological work on the summits before July 1. Some time during September the autumn rains may be expected and, once begun, many of the rainfalls are continuous and excessive.

GENERAL GEOLOGY

The rocks of the area fall naturally into three major groups. The oldest is an assemblage of volcanic rocks with some interbedded limestone, argillite, and quartzite, varying in age from late Palæozoic to Triassic and possibly Jurassic. The volcanics and sediments are cut by numerous granitic bodies collectively known as the Coast Range intrusives and of late Jurassic or early Cretaceous age. These two older groups of rocks are, in different parts of the area, overlain unconformably by sandstones, shales, and conglomerates, of Upper Cretaceous age and containing the important coal beds of Cumberland and vicinity. The accompanying generalized map (Figure 5) shows the distribution of the three groups.

The first-mentioned assemblage includes the early Mesozoic volcanics and interbedded sediments of the Vancouver group, and in addition an underlying series of crystalline limestone and volcanic rocks with minor

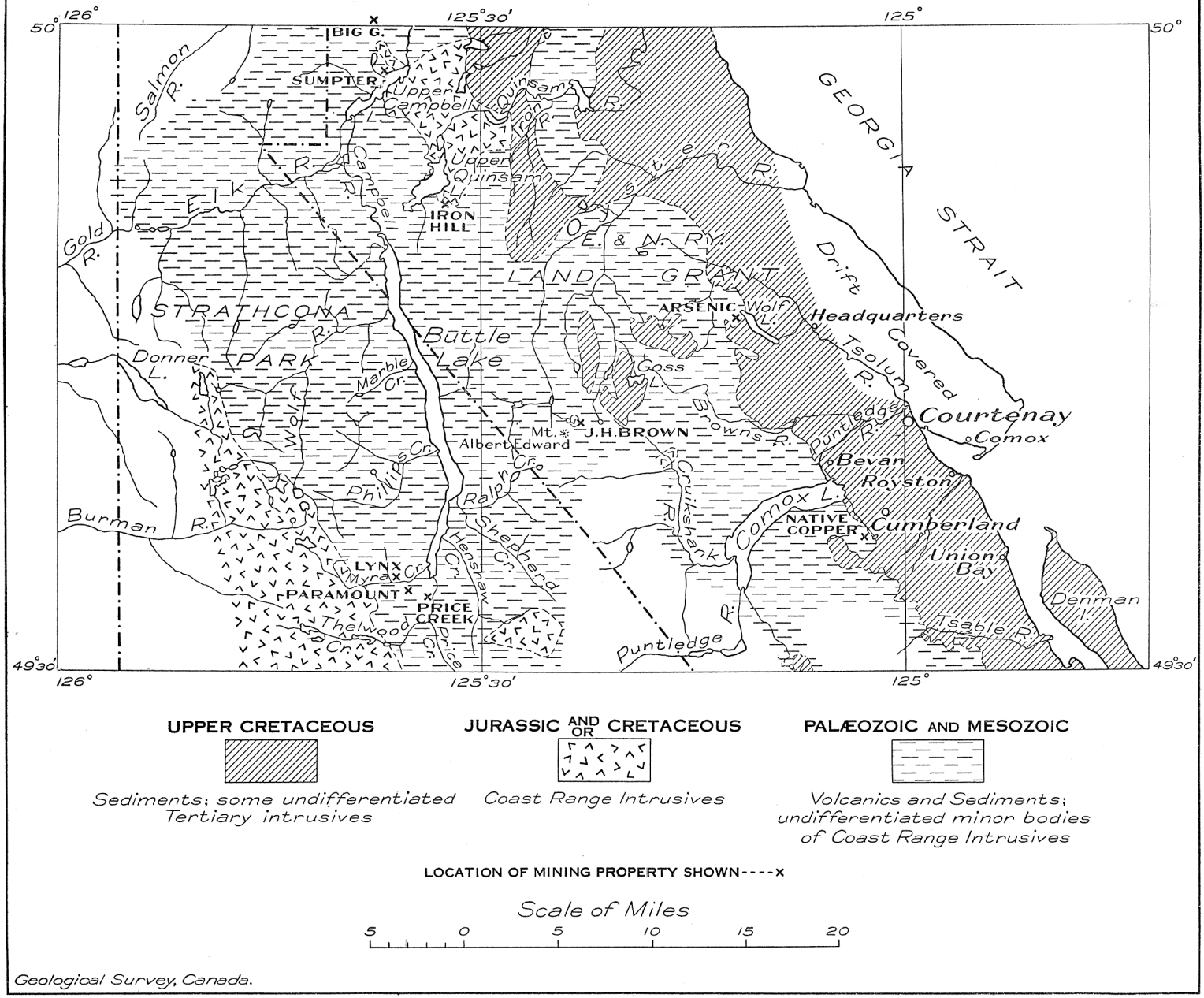

Figure 5. Buttle Lake area, Vancouver island, British Columbia.

amounts of argillite and quartzite. Fossils of Permian age were collected from certain of the limestone horizons and for the first time afforded definite proof of the occurrence of rocks of Palæozoic age on Vancouver island.[1]

The Upper Cretaceous sediments, known along the east coast as the Comox sandstone and Trent River shales, are correlated with part of the Nanaimo series.[2] They are intruded by several bodies of igneous rock tentatively placed as of Oligocene age (*See* Map 196A, Vancouver sheet).

PERMIAN

The oldest known rocks within the area were found in the vicinity of Buttle lake. They consist of a thick series of volcanic rocks including andesitic to basaltic flows, tuffs, and coarse volcanic breccias with at least two and probably three interbedded horizons of white, grey, or pink, crystalline limestone and minor amounts of argillite and quartzite. The uppermost horizon of limestone is the only one that is well exposed for any distance (*See* Plate I A). In it, around the headwaters of Marble creek, are many well-preserved fossils from which several collections were made.

The bryozoa, which formed the bulk of the collections and were collected principally from several dark grey, carbonaceous lenses in the limestone, were sent to Miss Madeleine A. Fritz of the Royal Ontario Museum of Palæontology, Toronto, who identified the following genera.

Acanthocladia	2 species
Clausotrypa	1 species
Fenestella	Several species
Goniocladia	1 species
Pinnatopora	2 species
Phyllopora	1 species
Polypora	Several species
Streblotrypa	1 species
Ulrichotrypa	2 species

Miss Fritz states: "I propose to correlate this fauna with the one recorded by Dr. Bassler from the island of Timor in the East Indies which is considered to be of Permian age."

The remainder of the collections, including spirifers, a few bryozoans, and crinoid stems were sent to Dr. G. H. Girty of the United States Geological Survey who reported[3] that the evidence as to age is not conclusive. He stated, as his best guess on the material available, that the spirifers may belong in an horizon high up in the Pennsylvanian, this being at least more probable than that the horizon is Permian.

The quite definite statement by Miss Fritz places the fossiliferous limestone in the Permian. The considerable thickness of volcanic rocks and other sediments lying stratigraphically below the limestone and well exposed in the area may, however, be Pennsylvanian or older. It does not seem advisable as yet to give these Palæozoic rocks a definite formational or group name. When their age, characteristics, etc., are more fully known, the name Buttle Lake group or formation for all or part of them is

[1]Dawson, G. M.: Geol. Surv., Canada, Ann. Rept., vol. II, pt. B, p. 10 (1887).
Clapp, C. H.: Geol. Surv., Canada, Mem. 13, p. 9 et seq. and Mem. 96, p. 92.
[2]MacKenzie, J. D.: Op. cit, p. 7 of Separate.
[3]Personal communication to E. M. Kindle.

suggested. That they should be separated definitely from the overlying Vancouver group, even though possibly conformable with it, is self evident and it is interesting to note a remark Dawson made many years ago in this connexion[1]. . . . . "If this great mass of rocks (Vancouver series) should eventually prove separable into Triassic and Carboniferous portions, I would suggest the retention of the name Vancouver series for the former."

This same uppermost limestone horizon is well exposed along the summits on the west side of the south fork of Wolf river dipping to the west, and extends to the north across the head of the north fork of that river. What is almost surely the same horizon is again exposed on the slopes on the east of Price creek from the south end of Buttle lake to the southern boundary of the sheet, dipping at low angles to the east. Above this limestone are several thousand feet of volcanic rocks apparently conformable with the limestone (*See* Plate I B). The first fossiliferous horizons above the limestone are impure limestones and argillites on Iron river, and these contain Triassic fossils. Therefore, the uppermost Permian limestone has been taken as the upper limit of the Palæozoic rocks and it appears that there may quite probably be a conformable succession of volcanic and sedimentary rocks from the late Palæozoic well up into the Mesozoic. At least two other beds of limestone, lower in the Palæozoic section, are exposed on the west side of Buttle lake, one on the bay just north of the mouth of Phillips creek and the second on the first point south of Marble creek. In most of the limestone there are large but varying amounts of dark grey to white or resinous chert. The other rocks, below the uppermost limestone, are largely green to purple, andesitic breccia and tuff. Andesitic and more basic flows are relatively sparingly developed, but, mixed with dense, banded, green, cherty, tuffaceous beds seemingly become more abundant in the lower part of the section. There are also numerous andesite or diorite dykes which presumably were feeders of overlying flows. The predominant colour throughout is light to dark green.

Intruding the Palæozoic rocks are large bodies of medium to fine-grained, brownish green gabbro. This rock is most abundantly developed in the area east of the south fork of Wolf river to Buttle lake. In the western part of the area the contacts of the gabbro with the upper limestone are generally sill-like, following the bedding quite persistently, whereas in the east they are extremely irregular, the gabbro evidently occurring in a great number of irregular bodies, dykes, and sills. Where the gabbro forms sill-like masses in or below the upper limestone, it commonly exhibits excellent columnar jointing. The effects of this intrusion on the older rocks have been remarkably slight. No important mineralization could be definitely attributed to it, although there are small amounts of chalcopyrite and pyrite in some of the limestone near gabbro. The limestone, apart from being recrystallized, is silicified and otherwise altered for a few feet from the contact and in places has been converted to a red jasperoid consisting entirely of finely crystalline quartz and hematite. The gabbro is older than the Coast Range intrusives, and may be connected with the late Palæozoic or early Mesozoic vulcanism.

[1]Dawson, G. M.: "Report on a Geological Examination of the Northern Part of Vancouver Island and Adjacent Coasts"; Geol. Surv., Canada, Ann. Rept. 1886, pt. B, p. 10.

In the district around the head of Price creek and west thereof the Palæozoic volcanic rocks are intruded by a vast number of dykes and irregular bodies of rocks varying in composition from fairly basic porphyries to quartz and feldspar porphyries and aplites. Included in the complex are normal volcanic rocks, dykes, and sills connected with the Palæozoic or early Mesozoic vulcanism and also many dykes belonging to the Coast Range period of intrusion.

The structure of the Palæozoic rock is clearly shown by the limestone beds. The rocks are folded into a broad anticline pitching to the north. Within this major structure there are at least two minor synclinal folds. One of these is beautifully exposed on the divide between Phillips and the south fork of Wolf creek; the second is less definite and lies farther east. The axis of the major structure trends almost due north. All the folds are open, the westerly limb of the anticline dipping from 20 degrees to 30 degrees west and the easterly limb, on Price creek, at lower angles to the east. The minor synclinal folds are gentle flexures and the flat dips imparted to the limestone account for the extensive exposures of that rock which cover the summits between Phillips and Marble creeks. The continuation of the Palæozoic rocks south of the map-area has not been thoroughly investigated, but similar limestone is known to pass through Big Interior mountain and to swing east from it, dipping west and south, suggesting that this is probably about the southern limit of the series. The maximum observed thickness of the uppermost Permian limestone is about 500 feet, the minimum probably about 100 feet.

In the area south and west of Buttle lake, between Phillips and Price creeks, the volcanic rocks along several more or less definite zones striking in a northwesterly direction are extensively sheared and altered to chlorite, sericite, and quartz-sericite schists and the alteration is accompanied by some important mineralization. On the north, between the mouth of Marble creek and the north fork of Wolf creek, the Palæozoic rocks are cut off by several important faults, striking northwesterly, so that they abut directly, along the strike, against younger volcanics; that is, the horizontal displacement along the faults, of the northeast wall relative to the southwest wall, has been to the southeast. Wherever limestone is exposed for any considerable distance, faulting was observed. Where limestone is absent, the volcanic rocks of the series are sufficiently similar in appearance to render faulting inconspicuous. It may be concluded, however, that the whole Palæozoic section is broken into a number of blocks by numerous faults.

VANCOUVER GROUP

Overlying the Permian limestone, apparently conformably, is a great thickness of lavas and fragmentals. For at least 5,000 feet stratigraphically above the limestone these rocks are not known to contain any fossiliferous horizons. They include pillow lavas, breccias, andesite, and amygdaloidal basalt, very minor thicknesses of dacite and felsite, and all are cut by dykes of andesite and diabase, and by a few more acidic dykes. In ascending the section the first fossiliferous sediments—impure dark grey limestone and argillite—were encountered on the upper reaches of Iron river which drains into Quinsam river. A poor collection of the fossils has been placed in the

Triassic by F. H. McLearn. As yet no horizon can be defined as marking a break between Palæozoic and Mesozoic and it seems probable that volcanic activity was more or less continuous, unbroken by any important erosion interval. The characteristics of the volcanic and sedimentary rocks of the Vancouver group have been quite fully described in reports by Clapp[1]. Pillow lavas and amygdaloids are much more abundantly developed than in the underlying Palæozoic section. The distribution of the sediments of the Vancouver group is of some economic importance, as many of the mineral deposits of the island are found in limestone. In the section between Wolf river and the summit north of Elk river and as far east as Upper Quinsam and Upper Campbell lakes nothing but volcanic rocks have been observed. Limestone outcrops on the north-central shore of Upper Campbell lake and continues north beyond the 50th parallel, outcropping in Greenstone creek about 3 miles above the mouth. A few remnants of the same bed are found capping knolls along the west contact of the Quinsam granodiorite, south of Upper Campbell lake, and what is presumably the same horizon is in part replaced by magnetite on the Iron Hill claim just south of Upper Quinsam lake. What may be a continuation of this horizon to the southeast was encountered on the west fork of Oyster river 16 miles south of the 50th parallel. What is probably the thickest and most continuous section of sediments in the Vancouver group of the map-area was encountered on Campbell river west of Greenstone creek, on Iron river, on the slopes west of Wolf lake, and around the headwaters of Dove creek. All the exposures are adjacent to basal members of the Comox sandstone. The outcrops occur in heavily timbered and drift-covered parts of the district at fairly low elevations and their continuity as parts of one section could not be indisputably established. The best exposures are on Iron river where fossiliferous, impure limestone and argillite, and quartzite are interbedded with volcanic rocks and are much contorted, their strike varying from northwest to northeast and the dips being either to the east or west. The only other locality where sediments were noted in the group is to the southeast of Divers lake immediately below an outlier of Upper Cretaceous sediments.

COAST RANGE INTRUSIVES

The Coast Range intrusives occur as dykes, stocks, and batholiths cutting the Palæozoic and Vancouver group rocks. They are not known to cut the Upper Cretaceous sediments. The conglomerates of that series contain pebbles and boulders of granodiorite believed to be derived from the intrusives; and Upper Cretaceous sandstones rest unconformably on an eroded surface of the Quinsam granodiorite. Consequently the intrusions are younger than the Vancouver group, but older than the Upper Cretaceous strata. They are generally dated as either late Jurassic or early Cretaceous. They are economically important because they are believed to be the original source of most of the metallic mineral deposits of the area. They are green to dark grey to almost white, holocrystalline rocks including diorite, quartz diorite, granodiorite, and some granite. The largest body, of batholithic proportions, is on the southwest side of the area and continues south past Big Interior mountain. Its western boundary has not been

[1] *See also:* "Geology and Mineral Deposits of Quatsino-Nimpkish Area, Vancouver Island", by H. C. Gunning; Geol. Surv., Canada, Sum. Rept. 1929, pt. A.

determined, but the body is at least 10 miles wide in the vicinity of Thelwood and Myra creeks. Typically this body is a medium-grained granodiorite, but quartz diorite is not uncommon and soda granite was encountered on the ridge north of Myra creek. The easterly contact cuts diagonally across the strike of the Palæozoic rocks and the overlying members of the Vancouver group. The second largest body is exposed in the vicinity of Upper Campbell and Upper Quinsam lakes and may be termed the Quinsam granodiorite, although it varies considerably in composition and in appearance from dark green mafic varieties to fine or medium-grained, acidic phases. The body at the head of Henshaw creek is essentially quartz diorite, although parts of it grade into quartz gabbro. It contains a large percentage of hornblende. Several other smaller masses of granodiorite are known. Still smaller bodies of granodiorite were encountered along the upper valley of the east fork of Oyster river; these occur in two places between Divers and Circle lakes: (1) on a stream draining into Divers lake from the southeast; and (2) near the divide between Oyster and Browns rivers north of Goss[1] lake. It seems probable that the whole area surrounding the headwaters of Cruickshank, Oyster, Browns, and Ralph creeks may be underlain by granodiorite at no very great depth, the small bodies that outcrop being merely the higher projections of a much larger buried body.

Certain intrusives, described on page 64, cut the Upper Cretaceous sediments and in appearance and composition are similar to some of the Coast Range intrusives. They are tentatively placed as being of Oligocene age. It is possible that some of the smaller bodies cutting the Vancouver group and that have been classed with the Coast Range intrusives, may be Tertiary. More particularly this may be true of some of the smaller intrusions on the upper reaches of Oyster river.

UPPER CRETACEOUS SEDIMENTS AND YOUNGER INTRUSIVES

Field notes and manuscript maps of J. D. MacKenzie have supplied the information defining the westerly contact of the area of Upper Cretaceous sediments along the east coast[2] and the small area south of Comox lake.[3] The three isolated areas of Cretaceous sediments in the region, known as Forbidden plateau, around the headwaters of Cruikshank, Oyster, and Browns rivers, were mapped for the first time during the past season. They are preserved on more or less pronounced elevations and are separated by narrow areas of the older, underlying rocks exposed along intervening valleys. There can be little doubt that all three areas are underlain by parts of the same rock series. The sediments of the three areas are sufficiently alike, allowing for local variations such as intercalated beds of conglomerate, to support this premise, and the structures permit of direct correlation across the eroded depressions.

Near the base of the series coarse conglomerate, containing angular to subangular pebbles and boulders, on the average some 2 inches in diameter but varying greatly in dimensions, of volcanic rocks, granodiorite, argillite, and quartzite, is commonly found. There are excellent exposures of this rock at the head of Cruikshank canyon on the north side where a maximum

[1]Named, in the B.C. Gazeteer, Helen Mackenzie lake.
[2]MacKenzie, J. D.: "Coal Measures of Cumberland and Vicinity, Vancouver Island"; Trans. Can. Inst. Min. and Met., vol. XXV (1922).
[3]MacKenzie, J. D.: "Alberni Area, Vancouver Island, B.C."; Geol. Surv., Canada, Sum. Rept. 1922, pt. A, pp. 51–67.

thickness of about 100 feet was observed. Narrow layers of grey sandstone are interbedded with the conglomerate. Above is similar sandstone and intercalated shales with local developments of conglomerate, the latter notably on Limestone ridge just west of Goss lake. Within 100 feet or so stratigraphically above the basal conglomerate are two or three horizons, quite probably very local in extent, of highly carbonaceous shale containing numerous plant markings. There has been a little prospecting for coal and a small amount of bright, coaly material has been found. The total thickness of sediments in any area was not accurately measured, but in the Mount Washington and the Goss Lake areas (northeastern and southeastern, respectively) there must be at least 600 feet of conglomerate, sandstone, and shale. In both these "basins" minor faulting is not uncommon. The structure of each is essentially an open basin or trough-shaped syncline with the dips, where not locally disturbed by intrusion, seldom exceeding 15 degrees towards the centre of the "basin."

In each area the sediments are cut by dykes, sills, and irregular bodies of granodiorite and quartz diorite which are light to greenish grey, medium, even-grained, or porphyritic. In both the Mount Washington and Goss Lake "basins" the intrusives form well over 25 per cent of the total outcrops. They are quite similar to the intrusive bodies that cut the Comox sandstone in the vicinity of Wolf lake and at Anderson hill just north of Bevan (*See* Map 196A). Clapp[1] terms the latter a dacite porphyry, and suggests that it may be of Eocene age. However, he later suggests[2] the more likely correlation with the Lower Oligocene intrusives of Sooke map-area. In all probability the rocks under discussion should be placed in the same period. It appears that the intrusions produced some slight mineralization, for at one or two places where granodiorite dykes cut carbonaceous shales, small veins of calcite, with pyrite and a little chalcopyrite, were noted and the granodiorite itself is somewhat altered and contains disseminated sulphides. It should be remembered that copper mineralization of some importance is connected with the Tertiary intrusives of Sooke and vicinity on the southern end of the island.[3] It must also be emphasized that it is not easy to separate the Tertiary intrusives from the normal Coast Range intrusives by their appearances. Consequently, unless found to cut Cretaceous or younger rocks, any intrusives would probably be correlated with the Coast Range bodies, but might quite easily be of Tertiary age. Several of the granitic bodies found cutting the rocks of the Vancouver group in the vicinity of Forbidden plateau may quite possibly be of Tertiary age, although they have been described above under Coast Range intrusives.

A few fossils were collected from the sandstones of the Goss Lake basin. F. H. McLearn reports as follows on a collection from Limestone ridge, just west of Goss lake.

"*Glycimeris* sp.
Trigonia (*aliformis* subgroup) sp.

Probably Nanaimo fauna, Upper Cretaceous. It is difficult to say whether the beds are to be correlated exactly with the Comox sandstone of the Cumberland district . . . . . All that can be said is that, like the Comox sandstone, they are, probably, part of the Nanaimo series."

[1]Clapp, C. H.: Geol. Surv., Canada, Sum. Rept. 1911, p. 106.
[2]Geol. Surv., Canada, Mem. 96, p. 304.
[3]Geol. Surv., Canada, Mem. 96.
Geol. Surv., Canada, Sum. Rept. 1919, pt. B, p. 20.

Regarding a collection from Strata ridge, one mile south of the above, McLearn states:

"Pelecypods including *Corbis*? sp.

May be Nanaimo fauna, but nothing present to date it by."

Thus it appears that there is not sufficient palæontological evidence to justify correlating the measures directly with the Comox sandstone. However, the eastern contact of the Washington basin is less than 2 miles from the western contact of the Comox sandstone and the difference in elevation is only a few hundred feet. Also, the sandstones and conglomerates of the Washington basin are lithologically identical with the same rocks in the Comox formation. Thus, indirect field evidence increases the probability that the Cretaceous rocks of the three areas on Forbidden plateau may be correlated in part or in toto with part of the Comox formation.

ECONOMIC GEOLOGY

This section will be devoted entirely to a discussion of the metallic mineral deposits of the area. The coal resources have been described previously by Richardson, Clapp, MacKenzie, and others.

Buttle Lake map-area is divided into two parts by the boundary of the Esquimalt and Nanaimo Railway Land Grant. The grant extends south from the 50th parallel. It is open to prospecting under the usual conditions of the "Mineral Act" for British Columbia, but claims staked in it are also subject to certain regulations laid down by the railway company. These regulations have been summarized by G. A. Clothier[1]. They are not prohibitive. Some prospectors, however, have but a hazy knowledge of the regulations and evidently are of the erroneous opinion that any profits that might result from mineral discoveries would be largely appropriated by the railway company. Every prospector interested in the area should, therefore, obtain a copy of the regulations from the Land Agent, Esquimalt and Nanaimo railway, Victoria, B.C. At the request of the railway company, the Consolidated Mining and Smelting Company of Canada had several field parties prospecting the grant after the close of the war. This work was done largely within the Nanaimo mining division—that is, in the northern part of the grant—but the results obtained have not been made public. However, the fact that much of the area has been prospected by qualified men naturally renders it less attractive to the prospector.

That part of the map-area west of the Land Grant includes Strathcona park and is open to prospecting under the ordinary mining regulations for British Columbia, but except for one rather small part has not been very extensively prospected.

Taken as a whole the Buttle Lake map-area can hardly be said to be an attractive prospecting field. Large parts of it are underlain entirely by great thicknesses of massive, volcanic rocks far removed from any granitic intrusions and not extensively sheared or otherwise altered, and it is now fairly generally recognized that unless these rocks are strongly

[1]Ann. Rept. Minister of Mines, B.C., 1929, p. 367.

sheared they offer poor possibilities for mineralization, except in the immediate vicinity of deep-seated intrusives. Such unfavourable conditions are found in the region that extends from Buttle lake and Campbell river as far west as the divide between the east and west coast drainage systems and from the north fork of Wolf river northward at least as far as the summits north of Elk river. The same unfavourable conditions obtain over a strip, some 2 to 4 miles wide, east of Buttle lake and north of Ralph river, and also over a considerable area west of the Cretaceous sediments of the east coast belt, particularly in the vicinity of Comox lake and north as far as Wolf lake. Exceptions to these general statements may, of course, be furnished by deposits in basic lavas such as of native copper or bornite believed to be more or less directly derived from the volcanic rocks. Certain parts of the map-area have, however, distinct possibilities and some of the mineralization already discovered is quite encouraging. Chalcopyrite, magnetite, sphalerite, and galena are the most important ore minerals. Native copper, realgar, and native arsenic are of minor importance. Gold and silver values are not high in any of the known deposits.

BUTTLE LAKE SECTION

At the south end of Buttle lake, in the vicinity of Myra and Price creeks, extensive copper, zinc, and lead mineralization has been developed on three groups of claims. The rocks in this area are Permian or older greenstones including tuffs, breccias, and andesitic flows and andesite, diorite, or diabase dykes believed to be intruded during the period of vulcanism. Near the mouth of Myra creek and to the north on the shore of Buttle lake, finely banded, light green, siliceous tuffs are well exposed and strike north 10 degrees west, dipping 10 degrees to 15 degrees west. On Myra creek they form a number of gently dipping open folds, the dip increasing to 35 degrees west within one-quarter mile of the mouth, but flattening again west of that. These rocks form part of a large anticline and the mineralization occurs towards the middle of the structure in steeply dipping shear zones that cut diagonally across the strike of the rocks. All the rocks except some of the finer-grained siliceous varieties are extensively altered to chlorite and contain variable, small amounts of carbonate, sericite, pyrite, and epidote. Numerous faults of large offset have been observed in the rocks. Two faults of unknown offset cut across Myra creek above the falls and it is probable that many others will be found if the area is investigated carefully. The easterly contact of a batholith of granodiorite intruding the volcanic rocks crosses Myra creek just under 4 miles west of Buttle lake, the contact trending in a northwesterly direction roughly parallel to the broad shear zones in which the mineralization is found. The granodiorite is presumably a member of the Coast Range intrusives and the mineral deposits have, in all probability, been formed by solutions emanating from its magma. On the summits north of Myra creek, within 2 miles of this contact, the rocks, here including much limestone, are considerably contorted and somewhat sheared and are intruded by large dykes and irregular bodies of dark green gabbro older than the granodiorite. The mineralization of the claims occurs along broad zones, trending from north 60 degrees west to north 15 degrees west and in which the volcanic rocks are sheared and altered to green chlorite schists,

serpentine, or light grey to greenish grey quartz-sericite (and some chlorite) schists. Possibly some talc is associated with the sericite, but none has as yet been definitely identified. The schistified zones vary in width from a few feet to at least 125 feet, but the larger ones enclose irregular masses of relatively unsheared greenstone. In the schistified zones, which are vertical or dip steeply either northeast or southwest, are numerous fault planes along which the rocks are generally mashed or converted to gouge. The mineralization consists of pyrite, chalcopyrite, sphalerite, and galena with minor amounts of grey copper. The gangue is altered rock consisting of chlorite, quartz, sericite, barite, and epidote in varying proportions, but the richer zones are where the original rocks are converted almost entirely to light grey quartz-sericite schist. Barite is developed in quantity at one or more localities on each group and where it is present galena is commonly more abundant than elsewhere. The proportion of zinc in the ore is high and all the mineralization exposed is low grade; at the best it will require concentration before shipping.

Price Creek Mining Company

This company, under control of Messrs. Cross, Patrick, and associates of Victoria, owns twelve claims on the west side of Price creek, 1½ miles south of Buttle lake. A trail leads to the workings from the southwest corner of Buttle lake. The showings are on a heavily wooded mountain side that slopes very steeply eastward towards Price creek. Development consists of three open-cuts. The only rocks observed on the claims were volcanic greenstones including tuffs, andesitic flows, and probably some dykes. Their structure is not easy to determine, but scattered outcrops along the side of Price Creek valley indicate that they may strike north 40 degrees west and dip 15 degrees or 20 degrees to the southwest.

The highest working, 2,000 feet above sea-level, on the side of a narrow gulch, is an open-cut 50 feet long and about 10 feet high at the face. The cut runs south 70 degrees west. On the east there is 15 feet of slightly pyritic and partly schistified greenstone which was in part originally a cherty tuff. This is followed to the west by 6 feet of rusty weathering, light grey, pyritic, quartz-sericite schist bounded on the west by a pronounced fault wall striking north 50 degrees west and dipping 60 degrees northeast, parallel to the schistosity. West of the fault is 17 feet of greatly schistified material mixed with gouge, partly replaced by chalcopyrite, zinc blende, and pyrite and also cut by several irregular, lenticular, vein-like bodies of the same minerals with a maximum width of 30 inches. Zinc is the most abundant metal. Under the microscope numerous tiny specks of grey copper are visible in the ore and the chalcopyrite and zinc blende form a very fine-grained, intimate intergrowth. Although the mineralization is very irregular in detail yet the whole 17 feet would probably constitute a fair grade of milling ore if the sulphides could be successfully separated. Clothier[1] gives the following assays: (1) across 18 inches near bottom of cut—gold trace, silver 1 ounce, zinc 27·9 per cent, copper 2·4 per cent; (2) near top of cut—gold trace, silver 1 ounce, zinc 28·7 per cent, copper 3·3 per cent. At the west side of this mineralized section a

[1]Ann. Rept., Minister of Mines, B.C., 1929, p. 384.

second wall trends north 70 degrees west and dips steeply northeast and beyond it is 10 feet of oxidized and leached pyritic schist containing, particularly, beside a third fault on the west which strikes north 40 degrees west and dips steeply northeast, a little residual copper and zinc. Thus, there is some 27 feet of mineralized material which seems well worth more extensive exploration. West of the cut, chlorite schist and quartz-sericite schist are exposed for about 150 feet up the steep creek bed. The schist strikes north 20 degrees west and is vertical, so that the mineralized zone appears to be cutting it at a low angle. In the creek, 50 feet above the workings, is a small, irregular band of zinc blende containing pyrite, chalcopyrite, a little galena, and considerable grey copper as tiny microscopic specks and veinlets. Barite is present in the gangue at this point. The showing has not been developed.

About 400 yards northeast of, and 675 feet below, the upper showing, a cut 14 feet long north and south, exposes 5 feet of crystalline barite partly replaced by pyrite, sphalerite, galena, chalcopyrite, and grey copper. Quartz and sericite are sparingly present. Both south and north of the barite, up to 8 feet of pyritic, light grey, siliceous sericite schist is exposed. In a small creek just south of the showing, pyritic, partly schistified greenstone, but no ore, is exposed. On the edge of Price Creek flat, 500 feet below, 8 feet of quartz and silicified schist, heavily mineralized with pyrite, occurs in a narrow zone of quartz-sericite schist in relatively unaltered andesite. Chalcopyrite is present in small amount and galena, sphalerite, and grey copper were identified under the microscope. The gangue consists of dense, grey quartz, some barite, and lesser quantities of epidote, sericite, and fresh plagioclase, probably albite. Judging by the smell when hammered there is probably a little arsenopyrite in the ore. The showing is clearly banded and strikes north 15 degrees west, dipping 80 degrees northeast. The mineralization where exposed is undoubtedly very low grade, but gives promise of being fairly persistent and is easily accessible. It merits further exploration to the northwest or up the hill.

Some 300 yards north of this showing there is a small outcrop of rusty, pyritic schist which has not been prospected.

Paramount Mining Company, Limited

This company was incorporated in 1919 with a capitalization of $500,000 and at that time held some forty claims on Myra and Price creeks. During 1900 and 1921 it prospected the Paw and Lynx groups and in 1920 did about 2,000 feet of diamond drilling. No work has been done since 1925, but the company still holds some eight claims on the south side of Myra creek, 2 miles west of Buttle lake and just northwest of and over the ridge from Price Creek Mining Company ground. Joseph Errington and associates of Toronto are in control. During 1930 no person connected with the property was in the district and the writer merely visited one or two of the lower showings. The claims cover a steep, heavily timbered mountain side sloping north towards Myra creek. At the lower working there is at least 100 feet of rusty weathering, light grey or white, pyritic quartz-sericite schist mineralized with irregular quartz veinlets carrying some chalcopyrite. There is a little galena, and barite

and calcite are sparingly developed. The schistosity strikes north 50 degrees west and is vertical. Two diamond drill holes have been put in here in a southeasterly direction. Some two hundred yards southeast and 90 feet higher, an adit has been driven 60 feet in a southwesterly direction across similar schist faulted and slightly mineralized with chalcopyrite along narrow zones. Just above and southwest of the adit, 5 feet of rich, banded, chalcopyrite-sphalerite ore is exposed in contorted schist probably derived from flat-lying or gently rolling volcanics. A little pyrite, galena, and grey copper are present in this ore. Straight above the portal there is a small exposure of quartz-sericite schist mineralized with lead, zinc, iron and copper sulphides, and barite. Immediately east of the portal massive or slightly sheared andesitic lava outcrops on a 40-foot bluff. A poor system of jointing is developed in the workings, trending north 30 degrees east or about at right angles to the schistosity. There are said to be numerous other workings scattered over the hillside above.

Lynx Group

This old group of claims is on the north side of Myra creek, 2½ miles by trail from Buttle lake, and adjoins Paramount Mining Company ground on the southeast. Two cabins on the claims are still in fairly good repair and are 1,375 feet above sea-level or 650 feet above Buttle lake. The claims are staked on a heavily timbered mountain side sloping on an average 30 degrees to the south towards Myra creek and the workings are about 100 feet above, and a short distance northwest of, the cabins. James Cross and associates of Victoria, B.C., are the owners. Development consists of eight open-cuts and an adit 10 feet long.

The rocks underlying the claims are not well exposed, but the information obtained indicates that they include andesitic or more basic flows and andesitic tuffs and breccias. Near the workings flows and tuffaceous rocks are the principal types, but farther up the mountain side breccias become increasingly abundant. In the vicinity of the workings the volcanic rocks are extensively sheared and are largely converted to green, grey, or almost white, chlorite and sericite schists. The schistosity trends, on the average, north 35 degrees west, and is vertical or very steep. The heaviest mineralization occurs where the rocks are converted to light grey or white quartz-sericite schists. Mineralization consists of pyrite, sphalerite, chalcopyrite, and galena with a gangue of quartz, chlorite, and sericite, with varying small amounts of barite, calcite, and titanite. The ore is generally fine grained and the sulphides, with or without gangue minerals, are intimately intergrown, so that concentration will entail fairly fine grinding. Under the microscope, numerous, tiny grains of a grey mineral, probably grey copper, were observed. In some cases a banded structure, due to replacement of the schist by sulphides, is well preserved in the ore.

The accompanying plan (Figure 6) illustrates the work that has been done.

Cut No. 1 is 39 feet wide and exposes grey to green, sericite and chlorite schist with much pyrite disseminated throughout and in stringers 1 inch to 6 inches wide parallel to or cutting across the schistosity. A little quartz accompanies the pyrite, but chalcopyrite is not present in important amount. The schistosity here strikes north 15 degrees west and is vertical.

Cut No. 2 is 12 feet wide and exposes schist like that found in cut 1, but slightly more siliceous and containing a little chalcopyrite. The best mineralization occurs within 5 feet of the east side of the cut.

Cut No. 3 is 20 feet wide and exposes pyritic schist with, in the centre of the cut, an irregular, flat-lying body, 8 feet wide east and west and 4 feet thick vertically, of well-mineralized material containing pyrite, sphalerite, galena, and chalcopyrite. A band of almost pure, mixed sulphides 5 to 8 inches wide forms the base of the body.

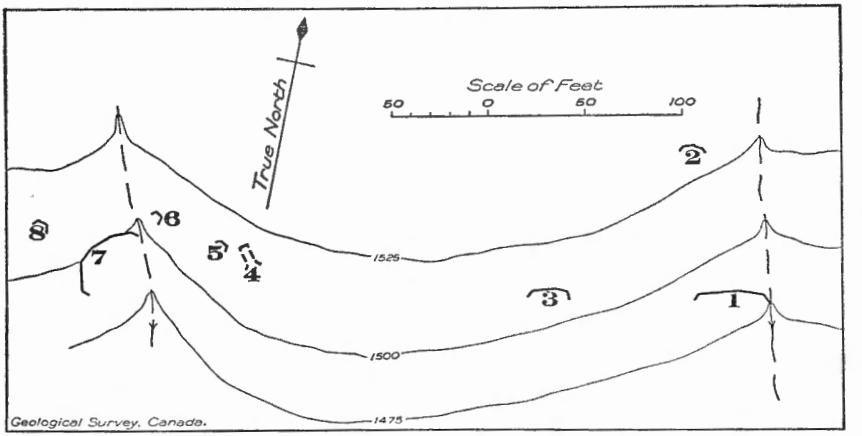

Figure 6. Showing positions of open-cuts on Lynx group, Myra creek, Vancouver island, B.C. (contours approximate).

Between cuts Nos. 3 and 4 are several outcrops of poorly schistified and slightly pyritic volcanics.

At cut No. 4 an adit has been driven north 35 degrees west 10 feet along the schistosity, here dipping 75 degrees northeast. The adit follows a narrow zone of gouge in pyritic quartz-sericite schist showing little or no chalcopyrite.

Cut No. 5 is a small one in chlorite schist on the foot-wall of the zone followed by the adit and the same schist is exposed to cut No. 6 and 20 feet beyond to a small creek. The schist contains disseminated pyrite and is cut by a few small stringers of pyrite and calcite, but no commercial mineralization is exposed.

Cut No. 7, 40 feet wide, is the largest and most interesting on the property. Just west of the cut massive green schist is exposed for 10 feet. Immediately east of this a pronounced wall trends north 75 degrees west, and dips 50 degrees southwest, and east of it is 10 feet of greatly schistified

rock and of gouge, all heavily oxidized but containing small, residual particles of pyrite, sphalerite, galena, and chalcopyrite. As this zone is extensively leached it is impossible to judge its actual value, but there is every reason to believe it is well mineralized beyond the leached portion. To the east is 11 feet of pyritic, greenish grey, quartz-sericite schist slightly mineralized on the east near a second wall trending north 67 degrees west and dipping 75 degrees southwest. For 26 feet east of this the schist is well mineralized by veins and disseminations of sulphides and, in the centre, there is a 6 to 12-inch band of almost solid sulphides following the schistosity of the rock. The whole 26 feet would probably constitute a good grade of milling ore if all values could be saved and as mineralization, growing gradually less, extends east and west, the width might be increased over that indicated.

Cut No. 8 is above No. 7 and is almost surely on the same zone of mineralization. It exposes 6 feet of well-mineralized schist; barite is present in the gangue. On the west side of the cut mineralized schist is covered with drift, so that the full width of mineralization is not exposed. The sulphides occur disseminated in the schist or in veins, not over 4 inches wide, cutting across or parallel to the schistosity, and to a minor extent following joint planes in the rock.

The same, broad, schistified zone exposed in the cuts can be seen at several places on the hillside above, but has not been developed. A small exposure of fairly well-mineralized schist was noted 550 feet above cut No. 7 towards the west of the zone. Between this and the top of the mountain, a vertical distance of 2,000 feet, very little work has been done, but Mr. Cross, one of the owners, states that he has followed the schistified zone nearly to the summit.

Summary for Myra-Price Creeks Area

It will be seen from the descriptions of the three properties that there is a broad zone or a number of zones passing through the three groups, along which the volcanic rocks have been converted into grey or green, chlorite and quartz-sericite schists; that this zone or zones has been found at numerous intervals, over a distance, in a northwest-southeast direction, of about 3 miles, to contain copper-zinc-lead mineralization of probable milling grade over variable widths up to at least 25 feet; that the mineralization is in large part an exceedingly fine-grained intergrowth of sulphides, and has formed by replacing and veining of the more thoroughly schistified and silicified parts of the zone or zones. The present workings, unless it be the undisclosed results of the diamond drilling of the Paramount Mining Company, do not prove continuity, with commercial dimensions, either vertically or horizontally. But the showings are sufficiently good to encourage more extensive development than has yet been undertaken; it would seem that preliminary work should include surface stripping across the whole schistified zone at several horizons on the mountain sides, as there is as yet no way of telling just where commercial mineralization might best be expected within the zone. In this connexion, however, it is evident on the Lynx group that the best mineralization has been encountered near the western wall of the zone and consequently particular attention should be paid to that section on the Lynx group and an attempt be made to delineate the westerly wall.

To thoroughly test the commercial importance of the deposits will require expert technical advice, a great deal of surface and underground work, and, probably, considerable diamond drilling, all accompanied by careful sampling, for the mineralization already exposed indicates quite clearly that the principal possibility is of developing a large tonnage of ore of milling grade.

SUMPTER GROUP

This old group, which originally included eight claims on the north side of Upper Campbell lake, 1 mile west of the outlet, has been allowed to lapse and at present Mr. J. Forbes of Forbes Landing owns the Lorrain F. and Elizabeth F. claims which cover the principal showings. There is a good cabin on each claim. The Lorrain F. is west of the Elizabeth F. and on it, 200 feet above the lake, a shaft has been sunk 17 feet on a showing of garnet and epidote, containing a little bornite and chalcopyrite in crystalline grey limestone. A narrow fissure cutting across the shaft is slightly mineralized, at the bottom, with garnet and quartz and the same two sulphides. From a point 140 feet due south and 55 feet below the shaft an adit has been driven until its face is within 5 feet of being directly below the shaft. It penetrated limestone converted in large part to garnetite with a little magnetite, but encountered no important mineralization. On the Elizabeth F. claim a deep open-cut exposes 8 feet of copper-stained garnetite, with magnetite, in altered crystalline limestone. A pronounced fault wall on the north side of the mineralized zone strikes north 40 degrees east along the sidehill and signs of similar mineralization are exposed in that direction for about 75 feet. The westerly contact of the Quinsam granodiorite which intrudes the limestone lies 100 feet west of the cut. Fifty feet southeast of the cut is the portal of a caved adit.

BIG G. GROUP (GILKEY'S MINE)

A traverse was made up Greenstone creek, which flows into Campbell river 2½ miles west of Lower Campbell lake, to this old property on the 50th parallel. No guide was available. A trail, just over 5 miles long, leads to the workings from Campbell river. Thirteen years ago it was used as a skid road for hauling supplies and ore, but it is now badly overgrown and out of repair. One cabin still stands near the workings, some 1,400 feet above sea-level, on the edge of a deep canyon in Greenstone creek. The rocks in the vicinity include andesitic tuffs, lavas, and some intercalated limestone all cut by basic porphyry dykes. The dips vary from 10 degrees to 20 degrees to the north. On the north wall of the canyon, just below the cabin, is an open-cut some 150 feet long and at least three old adits. In the open-cut is exposed 10 feet or so of heavily mineralized material, containing abundant pyrrhotite and small amounts of chalcopyrite, pyrite, calcite, garnet, chlorite, and foliated magnetite. The last mineralization appears to have replaced an andesitic tuff immediately below a massive flow and the ore, following the bedding, dips 20 degrees and less to the north. In one place a foot of almost pure chalcopyrite was noted. In addition there are small veins of sulphides along joints and cracks in the country rock. What was taken to be the main adit follows the flat-lying zone of sulphides for about 30 feet and the ore seems to pinch out almost entirely at the face. It is reported that 40 tons of copper ore were shipped from the property in 1916.

One and one-third miles below the old mine, where the trail follows the edge of Greenstone creek, banded, silicified, and otherwise altered, crystalline limestone outcrops for 25 feet at the water's edge, striking north 60 degrees east and dipping 25 degrees southeast. Sphalerite, galena, pyrite, and chalcopyrite were found across a breadth of one foot. A thin section showed that the limestone is largely replaced by quartz, wollastonite, diopside, garnet, and the sulphides. The locality seems worth prospecting.

IRON HILL CLAIM

This old magnetite property is located on the southeast side of Upper Quinsam lake. A trail 5 miles long leads from the Upper Campbell Lake auto road to Little Quinsam lake, from where it is 3 miles by canoe to a trail, ½ mile long, leading from the lake to the property. No work has been done on it in recent years. Two old cabins are still in fairly good repair. The property has been described in considerable detail by G. A. Young.[1] He states that limestone, dipping gently northeast and underlain by volcanic rocks, has been replaced by magnetite, garnet, etc., probably derived from a nearby intrusion of granodiorite (the Quinsam granodiorite). Also that the volcanic rocks are replaced by magnetite and garnet at one or two localities. He estimates provisionally that the deposit may contain 1,700,000 tons of iron ore, but suggests that further development is necessary before the tonnage can be accurately estimated. It is undoubtedly one of the largest magnetite deposits known on Vancouver island.

MAGNETITE ON IRON RIVER

There are several outcrops of magnetite on the west side of Iron river 1·5 miles above where it joins Quinsam river. Young has described the deposit[2] and the writer did not examine it. In the vicinity, volcanic rocks and altered argillite and quartzitic argillite of the Vancouver group are exposed, principally in stream beds. These rocks are intruded by a variety of dykes and on a new logging railroad grade a short distance north of the property are good exposures of granodiorite with which is associated a little copper mineralization. The granodiorite is presumably part of the Quinsam intrusive mass. All these rocks are overlain, unconformably, to the south and west of the deposit, by Upper Cretaceous coal-bearing sediments. The magnetite is described as outcropping in three separate areas on a heavily timbered hillside, the largest area covering about 2,000 square feet. Chalcopyrite is sparingly disseminated in much of the magnetite. There are no outcrops of country rock near the magnetite.

MINERALIZATION ON AND NEAR MOUNT ALBERT EDWARD

Mount Albert Edward, at the headwaters of Cruickshank, Oyster, and Ralph rivers, is over 6,800 feet high and is easily ascended by trail from the Forbidden plateau to the north. It is composed entirely of volcanic rocks including pillow lava, andesite, dacite, and breccia cut by a variety of diabase and other basic dykes, all intruded by two or three small bodies

[1]Geol. Surv., Canada, Ec. Geol. Series No. 3, vol. I, pp. 73–78.
[2]Op. cit., p. 71.

and many associated dykes of granodiorite. The volcanics are poorly bedded, their strike varying from north 60 degrees east to north 80 degrees east and their dip from 10 degrees to 20 degrees north. A pronounced system of jointing trends northeast.

On the lower northern slopes of the mountain, near Circle lake, a number of "veins" or replacement zones, varying in width from a few inches to 20 feet, have been found in the volcanic rocks. J. H. Brown of Cumberland has traced one such vein from an elevation of 4,300 feet just south of Circle lake, up the steep mountain side for at least 400 feet vertically. It strikes northwest and dips steeply southwest. This "vein" varies in width up to a maximum of 20 feet, but in its thicker parts is but sparsely mineralized with pyrite. At the lower showing there is a width of 4 feet containing much pyrrhotite, a little chalcopyrite, and some quartz. On a shoulder at 4,800 feet elevation, pyrite and chalcopyrite are sparingly developed in two undeveloped showings of quartz. No development has been done on any of these showings.

Mr. Brown's principal holdings are in a deep and precipitous valley that lies immediately north of Albert Edward peak and drains west into Oyster river. To reach the showing from the east or north one must cross a summit 5,100 feet or more above sea-level. On the north side of the valley, at about 4,000 feet elevation, andesitic flows and breccias and associated feldspar porphyries are cut by numerous aplite and granodiorite dykes and by a small, stock-like intrusion of granodiorite that contains many fragments of the volcanic rocks. The volcanics and the granodiorite are extensively jointed and fractured and mineralized with irregular, tiny seams and lenses of pyrite and chalcopyrite with occasional quartz, magnetite, and molybdenite. The mineralization appears to be entirely confined to tiny seams or cracks and was not found to replace the country rock to any appreciable extent. The most encouraging showing is a bluff, some 300 feet long and about the same height, which is extensively coloured with iron and copper stains. As the wall is vertical or overhanging it cannot be examined without ropes or ladders, but there is a large collection of blocks and fragments of the mineralized material at the base. The writer examined much of this material carefully and, although there is much chalcopyrite and pyrite present, yet there is so much absolutely barren rock between the mineralized cracks or seams that it seemed very doubtful if any large quantity of the rock would contain a commercial proportion of copper. Thus it seemed that unless gold or silver were present in appreciable amount the deposit would be of very doubtful value. Consequently, a sample, weighing over 2 pounds, of about as well-mineralized material as could be found and certainly containing much more pyrite and chalcopyrite than the average, was taken. On assaying it was found to carry per ton of 2,000 pounds: gold, 0·3 ounce; silver, 0·49 ounce; and copper, 4·07 per cent. Judging by this, high gold or silver values may not be expected. However, it must be admitted that in deposits of this sort extensive, large-scale sampling of unweathered surfaces is generally necessary before any reliable average values can be obtained.

In Oyster river about one-half mile below Circle lake, at 3,300 feet elevation, J. F. Davies and associates of Port Alberni have recently staked the Three Musketeers and other claims on a showing of pyrite and chalcopyrite. These minerals are irregularly and sparingly developed along a

rusty, vertical shear zone, 2 to 4 feet wide, which strikes north 20 degrees east in a series of gently dipping volcanic rocks intruded by numerous dykes of granodiorite. Along the zone the volcanic rocks are altered to chlorite and actinolite. As much as 3 or 4 inches of solid pyrite and some chalcopyrite were noted along the northwest wall. Above, in the bed of Oyster river, similar volcanic rocks and dykes contain tiny seams and disseminations of pyrite and an occasional small amount of chalcopyrite. Between the claim and Divers lake are at least two small granodiorite and quartz diorite, stock-like intrusions.

NATIVE COPPER ON COAL CREEK

One mile southwest of Cumberland, the base of the coal-bearing Comox sandstone is exposed along Coal creek. Underlying the sandstone are volcanic rocks of the Vancouver group including amygdaloidal basalts and volcanic agglomerates. These rocks are well exposed in a tributary draining into Coal creek from the southwest one-quarter mile below Allan lake. The volcanics are probably striking northwest and dipping northeast from 10 degrees to 20 degrees, that is, downstream. E. Pirodi of Cumberland staked claims here in 1929 and they were developed for a short time during 1930 by Canadian Collieries (Dunsmuir), Limited. At elevation 1,200 feet, on the Columbus claim, a partly exposed bed of green and purple agglomerate is seamed with native copper and 150 feet downstream dark green amygdaloidal basalt is similarly mineralized over several score square feet. Both exposures are in the stream bed. The copper seams are seldom over $\frac{1}{32}$ inch in thickness and are individually irregular and discontinuous. The basalt is partly epidotized; chlorite, rarely accompanied by a speck of native copper, fills many of the amygdules. Quartz and calcite are not abundant. The copper in the seams is seldom accompanied by any gangue other than chloritized rock. The rocks are jointed and possibly faulted along two principal series of vertical planes, one trending northwest and the other approximately northeast. Below these showings, for several hundred feet, barren porphyritic and amygdaloidal volcanics are exposed in the creeks. At elevation 1085, on the Venus claim, in a small open-cut, basic porphyry and amygdaloid are sparingly mineralized with specks of chalcopyrite and bornite. At elevation 735, a short distance below the base of the Comox sandstone, badly sheared and chloritized volcanics, probably basalt, are exposed in the creek and an adit has been driven for 80 feet northwesterly along a pronounced shear zone dipping steeply northeast. The sheared material along this zone is slightly copper stained and, 10 feet northeast of the wall, near the portal, a narrow stringer of calcite containing copper was encountered. There is pyrite throughout much of the sheared volcanic, but nothing approaching commercial importance has been revealed. The showings are similar to those found at many places in basic volcanics of the Vancouver group and unless mineralization of commercial grade can be found at the surface along some definite horizon or following some pronounced system of fracturing or shearing it seems rather futile to proceed with underground development. Where the rocks and mineralized portions are fresh, or but very little altered at the surface, as they are in most parts of the island, there is no logical reason for believing that mineralization of this type will be markedly different at depth from what it is at the surface. The upper showings of native copper are undoubtedly the most promising seen on the claims.

BEAVER CLAIM

On this claim, staked by Fred. A. Fraser of Bloedel, B.C., on the east edge of Campbell river 2 miles north of Forbes Landing, amygdaloidal basalt and purple andesitic lavas are well exposed in a logged area and probably strike north 30 degrees west and dip at 15 degrees or less to the northeast. Quartz, epidote, calcite, and chlorite are present in amygdules and veinlets. The principal mineral showing consists of from ¼ to 2 inches of bornite with quartz, along two subparallel fissures which do not appear to continue along their strike for more than 25 feet. Slightly mineralized branch fissures leave these two, but cease within very short distances and a pronounced shear zone striking north 70 degrees east cuts across the north end of the showing at 45 degrees. An assay made for Mr. Fraser shows 0·05 ounce of gold and 6·8 ounces of silver in material assaying 43 per cent copper. Very little work had been done on the property which is very accessible, the showings being on a logging railway grade.

ARSENIC AT WOLF LAKE

No work has been done on this property since M. E. Hurst examined it,[1] nor, so far as known, is it at present held by anyone. The showings are in a small creek and ½ mile southwest of Wolf lake which is 3 miles by trail from Headquarters. There is an old dugout canoe on the lake by which one may paddle to the cabin at the northwest end of the lake, whence there is a poor trail to the property. Hurst states that a brecciated zone, from 2 to 12 feet wide, in andesitic rocks, is exposed for nearly 250 feet in the creek bottom. The zone strikes north 35 degrees east and contains lenses and veins of calcite, up to 6 feet in width, in which are numerous angular fragments of the country rock. The lenses outcrop for 150 feet and contain occasional lenticular masses of realgar the largest of which measured 4 feet by 9 inches. There is a little arsenopyrite in the wall-rock and in included fragments in the vein and there is also a little quartz in the calcite. In part, the realgar has been altered to native arsenic by leaching of sulphur. Where the shear zone passes out of the creek to the south it is covered by soil, so that trenching would be necessary for further exploration in that direction. The mineralization has in all probability been formed by solutions emanating from a body of quartz diorite porphyry (hornblende porphyry) which intrudes the rocks near the property and also invades overlying Upper Cretaceous sandstone a short distance south of the workings and on the east side of Wolf lake. As the intrusive is placed tentatively as of Oligocene age, the mineralization would then likewise be Oligocene or younger.

ADDITIONAL MINERALIZATION AND PROSPECTING POSSIBILITIES

The properties described above include all the more important discoveries that have been made within the map-area. During the field season, however, signs of mineralization were encountered at several places.

[1] "Arsenic-Bearing Deposits of Canada"; Geol. Surv., Canada, Ec. Geol. Series No. 4, p. 36 (1927).

On the summit between Myra creek and Phillips creek, east of the granodiorite, irregular remnants of limestone contain numerous small lenses and veins of chalcopyrite and pyrite and farther east a few small areas of pyritization were observed. None appeared to be of commercial importance, but they serve to emphasize the fact that the continuation of the Myra-Price Creeks mineralized section to the northwest should be worth prospecting. The position of the east contact of the large body of granodiorite is shown on Figure 5 and it is suggested that a broad zone, some 3 miles wide, to the northwest of the contact, merits attention. The south fork of Phillips creek cuts deep into the rocks of this section and is not known to have been carefully prospected nor, as far as known, has the area northwest of this towards Donner lake received even a cursory examination. It should be remembered that, in addition to the properties described above in the vicinity of Myra creek, there is, about 7 miles due south, on Big Interior mountain, extensive and important mineralization in the same belt of rocks as is exposed southwest of Buttle lake and adjoining the westerly contact of the same granodiorite batholith. It is remarkable that there has been very little prospecting of the whole contact zone, except in the vicinity of the two known mineralized areas.

In the vicinity of the quartz diorite intrusion at the head of Henshaw creek the intruded volcanic rocks are in part sheared and impregnated with pyrite. No copper mineralization was observed, but the area surrounding the intrusion and extending south and east from it, is little known and might well merit some investigation. The approach could be either from Comox lake via Puntledge river, where logging operations are being extended, or from Great Central lake, or from Buttle lake.

There is ample evidence of pyritic mineralization, in places accompanied by copper, magnetite, or other minerals, around the periphery of the Quinsam granodiorite. Several of the described properties occur there. Much of the ground surrounding this intrusion has been fairly carefully prospected, but the stretch between Upper Campbell lake and Upper Quinsam lake has not, as far as known, received much attention. There the adjoining rocks, either volcanic or limestone, are in places extensively pyritized and small amounts of copper were noted. The granodiorite itself is cut by many basic and acidic dykes, and is extensively sheared and mineralized with pyrite at several points, particularly in a small stream 2 miles and less directly south of the east end of Upper Campbell lake. Garnet and magnetite are developed elsewhere within the granodiorite, so that it cannot be considered as necessarily barren ground, although, on the whole, it is not as favourable a host as the rocks which it intrudes. For a resident of the district wishing to do some prospecting this area is very accessible and is worth some attention. The northwesterly continuation of this zone, which passes the 50th parallel along Greenstone creek, also seems to offer some inducement to the prospector, although sufficient geological work has not as yet been done to fully reveal its possibilities.

Between Upper Quinsam lake and mount Albert Edward, or the headwaters of Cruickshank river, there is a broad stretch of rugged and heavily timbered country, large parts of which are difficult of access and very difficult to prospect. The upper reaches of Iron river show some

signs of mineralization, and, as noted above, there are several intrusive bodies of granodiorite and quartz diorite along the upper reaches of the west fork of Oyster river and in the neighbourhood of mount Albert Edward, with which are associated veins and disseminations of chalcopyrite, pyrite, and other sulphides. This whole belt, from Upper Quinsam lake to mount Albert Edward and beyond, and for some distance down Cruickshank river, seems to merit a little prospecting by those who can do it without undue expense. It should be remembered that the intrusive rocks generally outcrop below 4,500 or 4,000 feet elevation, in the valleys, and do not, with the exception of two or three localities on Forbidden plateau, appear to have penetrated much above this horizon. For this reason and since the mineralization seems to be clearly related to the intrusions, prospecting should be confined at first to the vicinity of the valley bottoms where, also, outcrops are more abundant than on the heavily timbered mountain slopes.

LIGHTNING PEAK AREA, OSOYOOS DISTRICT, B.C.

By C. E. Cairnes

CONTENTS

INTRODUCTION

Lightning Peak area is situated at the headwaters of Granby (North fork Kettle) river and Rendell creek (East fork Kettle river), Osoyoos district, British Columbia. As mapped it is an area of some 18 square miles partly surrounding, but mostly lying to the north of, Lightning peak, a prominent mountain from which the area derives its name. The area is accessible from Edgewood on Upper Arrow lake via the Edgewood-Vernon highway and a tractor road which branches to the west from the highway at a distance of 24 miles from Edgewood. The tractor road, built by the provincial government, is about 17 miles long. At the time visited it was being reconditioned for more general traffic and was passable by automobiles for 9 miles from the highway. Its terminus is at the Waterloo mine situated towards the western side of the area.

The latter half of August and the first few days in September were spent by the writer in an investigation of, principally, the economic possibilities of this area. The work included a brief study of general geological conditions with more extended examinations in the vicinity of the more important properties. Traverses were run along most of the trails and also across several less readily accessible sections. Control for these surveys was afforded by a topographic map[1] prepared by the Department of Lands, Victoria.

The work was greatly facilitated by the hearty co-operation of the various property owners and operators, among whom R. L. Clothier and John Morrison of Waterloo Consolidated Mines, Limited, W. A. Calder, and James Graham are specially mentioned. In the field work the writer was ably assisted by Mr. N. D. McKechnie.

Little is known of the early history of Lightning Peak camp. Apparently considerable prospecting during a period of seven or eight years had been done before the camp was first referred to in the annual reports of the provincial government. The principal route into Lightning Peak camp in the early years, and one maintained until quite recently, led from Fire

[1]Part of the Kettle River valley, Headwaters sheet.

Valley Landing on the west side of Lower Arrow lake about 6 miles north of Edgewood, westerly across a low divide for about 4 miles to Fire valley, which is drained by Inonoaklin creek, thence up this valley to near the junction of Sand creek, a western tributary of the Inonoaklin. The trail then

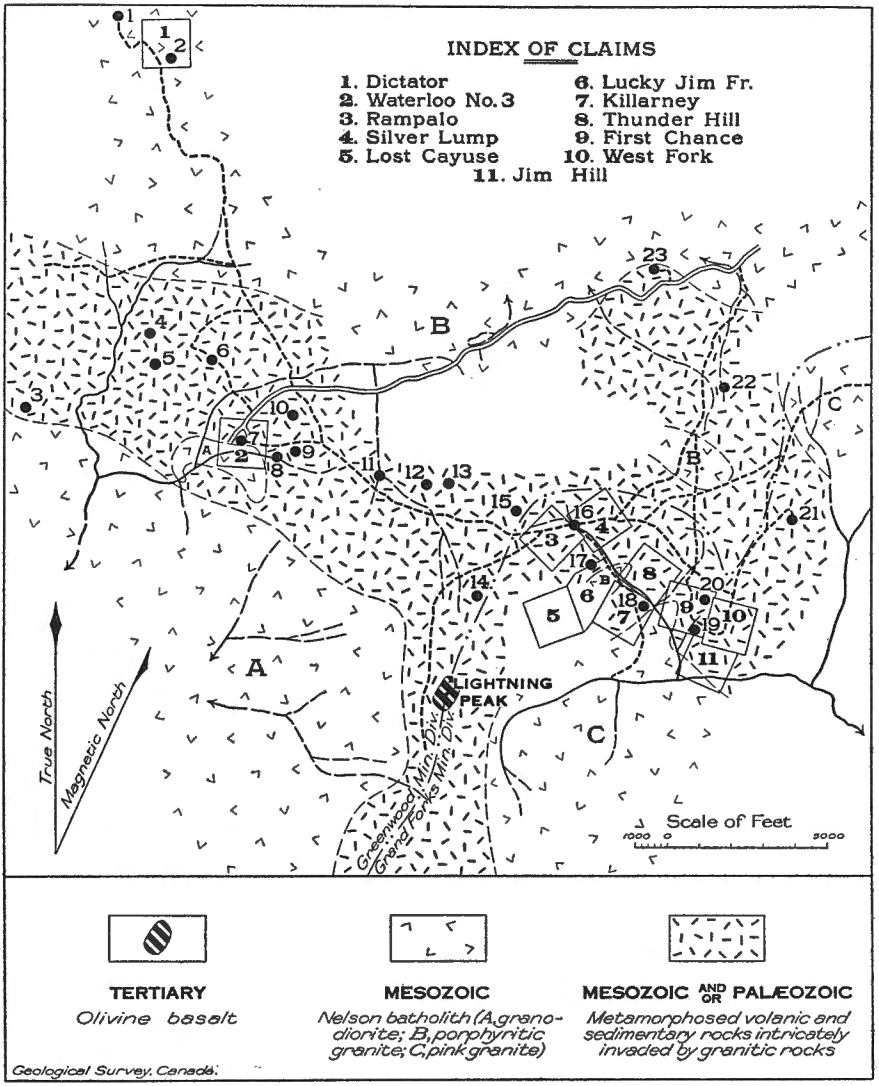

Figure 7. Lightning Peak area, Osoyoos district, British Columbia. Positions of mines, prospects, and other mineral discoveries are indicated by solid circles numbered as in text.

followed up Sand Creek valley and thence westerly via Galloping mountain to Lightning Peak camp, a total distance from Lower Arrow lake of about 26 miles. Another, but less frequented, route led northerly along the divide between the east and west forks of Granby river from Franklin Camp.

The Rampalo was the first claim staked in the area and was located in 1897 by Adam and Louis Scaia and Axel Johnson. By 1904[1] three properties had received considerable attention, viz., the Lightning Peak, Waterloo, and Rampalo groups, and small ore shipments had been made from the first two. No further reference is made to the Lightning Peak country until 1917 and the years following. The Waterloo and Lightning Peak groups continue to be centres of principal attraction, but a number of other properties, including the Killarney, Pay Day, Rampalo, Potosi, Dictator, and Lumpy had furnished mineralization of an encouraging nature and still others of lesser interest had received some attention in the way of prospecting.

Developments at this camp have been greatly handicapped by transportation difficulties. Prior to 1917 all supplies had to be carried in and all ore shipments taken out by packhorse over the Galloping Mountain trail. In 1917 and 1918 a snow-trail was constructed, with government assistance, to connect the camp with the Edgewood-Vernon road. This new trail was employed to rawhide ore out on during the winter months and for this purpose was a considerable improvement over the old pack-trail. Even under these conditions, however, the cost of haulage to Edgewood, amounting to about $30 a ton, was prohibitive for anything but high-grade ore. In 1929, the tractor road previously mentioned was constructed and in 1930 this road was being rapidly widened and surfaced, so that it may be possible in the near future to run an auto over the entire distance from Edgewood to Lightning Peak area.

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GENERAL GEOLOGY

INTRODUCTION

Lightning Peak area is in the heart of the Columbia system of mountains. These are bordered on the east by the great valley of Columbia river and on the west they merge into the Interior Plateau region of British Columbia. The mountain system has been subdivided into a number of mountain groups or ranges, of which that in the vicinity of Lightning peak is commonly referred to as the Monashee mountains.

Relief ranges from about 5,000 feet above sea-level, in the lower valleys, to 7,035 feet at the summit of Lightning peak, the highest point in the area. Save, however, for the principal valleys which are deep and cut steeply below the general surface, this surface has more the characteristics of a plateau region than of an alpine district such as features much of Columbia mountains.

Lightning Peak area is mostly timbered, but, largely as a result of its altitude, not heavily so and in general is readily traversed on foot in almost any direction. Meadow-like expanses are common and at the higher elevations (about 6,000 feet) the hill slopes are bare or but scantily forested. Rock exposures are here best shown, though almost continuous outcrops were also noted at lower elevations along some of the smaller tributary streams. For the greater part, however, the underlying rocks are obscured by accumulations of glacial drift, soil, and vegetation, all of which have proved a handicap to surface prospecting.

The hard-rock formations of the area may be conveniently described under four main subdivisions, namely: Tertiary basalt, minor intrusives, batholithic intrusives, and pre-batholithic rocks. The first is represented only at one locality where it forms the upper 200 feet or so of Lightning peak, the highest point in the area. Minor intrusives are widely distributed within the areas occupied chiefly by pre-batholithic formations and are represented mostly by acidic types. Of these, quartz-porphyry dykes are most abundant. Other types include dyke-like bodies of more granitic texture and, still others, mostly small, of a pegmatitic facies. These acidic intrusives are commonly associated with mineralized veins and have been looked upon with considerable favour in mining operations to date. Minor basic intrusions are relatively scarce and economically less interesting than the more acid types. Batholithic intrusions occupy the larger

part of the area. They vary in composition from granite to diorite, the more acid types constituting the bulk of these intrusives as mapped, whereas the more basic rocks are, in general, intimately associated with the formations they intrude. The pre-batholithic formations occur mostly within a belt, about a mile wide, which stretches in a general east and west direction across the area. They include a variety of both sedimentary and volcanic rock types and have been greatly altered by batholithic intrusions. Most of the mineral deposits of the camp lie within this belt of older rocks.

TERTIARY BASALT

The upper 200 feet or so of Lightning peak is composed of a black or dark bluish grey, massive, fresh-looking lava. The rock varies from dense to slightly granular and carries an abundance of fresh olivine crystals that are in part disseminated through the rock and in part segregated in nests varying in size up to several inches in diameter and composed principally of olivine and pyroxene. Under the microscope a thin section of the lava was observed to contain abundant crystals of olivine and pyroxene (diallage) in a microcrystalline groundmass composed in part of feldspar and carrying small grains of magnetite and other minerals.

The contact of the lava with the underlying older rocks is obscured by talus so that its nature could not be determined. It appeared, however, that the rock was denser towards the base than at the summit, though there was little evidence in that to indicate whether the occurrence represents a heavy flow or succession of flows covering a large area in Tertiary time and since removed by erosion, or whether Lightning peak is the site of an old volcano. No other occurrences of such lava are known anywhere in or near this area in spite of the fact that some nearby summits reach almost to the height of Lightning peak and others not many miles away are considerably higher. The top of Lightning peak has been strongly glaciated and large blocks of the lava observed towards the head of Soda creek over 3,000 feet to the southeast of Lightning peak seemed to indicate the general direction of movement of the ice. Lightning peak is somewhat cone-shaped, a feature that serves to distinguish it from other mountain tops in and near this area. The suggestion is that, although erosion has doubtless played a principal role in developing its contours, the present prominence of this peak is an inherited characteristic, developed, in the first place, from local volcanic eruption.

MINOR INTRUSIVES

Of the minor intrusive rocks those of more acid composition are the more numerous and economically are the most interesting. They may be divided into three principal types: quartz porphyries; granitic porphyries; and pegmatites.

Quartz Porphyries

Rocks classified as quartz porphyry are abundant within areas of the pre-batholithic formations. They form long, dyke-shaped masses mostly only a few feet wide, but traceable in some instances for at least several hundred feet. They are massive and so alike in general appearance that in most cases they can be readily identified even in the smallest exposures.

They are typically light to creamy grey, medium grained, and of uniform texture and acid composition. Hand specimens rarely show appreciable amounts of dark minerals and seem to be very largely composed of quartz and feldspar. Weathered surfaces are commonly speckled or spotted rather than uniformly coloured. Where pyrite is present, the rock may weather a rusty brown. Under the microscope a specimen, typical of a number of dykes observed on the Waterloo property and obtained from the A.U. claim, was found to contain much quartz in more or less granular forms, showing strain and full of minute inclusions. Other essential minerals include microcline and plagioclase (about oligoclase), numerous patches of sericite, and small pyrite cubes. Another specimen obtained from the upper Rampalo adit of the Rampalo property, and more feldspathic in appearance than the specimen just described, was seen, microscopically, to carry abundant quartz, some orthoclase but more microcline, altered plagioclase, and a little altered mafic mineral, probably biotite. The mineral constituents, particularly the quartz, are notably strained and partly granulated.

The quartz porphyry dykes were found intruding the pre-batholithic formations, but were not observed cutting batholithic rocks. They are in many cases closely associated with quartz veins carrying values in gold and other metals. Such quartz veins may occur along either the foot- or hanging-wall of the dykes, or cross the dykes, but are commonly most continuous where developed along the foot-wall. It seems unlikely, however, that the dykes and veins are genetically connected. The dykes in places carry a little pyrite, but in general are notably lacking in ore-minerals. Quartz veins similar to those associated with the dykes also occur quite independently of the dykes. In certain instances, too, as at the Waterloo and Lightning Peak mines, the quartz porphyry dykes were observed to have been faulted and mineralized vein quartz to be distributed along the fault zones. In most instances where the association of dyke and vein-matter was noted it appeared that the relation was structural rather than genetic as if the dykes had provided lines of weakness followed by the vein solutions.

Granitic Dykes

A number of dykes and small intrusive masses of granitic texture, and in mineral composition much resembling the members of the batholithic rocks, were observed within areas underlain by pre-batholithic formations. A number of such bodies, for example, cross Rampalo creek and resemble one or other of the batholithic members in that vicinity, except that, as a rule, they are finer textured. Others were noted at the Lightning Peak mine and are intersected by the main vein at that property. The dykes vary up to 100 feet or more in thickness. The other bodies outcrop over irregular areas which, owing generally to incomplete exposures, are of doubtful size.

Pegmatites

Pegmatites and pegmatitic rocks are abundantly represented in certain parts of the area. A number of occurrences were noted, for example, on the A.U. claim of the Waterloo group and on the West Fork claim of the Lightning Peak group. These pegmatitic intrusives are typically coarse-grained rocks of irregular texture and composed chiefly of quartz and alkali

feldspar. One occurrence noted on the A.U. claim, 200 feet or more east of the shaft, is composed of large masses of microcline feldspar full of small, irregular cavities whose outlines resemble those of graphic intergrowths of quartz, but, in this case, quartz occurs only as microscopic crystals lining the walls of the cavities.

The pegmatites are apparently more or less dyke-shaped, but are less regular than the quartz-porphyry intrusives. These two types are, however, probably closely related in age and though not observed in contact some of the pegmatitic rocks grade into finer grained types much resembling quartz-porphyry.

Some vein quartz carrying, in places, pyrite and a little galena, was observed associated with pegmatitic intrusives on the A.U. claim. In general, however, these rocks have provided little mineralization of economic interest.

Minor intrusions of basic composition are scarce as compared with the acid types. Occasional dyke-like bodies a few feet wide, of massive, medium to fine-grained, dark greenish grey rocks, were observed at widely separate localities within the outcrop areas of pre-batholitic rocks. They were not examined microscopically, but appeared to have about the composition of diorite and are probably related to neighbouring batholithic intrusions. Nothing of economic interest was observed in their vicinity.

In addition to the above, one dyke of more basaltic character was noted on the Pilot and Uta claims. It is a dark olive-green, fine-grained rock carrying small, black crystals of hornblende. Under the microscope this rock was observed to carry abundant crystals of brownish amphibole, resembling basaltic hornblende, and numerous clear pyroxene crystals, in a finer grained groundmass composed largely of feldspar. The larger crystals of feldspar are commonly lath-shaped, well-twinned, and fresh in appearance and were determined to have about the composition of labradorite. Accessory minerals include abundant disseminated grains of magnetite, and a little calcite and quartz. It seems possible that this rock may be related to the period of vulcanism with which the basalt rock on the top of Lightning peak is connected.

BATHOLITHIC INTRUSIVES

Batholithic intrusives occupy a large part of the Lightning Peak area and except to the west, in which direction the extent of the pre-batholithic formations is unknown, completely surround it. For convenience in description these batholithic rocks may be subdivided into three members each of which possesses certain distinctive lithological features. These members are referred to as: (1) porphyritic granite, (2) granite-diorite complex, and (3) pink granite.

Porphyritic Granite

This granite occupies much of the northern half of the area and also forms two comparatively small bodies near the centre but towards the eastern side of the area. It is a grey, coarse-grained rock, particularly distinguished in outcrop by conspicuous phenocrysts of potash feldspar

averaging half an inch or so in length. Otherwise the rock is a coarse-grained aggregate of quartz and feldspar with from 5 to 10 per cent of ferromagnesian minerals, chiefly biotite. Under the microscope a specimen from the Dictator claim was found to carry about equal proportions of quartz, orthoclase, and plagioclase with some microcline and biotite. The quartz, in particular, showed evidence of strain and was partly granulated. This granite near its main contacts with pre-batholithic rocks, and where it occurs in small, isolated bodies within these older rocks, is generally less quartzose and takes on more of the composition of a syenodiorite. A specimen of this sort of rock obtained from a small body was studied under the microscope. It carries about equal amounts of orthoclase and plagioclase, but comparatively little quartz. Both green hornblende and brown biotite are present. One large phenocryst of orthoclase contains smaller crystals of hornblende and plagioclase. The plagioclase shows albite, pericline, and Carlsbad twins and seems to be about oligoclase in composition. Vermicular intergrowths of quartz in orthoclase were observed. Both of these minerals show strain.

The porphyritic granite is the principal member of the "Nelson" granite referred to by Brock[1] in earlier explorations west of Columbia river and is correlated with the granite in the vicinity of Nelson and northward into Slocan district, this granite being the most conspicuous and lithologically most easily recognized member of the Nelson batholith complex.

Granite-Diorite Complex

This term has been applied to the large body of granitic rocks occupying the southwestern part of the Lightning Peak area; to a smaller body in the vicinity of the Waterloo No. 3 claim; and to innumerable occurrences intimately associated with the pre-batholitic formations and for the most part either too small, or too incompletely exposed, or too intricately associated with the older rocks to permit of separate mapping.

These rocks are mostly grey to greenish grey, medium to coarse-grained, equigranular, and vary in mineral composition from diorite or quartz diorite to granite. Intermediate types of about the composition of granodiorite are the most abundant and are the chief components of those areas mapped. So far as could be observed contacts between types of varying acidity are quite gradational. The more basic types are in general those associated most intimately with the older rocks and their variation from more normal composition is attributed to contact relations with these pre-batholithic formations. These relations are so intimate that, commonly, single outcrops of the older rocks a few square yards in extent are penetrated by intrusive material to the extent of 50 per cent or more of the volume of the outcrop. Contacts may be sharply defined or may indicate gradations from granitic to older rocks, so that it may be difficult to decide whether the rock at a certain point is intrusive or not. Farther from their contacts with the older rocks, the intrusives are more acid and more uniform in appearance and composition.

Specimens for microscopic examination were obtained from three widely separate localities: one about a mile south of the Waterloo mine; another about a mile southwest of Lightning peak; and the third from the

[1]Brock, R. W.: Geol. Surv., Canada, Sum. Rept. 1900, pt. A, p. 71.

Granite range west of the junction of Waterloo and Rendell creeks. These specimens are much the same in appearance and composition. Each carries abundant quartz which is more or less strained and fractured. In each, feldspar constitutes a somewhat greater proportion of the rock than the quartz and includes both orthoclase and plagioclase, the latter of which is the more plentiful, though not notably so, and is about oligoclase in composition (Ab_{72} An_{28} for the specimen south of the Waterloo mine). Both hornblende and biotite are present, but in minor proportions to the felsic constituents, and are partly altered to chlorite. Accessory minerals include titanite, magnetite, and apatite.

A variety of somewhat different appearance outcrops on a hill 1½ miles about west-southwest from Lightning peak. Below, approximately 250 feet from the summit of this hill on the eastern and northern slopes, the well-exposed rock is a massive, grey to slightly pinkish type carrying abundant dark green, chunky crystals of pyroxene and a smaller but conspicuous amount of fresh-looking biotite. The remaining 60 per cent or so of the rock is chiefly feldspar of grey to slightly pinkish cast. Under the microscope the rock was found to be a quartz diorite composed largely of plagioclase occurring in lath-shaped crystals and about andesine in composition. Otherwise the rock carries scattered, comparatively large crystals of diallage, more abundant flakes of dark brown biotite, a little quartz, probably between 5 and 10 per cent of orthoclase, and accessory apatite.

Pink Granite

The third principal member of the batholithic rocks is widely exposed in the southeastern part of the map-area and also appears to underlie a large area on either side of the Galloping Mountain trail. It seems likely that the intrusives of these two localities are parts of one mass and join east of the map-area.

The pink colour of this granite is due to the large proportion of pink feldspar present. Otherwise the rock carries abundant quartz, commonly somewhat smoky, and a small but variable percentage of dark minerals of which biotite is most conspicuous. In some places almost no dark minerals can be seen. Under the microscope specimens obtained from the main outcrop area southeast of Lightning peak and from Rampalo creek were found to be almost exactly alike and to have the composition of a very acid granite. The rock carries about equal amounts of quartz and feldspar. The former shows some strain. The feldspar is in part orthoclase and in part plagioclase of about the composition of albite-oligoclase. A very little biotite is present and is mostly altered to chlorite. Accessory minerals include quite a lot of titanite and magnetite. The pink granite is distinguished mineralogically from the other batholithic rocks by the more sodic character of its plagioclase feldspar and by the relatively small percentage of mafic minerals present.

This granite is mostly quite massive and as such exhibits but little evidence of deformation. Locally, however, it is quite strongly sheared and fractured and the rock loses the fresh appearance which characterizes it in its more massive outcrops. A belt of sheared granite about 200 yards wide and striking northeasterly was observed in the granite area about

a mile southeast of Lightning peak near the contact with pre-batholithic rocks. What may be a continuation of this same sheared belt is represented by a similar width of the same type of granitic rock crossing Rampalo creek about 2,000 feet from its mouth.

A very similar pinkish granite was observed along the trail to Galloping mountain and also outcrops widely in the vicinity of this prominent hill.

Relations of the Batholithic Rocks

There seems little doubt but that the porphyritic "Nelson" granite and the members of the granite-diorite complex are closely related in origin and that they were intruded at about the same time. Their chief difference is a textural one and though they vary from granite to diorite or quartz diorite in composition this variation appears to be the result of local conditions, the chief of which relates to the intimate association of the more basic types with pre-batholithic formations. Otherwise these rocks have much the same general appearance; are composed of essentially the same minerals; have experienced alteration of a similar character; and are structurally alike. The porphyritic texture so characteristic of the "Nelson" granite is not uncommonly well developed in the granite-diorite member, all gradations being observed in such instances between the more porphyritic and equigranular types. Such porphyritic phases were, for example, noted in a number of the dyke-like bodies and small masses of intrusive associated with the pre-batholithic rocks where they outcrop along the Granite range, and elsewhere in more central parts of the areas, as in the vicinity of the Waterloo and Rampalo properties. The same texture was also noted here and there within the main area of the granite-diorite complex. In most cases, however, this texture was less characteristically developed in the outlying areas than in the main body of porphyritic granite and was most commonly noted where nearest to this main body.

In the case of the "pink granite", however, there is little evidence of direct relationship with the other two types. Its pinkish colour; great abundance of quartz of a slightly smoky appearance; paucity of dark minerals as compared with the other batholithic members; non-porphyritic texture and in general fresh appearance in comparison with the "Nelson" granite; all render it easily separable from the other batholithic rocks. As contrasted with the other batholithic intrusives, it appeared, on the whole, to be notably deficient in sulphides or other metallic minerals. As developed at and in the vicinity of Galloping mountain this pinkish granite is included with the Valhalla granite of the West Kootenay map-sheet[1]. In referring to it Brock states[2] "From near the head of Gloucester creek [north of Franklin mountain] to Fire Valley ridge [i.e. the ridge extending northwest-southeast on either side of Galloping mountain to the southwest of Fire valley] the rock is a pink, quartzose, biotite-granite, seemingly related to the 'Rossland granites'." Brock also refers to this granite as carrying "inclusions of grey granite" the latter apparently being the "Nelson" granite. In Lightning Peak area no contacts between the pink granite and the other batholithic members were observed.

[1]Geol. Surv., Canada, Map 792.
[2]Brock, R. W.: Geol. Surv., Canada, Sum. Rept. 1900, pt. A, p. 71.

The features mentioned above seem to support the view that the pink granite is later than the Nelson granite and granite-diorite complex. The difference in age may not, however, be very great. The pink granite is locally strongly sheared and exhibits even greater deformation than was noted in the other batholithic intrusives. At the Lightning Peak mine, on either side of the shaft, is a crushed dyke 100 feet wide of biotite granodiorite porphyry which bears quite a strong lithological resemblance to the more sheared phase of the pink granite. This dyke is intersected by the main vein at this mine and is consequently pre-mineral in age. On the supposition that the dyke is an offshoot from the pink granite the latter would, as in the case of the other batholithic members, be of pre-mineral age.

The age of the batholithic rocks cannot be deduced from their relations within this area. Their correlation, with the possible exception of the pink granite, with the Nelson granite of Kootenay district where this granite has been observed intruding Triassic and older formations, places them as post-Triassic in age and their probable connexion, in time of intrusion, with the Coast Range intrusives of British Columbia, suggests that they are probably of Jurassic or post-Jurassic age. The pink granite is most readily correlated with the Valhalla granite as developed in the vicinity of Galloping mountain. This Valhalla granite, as depicted on the West Kootenay sheet, was regarded as post-Cretaceous.[1] In the Lightning Peak area, however, there are reasons for believing that the pink granite is little if any younger than the Nelson granite which, on the same sheet, is doubtfully referred to post-Jurassic time.

PRE-BATHOLITHIC ROCKS

Pre-batholithic formations occupy a large part of the central part of Lightning Peak area where they occur chiefly within a belt averaging a mile or more in width and extending in a general east and west direction across the map-area.

These formations include a variety of both sedimentary and volcanic rocks, but all have been much altered, chiefly by the numerous intrusions, so that their original characters have been in most places very largely obscured. Some of the rocks, particularly in the western and southwestern parts of the area, are well bedded, but of these only those that are limestone present definite evidence of a sedimentary origin. Most of the bedded formations, as well as those in which such structures are less obvious or wanting, are massive types varying in colour from grey and greenish grey to green. Most of them are fine-grained to dense rocks, the former possessing a microcrystalline, igneous appearance, that is particularly pronounced where the association with granitic intrusives is more intimate and which is attributed to recrystallization and granitization. In many places, however, the rocks from their colour, texture, structure, or mineral composition are regarded as of volcanic origin and as including lavas, tuffaceous rocks, and, possibly, basic intrusives.

Limestone

A great deal of limestone was observed within an elongated elliptical area extending from the vicinity of the Lumpy workings (about 3,000 feet north-northeast of Lightning peak) northwesterly across the Waterloo

[1]Geol. Surv., Canada, Map 792.

and Potosi properties to the Granite range. The widest exposures occur in the vicinity of the Waterloo mine, on either side of which a width of about 3,000 feet is about one-third underlain by limestone and the remainder largely by intrusive rocks. The widest single exposure of limestone occurs partly on and partly to the north of the Waterloo No. 3 claim and has a maximum observed width of between 500 and 600 feet. Other conspicuous widths of limestone occur: (1) within the northern two-thirds of the Waterloo claim; (2) at the junction of Silver Spot and Waterloo creeks; (3) on the Potosi group to the northwest of and in line with the limestone exposures on the Waterloo No. 3 claim; (4) on the Silver Spot claim of the Waterloo group to the southeast of and in line with limestone exposures on the Waterloo No. 3 claim; (5) on the Silver Spot No. 3 and No. 4 claims within a mile to the east-southeast of the Waterloo No. 3 claim; and (6) at the Lumpy workings on the Lumpy claim. A little limestone was also observed crossing the Granite range near the northern contact of the southern area of batholithic intrusives.

The limestone is medium to coarsely crystalline. According to the amount and character of impurities it varies from dark grey to nearly white. In general it is quite massive and structureless, but in places is well bedded, bands of nearly pure crystalline limestone a fraction of an inch to several inches wide alternating with, generally, narrower, darker, impure bands. In places the limestone has been altered to massive garnetite composed largely of a reddish garnet associated with some crystalline calcite. One occurrence of bunches of fibrous wollastonite was noted in a limestone outcrop near its contact with diorite intrusives about half a mile south of the Waterloo claim.

The limestone is in contact with other pre-batholithic formations and with intrusive rocks. It forms irregular inclusions in the latter or is sharply cut off by them. Contacts with other pre-batholithic rocks are mostly irregular, but quite sharply defined. Bands of limestone may pinch out abruptly along their strike or may branch to form two or more spurs in the associated rocks. Individual bands several hundred feet wide disappear or narrow to a width of a few feet along their strike within a distance not much greater than their maximum width. Such features may indicate original variations in thickness, or may be due in part to the comparatively high degree of plasticity exhibited by limestone when subjected to deformation.

Other Sedimentary Rocks

Sedimentary rocks other than limestone are difficult to distinguish. Certain, thin, brownish-weathering beds, probably calcareous argillite, occur between heavier limestone beds at the Waterloo mine within or close to the vein zone. Elsewhere on this and other properties are outcrops of massive, dark grey to slightly greenish grey, less commonly brownish, crystalline or finely granular, rocks of quartzitic aspect, but which when examined microscopically resemble tuffs or tuffaceous sediments. A brownish grey, massive, finely granular, rusty weathering rock outcropping 700 feet northeast of the Potosi cabin was found, on microscopic study, to be composed chiefly of a clear, granular mosaic of quartz and feldspar grains

through which are scattered numerous small blades of light green amphibole, a few small crystals of a pyroxene, probably diopside, and abundant grains or cubes of pyrite. No bedding structures were observed, but the rock is probably a recrystallized feldspathic or, possibly, tuffaceous sandstone.

Volcanic Rocks

A large proportion of the pre-batholithic rocks are probably of volcanic origin. They include three general types: (1) greenish, fine-grained to dense rocks which are either massive or exhibit varying degrees of schistosity; (2) bedded rocks which vary from fine to coarsely fragmental, are commonly greenish or greyish green and, in general, carry conspicuous, dark green crystals of amphibole; and (3) rocks much resembling quartzites, but which have a composition more like volcanic rocks.

The fine-grained to dense, greenish rocks forming the first type are probably lavas. They are the predominant country rocks at Lightning Peak and Killarney workings where they are, in part, strongly sheared and are also, in part, altered by vein solutions. One specimen of a massive, light green, fine-grained rock intersected by tiny veinlets of calcite, obtained about half-way to the face of No. 4 adit at the Lightning Peak mine, was examined in thin section under the microscope and found to consist of a fine-grained, indeterminate groundmass holding numerous, small, lath-shaped feldspars and many pseudomorphs of pyroxene and, possibly, also, olivine, composed of serpentine, chlorite, and calcite. Pyrite is finely disseminated through the rock. Very similar looking rock was observed in the adit on the Pay Day mine and also near workings on the Silver Spot No. 4 claim. Large outcrops of a massive, dark green rock carrying, in places, small, angular fragments, mostly very similar in appearance to the matrix, were observed about a mile south of Lightning peak. This rock appears to be an andesitic flow breccia and shows gradations to rocks of the second type mentioned above.

The second type is represented in part by well-bedded rocks. All are distinguished by the presence of dark green, chunky crystals of amphibole varying mostly from 2 to 3 millimetres in length and, in some of the rocks, closely crowded together. There appear to be gradations from rocks in which such crystals are abundant to others in which they are comparatively few and scattered and as these latter types include members that are distinctly fragmental and in part well-bedded, it seems likely that all are related in origin.

An abundant type is coarse-textured, bedded, and of somewhat conglomeratic appearance. The rock is grey to greenish, and carries numerous fragments that are mostly elongated parallel to the bedding and vary in length up to several inches, though most are much shorter than this. The fragments are fine grained, predominantly either green or light grey, and, probably, at least most of them, are of volcanic origin. They generally have a squeezed appearance and though their edges are in part quite sharp yet the fragments commonly are not sharply defined. The matrix in which the fragments lie composes the greater part of the rock, is of a finer texture, and through it are scattered dark green crystals of amphibole averaging probably about 2 millimetres in diameter. The matrix possesses an irregular texture and somewhat ashy appearance.

At least two belts of this rock were observed, one about 800 feet east and the other about 1,000 feet west of the summit of Lightning peak. These belts strike nearly north and south and on Lightning peak dip to the east. About half a mile to the north and again less than a mile to the south of the peak, these two belts seem to unite and, therefore, may be supposed to be a single horizon which underlies Lightning peak in a somewhat basin-shaped structure. The thickness of this horizon south of Lightning peak where the best exposures are, is estimated to be between 200 and 300 feet. The horizon on both sides grades into a finer-grained, probably tuffaceous, green rock carrying abundant crystals of amphibole.

The bedded rocks are thought to be waterlain breccias and tuffs. They are in contact with rocks whose mode of origin is more obscure. Among the latter are those previously referred to as holding abundant crystals of green amphibole. Such rocks are apparently most abundant on the hills to the south of Lightning peak and on the upper east and west slopes of this peak. On a ridge at the south edge of the map-area and close to the west edge of the area of pre-batholith strata, a belt striking northerly and about 1,000 feet wide is composed largely of rocks of this type. Doubtless they occur elsewhere, but were not located. Three specimens for microscopic study were taken; one from the northwest slope of Lightning peak about 600 feet below the summit; another about a mile directly south of this peak; and a third from the broad belt referred to above. The first specimen contains many large crystals of green, pleochroic hornblende, possessing, mostly, ragged boundaries fringed by numerous, small, clear crystals of diopside. Other larger crystals of a pyroxene, probably augite, are present and the rock also carries much brownish red biotite. These more prominent minerals lie in a finely crystalline ground of uncertain composition, but seemingly mostly feldspathic. A little calcite was also noted. The rock has a recrystallized appearance. The presence of diopside and a little calcite and the fact that in the outcrop this rock is interbanded with volcanic tuffs and breccias suggest that the rock is probably an altered, limy tuff. The second specimen has about the same appearance under the microscope except that very little pyroxene was observed and considerable titanite is present. The amphibole crystals are crowded with inclusions and commonly show extinction angles up to 40 degrees. Some have ragged edges and others sharply defined crystal boundaries. The third specimen carries: abundant large hornblende crystals, some well twinned; numerous small blades of green amphibole resembling actinolite; considerable diopside in large and small crystals; a little biotite and titanite; and a few crystals of plagioclase feldspar. A fine-grained groundmass constitutes a relatively small proportion of the rock. All three specimens have a distinctly recrystallized appearance. Their composition, and their association with volcanic breccias, tuffs, and, probably, lavas, indicate that they are related products of vulcanism. Their contacts were nowhere observed to be definitely intrusive. In general the belts composed of these rocks appeared to parallel the structures of the adjoining volcanic formations and into which they seem to grade. All this suggests that these rocks are extrusives, in part definitely fragmental and, in part, lavas or flow breccias.

The third type of volcanic rock, those resembling quartzitic sediments, prove on microscopic examination to have much the same mineral composition as members of preceding types. A specimen from the A.U.

claim about 800 feet north of the shaft has a clear, finely crystalline, feldspathic groundmass in which little or no quartz appeared to be present. Lying in this groundmass are: occasional, large crystals of green, pleochroic amphibole; numerous, small, colourless crystals of pyroxene (probably diopside); some shreds and flakes of reddish brown biotite; and a little epidote and zoisite. Most, at least, of the feldspar of the groundmass is plagioclase, about oligoclase in composition; a little calcite is also present. The rock is thought to be a recrystallized, limy tuff. Another specimen of a somewhat similar rock was obtained on the west slope of Lightning peak about 500 feet below the summit, where the rocks are noticeably saturated with later granitic material. Under the microscope about 50 per cent of rock was found to be composed of amphibole. The amphibole is green, highly pleochroic, has an extinction angle of from 30 to 35 degrees, and occurs in large and small crystals and in shreds. The larger crystals contain numerous, well-formed flakes of biotite. The remaining 50 per cent of the rock is a fine-grained, granular aggregate of fresh-looking plagioclase and a little quartz. This rock is somewhat doubtfully classified as a recrystallized andesite tuff.

Structure and Succession

Locally the structures are complex, but the general structure seems to be that of a syncline plunging westerly or northwesterly. The strata in the vicinity of the edges of the main batholithic bodies tend to strike parallel with the line of contact and to dip away from the granitic bodies. Judging from attitudes of the bedded rocks as obtained here and there across their area and from general differences in the character of the formations, as observed at a great number of points, there are probably two or more principal folds, though the structure as a whole, as already stated, is that of a syncline plunging westerly. Such an interpretation indicates that the massive volcanic types, chiefly lavas, exposed in the more easterly and southeasterly parts of the area, are the oldest, that these are succeeded by coarse and then fine-grained, tuffaceous rocks, including probably, some more normal sedimentary types, and that the youngest members are chiefly limestones.

Age and Correlation

No definite age can be assigned to the pre-batholithic formations. They are older than the Nelson granite which is of Mesozoic, not improbably Cretaceous, age. Because they are mainly volcanic rocks with associated limestone beds, they are tentatively correlated with the rocks occurring at intervals to the northwest of the Lightning Peak country, which were mapped by Dawson[1] with the Cache Creek series. This series is considered to be about Carboniferous in age.

ECONOMIC GEOLOGY

GENERAL STATEMENT

Interest in Lightning Peak camp has been sustained by small shipments of high-grade silver ore carrying, in some cases, important percentages of lead and values in gold and zinc. Attractive mineralization

[1]Geol. Surv., Canada, Shuswap Sheet, Map 604.

has been discovered at many places and though, at most of these, it occurs in too small amounts or is too low grade to be profitably mined, yet its presence has encouraged prospecting in the hope of finding better values and more substantial deposits.

A belt of highly altered volcanic and sedimentary rocks, a mile or more wide and extending for several miles in a general east and west direction is flanked by wide areas of batholithic intrusives and is soaked with granitic material and penetrated by many acid dykes of probably related origin. The older rocks are everywhere more or less severely altered, and as a direct indication of mineral possibilities, outcrops commonly carry liberal impregnations of iron sulphide regardless of whether vein matter is present or not. The porphyritic granite member of the batholithic intrusives is correlated with the Nelson granite which in Slocan district is host rock to many valuable ore deposits and is regarded as chiefly responsible for the extensive mineralization occurring elsewhere in that district. In Lightning Peak district this granite also contains significant mineral deposits.

Mineralization at Lightning Peak camp occurs mostly within the belt of pre-batholithic rocks, but a couple of prospects of possible commercial value have been located in the Nelson granite over a mile to the north of this belt. Within the belt, mineralization sufficiently attractive to warrant further exploratory work has been discovered at a dozen or more localities situated at intervals over a distance of about 4 miles. Still others of less prospective value have been located at intermediate points, and doubtless other discoveries would have been made were it not that prospecting is in most places handicapped by an overburden of glacial drift, stream wash, and soil.

The mineral deposits discovered to date occur mostly as veins belonging to one or the other of two principal types. In one type, the vein matter occurs within strongly developed shear zones striking about east and west and dipping, in general, steeply to the north. These shear zones vary from a foot or so to several feet in width and are of unknown length, but in certain instances have been traced by underground and surface workings for at least several hundred feet. They are partly filled with fractured and crushed wall-rock and in part by vein matter. Where, as at the Waterloo mine, the rock involved is mostly limestone, replacement by mineralizing solutions has been a significant factor; elsewhere it is less important. The ratio of vein minerals to associated wall-rock is extremely variable and the proportion of ore to gangue minerals is also variable, so that only locally are the ore minerals sufficiently concentrated to provide ore. Such ore occurs in shoots up to several feet wide, 50 feet or more long, and of yet unproved depth. The ore minerals include galena, sphalerite, pyrite, chalcopyrite, and, generally, important amounts of ruby silver, argentite, native silver, and other high-grade silver minerals. The gangue is chiefly quartz, but some calcite is everywhere present and in limestone rocks may be the more abundant.

Production to date has come entirely from veins of this sort and is mostly credited to the Waterloo and the Lightning Peak mines situated 3 miles apart near the west and east side of the camp, respectively. Owing to transportation costs only the highest grade material has been shipped.

The Waterloo mine is recorded to have made shipments aggregating over 150 tons, in which silver values varied from 250 to over 700 ounces a ton and probably averaged between 300 and 350 ounces. The shipments also contained, on an average, a small per cent of lead and zinc. Several hundred tons of lower grade material with values in silver, lead, and zinc are piled on the dumps. The Lightning Peak mine is credited with aggregate shipments of 200 tons or more of high-grade silver and silver-lead ore. Average values are not known, but would probably be considerably lower in silver and higher in lead than those of the Waterloo ore. Some silver-lead ore, amounting, possibly, to a few tons, has been shipped from workings on the Killarney property situated half a mile to the east of the Lightning Peak mine.

The other type of vein is represented by numerous quartz veins striking nearly north and south. These vary from a few inches to several feet in width and have been traced for distances up to 1,000 feet or more. In many cases they follow along one or other wall, preferably the foot-wall, of narrow dykes of quartz-porphyry, or may even occur in such dykes. These veins carry a sparse dissemination of pyrite. More locally and for distances of a few yards, mineralization may be much more pronounced and in such cases it generally includes other sulphides among which galena, sphalerite, chalcopyrite, and grey copper or other high-grade silver minerals may be recognized. Commonly, too, these veins carry low values in gold amounting to a few dollars a ton. In places, selected samples are reported to have assayed $30 or more in gold and up to 200 or 250 ounces in silver. The gold values are thought to be associated with pyrite and chalcopyrite. No free gold has been observed. Quite a little surface or near surface work has been done on a number of these quartz veins, but no production is recorded. On the A.U. claim of the Waterloo group, a shaft has been sunk on such a vein for 35 feet, in which distance it increases from less than a foot to nearly 2 feet in width and shows, in general, progressive increase in mineralization, including towards the bottom and along either wall, bands or long, narrow lenses up to several inches wide composed of nearly solid sulphides. On the Rampalo property, situated towards the centre of the camp, a drift adit 60 feet long follows a quartz vein which varies from several inches to 2 feet thick and carries a conspicuous amount of pyrite and, locally, a little galena and silver-rich sulphides. On the Morning claim, situated in the Nelson granite, a quartz vein exposed by surface workings and varying from a foot to 4 feet thick is conspicuously mineralized with pyrite and, more locally, with galena and sphalerite. Pyrite also abundantly impregnates the adjoining granite wall-rock for widths of from one to several feet, on both sides of the vein. Average values are not known.

The relation between the north-south system of quartz veins and the east-west trending mineralized shear zones is uncertain. Though much the same suite of ore minerals is present in both, the proportions are quite different. Pyrite, rather coarsely crystallized in general, is the characteristic and, commonly, the only visible mineral present in the quartz-veins, whereas it is a very minor constituent of the other system of veins where, too, it mostly occurs in finely crystalline form. For the reason that gold probably accompanies the pyrite, gold values are a significant

feature of the quartz veins and of negligible importance in the east-west veins. High-grade silver minerals are present in both vein systems, but are more abundant in the east-west veins which include conspicuous amounts of ruby and native silver, whereas the north-south veins are more apt to contain grey copper. The inference is that either the two vein systems were formed at different times or under different conditions.

The curious persistence with which so many of the north-south quartz veins follow along a wall or angle across dykes of quartz porphyry suggests either a structural or genetic relationship between the two. That the relation is probably structural is indicated by the facts: that some of the quartz veins occur quite independently of dykes; that others cut across the dykes; that the dykes themselves are rarely mineralized to any appreciable extent; and that in places where the dykes are faulted, mineralized vein quartz may occur along the fault planes.

No intersections of north-south and east-west veins were observed. The "Shaft" vein on the A.U. claim of the Waterloo group is, however, cut off, to the north of the shaft, by a strong east-west shear zone, suggesting that this shear zone as a whole is later than the north-south vein. This shear zone is apparently not mineralized, though even if it were it might be difficult to determine whether mineralization had not occurred in both veins at about the same time and that displacement of the "Shaft" vein was due to post-mineral movement along the east-west shear zone. The matter appears to be worth investigating as there is a possibility that if the two series of veins were formed at or about the same time, some concentration of values might be expected at their intersection. Such a possibility might be readily tested at the intersection of the "Big" vein on the Silver Spot claim of the Waterloo group with a smaller north-south quartz vein.

A mineral deposit of character somewhat different from those above mentioned occurs on the Pay Day group about a mile north of the Lightning Peak mine. There, a zone of heavy sulphide mineralization occurs at and near the contact of granodiorite with altered, greenish, probably volcanic, rocks. As exposed in a short crosscut adit 30 feet below the outcrop this zone is 20 feet wide and carries a varying but high percentage of mixed sulphides occurring in both massive and disseminated form and including chiefly pyrite, sphalerite, chalcopyrite, and magnetite. A sample taken by the Resident Engineer of the district across an aggregate width of 10 feet of the more solid sulphide material assayed: gold, trace; silver, 30 ounces to the ton; copper, 4·2 per cent; lead, nil; zinc, 12 per cent; nickel, nil; arsenic, nil; bismuth, trace.

DESCRIPTION OF PROPERTIES

Morning Claim (Locality 1)[1]

The Morning claim, held by location, is owned by Nels Melstrom, Edgewood, B.C. It is situated at the extreme north edge of the map-area to the northwest of the Dictator Crown-granted claim and is accessible by trail, half a mile long, from the Dictator cabin.

[1]This and other locality numbers appear on Figure 7.

The claim lies within an extensive outcrop area of the Nelson porphyritic granite. Workings include two deep pits and one trench, all of which cut well into the underlying rocks. The two pits, 100 feet apart, expose a quartz vein 20 inches wide, striking nearly north and south and dipping 75 degrees west. The vein carries, in order of relative abundance, disseminated pyrite, zinc blende, and galena. In most places, the sulphides do not exceed 2 per cent of the total volume of vein matter, though in places and across widths of several inches the amount probably reaches 10 per cent. The wall-rock on either side of the vein is heavily impregnated with pyrite for a width, on the foot-wall side, of about 3 feet, and for a lesser distance on the hanging-wall. The wall-rock is a medium-grained, highly quartzose, sheared granite which seems to be a phase of the Nelson granite. In the vicinity of the quartz vein this granite has been altered by vein-forming solutions.

The trench lies 55 feet north of the more northerly pit. Here the quartz vein is 4 feet wide and intersects pyritized granite which, 6 feet above the hanging-wall of the main quartz vein, carries a 6-inch vein of heavily mineralized quartz tightly "frozen" to the wall-rock. Where exposed by this trench the main quartz vein is sparsely mineralized.

Mr. Melstrom claims that the main vein does not appear to extend more than a few yards north of the trench, but that in the opposite direction it has been traced for a distance of about 700 feet. Claims have been staked to the north and south of the Morning claim and are owned by Adam Scaia, Edgewood, B.C.

Little is known of the values contained in the main vein or adjoining wall-rock. The prospect warrants further prospecting as well as careful sampling.

Dictator Claim (Locality 2)

The Dictator Crown-granted mineral claim is owned by John Glover, Queens Hotel, Nelson, B.C. The claim is situated at the headwaters of Rendell creek near the northern boundary of the map-area and is accessible by a trail 2¼ miles long leading from the main tractor road to the Waterloo mine. A substantial cabin has been erected close to the Dictator workings.

The claim was first staked some thirty years ago by Mr. Glover and was Crown-granted on October 9, 1920. The only reference to it or to development work done on it is contained in the Resident Engineer's (Mr. Freeland) report for 1919[1] from which the following extract is taken:

....."The country-rock surrounding the claims (Dictator and Cloriator) is a medium coarse, grey granite . . . . The ore consists of galena, sphalerite, and iron, carrying gold and silver, in a gangue of quartz and broken country rock. The vein has a northerly and southerly strike, dipping 75 degrees to the west. The lead, which outcrops for about 300 feet, is developed by open-cuts and shafts varying from 10 to 30 feet in depth. Owing to the bad state of repair of the deepest shaft it was impossible to visit it, but the owner claims an 18-inch lead in the bottom. The flatness of the surrounding country prohibits any developments by tunnels."

The property lies within the same large area of Nelson porphyritic granite as that which includes the adjacent Morning claim described above, and the quartz vein explored by the several small workings is almost exactly parallel with the Morning vein. The deeper workings are inaccessible and the smaller workings do not show much of the vein in place.

[1]Ann. Rept., Minister of Mines, B.C., 1919, p. 167.

Specimens of the vein matter are composed chiefly of massive to, in places, quite vuggy white quartz, mineralized chiefly by pyrite with some galena and zinc blende. A little native sulphur was noted in small cavities in the quartz, formerly occupied by other ore minerals. Both pyrite and galena occur in small, mixed masses or disseminated grains through the quartz. Values are not known.

Granite Range (Locality 3)

Old claim posts were observed on the summit of the Granite range to the northwest of the junction of Rendell and Waterloo creeks. The names of the claims could not be ascertained nor did it appear that any extensive exploratory work had been done. Some crystalline limestone associated with other highly metamorphosed rocks, the whole striking nearly east and west and dipping to the north at about 60 degrees, is in contact to the south with a large body of grey granite and is intersected by minor intrusive masses of similar composition to the main body. These conditions are analagous with those that elsewhere in the area have proved coincident with mineralization.

Potosi Group (Localities 4, 5, and 6)

The Potosi group, consisting of Potosi Nos. 1, 2, 3, and 4 claims held by location, is the property of James Graham, Greenwood, B.C. It is situated northwest of the Waterloo property and is accessible either by a short trail from the Waterloo mine camp or by a trail that branches off the Dictator trail half a mile northwest of the Waterloo tractor road. When visited by the writer a cabin was being constructed on this property by Mr. Graham.

The group lies about in line with the northwesterly continuation of the belt of metamorphic rocks occurring on the Waterloo No. 3 claim and vicinity. Crystalline limestone is abundant in the southwestern half or more of the area occupied by this property. Otherwise the prevailing rocks are metamorphosed types, chiefly volcanic rocks, associated with granitic intrusives and occasional acid dykes.

The property occupies a central position on the broad-topped ridge lying between Waterloo and the West fork of Rendell creek, a ridge referred to locally as the Baby range and having a maximum relief of about 700 feet. On the whole, the underlying rocks are poorly exposed, though locally, as along or near stream bottoms or on the axis of the ridge, outcrops are abundant.

Considerable surface prospecting has been done on the Potosi group, chiefly in the vicinity of localities shown by numbers on Figure 7.

At locality 6, two parallel quartz veins strike a few degrees east of north and lie about 160 feet apart. The westerly vein has been exposed by five open-cuts at intervals over a length of 300 feet. It varies from 2 to 3 feet in width and is mineralized with disseminated pyrite and a little galena. The eastern vein is wider than the other, but, where observed, is not as well mineralized. About 800 feet to the north of locality 6, four or more trenches have explored the continuity of another, or, possibly, one of the same quartz veins, over a distance of about 400 feet. In one pit the vein was 4 feet wide, but carried little or no visible ore minerals.

A few hundred feet northwest of the Potosi cabin, a series of three or more trenches exposes more vein quartz associated, in places, with calcite and carrying a little pyrite.

At locality 4 a couple of trenches expose a zone of crushed rock several feet wide striking about north and south. The rock involved is principally a light grey, decomposed variety of uncertain origin, probably a dyke. It is brecciated, is stained with iron and manganese oxides, carries some vein quartz, and is mineralized with a little pyrite. Between 400 and 500 feet northeast of these trenches another trench exposes an 18-inch quartz vein in a pegmatitic dyke rock. It is possible that this is the rock involved in the crushed zone at locality 4.

At locality 5 some trenching has been done in a belt of crystalline limestone which, at this locality, is cut by a small, acid dyke and carries a little vein matter represented by calcite and iron sulphide. This limestone belt might be more profitably investigated farther to the southwest in line with the possible continuation of the Waterloo vein zone.

Waterloo Group (Localities 7, 8, 9, 10, 11, 12, and 13)

The Waterloo group comprises the Waterloo No. 3 Crown-granted claim and nineteen other claims held by location. The group is at present being developed, under option to purchase, by Waterloo Consolidated Mines, Limited, of Penticton, B.C. Dr. C. M. Kingston, Grand Forks, B.C., is president of the company and R. L. Clothier, Victoria, B.C., is in charge of operations at the mine. The local address is Edgewood, B.C.

The property is situated at the headwaters of Rendell[1] creek, at the western terminus of the tractor road leading into Lightning Peak area. The claims form three parallel, adjoining rows extending easterly from the mine workings (Locality No. 7) on the Silver King and Waterloo No. 3 claims, the most westerly and second most westerly claim, respectively, of the middle row of the group. Other claims on which considerable work has been done are the A.U. (Locality No. 10), Silver Spot (Localities Nos. 8 and 9), the Silver Spot No. 3 (Locality No. 11), and the Silver Spot No. 4 (Localities Nos. 12 and 13). A little surface work has also been done on the Gold Plate claim situated north of and adjoining the Silver Spot No. 4 claim.

Waterloo Mine (Locality 7)

The Waterloo No. 3 claim was the first location made on this group. It was staked in 1903 by Adam Scaia, owner of the Silver Spot claim. In the same year Scaia sold the Waterloo claim to George McLeod who took out a little high-grade silver ore and later in the same year turned the property over to Dr. C. M. Kingston and G. A. Rendell who held it until the recent arrangements with the present organization. During part of the period of their ownership the property was leased to George S. Boug and Charles Hammarstadt who extracted several tons of high-grade ore. This ore was packed out at a reported cost of $64 a ton. During the same period it cost $80 a ton to pack provisions in to the camp.

[1]Named after G. A. Rendell, Trail, B.C., a director in the company's organization.

Production to date has come entirely from workings on the main or Waterloo vein as developed on the Waterloo No. 3 claim. The first official reference to production is made in 1904 by Mr. Wm. Thomlinson[1] who states that up to that time "Two small shipments of ore have been made, one of which gave the high returns of 669 ounces silver, $10.30 gold to the ton, and 45 per cent lead". The next reference is a brief statement in the Annual Report for 1917 to the effect that the vein carries values in both gold and silver. Reports for 1918[2] state that "Lessees George Boug and Charles Hammarstadt packed on horses 9,381 pounds of high-grade ore to Edgewood to be forwarded from that point to the Trail smelter for treatment. The shipment netted $3,244.53. The ore contained silver almost entirely, but 375 pounds lead was extracted." Some of this ore is reported to have assayed over 700 ounces in silver. In the following year[3] the "development work consisted of driving a tunnel below No. 1. . . . . Ore was struck in this tunnel and a shipment of 13 tons made"; 10 tons of this[4] shipped in March had an average content of 528 ounces silver to the ton and 5 per cent lead, and 3 tons shipped in April carried 293 ounces silver to the ton and 4 per cent lead.

In 1920[5], 22 tons of high-grade silver-lead ore was packed out on horses. The report for 1927 indicates that the ore shipped in 1920 was of about the same class as that shipped in 1919.

The present writer is informed that since the property was taken over in 1929 by the present organization three shipments have been made. The first, amounting to 31 tons, and obtained from Nos. 1 and 2 adits, was shipped in December, 1929, and averaged 482 ounces silver a ton; the second, 49 tons, and obtained from the same workings, was made in February, 1930, and averaged 250 ounces in silver; and the last, about 30 tons from No. 2 adit, was shipped in March, 1931, and ran 472 ounces silver and $7 to $9 gold to the ton[6].

The workings at Waterloo mine (*See* Figure 8) include four adits which, in order from east to west and from highest to lowest, are: No. 1, 1,120 feet long; No. 2, 250 feet long and 24 feet below No. 1; No. 3, 40 feet long and 52 feet below No. 2; and No. 4, 10 feet long and 36 feet below No. 3. These adits are driven in on the main Waterloo vein zone which outcrops down the slope below No. 1 adit. This slope is steep, averaging about 25 degrees to No. 4 adit. No. 4 adit is close to the bottom of a narrow, dry ravine on the other side of which the ground rises again to form a low ridge before resuming its downward slope into the main branch of Waterloo creek. The vein zone if continuous to or beyond this creek would, at creek level, gain an additional depth of about 200 feet. In the opposite direction, in line with the strike, the ground rises very slowly above No. 1 adit.

No. 2 adit is connected with No. 1 and with the surface by a raise and stopes. At the surface a number of trenches have explored the easterly continuation of the vein for a distance of 200 feet or so beyond the face of No. 2 adit (the most easterly underground workings).

[1]Ann. Rept., Minister of Mines, B.C., 1904, p. 224.
[2]Ann. Rept., Minister of Mines, B.C., 1918, pp. 204 and 221.
[3]Ann. Rept., Minister of Mines, B.C., 1919, p. 167.
[4]Idem, p. 174.
[5]Ann. Rept., Minister of Mines, B.C., 1920, p. 156.
[6]It is also reported that this ore carried values in tin to the amount of several dollars a ton.

A large proportion of the rock in the vicinity of the workings is crystalline limestone, a feature that distinguishes this locality from the other more important showings in the area. Associated with the limestone are bodies of highly metamorphosed, commonly greenish rocks presumably of volcanic origin. They are locally referred to as "schists", though in general quite massive. The greater part of these "schists" is soaked with material of about the composition of diorite or quartz diorite which has partly replaced and has otherwise been injected into the older rocks. So intimately are the two intermingled that in places outcrops may only doubtfully be referred to as being composed mainly of pre-intrusive or of intrusive material. The trend of the "schists" and limestone is nearly east and west (magnetic) and the prevailing dips appear to be to the north. Limestone contacts are generally sharp, though very irregular in detail. One hundred to two hundred feet south of the workings is the northern edge of a comparatively large area underlain by granodiorite and very like the intrusives elsewhere so intimately associated with the pre-batholithic rocks.

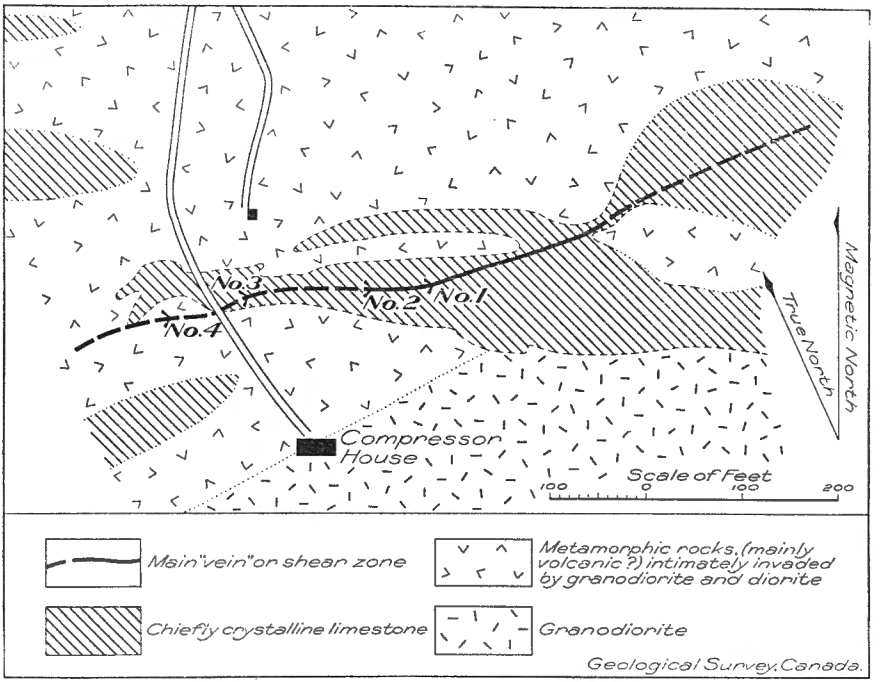

Figure 8. Waterloo mine, Lightning Peak area, British Columbia.

The main Waterloo "vein" is a strong, mineralized, shear zone averaging about 4 feet wide, striking a few degrees south of east, and dipping steeply to the north. This shear zone so far as it has been developed to date intersects, mainly, crystalline limestone, but bands, a few inches thick, of brownish, shaly sediments occur within the shear zone. The zone also cuts two or more acid dykes and, towards the face of No. 2 level, a plug of granodiorite about 25 feet in diameter.

Movement along the shear zone appears to have been along one principal plane and others of subsidiary importance on either side. These planes are irregular in strike and dip and, in consequence, may merge with, or branch from, those on either side. The hanging- and foot-walls of the shear zone are, therefore, difficult to recognize except by crosscutting. Along the walls of the principal plane of shearing, on Nos. 1 and 2 levels, strong grooves dip about 35 degrees to the east. The relative positions of dislocated parts of dykes on either side of this plane of shearing indicate that the south wall has moved upwards and towards the west with respect to the north wall. The amount of displacement is uncertain, but does not appear to be very great. On No. 2 level a dyke in the north wall of the shear zone is offset in the south wall 35 feet to the west. The plug of granodiorite towards the face of No. 2 level appears to have been offset a few feet in the same direction. On No. 2 level, a fault striking nearly north and south and dipping 30 to 35 degrees west is offset by the main shear zone and the latter intersected by a strong fault striking about 20 degrees west of north and dipping 30 degrees northeast. At about 130 feet from the portal of No. 2 level, a strong fault striking north 40 degrees east and dipping about 20 degrees southeast cuts across the fissure zone and persists to the surface. Ore occurs on either side of this fault and above No. 2 level formed a high-grade shoot which extended to the surface.

The main "vein" or shear zone is mineralized along its entire investigated length, but, as yet, mineralization of economic value has been found only within one relatively restricted section. This section extended from the surface to No. 2 adit level, below which its extent has been only slightly investigated. Within this section, above No. 2 level, the high-grade ore has been mostly stoped out. It occupied a length of about 40 feet at the surface and at the levels of No. 1 and No. 2 adits. Shallow pits in the floor of No. 2 level were filled with water and could not be examined. The high-grade ore at the surface is almost vertically above or slightly to the east of the high-grade ore at No. 2 level. The strong, easterly dipping grooves on the walls of the vein, and the possibility that mineralization may have been guided into the shear zone by the southeasterly dipping fault mentioned above, suggest that if the ore-shoot continues below No. 2 adit it should rake to the east. On the other hand and because most of the high-grade ore extracted from below No. 1 level underlay the southeasterly dipping fault, whereas the high-grade ore above No. 1 level lay above the same fault, it seems likely that this fault may be in part or entirely post-mineral and if so, that it is a normal fault which has displaced the part of the ore-body above No. 1 level to the east with respect to the part below No. 1 level.

Mineralization of medium to low-grade character occurs within the shear zone on either side, but chiefly west of the main ore-shoot. In this direction samples taken by the management for a distance of about 50 feet along No. 2 level indicated that over a width of 3 feet the average values were: silver, 4·0 ounces to the ton; lead, 3·0 per cent; and zinc, 4·2 per cent. On No. 2 level very little ore mineralization was observed beyond 130 feet from the portal until near and at the face where the shear zone is quite heavily mineralized with zinc blende and carries some galena. Values in silver are low, but the extent of mineralization at the face is such as to encourage exploration in this direction.

The main "vein", or what is presumed to be this vein, is picked up in the lower workings which consist of short adits and open-cuts, but to date no appreciable amount of ore has been found, though some attractive mineralization has been noted. Probably the most interesting discovery was made in an open-cut alongside the road to the Compressor House a few feet southwest of the portal of No. 3 adit. There, a vein of galena 2 inches wide occurs in a narrow, acid dyke. Its proximity to the main shear zone suggests that some work should be done to discover its connexion, if any, with the main "vein".

The ore of the shoot stoped out above No. 2 adit level included a conspicuous amount of native silver, argentite, ruby silver, stephanite, and grey copper associated with argentiferous galena and zinc blende. These minerals, according to report, occurred in lens-like masses and in stringers accompanied by a varying proportion of gangue mineral, chiefly calcite. A couple of specimens of vein matter from this high-grade shoot were examined microscopically under reflected light. One contained a solid chunk of native arsenic about 2 inches in diameter, moulded into a nest of coarsely crystallized calcite. The other specimen had the appearance of an ore-breccia in which angular fragments of ore minerals or groups of minerals were scattered through a gangue of mixed calcite and quartz. The ore minerals included sphalerite and galena associated with two varieties of ruby silver, each of which carried numerous microscopic bodies of native silver. The ruby silvers both appeared to be antimonial types, pyrargyrite and, probably, polyargyrite.

The low-grade mineralization consists of streaks and disseminations of, principally, zinc blende and lesser galena, occurring at intervals along and across the shear zone. The wall-rock is chiefly crystalline limestone. Gangue minerals include a varying proportion of quartz and calcite. At the face of No. 2 level the vein matter shows a brecciated structure in which chunks and bunches of pale yellow or brownish zinc blende, associated with some fine to coarse-cube galena, are moulded in a calcite gangue.

A.U. Claim of the Waterloo Group (Locality 10)

Considerable development work, chiefly in the form of surface trenching, has been done on the A.U. claim within about one-third of a mile northeast of the Waterloo mine workings. This work has uncovered portions of some half a dozen quartz veins. The veins vary from a couple of inches to 2 feet or more in width, strike in a general north and south direction, and dip at high angles either to the east or west. The two that have received most attention are about 30 feet apart. One of them, known as the "Shaft" vein, has been traced for 400 feet, and the other, the more westerly, for 500 feet. About 75 feet west of the south end of the investigated part of the latter vein, a third vein has been picked up and traced northerly for over 100 feet. Vein exposures farther south on the adjoining Silver Spot claim suggest from their position, alinement, and association with an acid dyke that they are continuations of the middle vein mentioned above and, if so, they represent an additional length of 875 feet.

The Shaft vein, as its name implies, has a shaft sunk on it, This is mostly a recent piece of work and at the time visited was down 25 feet

on the vein which averaged 11 inches in width in this distance. Towards and at the bottom of the shaft solid sulphide mineralization up to 3 or 4 inches in width was encountered and consisted chiefly of an intimate mixture of pyrite, galena, zinc blende, and chalcopyrite. Elsewhere the quartz vein carries streaks and disseminations of these minerals, principally pyrite. Surface exposures carried much less mineralization and this largely as pyrite. Chalcopyrite was not observed in the surface workings, but becomes increasingly abundant with depth where, also, films of native copper were observed on fracture surfaces of the quartz. The walls of the vein are sharply defined. The vein matter is in places distinctly banded, quartz carrying abundant pyrite in streaks and bunches lying close to the walls across widths of a couple of inches and succeeded inwards by bands of nearly solid sulphide including abundant galena, pyrite, chalcopyrite, and sooty decomposition products. A specimen of such vein matter was polished and examined microscopically by reflected light. It revealed an intimate association of pyrite, galena, zinc blende, and chalcopyrite; the chalcopyrite being in part minutely disseminated through the sphalerite. The galena carries minute areas of a pale grey mineral which reacts quickly with ferric chloride and may be argentite.

The vein quartz is milky white and where associated with streaks and bands of ore minerals is, in general, quite vuggy. A sample taken by the resident engineer[1] at a depth of 10 feet in the shaft and across the vein where it is 10 inches wide, "assayed 0·12 ounce in gold and 24·5 ounces in silver to the ton, 13 per cent lead, and 4·5 per cent zinc." The writer has been informed by the mining engineer of the company that at the close of 1930 the shaft had been continued to a depth of 36 feet; that at this depth the vein is 22 inches wide; that values in the solid iron sulphide ran from $20 to $26 in gold and about 10 ounces silver a ton; that a sample of the solid mixed sulphide ran $36.80 gold, about 25 ounces silver to the ton, and 35 per cent lead.

The Shaft vein dips to the west at about 50 degrees and appears as though it may eventually intersect the vein to the west whose dip, so far as surface workings indicate, is steeper though in the same direction. The Shaft vein ends about 85 feet north of the shaft, against a strong shear zone striking about east and west.

The vein lying 30 feet west of the Shaft vein occurs along the foot-wall of a narrow, acid dyke which dips steeply to the west. Where exposed by a number of trenches on the A.U. claim this vein would not average over 6 inches in width and is poorly mineralized. Other quartz veins picked up in surface workings on the A.U. claim carry here and there a little pyrite and lesser amounts of galena. A couple of small veins of this sort have been uncovered towards the north end of the claim within 200 feet south of the main tractor road. Another small vein is exposed 400 feet west of the shaft; it underlies an acid dyke dipping steeply to the east and carries some pyrite. Another vein, referred to as the "Red" vein, is exposed 150 feet southwest of the shaft and has been explored in a southerly direction by small trenches. This vein has the appearance of a shear zone impregnated with quartz and carrying some iron sulphide whose oxidation has lent a rusty colour to the outcrop across a width, where noted, of 3 feet.

[1]Ann. Rept., Minister of Mines, B.C., 1925, p. 196.

Silver Spot Claim (Localities 8 and 9)

This claim adjoins the A.U. to the south. Three veins have received particular attention. One (near Locality 9) has already been referred to as the probable continuation of a vein on the A.U. claim. It has been picked up in five trenches over an aggregate distance of 550 feet. This vein is closely associated with an acid dyke and occurs in places along the foot-wall and in other places within the dyke. In a deep pit sunk beside the Discovery post of the Silver Spot claim, the vein is 12 inches wide, and underlies the dyke which is about 10 feet thick and dips 40 degrees west. There and in trenches farther south the vein carries much pyrite and, more locally, some galena and zinc blende. Samples carrying encouraging values in both gold and silver are reported to have been obtained from these workings. One hundred feet east of the Discovery post, a trench exposes an acid dyke with vein quartz on either side and also intersecting it. The quartz carries some pyrite. One hundred and ten feet south of the Discovery post, a wider vein or vein zone is exposed and has been traced westerly for nearly 200 feet, in part of which distance it outcrops on a steep, rocky bluff of granitic and older greenish rocks. This "vein", from what could be seen of it, appears to be a shear zone along which occurs more or less vein quartz carrying a little sulphide mineralization. Its maximum width seems to be about 3 feet.

A third vein, known as the Silver Spot vein, is exposed on the south bank of Silver Spot creek at an elevation of about 5,600 feet. What is presumably the same vein has been traced for about 300 feet by three trenches above the north bank of the creek. About midway of this distance, an adit 65 feet long (Locality 8) intersects the vein at 35 feet from the portal. The vein is of quartz, has a northerly strike, and dips steeply to the west. It has formed along a shear zone in rocks that are chiefly pre-batholithic and, in part, are well banded, dipping about 60 degrees to the northeast. The only mineralization of consequence was observed in exposures at creek bottom where the vein quartz, about 6 inches wide, carries grey copper as well as some pyrite and galena.

Silver Spot No. 3 Claim (Locality 11)

On this claim, at the junction of two tributary creeks, a shear zone about 8 feet wide and striking about east and west carries two bands of mineralized vein matter up to several inches wide, one near the foot-wall of the shear zone and the other about midway between the walls. The chief vein mineral is quartz which, in part, replaces the crushed wall-rock. The latter is mostly a dense, greenish, altered rock associated with some dioritic intrusive. The ore minerals are principally fine-grained galena and zinc blende and occur as narrow streaks in the quartz. Some high-grade silver mineral or minerals may be present, as selected samples are reported to have assayed up to 100 ounces of silver to the ton. The wide shear zone lies rather closely on the projected course of the main vein of the Waterloo mine.

Silver Spot No. 4 (Localities 12 and 13)

On this claim, which adjoins the Silver Spot No. 3 on the east, a great deal of trenching has been done, partly with a view to ascertaining whether the east-west shear zone found on the Silver Spot No. 3 claim continues.

One trench, 3,000 feet long, extends in a westerly to northwesterly direction across the claim and for about 1,200 feet into the adjoining Silver Spot No. 3 claim, where it ends at the shear zone. Another trench, 1,000 feet long, leads westerly from the longer trench. Bedrock is not continuously exposed in these long trenches, but does appear along considerable portions. A few, small, north-south trending quartz veins and a number of narrow, acid dykes were uncovered. It is not certain, however, whether the east-west shear zone was located, as the rocks are not well exposed where it should cross.

Vein matter has been found in two places north of the main trench. The westerly (Locality 12) of these occurrences is exposed by three trenches lying 240 to 315 feet away from the main trench. In the two more southerly trenches limestone occurs across an exposed width of several feet and has been altered to a highly garnetiferous rock in which some vein quartz carrying pyrite was noted. The northernmost trench shows a 6-inch quartz vein, carrying pyrite and galena striking northerly, and intersecting metamorphosed tuffaceous sediments and dioritic intrusives.

The more easterly showing (Locality 13) lies towards the northeast corner of the Silver Spot No. 4 claim. There, a short adit and some surface work have exposed a quartz vein, 1 foot thick, striking north 35 degrees west and dipping 15 degrees northeast. It is well mineralized with pyrite, galena, and zinc blende. The vein is cut by a fault in the adit and at the face it stands nearly on edge and strikes north 35 degrees east. About 150 feet south of the adit, a 6-inch quartz vein is uncovered by a short trench. This vein strikes nearly north, dips 30 degrees east, underlies a quartz porphyry dyke, and is mineralized with pyrite and some galena.

Gold Plate Claim

This claim adjoins the Silver Spot No. 4 on the north. Some surface work has indicated the presence of quartz veins similar to, and possibly in part continuous with, those discovered on the more southerly claim.

Lumpy Claim (Locality 14)

The Lumpy claim, owned by Messrs. George Boug and Robert Lee, Edgewood, B.C., is situated on the northern slope of Lightning peak. The workings lie within about 3,000 feet of, and 600 feet below, the summit and are most readily accessible by trail from the Rampalo property.

The claim was staked by John Prough and Walter A. Johnson in the autumn of 1918. Some high assays were obtained by these men from surface samples. An adit was driven to investigate the character of the mineralization at depth, but as the results of this work did not prove encouraging the property was abandoned and lay open until about 1927 when it was restaked by the present owners.

Mineralization on this property is associated with a belt of limestone that is 100 feet or more wide and strikes north 55 degrees west and dips 60 degrees southwest. This limestone is thought to extend northwest towards the limestone exposures on the Silver Spot No. 3 and No. 4 claims of the Waterloo group.

On the Lumpy property the limestone is a coarsely crystalline grey rock, in part quite impure. It is associated with granitic intrusives and with some greenish, probably volcanic, rocks. In the vicinity of the workings the limestone is conspicuously jointed along a north 60 degrees east direction and along these joints occur seams of vein matter, a small fraction of an inch wide. The presence of these seams has induced the owners of the claims to explore for deposits of more substantial size, but to date such deposits have not been discovered. Workings include two short adits on the same level and 50 feet apart, one about 70 and the other 30 feet long, and a number of open-cuts and trenches above them. This work has revealed a sparse dissemination of pyrite here and there in the limestone and adjoining rocks, but has not furnished direct clues as to where further work might advantageously be done. The thin seams of vein matter, occurring along joint fractures in the limestone, carry zinc blende, lesser amounts of galena, unidentified silver-sulphides (probably chiefly ruby silver), and traces of native silver and (?) free gold.

Rampalo Group (Localities 15, 16, and 17)

The Rampalo group consists of the Rampalo and Silver Lump Crown-granted claims and the Victoria, Condor Fraction, Southwestern, and Southwestern Fraction claims held by location. One-fourth interest in the Crown-granted claims and one-half interest in the others is owned by Adam Scaia, Edgewood, B.C. The remaining interest in the Crown-granted claims is retained by the estate of the late T. Cortiana. The property is situated about 2½ miles by trail east of the Waterloo mine camp.

The Rampalo was the first claim staked in the district. It was located in 1897 by Scaia Bros. and Axel Johnson. Subsequently it and the adjoining Silver Lump claim were purchased by T. Cortiana who held them until his decease, about 1921. The two claims were Crown-granted in April, 1902.

The rocks on the Rampalo group are chiefly an intimate association of greenish, mostly finely crystalline, metamorphic rocks and abundant granitic intrusives. The intrusives are commonly medium grained, equigranular, dark grey to greenish grey, and of about the composition of biotite-hornblende granodiorite, but in places they are more basic and in other places they grade into coarser-grained porphyritic varieties like the Nelson granite. The rocks invaded by the intrusives show varying degrees of alteration and in places are difficult to distinguish from the invading rocks. They seem to be chiefly of volcanic origin. An occasional quartz porphyry dyke was observed and these have, to some extent, guided development work.

The principal work has been done at locality 16 on either side of the boundary between the Rampalo and Silver Lump claims. There three adits varying in length from 60 to 390 feet have been driven to develop a quartz vein which at the time visited was seen to best advantage at the level of the uppermost or No. 3 adit. This adit is 60 feet long and follows the vein which, in the adit, varies from several inches to over 2 feet in thickness, strikes north 37 degrees east, and dips southeast at about 62 degrees. It lies partly within and partly beneath a 10-foot dyke of light grey quartz porphyry, the courses of the dyke and vein making a small

angle with one another. Near the portal the vein is offset a few feet by a fault striking nearly north and dipping 45 degrees to the west. The quartz is milky white and in places, particularly near the foot-wall, is banded. It carries disseminated crystals and small bunches of pyrite and, locally, a little galena and silver-rich sulphides. Values are reported to have varied greatly and to have been best near the portal, in the vicinity of the fault, where assays as high as 250 ounces in silver and $10 in gold are said to have been obtained. Some native silver is stated to have been found in this section of the adit. Elsewhere values are mostly too low to be economically important. The same vein is reported to have been picked up in No. 2 adit about 50 feet below No. 3 adit and commencing about 185 feet northward along the strike of the vein. A third adit (No. 1) was driven by Cortiana to cross this vein at a depth a few feet below that of No. 2 adit and at the same time to investigate the ground to the east of the other adits. This lowermost adit is 390 feet long and at the face encounters a 3-inch quartz vein which appears to be repeated by a series of parallel slips striking nearly north and dipping west at about 40 degrees. Samples from this vein are reported by Adam Scaia to have given 40 ounces silver and $3 to $4 gold to the ton. Though this small vein (or veins) is about in the right position to represent the downward continuation of the quartz vein in No. 3 adit, no quartz porphyry dyke occurs in its vicinity and it is possible that the crosscut has not been driven quite far enough to strike the vein seen in the upper adit. The long crosscut intersects greenish, altered rocks interrupted at three points by strong, shear zones striking nearly north and dipping at about 30 degrees to the east. At 18 feet from the portal, a quartz vein, about a foot thick and mineralized with pyrite, cuts across the adit and dips steeply to the east beneath a 10-foot dyke of quartz porphyry. The walls of this vein are strongly sheared. Values in the vein are not known.

On the Victoria claim (Locality 15), surface work has exposed two narrow quartz veins, each about 6 inches wide, in which some mineralization occurs. One vein strikes about north 35 degrees west, dips 60 degrees northeast, and is associated with a small dyke of quartz porphyry. The other vein is exposed about 850 feet west of the first, strikes north 35 degrees east, and dips steeply southeast. Both veins intersect greenish, metamorphic rocks and granitic intrusives.

On the Condor fraction (Locality 17) a little surface work has been done, principally to investigate a shear zone several feet wide striking north 75 degrees west and dipping steeply to the north. This shear zone cuts greenish, altered rocks and associated granitic intrusives and has a rusty, oxidized appearance.

Killarney Group (Locality 18)

The Killarney group, comprising the Killarney, Thunder Hill fraction, and Lucky Jim fraction Crown-granted mineral claims, is the property of Wm. J. Banting, Edgewood, B.C. It is situated in the valley of Rampalo creek and the principal workings are accessible by trail, over half a mile long, from the Rampalo cabin. The Killarney claim was staked about 1918. It and the Thunder Hill fraction were Crown-granted in August, 1925, and the Lucky Jim fraction in October of the following year.

Most of the work on this property has been done on the Killarney claim, on the southwestern slope of the valley of Rampalo creek and within 100 feet of the creek bottom where the valley slope is steep. Two main adits and three shorter adits have been driven and considerable trenching and stripping have been done. Vein matter occurring at a number of points has been investigated by this work.

The rocks in the vicinity of the workings are principally greenish, altered, probably volcanics which for the most part are greatly faulted and sheared. They are associated with greyish green intrusives and are intersected by two or more quartz porphyry dykes varying up to at least 10 feet in width.

Early work on this claim was concerned with the discovery of vein matter, carrying argentiferous galena, in wash and broken ground near the creek. "Two tunnels, 25 and 50 feet respectively", were driven and "a few tons of silver-lead ore taken out of this ground.....Samples from the (these) lower workings carried 0·02 ounce in gold, 62 ounces in silver, 60 per cent lead, and 4 per cent zinc."[1] Subsequent operations have been concerned with the discovery of vein matter in place at points higher up the valley slope.

No. 3 adit is the highest and is only a few feet long. At the portal a few inches of vein quartz carrying some galena strikes about north 60 degrees west and dips steeply northwest. A few feet above the adit roof there is a fault, but owing to lack of sufficient exposures here and higher up the hill, it is uncertain what happens to the vein at its junction with the fault. The fault strikes nearly north, dips at a low angle to the west, and has been prospected by a trench for a distance of about 90 feet north from No. 3 adit. At about 50 feet from No. 3 adit the fault as revealed in the trench intersects a narrow quartz porphyry dyke and that part of the dyke east of the fault has, apparently, been offset slightly to the south. The dip of the fault seems to steepen towards the north end of the trench and there an adit or open-cut (No. 3A) has been driven for a few feet in oxidized, broken ground.

The vein visible at the portal of No. 3 adit was apparently picked up in No. 2 adit at a point underground a few feet north of No. 3 adit and 25 feet below it and has been drifted on for 45 feet to the northwest. In this drift the vein dips 50 degrees or so to the northeast, varies in thickness up to a foot or more, and is of quartz carrying a streak of nearly solid sulphide up to several inches wide and composed chiefly of galena with some sphalerite and pyrite. A little stoping has been done above the level mostly near where the adit entered the vein and where the vein is cut off eastward by a strong fault striking nearly north and dipping 35 degrees to the west. Near the face of the drift the vein matter is dislocated and dragged along a fault which may be the one followed by the trench above. At the portal of No. 2 adit, about 40 feet northeast of No. 3 adit and 25 feet below it, a vein several inches wide strikes about north 40 degrees west and dips 60 degrees north. It has afforded a small quantity of silver-lead ore, mostly steely to fine cube galena with some sphalerite and a very little pyrite and chalcopyrite. Under the microscope the galena was seen to contain small bodies of a grey, probably silver-bearing, mineral. This vein may be the faulted continuation of the vein followed in the drift, 25 feet to the southwest.

[1]Ann. Rept., Minister of Mines, B.C., 1922, pp. 171–172.

The portal of No. 1 adit is 40 feet below and 50 feet east of the portal of No. 2 adit. At about 35 feet from the No. 1 portal, a point underground about 25 feet northeast of the entrance to No. 2 adit, a drift was run northerly for about 40 feet along a slip which dips steeply to the west. Some mineralization is reported to have been found along this slip. Owing, however, to the broken character of the ground no correlation of this mineralization with that encountered on the levels of Nos. 2 and 3 adits, is made. The suggestion advanced by Mr. Freeland[1] that the vein on this property is involved in a series of step-faults which throw it successively farther to the north seems logical in the case of the two upper workings and implies that no long, continuous sections are to be expected within the zone of faulting, whose limits have not yet been defined.

The vein or veins on this property have the general west to northwesterly strike and northerly dip characteristic of the main vein on the adjoining Lightning Peak group to the east and at the Waterloo mine 2½ miles to the west, and it may be that the same zone of shearing and mineralization is present on all three properties. If so, prospecting might be done to advantage towards the west boundary of the Killarney claim or beyond on the adjoining Lucky Jim fraction where it is possible that the east-west vein structures, if present, are less severely affected by faulting. A little surface work has already been done in this direction, but the results are not known.

Lightning Peak Group (Localities 19 and 20)

The Lightning Peak group—including the Thunder Hill, First Chance, West Fork, and Jim Hill Crown-granted claims—is owned by C. F. Deither, St. Paul, Minnesota, and W. A. Calder, Edgewood, B.C. The property lies mostly on the steep, northern slopes of Rampalo and Soda creeks and is accessible either by the Galloping Mountain trail which, farther west, reaches the Waterloo mine via the Rampalo group, or by a more recently constructed trail extending south from the Waterloo tractor road. This latter trail has been modified with the idea of providing a tractor route to the property.

Outcroppings of the main vein on this property were discovered and staked in 1901 or 1902 by Frank Fritz and Chas. Harrigan who, about 1903, turned their holdings over to some St. Paul people. The latter, according to Mr. Calder, gave the name Lightning Peak to the camp, having in mind the Thunder Hill camp in Oregon which at that time was attracting considerable interest. In 1904, a 5-ton general sample of ore from the Lightning Peak property gave smelter returns of 164 ounces silver to the ton and 26 per cent lead[2]. In May of 1905 the four claims of the group were Crown-granted, but shortly afterwards operations ceased. In 1906 the property was leased to W. A. Calder and Walter Bull, the former of whom has been identified with this property during most of its history. These lessees extracted shipping ore to the value of $3,200 obtained from operations on and from the uppermost or No. 1 adit on the West Fork claim.

[1]Ann. Rept., Minister of Mines, B.C., 1927, p. 227.
[2]Ann. Rept., Minister of Mines, B.C., 1904, p. 224.

No official records of developments or production between the years 1904 and 1917 are available. From 1917 until 1920 the property is referred to as the Equinox group and during that period was apparently being worked by or under the direction of Mr. Calder. In 1919, 10 tons, and in 1920, 6 tons, of silver-lead ore are reported to have been shipped to Trail[1].

In 1921 and the following three years, the property was worked under lease by William Williams of Edgewood and small shipments are recorded as having been made in 1922, 1923, and 1924. In 1922, No. 3 adit was run and No. 4 adit started; in the following two years development work was chiefly on the lowest level (No. 4 adit).

In 1925 the property was again leased by W. A. Calder who has continued to operate it since that time. Development work during this period has consisted principally in extending No. 4 adit for several hundred feet. Some surface work has also been done on another vein to the north of the cabin (Locality 20) on the First Chance and adjoining Wood Lot claims, the latter being held by location by Mr. Calder. In 1927, 35 tons of ore was rawhided out and shipped to Trail. Altogether, the property is credited with shipments of about 200 tons of silver and silver-lead ore, averaging, on the whole, about 150 ounces in silver to the ton and 35 per cent lead. Mr. Calder reports that in addition about 200 tons of milling ore has been left on the dumps.

The rocks exposed on this property are largely greenish metamorphic rocks, probably of volcanic origin. They are in part quite massive, but in places, as in the vicinity of the main workings, are greatly sheared and fractured. They are intersected by a variety of intrusives and their metamorphism is principally ascribed to intimately associated, irregular bodies of grey to greenish grey, granitic rock of about the composition of granodiorite or quartz diorite. On the First Chance and Jim Hill claims they are in contact with a large body of pink granite. In the vicinity of the main workings and elsewhere, they are intersected by a number of fine-grained, quartz porphyry dykes and by coarser-grained dykes of granodiorite porphyry. A number of small, coarse, pegmatitic dykes were also observed. The quartz porphyry and granodiorite dykes appear to have had some structural control over ore mineralization.

Work has been chiefly concerned with the exploration and development of the main vein or vein zone, a sheared and fissured zone, of uncertain width, which traverses the altered, greenish, volcanic rocks and associated intrusives in a general east and west direction. This zone is intersected by numerous faults having a general north strike and, mostly, a steep dip to the west. In the intervals between the faults, vein matter has been discovered along, in some cases, well-defined, but, in others, poorly marked, fissures or shear zones which terminate abruptly on encountering the north-south faults. The character of the mineralization in the segments between the faults varies from segment to segment, so that although the faults do not appear to be mineralized there nevertheless seems to be some grounds for supposing the faulting to be at least partly pre-mineral in age.

Workings on the main vein zone include a shaft, 95 feet deep, four adits, and considerable surface work and investigate the main vein over a vertical range of about 200 feet and a length of nearly 1,000 feet

[1]Ann. Repts., Minister of Mines, B.C., 1917–1920.

on either side of the First Chance and West Fork claim boundaries. Most of the production has come from workings in the vicinity of the main shaft on the West Fork claim. This shaft was sunk on the vein, which dips steeply to the north. From the bottom of the shaft, at 95 feet below the surface, a drift is reported to run to the east for 60 feet. Some good lead ore is stated to have been obtained from the bottom of the shaft, one carload carrying 37 per cent and another 35 per cent lead. At 35 feet, vertically, the shaft meets a drift which runs west for 60 feet to join crosscut adit No. 1 (now caved). Stopes extend to the surface west of the shaft. For 50 feet or so on either side of the shaft the vein lies in a dyke of sheared, medium-grained granodiorite porphyry. East of the shaft the main vein has been traced on the surface for about 250 feet and in this direction is stained with copper carbonates and carries a little galena. West of the shaft the same vein has been traced on the surface for 150 feet and near this point has been picked up by a short crosscut adit (No. 2) and drifted on for 25 feet. A little stoping has been done above the adit level, near the floor of which the vein is cut off by a fault striking about parallel with the vein but dipping to the south. Fifty-five feet west of the shaft a narrow quartz porphyry dyke is cut off at the hanging-wall side of the main vein and reappears on the foot-wall side 93 feet farther west.

Between No. 2 adit and No. 3 adit, 360 feet farther west, the vein encountered in No. 2 adit has been picked up in two open-cuts, in the more easterly of which narrow stringers of vein matter carrying argentite are reported to have been found.

No. 3 adit is 100 feet vertically below the collar of the shaft. This adit runs easterly, is 95 feet long, and follows the main vein. At 64 feet from the portal a winze connects with a raise from the end of a crosscut at No. 4 level. Referring to the drift and winze, Freeland reports that "the ore . . . . . occurred in lenses in a 4-foot lead. In the vicinity of the shaft (winze) high values in silver and lead were obtained."[1]

Work on No. 4 adit level has encountered more difficulties in the way of following vein matter than had been anticipated from work at the surface and in the upper levels. The adit commences 145 feet west of the mouth of No. 3 adit and 60 feet vertically below it. No. 4 adit runs east and is 745 feet long, the face being about 120 feet north of the shaft and 155 feet below the collar of it. In the first 60 feet or so the vein matter was much disturbed, but is stated to have provided between 8 and 9 tons of ore carrying 200 ounces of silver to the ton and about 1 per cent lead and 4 per cent copper. This ore was mostly stoped from about midway of this distance where the wall-rock is partly quartz porphyry, probably representing a spur or spurs from a large dyke which extends northerly up the slope of the hill a few feet to the west of the portal of No. 4 adit.

At 90 feet from the portal another dyke of similar character was encountered. It is about 20 feet thick and is bounded by faults. The fault along the west edge apparently displaced the vein to the south where it was picked up by a crosscut in this direction. The displacement effected by the second fault, on the east side, is not known. Beyond it, no vein

[1]Ann. Rept., Minister of Mines, B.C., 1922, p. 171.

matter was picked up for about 140 feet along the strike of the vein. The ledge matter where it is again struck in the drift dips steeply to the south and has been followed for about 70 feet to where it is apparently cut off by another north-south fault. In this distance of 70 feet the vein matter corresponds in character with that observed in No. 3 adit and in the two open-cuts mentioned as being situated east of No. 3. The open-cuts lie 40 to 60 feet south of, and 100 feet above, this section of No. 4 adit. West of where No. 4 adit enters the vein for a second time, a crosscut runs south and ends in a raise connecting with a winze from No. 3 adit. In the winze and raise the vein changes its dip with depth, from steep to the north on No. 3 level to steep to the south on No. 4 level. It, presumably, continues east from the foot of the raise through about 50 feet of unproved ground to where No. 4 adit again strikes the vein. On No. 4 adit-level the vein for the next 70 feet east lies along the hanging-wall of a narrow quartz porphyry dyke. At the end of the 70-foot section, the vein is abruptly cut off by a north-south fault. One hundred and thirty feet farther east along the general direction of strike, a quartz vein was struck and followed east for 140 feet to where it enters faulted ground. Fifty feet beyond this, towards the face of the adit, the ground is again extremely broken and sheared. East of a fault marked by a width of several feet of strongly sheared rocks, vein matter occurs and continues 15 feet to the face of the drift. This vein matter may be the faulted continuation of vein matter discovered in a crosscut run a short distance southerly at the east end of the 140-foot vein section. A little ore was discovered in this crosscut.

The vein matter still exposed in the underground workings varies in character and, judging from the values obtained from shipments to date, varied in like manner in different parts of the mine. Mostly this vein matter is represented by from one to several feet of sheared rock within which quartz forms narrow veins and lenses or occurs intimately distributed through, and partly replacing, the wall-rocks. A little calcite is associated with the quartz. The ore minerals are chiefly galena and sphalerite; lesser amounts of pyrite, chalcopyrite, and high-grade silver minerals are present. At the face of No. 4 level, fractures within the ledge matter carry a noticeable amount of native silver. Ruby silver has been reported to occur in the raise between Nos. 3 and 4 levels and argentite is stated to have been found in an open-cut. Doubtless high-grade silver minerals were also encountered in the more easterly workings in the vicinity of the shaft.

The 140-foot length of vein in adit No. 4 is a more regular vein of quartz several inches thick carrying streaks and sparse disseminations of ore minerals, chiefly sphalerite. It lies between strong walls. In these various respects it differs from the ledge matter occurring in this adit both to the east and to the west. It may be, therefore, that the 140-foot section is not a part of the same vein as is drifted on farther west for a length of 70 feet and which eastward terminates at a north-south fault. If the fault is younger than the vein ending against it, it seems likely, both from work done farther east along the level and from the disposition of vein matter in the surface and the near surface workings, that the offset continuation of the 70-foot vein section would lie 20 feet or so south of the adit level. This possibility might be investigated by a crosscut to the south from No. 4 level at some convenient point, or by locating the fault at the surface and finding the vein outcrop on either side of it. If, however, displacement

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along this fault occurred mostly or entirely in pre-mineral time, the vein mineralization that occurs on either side of it must be interpreted as representing separate veins which may or may not have any structural connexion with one another.

In addition to workings on the main vein or vein zone, some surface exploration has been done on a quartz vein (Locality 20) occurring along the hanging-wall, east side, of a wide dyke of quartz porphyry. This dyke strikes about north 20 to 25 degrees east, underlies the cabin on this property, and passes a little to the west of the portal of No. 4 adit. The principal showing occurs about 725 feet north of the portal of No. 4 adit or 450 feet north of the cabin. At this point the quartz vein is 2 feet wide, dips steeply east, and is conspicuously mineralized with disseminated pyrite and galena. The quartz has a somewhat banded appearance. The vein has been exposed for only a few yards at this locality and was not observed farther south, but outcrops of vein-quartz noted at intervals farther north on the First Chance and Wood Lot claims may be parts of the same vein. The more northerly showings are narrower and not as well mineralized as the main outcrop.

Pay Day Group (Locality 21)

The Pay Day group, consisting of the Pay Day and nine other claims held by location, is the property of Walter B. Johnstone, A. Williams, *et al.*, of Edgewood, B.C. The principal workings lie about 1,000 feet east of the Galloping Mountain trail and about a mile northeast of the Lightning Peak mine.

The rocks in the vicinity of the workings are in part metamorphosed greenish to greyish green, dense to finely crystalline types, in part of volcanic origin, and in part probably sedimentary. A specimen of a dark grey-green, rather vitreous, crystalline rock, much resembling a quartzite in the hand specimen and obtained from an outcrop 300 feet northwest of the tunnel on this property, was examined microscopically and found to be composed of a mosaic of quartz and feldspar with many large crystals of plagioclase, about oligoclase-andesine (Ab 65: An 35). Scattered through the mosaic are abundant small shreds and crystals of green, strongly pleochroic amphibole, considerable titanite, and small veins and patches of calcite. This rock is probably of tuffaceous or possibly sedimentary origin. It and others like it are associated with more greenish types much resembling rocks observed at the Lightning Peak mine and regarded as being, probably, altered andesitic lavas. The metamorphosed rocks are invaded by others of granitic facies and a body of granodiorite, between 200 and 300 feet wide, lies southwest of the main workings and extends northwesterly across the Galloping Mountain trail for a distance of at least several hundred feet.

Development work on this property includes numerous trenches and an adit 60 feet long. The trenches were for the purpose of tracing a mineralized zone lying within metamorphic rocks close to the northwest edge of the body of granodiorite referred to above. The zone has a general north to northwest strike, and is reported[1] to have been traced at the surface for 600 feet and to vary from 2 to 6 feet in width. In the adit, which is a crosscut at a depth of about 30 feet below the outcrop, the zone is

[1]Ann. Rept., Minister of Mines, B.C., 1929, p. 256.

entered at 40 feet from the portal and continues to the face. It lies mostly if not entirely between two faults striking about north. The fault at the face dips 60 degrees west, the other fault is nearly vertical. A third fault intersects the mineralized zone about 8 feet from the face of the adit.

Underground, the mineralized zone carries a varying but high percentage of sulphides, both massive and banded, and as heavy impregnations in the country rock. The sulphides are associated with quartz and lesser amounts of calcite and ankeritic carbonate. The more abundant sulphides are pyrite, sphalerite, and chalcopyrite. Magnetite is plentiful in places. Other minerals include a little pyrrhotite and galena. A sample taken by the resident engineer, across a width of 10 feet of the more solid sulphide material, assayed: gold, trace; silver, 30 ounces to the ton; copper, 4·2 per cent; lead, nil; zinc, 12 per cent; nickel, nil; arsenic, nil; bismuth, trace[1]. The greater width of the mineralized zone at the adit level as compared with its width at the surface may be due to duplication by faulting. At the surface the zone is strongly oxidized.

Big Hill Claim (Locality 22)

A little prospecting has been done on the Big Hill claim situated nearly 2 miles by trail, north of, and accessible from, the Lightning Peak property. It is owned by W. A. Calder, Edgewood, B.C.

There, on the east bank of Big Hill creek, a fault follows the contact of a granitic intrusive with a greenish altered rock. The fault strikes northerly and dips about 60 degrees west. No ore minerals were noted, though the rocks at the contact are stained with iron rust. It is reported that films of argentite have been found coating fractures within the fault zone, which is at least several inches wide.

Pilot and Uta Claims (Locality 23)

The Pilot and Uta are adjoining claims held by location by Messrs. Nels Melstrom and Adam Scaia, respectively, Edgewood, B.C. They are situated north of the Waterloo tractor road about 3 miles east of the Waterloo mine.

The claims lie within an area of highly altered, greenish rocks of uncertain but probably volcanic origin. The metamorphosed rocks are saturated with granitic material and are intersected by quartz porphyry dykes. At one point near the boundary line between the two claims, a dark, olive-green, basaltic dyke several feet wide was observed to strike northeast, and dip 60 degrees southwest.

This dyke is possibly of Tertiary age. On the southwest edge of the dyke a belt several feet wide of sheared and decomposed greenstone carrying a little disseminated pyrite has been investigated by three or more trenches.

The principal work has been done in the vicinity of the Discovery post on the Pilot claim where a trench 80 feet long, and other smaller trenches reveal greenish, highly altered rocks carrying disseminated pyrite and, more locally, chalcopyrite, and, in one place, some molybdenite. The mineralization so far discovered is not of economic value, but is widespread.

[1]Idem, p. 256.

ST. PAUL GROUP OF MINERAL CLAIMS, OSOYOOS DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes

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INTRODUCTION

The St. Paul group, comprising the Toughnut, Zilpah, Minerva, and Black Bess Crown-granted claims and the Pioneer, Iron Horse, and Sheppard claims, held by location, occupies part of the summit and northwestern slope of Monashee mountain, Vernon mining division, Osoyoos district, British Columbia. The property is owned by St. Paul Mines, Limited, a syndicate consisting of three individuals, Dr. O. Van Etter, New Westminster, B.C., and Messrs. O. M. Sheppard and Rube Brown of Bellingham, Washington.

The group is accessible from the Vernon-Edgewood highway. A branch road, one mile long, leads off from the highway about 42 miles east of Vernon, and is continued by a trail which follows up the valley of Yeoward[1] (Porcupine) creek on a gentle gradient for about 2½ miles to an old camp and 2-stamp mill belonging to the company and situated on the Sheppard claim. The trail here crosses to the south side of Yeoward creek and climbs rather steeply up the northerly slope of the mountain, passing the St. Paul mine workings on the Toughnut claim, at an elevation of 1,220 feet above Yeoward creek (about 4,800 feet above sea-level) and reaching the old Morgan workings (on the Minerva claim) on the summit of Monashee mountain, at an additional height of 1,000 feet. From this summit the trail continues westerly down the easterly slope of Monashee Pass creek to connect again with the Edgewood-Vernon highway.

The property has had a varied history extending over a period of about forty years, during which intervals of active prospecting and development have alternated with relatively long intervals of idleness. In the early days effort was entirely concentrated on the uppermost or Morgan workings, named after the trapper who first staked the claim on which they lie. This claim and adjoining ground after being restaked and after many changes in ownership was acquired, in 1926, by the present owners. In all, a few hundreds of tons of ore have been shipped or given mill tests and reported to carry high values in gold. More recently, in 1927, 11 tons of ore from No. 1 adit on the Toughnut claim were shipped to the Trail smelter and ran[2]: gold, 0·50 ounce and silver, 147·9 ounces, to

[1] A southern tributary on Monashee (South fork of Cherry) creek.
[2] Ann. Rept., Minister of Mines, B.C., 1927, p. 213.

the ton; lead, 12·4 per cent; zinc, 0·2 per cent; antimony, 17 per cent; sulphur, 17·4 per cent; silica, 25·4 per cent; iron, 13·2 per cent; and lime, 0·7 per cent, and had a gross value of $1,074.64. In addition, ore now stacked at the mine includes 8 tons or more of high-grade silver ore and about 40 tons of good-looking mill-feed.

The workings on the Minerva claim are quite inaccessible. They include two shafts, one reported to be 80, and the other 35, feet deep. The 35-foot shaft and a drift run from it are stated to have provided most of the tonnage produced from this claim. The St. Paul mine workings are in good repair. They include five adits varying from 35 to 330 feet in length, and a number of trenches which have exposed the underlying formations over distances of from a few feet to about 150 feet. A couple of open-cuts and two winzes complete the development work at this locality.

GENERAL GEOLOGY

The rocks exposed in the vicinity are largely greenish volcanics with some intercalated sediments. One intrusive body, of diorite, is known. The trail up Yeoward (Porcupine) creek exposes volcanic types at a number of places and similar rocks outcrop at intervals along the trail between the St. Paul and old Morgan workings. The hillside below the Morgan workings is heavily drift covered and no outcrops were observed. The St. Paul workings expose a belt of sediments, including argillaceous types and some limestone, and the same rocks appear in the bottom of a creek a few hundred feet west of the mine. These sediments were observed for only a short distance above the mine, but in the opposite direction they may have a more considerable width. The upper slopes of the mountain and the summit in the vicinity of the old Morgan workings are underlain chiefly by greenish, andesitic, volcanic rocks. The volcanics and sediments have a general east strike and for the most part a southerly dip. They lie in an area mapped by Dawson as occupied by the Cache Creek series regarded by him as being Upper Palæozoic.[1]

The St. Paul mine workings have exposed an intrusive body of diorite of unknown but, apparently, considerable dimensions. It is a medium-grained, nearly equigranular, dark grey rock carrying disseminated pyrite and in places quite heavily mineralized with this iron sulphide. At the surface and partly as a result of this mineralization the rock readily weathers to a highly decomposed, rusty rock. A specimen of the fresher rock obtained underground was examined microscopically and found to consist largely of plagioclase feldspar (about oligoclase-andesine, $Ab_{70}An_{30}$) and biotite, with 5 to 10 per cent of orthoclase and a like amount of a pyroxene, probably diopside. A very little quartz is present. Alteration products include chiefly calcite and chlorite. The plagioclase is partly zoned. Beyond the immediate vicinity of the mine workings the extent of the diorite body is unknown nor is it known whether other bodies of intrusives are or are not present beneath the drift on the slope of the mountain. The diorite may be supposed to be related to the Mesozoic batholithic intrusion so extensively represented a few miles to the south of Monashee mountain and between there and Arrow lakes.

[1]Dawson, G. M.: Geol. Surv., Canada, Shuswap Sheet.

ECONOMIC GEOLOGY

Mineralization at the Morgan and St. Paul workings occurs chiefly in the form of quartz veins. Those that have been investigated on the Minerva claim (Morgan workings) carry free gold and are valued chiefly for the gold content associated with the sulphide minerals, whereas the ore from the veins of the lower or St. Paul workings is notable for its high silver values and though always carrying some gold this has not been noted in the free form.

The vein system at the upper or Morgan workings is not clearly indicated by what could be seen. From earlier reports it appears that development work was concerned with two or more quartz veins averaging about 1½ feet thick, trending northwesterly, and dipping about 45 degrees southwest and with at least one important cross-vein striking about at right angles to the others. Specimens from small piles of broken vein quartz indicate that in addition to occasional specks of free gold the quartz carries an irregular dissemination of pyrite with some arsenopyrite and here and there a little galena and zinc blende. The "cross" vein was developed from the 35-foot shaft. The northwesterly striking vein or veins may extend down the hill to the vicinity of the St. Paul workings, though as the two localities are half a mile or more apart and are separated by an interval of poor exposures the continuity of particular veins over this distance would be difficult to verify.

The vein system at the St. Paul workings is better exposed. Vein quartz has been found at a number of places in surface and underground workings mostly within and not far from the southern contact of the diorite body. This contact is marked underground by strong faulting or shearing. The relative positions of the exposures of vein quartz underground and at the surface suggests that in the vicinity of the southern contact there are probably two principal veins with others of subsidiary importance. One principal quartz vein is exposed by Nos. 1, 2, and A adits (*See* Figure 9). In No. 2 adit it is visible for a length of 30 feet, commencing about 10 feet from the portal, and continuing to the right angle turn in the adit, it strikes northeasterly and dips at a low angle to the southeast. In the workings of No. 1 adit it dips at a low angle to the south, passing below the floor towards the south limits of the workings and rising to the roof towards the north limit of the workings. It is visible along the length of A adit, in which it strikes southeasterly and dips at low angles to the southwest. This vein probably averages a foot in thickness and has provided much of the ore extracted.

What appears to be a second vein of importance has been recently found in No. 3 adit about 50 feet from the portal. At the time visited this vein was continuous to the face of the adit, a farther distance of about 20 feet. In this distance the vein dips at a low angle to the south or southeast. At the face it has a maximum width of between 3 and 4 feet composed of heavily mineralized diorite and from several inches to 2 feet of nearly solid sulphides, principally a mixture of arsenical iron with streaks and small kidneys of antimonial sulphides, mostly jamesonite. A sample taken by the management across 2 feet of such ore is reported to have assayed 0·28 ounce gold and

11·7 ounces in silver to the ton. The writer is informed that since he examined the property, No. 3 adit has been extended 50 feet or so, all in diorite, and that at the present face a quartz vein 3 inches wide was encountered from which a sample assayed: gold, 5·12 ounces; silver, 5·5 ounces; and 9 per cent lead. This small vein is stated to dip about 40 degrees to the south. It may be a continuation of the vein developed in No. 1 adit.

A small quartz vein (or veins) is exposed in trenches Nos. 2, 3, 4, and 5 (*See* Figure 9). Whether these exposures represent different veins or the faulted continuation of one vein (or veins) is not certain. The vein quartz in each case varies from 2 to 6 inches in width and is poorly mineralized.

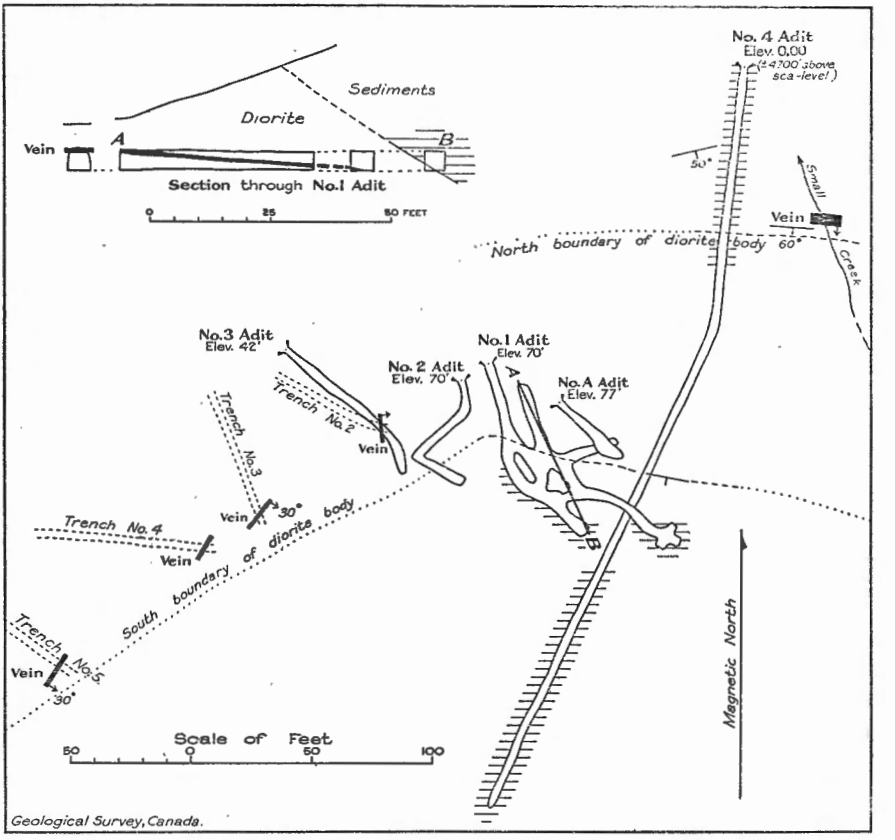

Figure 9. St. Paul workings, St. Paul group, Monashee mountain (the parts of underground workings driven in sediments are bordered by a pattern of parallel lines, other parts are in diorite.)

A showing somewhat similar to the main sulphide showing in No. 3 adit is exposed in the bed of a small creek 70 feet south of the portal of No. 4 adit. This is an outcrop of heavily mineralized vein matter of indefinite shape but evidently several feet in width[1]. It probably

[1]It probably is the "large body of arsenical-iron ore" referred to in the Ann. Rept. of the Minister of Mines for 1913.

represents a mineralized zone closely following the northern contact of the diorite body. Mineralization of somewhat similar character was encountered in No. 4 adit about 70 feet from the portal and it is understood that since the visit by the writer, some drifting has been done on this from the adit level. A number of assays of samples taken from the creek showing are reported in most cases to have disclosed low values in silver and gold, not exceeding $5 a ton combined. One sample representing about 100 pounds of massive sulphide material is stated by the owners to have assayed 0·41 ounce in gold and 38·8 ounces in silver to the ton.

The gangue of the veins in most of the showings at the St. Paul mine is largely quartz. With it is associated a varying proportion of sulphide minerals occurring as disseminations or as streaks, bunches, or small kidneys of nearly solid mineral. The sulphides are principally arsenopyrite, antimonial sulphides, pyrite, and pyrrhotite in about this order of abundance. Very small amounts of galena, sphalerite, and copper pyrites are present and native silver occurs in microscopic specks. The sulphides of the creek showing are chiefly arsenopyrite and pyrite and the proportion of quartz is smaller than elsewhere. Samples from all the various vein exposures are reported to have carried $2 to $10 in gold a ton. No free gold has been observed. Silver values vary with the amount of antimonial sulphides present. At least three such sulphides are present. The most abundant of these carries lead and resembles jamesonite in its physical and microchemical properties. Intimately intergrown with it is another with very similar properties and which, probably, is stibnite. The third is tetrahedrite (grey copper) and occurs in very minor amounts and mostly in microscopic particles. The sulph-antimonides occur in various ways: as streaks or irregularly lying bands in the quartz and varying from less than an inch to several inches in thickness; as bunches or small kidneys lying either in quartz or in masses of other sulphides; intimately associated with other minerals, chiefly arsenopyrite ; and as crystals disseminated through the quartz. They occur massive or finely granular or in masses with a coarsely fibrous and bladed structure.

Arsenopyrite is abundant. It occurs in small, well-formed crystals scattered through the quartz and in crystalline masses or aggregates intimately associated with the other sulphides. Pyrite is much less plentiful. A little pyrrhotite is also present. Galena and sphalerite are even less conspicuous. The gold values appear to be associated with the arsenical and iron sulphides or at any rate seem to be quite independent of the amount of antimony sulphides present.

As stated on an earlier page 11 tons of ore shipped to Trail in 1927 carried in addition to gold and silver:

	Per cent
Lead	12·4
Zinc	0·2
Antimony	17·0
Sulphur	17·4
Silica	25·4
Iron	13·2
Lime	0·7
	86·3

Arsenopyrite is an abundant constituent of the ore and if it be assumed: that the arsenic content of the shipment was 13 per cent and was wholly carried by the arsenopyrite; that the iron not present in arsenopyrite was combined with sulphur to form pyrite and pyrrhotite; that the lead was carried by jamesonite; and that the antimony not required for the jamesonite was present in stibnite, the mineral composition of the 11-ton shipment would be about as follows:

	Per cent
Arsenopyrite	28·2
Pyrite (and pyrrhotite)	6·9
Jamesonite	26·7
Stibnite	11·4
Quartz	25·4
Other minerals	1·4
	100·0

As stated on a previous page, very little can now be seen at the old Morgan workings on the Minerva claim. According to statements made in provincial reports, it appears that picked samples of the quartz veins carried attractive values in gold and that most of the gold was free gold. In 1914, 130 tons of ore were treated in a 5-stamp mill and the writer has been informed that the gold content was high. Any further work on the Minerva claim should first consist of systematic surface prospecting to determine the widths and lengths of the quartz veins and the veins should be carefully sampled at close intervals. The information thus obtained would indicate what development work, if any, should then be undertaken.

In the case of the St. Paul workings much information regarding the veins is available. Apparently they lie within or close to the edge of the intrusive body of diorite which at the workings is narrow and dips south at rather high angles. It follows, therefore, that any further prospecting work might profitably take the form of tracing, at the surface, the boundaries of the diorite body and of searching for mineralized veins in the vicinity of such boundaries.

MINERAL DEPOSITS ON ABERDEEN MOUNTAIN, OSOYOOS DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes

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INTRODUCTION

Aberdeen mountain is a large topographic feature in Vernon mining division, Osoyoos district, British Columbia. It is situated on the western edge of the Columbia system of mountains overlooking, to the west and south, parts of the great belt of Interior Plateaux and, towards the east and northeast, more rugged ranges of the Columbia system. The mountain is the high point of a large mountain massif lying about midway between Shuswap and Trinity valleys on the west and east, respectively, and between the main Shuswap valley to the north and Coldstream valley on the south. Though several hundred feet higher than other mountain summits within a radius of 20 miles or more, Aberdeen mountain, by reason of its comparatively gentle slopes and broad, round-topped summit, is less conspicuous than its superior height might seem to indicate.

The easiest approach to the mountain is from Vernon by a road and trail about 15 miles long, leading northeasterly up the valley of B.X. creek. Over two-thirds of this distance to a height of 2,600 feet above Vernon may be negotiated by car. From this elevation a good trail leads to the summit 6,200 feet above sea-level, an additional climb of 2,400 feet. An alternative route is by trail from the Trinity Valley road. This trail branches off about half a mile north of the mouth of Vance creek; is between 8 and 9 miles long; and reaches the summit after a climb of about 3,850 feet. It is not in good repair.

A lookout station of the Provincial Forestry service is located on the summit of Aberdeen mountain of which the upper 500 feet or so is scantily timbered. Bedrock is here well exposed and the rounded character of the summit is seen to have been partly the result of glacial erosion. Prominent grooves striking about 25 degrees east of south indicate the direction taken by overriding ice in the Pleistocene period.

Interest in Aberdeen mountain was aroused in the mid-nineties by the discovery, near the summit, of vein quartz carrying values in silver, lead, and gold. This discovery was staked as the *Silver Queen* mineral claim, and, about 1896, was acquired by the Silver Star Mining Company. A shaft was started at a point 2,500 feet northeast of, and 200 feet below, the summit of the mountain. It was sunk on a ledge, largely of vein quartz, reported to be about 5 feet wide. This ledge carried galena and iron sulphides and assays of samples from the surface are stated[1] to have given $50 in silver and $8 in gold to the ton.

[1]Ann. Rept., Minister of Mines, B.C., 1896, p. 579.

This discovery resulted in the staking of some twenty-five claims in the vicinity and northerly along the summit of the ridge over a distance of about 2 miles. On a number of the claims a little work was done in the shape of shallow shafts, short adits, and open-cuts. Samples from such workings were reported to hold rather high values, chiefly in silver and gold, but the samples appear to have been selected samples or specimens from small stringers or pockets of high-grade material occurring in vein quartz otherwise comparatively barren or too low grade to be worked at a profit.

More recently fragments of high-grade silver-lead ore were discovered in a slide on the east slope of the mountain below the workings on the Silver Queen claim at about timber-line.[1] Blocks up to several inches in diameter of nearly solid galena were found and, presumably, have come from some nearby source.

To obtain a general idea of geological conditions and economic possibilities of the Aberdeen Mountain massif, the writer, during the field seasons of 1929 and again in 1930, spent a few days traversing the mountain and examining the area in the immediate vicinity of the top of the mountain.

GENERAL GEOLOGY

A large part of the mountain massif, including the higher parts, is underlain by dark grey, argillaceous beds varying from massive to slaty types and interbedded with some quartzitic strata and, in places, a little dark grey limestone. Locally such rocks are also interstratified with a large proportion of grey to greenish grey, fragmental rocks of tuffaceous appearance. Associated chiefly with the tuff-like strata are beds, up to several feet thick, of rocks much resembling fine conglomerates. Strata of this latter sort are well exposed at and near the summit of the mountain where they have a squeezed appearance, and an abundant, chiefly argillaceous, matrix. The contained fragments are mostly quite angular and show up best on weathered surfaces. They are of fine-grained rocks, some of which resemble volcanics and others, sediments.

The general strike of the strata is about northwest on the eastern slopes of the massif, but towards and on the summit of the mountain it swings more to the north. The dips are prevailingly to the northeast and east.

Overlying this great assemblage of stratified rocks and observed particularly on the slope of Trinity valley, on the east side of the mountain, for a distance of well over a mile south of Putnam creek, is a wide belt of igneous rocks probably chiefly of volcanic origin. It was not determined where, if at all, this belt crosses the summit of the divide to the west, but, in any case, the contact would lie at least a mile and probably considerably more north of the summit of Aberdeen mountain.

Partly surrounding the Aberdeen Mountain massif and extending well up its eastern flanks are extensive areas underlain by highly metamorphosed rocks including much granitic and gneissic material. These rocks resemble Dawson's Shuswap series. They occupy much of the basin

[1]Ann. Rept., Minister of Mines, B.C., 1926, p. 200.

of B.X. creek and cover a large area extending from there northward to the vicinity of Armstrong. They also occupy much of the country lying between Spallumcheen and Trinity valleys for several miles south of Shuswap river and are exposed again for several miles in Trinity valley commencing about 1½ miles south of Putnam creek.

A number of small, intrusive bodies of rather basic composition were found at a few scattered points towards and on the summit of Aberdeen mountain. The bodies are small, some are dyke-shaped, but others may be small stocks. Such intrusives are exposed in the vicinity of the old Silver Star workings; in the vicinity of the slide on the east slope of the mountain where the float galena ore was recently found; and at two places about a mile southwest of the lookout station. One of these latter places is on the Vernon trail about 1¼ miles from, and 900 feet below, the Lookout. The intrusive there is a rather coarse-grained, dark green hornblende gabbro. It has an apparent width along the trail of about 250 feet. The same type of rock outcrops about half a mile to the north-northwest and probably the two exposures are parts of one broad dyke.

ECONOMIC GEOLOGY

Little information was obtained as to the character or quantity of mineralization encountered in the early years on the various claims. On the Silver Queen (Silver Star mine) two shafts were sunk to depths of 65 and 45 feet, respectively, on a quartz ledge striking east and carrying galena, pyrite, and chalcopyrite.[1] These shafts are now inaccessible. They are 300 feet apart and about in line with the strike of the enclosing strata which trend northerly and dip to the east. Some of the vein quartz on the dumps holds abundant pyrite and some galena and chalcopyrite. The wall-rocks appear to have been strongly impregnated with pyrite and to be of two kinds. The more abundant is a dark grey argillite, but the other, a greenish grey, crystalline rock carrying abundant brownish-weathering carbonate and evidently greatly altered, may have been a basic intrusive.

A number of other occurrences of vein quartz were noted at widely separate localities along and near the summit of the ridge. At some of these a little prospecting had been done. The associated rocks are mainly sediments of the types mentioned above. The quartz veins seen are for the most part barren of visible ore minerals, but here and there a little sulphide is to be seen.

[1]Ann. Rept., Minister of Mines, B.C., 1900, p. 886, and 1902, p. 188.

CLEARWATER RIVER AND FOGHORN CREEK MAP-AREA, KAMLOOPS DISTRICT, BRITISH COLUMBIA

By J. F. Walker

CONTENTS

Illustration

INTRODUCTION

Clearwater River and Foghorn Creek map-area lies between longitudes 119° 45′ and 120° 15′ and latitudes 51° 30′ and 51° 45′, and includes the country surrounding the junction of the Clearwater with North Thompson river about 80 miles north of the city of Kamloops. The main line of the Canadian National railways follows North Thompson valley across the map-area. The North Thompson highway, which will eventually connect Vancouver, Jasper, and Edmonton, follows the north and westerly side of the valley throughout the map-area. It is at present a narrow, unsurfaced road. Two ferries, one at Birch Island and one near Black Pool, connect the highway with the railway and with branch roads on the opposite side of the river, and operate between the spring break-up and the freezing over of the river in winter, when crossings can generally be made on the ice. A bridge at Clearwater, constructed in 1930, makes the railway accessible at all seasons to residents on the opposite side of the valley.

The Provincial Forestry service is constructing excellent pack-trails within and also beyond the map-area. One completed in 1930 is the Star Lake, Grizzly Lake, and Clearwater River trail. Good trails lead from Birch Island up Foghorn creek and Foghorn mountain. The old trails to Foghorn mountain from the road east of Queen Bess ridge are passable. A forestry lookout has been built on mount McClennan and it is reached by a good pack-trail from a point on the highway about 6 miles east of Birch Island. There is a good trail up Raft River valley, but the one now used leaves the highway a mile north of Irvine, and crosses a low divide into Raft River valley. Irvine is 14 miles northeasterly from Birch Island. The road and trail following Lemieux Creek valley in the south-west corner of the map-area join the highway at mount Olie about 6½ miles to the south.

The map-area comprises about 360 square miles, of which about 220 square miles were topographically mapped by D. A. Nichols in 1919. The geological field work of four months upon which this report is based was carried out during 1930. J. S. Stevenson, V. Y. McDowall, and R. A. Halet acted as field assistants. Field work was facilitated through the courtesies of forestry officials and residents of the district and the writer takes this opportunity of expressing his appreciation of the assistance thus rendered.

First mention of geological features in this area was made by A. R. C. Selwyn in the annual report of the Geological Survey for the years 1871 and 1872. W. L. Uglow, in 1921, mapped an area along North Thompson valley to the south and also made some observations within this area. The annual reports of the B. C. Minister of Mines for the years 1899, 1900, 1901, 1909, and 1913, to the present, describe the prospecting and mining activities within the area.

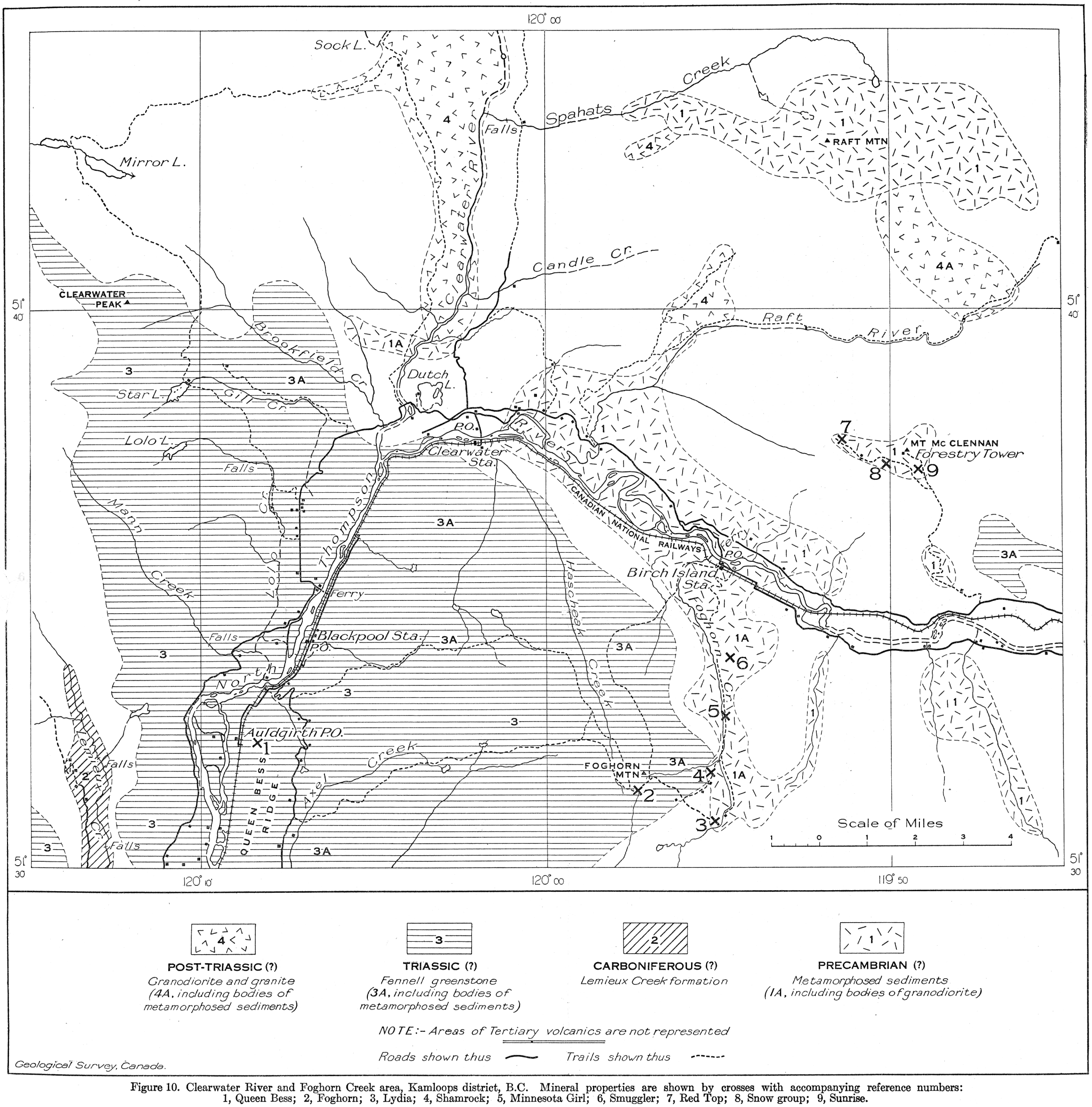
PHYSICAL FEATURES

The map-area lies in mountainous country on the eastern margin of the Interior Plateaux. The deep valley of the North Thompson traverses the map-area, following a direction north of west from the east side to the junction with Clearwater river where it makes a right-angled bend and follows a direction west of south. Clearwater valley, comparable in size with the North Thompson, follows a course west of south, joining the North Thompson at its bend. The valley bottom of the North Thompson averages about a mile in width and has an elevation of 1,300 to 1,400 feet above sea-level. The valley of the Clearwater has been filled with Tertiary lavas in which the river has entrenched itself, leaving a high bench on the eastern side. Raft river parallels the North Thompson in its upper reaches and occupies a wide valley with an elevation of about 2,500 feet, but near its mouth is confined.

The valley sides of the North Thompson and the Clearwater in places rise steeply for about 1,500 feet to elevations of 3,000 to 4,000 feet, above which the slopes are more gentle. This marked change in the rate of slope is also well displayed in the small valleys of Mann and Foghorn creeks. The height at which the change takes place in North Thompson valley, about 1,500 feet, is somewhat less than that given by Uglow[1] as applying to the same valley to the south.

Looking across the district from any of the higher summits, the impression received is that of an uplifted, mature, mountainous country. The uplift is indicated by the change of slope already alluded to and suggests that the old level of the valley bottom of North Thompson river now lies 3,000 feet above the sea. This being so the relief of the mature, mountainous surface would average about 3,000 feet, with occasional summits rising 2,000 feet higher. Except where erosion has attacked the higher summits, since the uplift, the district is one of rounded, wooded hills with intervening, broad valleys in some of which the larger streams have entrenched themselves.

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 89.



POST-TRIASSIC (?)
Granodiorite and granite (4A, including bodies of metamorphosed sediments)

TRIASSIC (?)
Fennell greenstone (3A, including bodies of metamorphosed sediments)

CARBONIFEROUS (?)
Lemieux Creek formation

PRECAMBRIAN (?)
Metamorphosed sediments (1A, including bodies of granodiorite)

NOTE:- Areas of Tertiary volcanics are not represented

Roads shown thus ——— *Trails shown thus* - - - - -

Geological Survey, Canada.

Figure 10. Clearwater River and Foghorn Creek area, Kamloops district, B.C. Mineral properties are shown by crosses with accompanying reference numbers: 1, Queen Bess; 2, Foghorn; 3, Lydia; 4, Shamrock; 5, Minnesota Girl; 6, Smuggler; 7, Red Top; 8, Snow group; 9, Sunrise.

CLIMATE, TIMBER, WATERPOWER

Temperature and precipitation records have been kept for seventeen years by Mr. T. C. Moilliet at his ranch on the south side of the North Thompson 2 miles west of Vavenby. Vavenby is 9 miles easterly by road from Birch Island. Average temperatures and average precipitations for the sixteen years ending in 1929 are given below.

—	Average temperature Degrees F.	Average precipitation Inches
January	18	1·59
February	24	0·59
March	35	0·78
April	45	0·57
May	53	1·15
June	59	1·63
July	64	1·44
August	62	1·23
September	53	1·36
October	44	1·19
November	31	1·09
December	21	1·56
Year	42	14·18

In 1929 the precipitation consisted of 10·15 inches of rain and 38·50 inches of snow; the maximum temperature was 100 degrees and the minimum, −38 degrees.

Agriculture is confined to comparatively small areas of bottom land along the North Thompson, mostly below Birch Island, to low bench land above Birch Island and between the Clearwater and North Thompson, and to some higher bench-land in the vicinity of Candle creek. The bottom land receives sufficient moisture through the subsoil from the river to produce good crops, but most of the bench-land requires irrigation. Dairying, sheep raising, and berry growing are at present the chief agricultural pursuits. The meadows about the summit of Foghorn mountain can maintain about 1,000 head of sheep for sixty days, commencing early in July.

The area is heavily wooded except where forest fires have swept along the sides of North Thompson and Clearwater valleys and over the summit east of Black Pool. Mr. W. E. Noble, District Forester at Birch Island, kindly supplied the following notes on the forest growth. "The forest trees of this district, up to 4,000 feet, would be principally fir, then spruce, jackpine, hemlock, balsam, and cedar. It is only in the creek bottoms or on northern slopes that hemlock is plentiful except above 4,000 feet elevation, where hemlock, spruce, and balsam are the principal species." Some poles and ties are being taken out, but otherwise there is little logging going on within the area at present.

The Clearwater is the only river within the map-area on which hydro-electric power can be readily developed in any quantity . The report of the Commission of Conservation, 1919, indicates the possibility of developing ,000 horsepower with a 40-foot head. The granite canyon above Candle

creek is in places almost 100 feet deep and affords good locations for a fairly high dam. The marked constriction of the river above the granite canyon is in flat-lying Tertiary lavas which would have to be cut well back and sealed with cement under pressure to form an anchorage for a dam.

A small amount of power for local purposes could be developed on Raft river.

North Thompson and Clearwater rivers are glacier fed and maintain a heavy flow during the summer months, whereas the other streams decrease in flow, and Lemieux, Brookfield, and some of the smaller creeks dried up in August, 1930. Water is rather scarce in much of the upland country.

GENERAL GEOLOGY

GENERAL STATEMENT

The map-area is divided by North Thompson and Clearwater valleys into three mountainous areas which may be designated, respectively, the northeastern, the southeastern, and the western.

The northeastern area, whose mountains culminate in Raft mountain, is underlain chiefly by argillaceous, arenaceous, and calcareous sediments showing varying degrees of metamorphism resulting in phyllites, schists, quartzites, and crystalline limestones. This assemblage is intruded by granodiorite to the west and south of Raft mountain and by numerous granitic dykes and sills. Outcrops are largely confined to the high ground in the vicinity of Raft mountain.

The southeastern area is underlain, in the eastern part, by sedimentary rocks similar to those just mentioned and in the western part by intrusive greenstone in which are many inclusions of the sediments. The Baldie granodiorite[1] mass borders this area to the south and a few dykes from it outcrop within the map-area. What is apparently the top of a granitic mass of unknown form outcrops on the east side of Foghorn creek.

The western part of the map-area is underlain in its southern part by intrusive greenstone and in the northern part near Clearwater river, by granodiorite. Limestone and argillite of Carboniferous (?) age outcrop along the bottom of Lemieux Creek valley.

A sheared Tertiary volcanic outcrops in McCarthy creek south of Black Pool. Tertiary basaltic lavas underlie the benches along Clearwater River valley and also outcrop on the west side of the North Thompson, northwest of Black Pool, in the valley of Mann creek.

Glacial deposits cover the greater part of the area and recent alluvium occurs in places along the bottom of North Thompson valley.

The oldest rocks are the metamorphic sedimentary series which corresponds in part with the Badger Creek formation of Uglow[2] and perhaps also with his Barrière formation. They are unfossiliferous, and are provisionally assigned to the Precambrian.

The name Lemieux Creek formation is here proposed for the fossiliferous Carboniferous (?) rocks exposed along the creek of that name. Their relation to the metamorphic series is unknown.

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, Map.
[2]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 76.

The greenstone intrudes the metamorphic series and the Lemieux Creek formation and corresponds to Uglow's Fennell formation[1] which he correlates with the lower part of Dawson's Adams Lake formation[2]. This intrusive mass of batholithic nature is referred to in this report as the Fennell batholith.

The granodiorite intrusions are similar in character to Uglow's Baldie granodiorite[3] and apophyses correlated with these intrusions cut the aforementioned rocks.

The sheared volcanic on McCarthy creek is similar to the sheared phases of Uglow's[4] Skull Hill formation with which it is correlated.

The basaltic lavas along Clearwater river and on Man creek are somewhat similar to the fresh phases of Uglow's[5] Skull Hill formation, but are undeformed and undoubtedly younger than the sheared volcanics of McCarthy creek, which, as stated above, are correlated with the Skull Hill formation. The lavas along Clearwater river were referred by Uglow[6] to his Skull Hill formation, whereas those on Mann creek were classed by him as Recent. Both assemblages are of Tertiary age and the name Mann Creek formation is now proposed for these basaltic lavas and intercalated sediments, the more appropriate name, Clearwater (after the river of that name), being preoccupied.

Table of Formations

Quaternary	Recent	Alluvium
	Pleistocene	Glacial till, gravel, and silt
Unconformity		
Tertiary		Mann Creek formation
	Unconformity (?)	
		Skull Hill formation
Unconformity		
Mesozoic	Post-Triassic (?)	Granodiorite, etc.
	Intrusive contact	
	Triassic (?)	Fennell batholith
Intrusive contact		
Palæozoic	Carboniferous (?)	Lemieux Creek formation
Relations unknown		
Precambrian (?)		Metamorphic sedimentary series

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 77.
[2]Dawson, G. M.: Geol. Surv., Canada, Ann. Rept. 1894, pt. B, p. 108.
[3]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 81.
[4]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 86–88.
[5]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 86–88.
[6]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 87–88.

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PRECAMBRIAN (?) SEDIMENTARY SERIES

To the south of the map-area Uglow has described two unfossiliferous sedimentary formations, namely the Badger Creek and Barrière, as being of late Palæozoic or Precambrian age[1]. The metamorphic sedimentary series within the map-area holds representatives of the sedimentary members of both the Badger Creek and Barrière formations. So far, it has been impossible to subdivide the series within the map-area. This is in part due to the varying degree of metamorphism, resulting from the proximity of granitic and pegmatitic intrusions, rendering the lithologic correlation of small, isolated exposures very difficult. As the Fennell greenstone is now considered to be intrusive and not extrusive as once supposed, it appears to the writer that one reason no longer exists that may have induced Uglow to erect the two formations, the Badger Creek and the Barrière, and that these two formations may be in part one and the same. On the other hand there is some evidence within the map-area to indicate that the sedimentary series is not an unbroken succession. Because of the uncertainty, the series is left unnamed and provisionally assigned to the Precambrian.

The sedimentary series appears to be predominantly arenaceous and is composed of a succession of strata varying from quartz schist to quartzite, mica schist, phyllite, slate, and limestone. The series is best exposed in the vicinity of Raft mountain where it comprises a great thickness of quartz-mica schist and quartzite with minor amounts of slate and limestone. The average strike in this part of the area is about 55 degrees and the dip, though variable, averages about 35 degrees to 50 degrees to the southeast. Similar rocks are exposed in many other places, as in the canyon near the mouth of Raft river, where the strike is 290 degrees and the dip about 30 degrees north.

A thick bed of crystalline limestone outcrops on both sides of North Thompson valley at Vavenby just east of the map-area. The northerly continuation of this particular horizon is lost in the timbered summit of mount McClennan. A 25-foot bed of limestone outcrops about one-half mile west of the Forestry tower and some minor beds immediately to the south of it. A large remnant of bluish grey limestone occurs in the greenstone about three-quarters of a mile west and north of Foghorn mountain.

A fine, quartz conglomerate underlying fissile clay slates outcrops east of the Mount McClennan trail about one-half mile north of the highway. A similar conglomerate is exposed on Jones creek about 2½ miles up from the road crossing.

Greyish white and greenish white to dark grey cherts occur closely associated with the Fennell greenstone. In some cases the cherts appear to be an original facies, whereas in other cases they appear to be silicified argillites and possibly have been produced by the baking of a highly siliceous argillite or fine-grained, impure quartzite. The cherts ordinarily are well banded, crumpled, and folded and as much as 100 feet thick. Uglow, in his account of the area to the south, has attributed the origin of the cherts to the interaction of lava with sea-water[2]. Within the map-area it is clearly evident that the greenstone intrudes the cherts and that they are of sedimentary origin and formed from the alteration of sediments.

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 74.
[2]U low, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 77.

In spite of the varying degree of metamorphism that so masks the characters of the sedimentary rocks, the quartz conglomerate, fissile clay slates, and cherty rocks appear to be distinct from the great thicknesses of quartz schists and quartzites. It may be the two classes only indicate a change in sedimentation, but the possibility exists that they indicate a time break in the succession. Dawson[1] noted the distinctive character of a cherty formation to the south and west of this area.

LEMIEUX CREEK FORMATION

The Lemieux Creek formation is named after Lemieux creek in the canyons of which it is well exposed. It comprises a succession of grey to almost black limestones and black argillites. The limestone is finely to coarsely crystalline, dark on fresh fracture, and weathers light grey. No determinable fossils were found within the map-area, but fragmentary fossils were found in limestone below the falls. The limestone is identical with fossiliferous limestone on the Lemieux Creek road 2 miles south of the map-area and again 2 miles farther south opposite the mouth of Eakin creek.[2] The strike of the formation within the map-area varies between 345 degrees and north and the dip averages 40 degrees to 60 degrees to the west. In the exposures south of the map-area the strike is approximately north and dip average 45 degrees west.

F. H. McLearn has furnished the following account of a collection of fossils obtained from the exposure of limestone 2 miles south of the map-area.

"*Tetractinella* ? cf. *trigonella* (Schlotheim)
Spiriferina ? several species
Terebratula ? sp.
Date: Triassic ?

NOTE: The recrystallization of the rock has destroyed the interior of the shells. If the shells labelled *Tetractinella*? have the interior of Athyridae they belong to Tetractinella. On the other hand if they are Terebratellids they resemble a species in the Indian Triassic, *Terebratula* cf. *julica*."

The Bryozoa from the collection were examined by Miss M. A. Fritz of the Royal Ontario Museum of Palæontology, who furnished the following report.

"I have been able to obtain a few thin sections from the bryozoa . . . . The material was very difficult to work with and the sections I got are only fair. They are good enough, however, to permit of a generic identification which is sufficient to determine the age within certain limits.

Two genera belonging to the Palæozoic order Trepostomata are represented in the collection, namely: *Stenopora* and *Lioclema*. *Stenopora* is essentially a Carboniferous genus, although recently Bassler has recorded it from the Permian. Lioclema ranges from the Silurian to the Carboniferous, but is quite abundant in the latter. The species, as might be expected, are probably new, but I am inclined to think they are Carboniferous forms. The present material does not justify description. I was obliged to sacrifice most of the specimens in order to obtain the sections."

E. M. Kindle, commenting on the foregoing determinations, advised that, since the two genera recognized by Miss Fritz are unknown in the Mesozoic and that since Mr. McLearn's reference to the Triassic (?) is provisional, the formation be referred to the Carboniferous.

[1]Dawson, G. M.: Geol. Surv., Canada, Ann. Rept. 1894, pt. B, p. 40.
[2]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, Fig. 14, p. 84 (called Threemile creek).

FENNELL BATHOLITH

Uglow has described the Fennell formation as developed south of the map-area as consisting "chiefly of a complex of altered basic rocks of intrusive, extrusive, and fragmental characters.[1]" The greenstones displaying ellipsoidal or pillow structures were interpreted as lava flows, probably of submarine origin. Within the map-area and between it and the area to the south, the Fennell rocks, including those displaying ellipsoidal structures, have everywhere been found to be intrusive. They outcrop over an area of 10 by 12 miles in the southwest part of the map-area and extend southerly at least to Barrière river[2] a distance of 20 miles. This intrusive mass has the proportions of a small batholith.

The rocks of the Fennell batholith vary greatly in appearance from a dense, cherty, light greenish grey rock to one of medium to coarse grain and dark greenish grey colour. Hornblende phenocrysts up to ¾ inch in length have been observed in the coarse-grained phases. The fine-grained rock is in places obviously a marginal phase. Ordinarily the rocks are massive with heavy jointing. In places they are finely jointed and break down into small, angular fragments a few inches in diameter; one such occurrence is near the road on the west side of the North Thompson one mile north of the south edge of the map-area and suggests shearing and possibly faulting. Prominent north-south jointing in the vicinity of Clearwater and Grizzly peaks cuts not only the Fennell rocks but an intrusive granitic dyke.

Ellipsoidal (pillow) structures occur in several places and give the rock the appearance of a pillow lava and, as already noted, it was this structure that led Uglow to believe similar rocks in the area to the south to be pillow lavas.[3] Ellipsoidal structures are well developed along the highway west of the North Thompson and just south of the map-area, also on the west slopes of Clearwater peak and at several other places. The best ellipsoidal structures occur 2 miles south of the map-area on the Lemieux Creek road where the greenstone is intrusive into the Lemieux Creek formation. The ellipsoids vary in size from a few inches up to 4 by 6 feet. A common shape roughly resembles a pillow slightly depressed in the middle and about twice as long as wide. The longer axes of neighbouring pillows are generally parallel, but otherwise there is no orderly arrangement with respect to size or shape. In some cases the surfaces of the ellipsoids appear to be chilled, but in many cases, upon close examination, this apparent chilling was found to be due to layer upon layer of slickensided surfaces. The well-developed ellipsoidal forms normally fade out into massive greenstone with irregular jointing. Epidote was found along the irregular joints and between the ellipsoids in several places. In the highly developed ellipsoidal phases, material with a brecciated appearance occurs between the ellipsoids. Examination of some of this material under the microscope showed it to be wholly composed of secondary minerals without any trace of a brecciated structure. The brecciated appearance in some places is due to differential weathering of the secondary minerals.

Along the Lemieux Creek road, 2 miles south of the map-area, the ellipsoidal greenstone has been crushed and brecciated and on casual observation has the appearance of a fragmental rock. The Lemieux

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 77.
[2]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, Map.
[3]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 77.

Creek limestone is well exposed on the road and a few feet east is a small greenstone outcrop. With the removal of a slight cover of soil the contact was exposed, showing the limestone to be contorted at the contact and highly altered fragments of it to be enclosed in the greenstone. A few yards south another contact showed similar relations with the development of much coarse calcite in the limestone close to the contact. The strike of the limestone is directly towards greenstone outcrops a short distance northerly. The observed relations all indicate the intrusive nature of the ellipsoidal greenstone.

On the north side of Joseph creek, southwest of Foghorn mountain, fine-grained greenstone was found intruding the Precambrian (?) metamorphic sedimentary series and it was there that the cherty and fine-grained phases were seen to be marginal to coarser-grained phases. Partly developed ellipsoidal structures were found at one place near the contact. The intrusive nature of the greenstone is well exposed at many places, and especially so in the area between Joseph creek and the North Thompson, where large remnants of the Precambrian (?) sediments are found in the greenstone and where greenstone tongues penetrate the sediments along irregular contacts.

East of the Mount McClennan trail and north of the highway, the greenstone is in part schistose and appears to be banded, having more the appearance of an eruptive than at any other place in the map-area. If its intrusive nature were not displayed at this locality it might easily be mistaken for an eruptive. A light greenish grey, medium to fine-grained, schistose and somewhat banded porphyritic rock outcrops on Foghorn mountain and to the north and east. The relations of this rock to the Fennell greenstone and the Precambrian (?) metamorphic sedimentary series are uncertain, but the rock appears to intrude the sediments and it is provisionally correlated with the Fennell greenstone and is presumed to be a large apophysis.

Microscopic examination of seventeen thin sections representative of the different phases of the Fennell batholith show the greenstone to be greatly altered, but apparently of uniform character. Fifteen sections show altered undeterminable feldspar. Chlorite occurs in fourteen sections, some of which may also hold serpentine. Leucoxene occurs in thirteen sections and in three is the alteration product of ilmenite. Epidote or zoisite occur in fourteen sections. Colourless amphibole occurs in seven and greenish or brown amphibole in three sections; calcite is present in six sections. Quartz occurs in four and possibly in seven sections. Pyroxene is present in three sections. It is impossible to definitely determine the original character of the rock, it appears to have been of a dioritic nature.

The greenstone alters along fissures, as in the Queen Bess property, to ankeritic carbonates[1], a phenomenon very common in Lardeau map-area. This alteration has also been observed to be a surface weathering phenomenon in a few places and in these cases may possibly be pre-Glacial.

The Fennell greenstone cuts the Carboniferous (?) Lemieux Creek formation and is cut by granitic dykes considered to be apophyses from a body of granodiorite similar to the Post-Triassic (?) granites and granodiorite extending southeasterly into Kootenay district. The Fennell batholith, thus, is presumably of Mesozoic age, Triassic, or younger.

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 102.

GRANODIORITE

The main mass of granodiorite within the area borders Clearwater river on the west and is well exposed on the burnt-over hillside and in the canyon of the river. It is reported to extend several miles north. Outcrops were observed north and west of the area and are also found on the north slope of the Grizzly peaks about 1 mile south of the second Grizzly lake. It is highly probable that granitic rocks underlie the great, wooded area north of the Clearwater peak.

Outcrops of granodiorite and granite southeast, southwest, and west of Raft mountain indicate the presence of a large body of granitic rock lying between the mountain and Raft river and possibly connecting with the main Clearwater mass. Granite is reported to outcrop one-half mile north of the Red Top prospect on mount McClennan and may be an extension of the large dyke north of the forestry tower, or may be the southern edge of the Raft Mountain mass.

The top of a granitic intrusion is exposed to the east of Foghorn creek and may be closely related to the Baldie granodiorite to the south.

The granodiorite is ordinarily medium to coarse grained and light coloured. It is porphyritic in some places. The rock shows but little alteration in hand specimens. The feldspars are white to light salmon in colour. Under the microscope the rock is seen to be composed essentially of orthoclase, oligoclase-andesine, and quartz with accessory biotite, hornblende, and muscovite, occasional grains of titanite, magnetite, or ilmenite and garnet and sparingly developed secondary minerals such as chlorite, epidote, sericite, and kaolin. The ratio of potash feldspar to soda-lime feldspar is about as 5 to 3, which classifies the rock as a granodiorite tending toward a granite.

The granodiorite intrudes the Precambrian (?) metamorphic sedimentary series and apophyses correlated with it intrude the Lemieux Creek formation and the Fennell greenstone. In appearance the granodiorite is like the ordinary Nelson granite or granodiorite of Kootenay district. Under the microscope the chief apparent difference is in the potash feldspar which in the Nelson granite is commonly microcline, whereas in this granodiorite it is almost always orthoclase.

The dyke rocks, presumed to be apophyses from the known large granodiorite masses or from unexposed bodies of the same rock, are chiefly granodiorites, or granites and aplites.

The granodiorite or granite dykes and sills are medium to fine-grained rocks, generally porphyritic, brownish white to white in colour, and almost free from ferromagnesian minerals. A 200-foot sill exposed on the second north fork of Brookfield creek, is a light grey, medium to fine-grained porphyry with clear white feldspar phenocrysts. Under the microscope, the groundmass is seen to be composed of kaolinized feldspar and quartz with brown amphibole and biotite and a little pyroxene, pyrite, and leucoxene. The phenocrysts are kaolinized plagioclase and orthoclase feldspar. A 60-foot granite dyke cuts Fennell greenstone on the south slope of a knob to the west of McCorvie creek at an elevation of 5,380 feet. The rock is brownish grey, rather fine grained and porphyritic. A thin section shows the groundmass to be chiefly a micrographic intergrowth of feldspar

and, presumably, quartz, with some chlorite, calcite, epidote, ilmenite, or magnetite and a very little leucoxene. The phenocrysts are plagioclase feldspar and the rock is apparently a fine-grained granodiorite or granite. A 6-foot dyke cuts greenstone on Grizzly mountain west of Clearwater peak. The rock is fine grained, porphyritic, and light grey with yellowish phenocrysts of feldspar up to ¼ inch in size. A thin section shows the groundmass to be composed of feldspar laths and brown amphibole with some quartz and chlorite and a few grains of epidote and pyrite. The phenocrysts are plagioclase and orthoclase feldspar and brownish amphibole. The rock appears to have about the composition of a granodiorite. An intrusive outcrops 800 feet north of the highway about 1 mile east of the Mount McClennan trail. It is of medium grain and brownish colour with green chlorite through it. A thin section shows the groundmass to be partly feldspar spherulites and partly feldspar individuals with sericitic mica, calcite, and, possibly, some magnetite and apatite. The phenocrysts are sericitized plagioclase and orthoclase. There appears to be little or no quartz in this rock and its composition would be about that of a monzonite.

The aplitic dykes and sills are dense, whitish rocks and may in some cases be latites. A 50-foot dyke cuts the Precambrian (?) metamorphic sedimentary series on the ridge on the north side of Axel creek at an elevation of 4,350 feet. It is a fine-grained, light brownish white rock with limonite specks throughout. A thin section shows it to be composed chiefly of feldspar spherulites and a very fine groundmass of feldspar and sericitic mica. There are a few phenocrysts of orthoclase. Quartz is believed to be present in the spherulites, but was not definitely identified. Most of the feldspar has an index equal to or lower than balsam and the rock is evidently an aplite porphyry. A dense, white rock speckled with limonite, outcrops on the 6,600-foot summit southeast of Foghorn mountain. A thin section shows a groundmass of feldspar and quartz with large spots of limonite. The rock is probably an aplite. A 20-foot dyke in the lower adit of the Shamrock group is a fine-grained, dirty greyish white rock with grains of pyrite through it. A thin section shows a groundmass composed of a micrographic intergrowth of feldspar and quartz (?) with some sericitic mica, chlorite, calcite, and a grain or two of apatite. Highly altered phenocrysts of feldspar can be distinguished. Many minute cavities occur throughout the section. The rock is probably an aplite. A whitish, fine-grained sill occurs in the Lemieux Creek formation at an elevation of 1,900 feet on Lemieux creek. A thin section shows a groundmass of feldspar spherulites and areas of kaolinized feldspar and quartz. Remnants of feldspar phenocrysts are visible. The rock is probably an aplite. Another, white, fine-grained sill occurs in the Lemieux Creek formation at an elevation of 2,200 feet on the creek. A thin section shows a micrographic fabric with sericitic mica and a little pyrite, calcite, and secondary (?) quartz. Quartz is presumed to be present in the micrographic fabric and the rock is probably an aplite.

A few lamprophyre dykes were found in the area. One, a dark grey, sheared rock, cuts the Precambrian (?) metamorphic sediment at an elevation of 2,050 feet on Foghorn creek. A thin section shows the rock to be composed of feldspar, mostly with indices lower than balsam, brown hornblende, and biotite with some quartz and a little apatite and zoisite, and considerable calcite. A dark grey, fine-grained dyke, 4 feet wide,

cuts the Precambrian (?) metamorphic sediments at an elevation of 1,600 feet on the hillside east of Raft river. A thin section shows a groundmass of feldspar and brown amphibole with some magnetite, chlorite, and areas of calcite, which latter may represent decomposed feldspar phenocrysts. Pyroxene phenocrysts are abundantly scattered throughout the section. The rock is an andesite or basalt. A brownish, rusty dyke 50 feet wide cuts the Precambrian (?) metamorphic sediments on a ridge 2 miles northeast of Raft mountain. A thin section shows a groundmass of fine plagioclase laths, olivine and pyroxene, and grains of magnetite. Phenocrysts of olivine, of untwinned feldspar with greater indices than balsam, and a few of pyroxene are present. The rock is a basalt or possibly an andesite and strongly resembles the Mann Creek lavas. Possibly this dyke, and perhaps, also, the preceding one, is related to the Tertiary volcanics.

SKULL HILL FORMATION

The Skull Hill formation was defined by Uglow[1] in the area to the south and described by him as consisting mainly of amygdaloidal andesitic lavas. The only outcrops of it found within the map-area are on McCarthy creek south of Black Pool. The rock is sheared, brown, and muddy in appearance and similar to rocks mapped by Uglow[2] as Skull Hill along the northeast end of Dunn lake 6 miles to the south. The relations to the other formations are not exposed on McCarthy creek. Fresher-looking volcanics resembling the Skull Hill occur on the gorge of the third creek north of Spahats (Bear) creek, north of the map-area; their relations to the Mann Creek basalts will be described in the following section.

MANN CREEK FORMATION

The Mann Creek formation is well exposed in the valley of Clearwater river. It also outcrops on the west side of the North Thompson one mile north of the Black Pool ferry crossing, and in the valley of Mann creek. The formation is composed chiefly of flows of olivine basalt with thick, lenticular interbeds of waterlain material largely derived from the erosion of the lava, or in some cases apparently due to decrepitation of the hot lava upon entering water. No ash beds were observed.

The best section of the Mann Creek formation within the map-area is in the canyon of Spahats (Bear) creek. Better sections are to be found north of the map-area, in the gorges of three small creeks crossing the Clearwater road 2·35, 2·85, and 4·15 miles, respectively, north from Spahats (Bear) creek.

A clean exposure of the base of the formation can be seen in a small bluff on the north side of the mouth of Candle creek. There the lava rests on a pocket of stream gravel in a depression in the eroded surface of a granodiorite body. The gravels are barely consolidated and can be easily torn down with a pick. The pocket is about 15 feet deep and perhaps four times as long. The gravels and boulders are chiefly of granodiorite and of lava with a few of quartzite and metamorphic rocks, all well waterworn with the exception of a few at the top of the pocket immediately

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 86.
[2]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, map.

beneath the lava. The waterworn boulders and pebbles of lava are lithologically identical with the overlying flows. Similar conditions exist in the gorge of Mann creek a few hundred yards above the highway crossing, only there the boulders underlying the lava are greenstone. Between three small flows exposed on Mann creek are lenticular interbeds of fragmental lava[1], some of which is waterworn and some of which appears to be caused by the decrepitation of hot lava entering water.

The lava flows are essentially flat lying and undisturbed. Though the flows are well defined in a section such as that exposed in Spahats (Bear) Creek canyon it is very difficult to follow them for any distance down valley, for they merge, die out, and overlap. This condition is well exposed in the cliffs about a mile north of Candle creek. A flow, for instance, with well-developed, ropy lava on its surface, may be followed for a few hundred feet to where it dies out and the overlying flow continues beyond it. A highly vesicular flow may change to dense lava. Columnar jointing dies out and comes in in much the same way. Though structure is so variable, the composition of the lavas is very constant.

A cliff on the west side of the North Thompson one mile north of the Black Pool ferry crossing, shows a most interesting section of the lavas and fragmental material. The north end of this cliff exposes a flow of lava that ends in a steep, very irregular face fronting south and exhibiting pillow structure. This structure was apparently formed by rapid cooling and balling up of the pasty lava on the front of the flow, probably as it advanced into water. Fluid lava welling over this cooling front repeated the process and formed layer upon layer of pillows. Fragmental material, in part the product of erosion, and, in part, perhaps due to the decrepitation of the hot lava on entering water, lies on the face of the pillow lava and dips gently to the south. Isolated pillows are scattered through this material and vary in size from a few inches up to 4 to 6 feet and are irregular in shape. They are radially fractured and concentrically chilled, with as much as one-half inch of black glass on the surfaces.

The sections throwing most light on the history of the lavas are found in the creek gorges previously mentioned as being situated north of the map-area.

In the first of these gorges on a small creek crossing the Clearwater road 2·35 miles north from Spahats (Bear) creek, the following section was observed. At an elevation of 2,050 feet above sea-level lava rests on the eroded surface of Precambrian (?) sediments, the surface sloping westerly at an angle of 24 degrees toward the bottom of Clearwater valley. A conglomerate of unassorted river gravel and boulders lies on a surface of the metamorphosed sediments just to the west and at a lower elevation than the base of the lava. The lower flows of lava total 150 feet in thickness. Pillow lava rests on columnar lava, the pillows vary in size and shape and exhibit radial jointing. At a distance the radial jointing gives the rock the appearance of a breccia. Overlying the lower flows is 90 feet of stratified, fragmental material composed chiefly of fragments of lava. Overlying the fragmental material is another succession, 260 feet thick, of flows capped by stratified clastics. Above are other lavas.

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 88.

In the second gorge, on a creek one-half mile north of the first, a few feet of yellowish, fine-grained sandstone containing some fragments of lava rests on an eroded surface of granodiorite and is overlain by lava. At road level, 250 feet higher, stratified clastics composed largely of lava dip westerly, rest upon lava, and are overlain by glacial drift. This clastic material is loosely cemented and the dip appears to be original. It appears to be the remnant of a fan built up by a stream debouching into the valley high above the present valley bottom.

In the third gorge, 1·3 miles north of the second, the relations between the Mann Creek lavas and older volcanics referred to the Skull Hill formation, are fairly well exposed. The base of the Mann Creek lava is exposed at 2,000 feet elevation where the lavas rest on fractured granodiorite. About 125 feet westerly and 25 feet lower in elevation, is an outcrop of reddish brown, sheared volcanics. The base of the sheared volcanics is not exposed, but they evidently lie on granodiorite which is exposed on the north side of the gorge a short distance away. The shearing or fracturing of this outcropping granodiorite is no more pronounced along the direction of the shearing in the Skull Hill volcanics than that of the granodiorite beneath the Mann Creek lavas. Apparently the shearing of the Skull Hill volcanics must have taken place before the Mann Creek lavas were formed. These lavas, therefore, must be considerably younger than the sheared volcanics referred to as Skull Hill.

A great thickness of pillow lava is exposed in the gorge of this creek at road level. Along the southern side of the creek above the road, a great deal of cemented fragmental lava, with a few sandy interbeds, is exposed, filling the old gorge of Tertiary time and dipping toward the Clearwater. At 4,000 feet elevation broken and jointed lava containing highly vesicular areas and with glass developed on some joints, outcrops. At a higher elevation, flat-lying, vesicular lava is present and continues to the highest exposures at 4,600 feet elevation. At this elevation the steep, lower slopes of Clearwater valley flatten to long, gentle slopes rising easterly to the Trophy peaks at an elevation of over 8,000 feet. Lava boulders were found in glacial debris to an elevation of 5,200 feet, above which no trace of lava was found.

Thin sections of nine representative specimens of the lava from Mann creek, Clearwater river, and Spahats (Bear) creek show it to be quite uniform in character and very fresh. The lava is generally fine grained and porphyritic. It is composed of plagioclase feldspar (labradorite to andesine-labradorite), olivine, pyroxene, and magnetite. The groundmass varies from very fine to slightly coarser than fine and the phenocrysts measure up to 5 mm. in the case of the feldspar, those of olivine are smaller and those of pyroxene still smaller. Plagioclase, olivine, and pyroxene occur together as phenocrysts in four sections; plagioclase and olivine in one section; olivine and pyroxene in one section; and olivine alone in two sections. The olivine shows but little alteration. Most of the olivine phenocrysts show a rounding of the crystal form and some are fractured and the fractures filled with minerals of the groundmass. Gas vesicles cut into the crystals, particularly the larger plagioclase phenocrysts.

QUATERNARY GEOLOGY

During the glacial period the district was covered by ice and there is evidence that it covered peaks of nearly 8,000 feet elevation. It was sufficiently thick to permit of a southerly movement across summits 6,600 feet in elevation, polishing in places the greenstone of which the summits are composed so intensely as to produce glassy surfaces. This phenomenon is beautifully shown on the Grizzly peaks, immediately north and west of Clearwater peak, where the glassy surfaces on the greenstone shine like mirrors in the sunlight. Granite erratics, evidently from outcrops to the north, are profusely scattered over these rounded summits.

Mann creek flows in a steep-walled, V-shaped valley showing no evidence of glacial modification, yet not far to the north of it are the summits displaying the glacial phenomenon just described. The V-shaped nature of this valley was, apparently, what led Uglow[1] to believe that the basaltic lavas occurring in the bottom of it near the road were of recent age, though in a later paper[2] he refers to the recent lavas occurring in the bottom of glaciated valleys. The improbability of this valley which shows a deepening similar to that of the North Thompson—proved by Uglow[3] to be early Tertiary—being post-Glacial in age, evidently led to the change of opinion. The lavas in Mann Creek valley are of Tertiary age and the present form of its valley is much the same as in Tertiary time. The explanation offered is that Mann creek follows a course transverse to the direction of movement taken by the ice and, therefore, that in the deeper part of the valley movement of the ice did not take place and erosion was limited in amount. Upon the recession of the ice-sheet a valley glacier probably remained, but Mann creek heads in low ground and the life of the valley glacier would be restricted and its erosive power comparatively feeble.

This phenomenon has been observed by the writer in numerous instances in southeastern British Columbia and the explanation offered is that upon the retreat of the main ice-sheet two types of valley glaciers remained: (1) active valley glaciers occupying valleys heading in high ground and perpetuated through a supply of fresh material derived from the greater precipitation and collection of snow at high altitudes; and (2) inactive glaciers occupying valleys heading in low ground where there was little or no source of supply to perpetuate them. Some of the former still exist in many parts of the province and occupy valleys of the conventional, modified, U-shaped form, whereas the latter type of glacier early disappeared, leaving little or no evidence of its presence. Similar conditions may also have existed during interglacial periods. The conclusion reached is that the form of a valley does not necessarily indicate a preglacial or glacial origin, i.e. age, but whether an active or inactive glacier occupied the valley.

Glacial till covers the greater part of the district. Silts and gravels, for the most part believed to be of Glacial age, occur in the valley of the North Thompson, but have been largely removed by subsequent erosion. Recent alluvium is found in places along the flood lands on the bottom of North Thompson valley.

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[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 88.
[2]Uglow, W. L.: Bull. Geol. Soc. Am., vol. 34, No. 3, p. 567.
[3]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 89.

ECONOMIC GEOLOGY

Most of the mineral deposits so far discovered in the map-area occur in sedimentary rocks. They are chiefly small, quartz-sphalerite-galena veins and small replacements and disseminations of sphalerite and galena in quartzose sediments. There is one occurrence of chalcopyrite with pyrite in bedded quartz veins and disseminations in the adjacent country rock. Fluorspar and celestite occur as disseminated replacements in the contact phase of an aplitic intrusion.

The large area of Fennell greenstone, except where it has been sheared and altered to ankeritic carbonates, seems to have been an unfavourable host rock for mineralization.

Though to date the results of prospecting and development work have not been very encouraging, the fact that mineralization does occur warrants further search for deposits of commercial grade and size. In the future search for minerals, particular attention should be given to those minerals commonly associated with the higher temperature type of deposit. Many difficulties confront the prospector, for the area is largely covered with overburden and, considering all aspects of the situation, it would seem wisest that prospecting should be carried on by residents of the district who can devote some time to the search for mineral but have some other means of gaining a living.

Description of Properties

QUEEN BESS

The Queen Bess property is on the steep westerly slope of Queen Bess ridge facing North Thompson river at Auldgirth. A Seattle syndicate bonded the property in 1918, commenced development, and erected a small 50-ton concentrator.[1] The mill was in operation for a short time in 1919 and again early in 1920 before development was suspended. In 1919 the mill is reported to have produced 27 tons of lead concentrates, assaying 40 to 50 per cent Pb, 12 per cent Zn, and 48 ounces Ag to the ton, and 78 tons of zinc concentrates assaying 48 per cent Zn, 7 to 8 per cent Pb, and 14 ounces Ag to the ton.[2] The property remained idle from some time in 1920 until 1927 when new equipment was installed in an attempt to exploit it.[3] The property was closed down in September, 1927, and the equipment has since been removed.

Mineralization, chiefly sphalerite, occurs in the form of small veins in greenstone of the Fennell batholith. The greenstone along the fissures has been changed to ankeritic carbonates and in places the alteration has spread widely. Mineralizing solutions succeeding those which produced the alteration in the greenstone, have veined and replaced the ankeritic carbonates.

The property is developed by one main adit at an elevation of 1,950 feet, or 650 feet above the track at Auldgirth, and small workings at elevations of 1,730, 2,190, 2,235, and 2,280 feet, respectively.

[1] Ann. Rept., Minister of Mines, B.C., 1918, p. 234.
[2] Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 103.
[3] Ann. Rept., Minister of Mines, B.C., 1927, p. 191.

The main adit has been driven almost due east for 720 feet in Fennell greenstone. Numerous well-defined joints, slips, and small fissures cross the adit and dip to the west or east, the former direction predominating. The greenstone in the adit is massive and fine grained from the portal to 510 feet where it shows intense alteration which continues most of the distance to the face. In places this alteration (produced in part by ascending solutions and later by circulating groundwater) has been so intense as to reduce the greenstone to mud.

Two pronounced, mineralized fissures are intersected at 180 and 360 feet from the portal and are known, respectively, as the Cameron and Bigelow veins. Both veins have been drifted on to the north and south. A more easterly fracture, 592 feet from the portal, has been drifted on to the south and a small lens of mineral opened up.

The Cameron vein strikes 53 degrees and has an average dip of about 60 degrees northwest. The southwest drift on this vein is 90 feet long. A winze reported to be 100 feet deep was sunk at the beginning of the drift with a sub-level at 50 feet from which ore was stoped.[1] The fissure, called the vein, is well defined in this drift and at the face dips 60 degrees to the northwest. A little mineralization is exposed at the start of the drift and a specimen examined under the reflecting microscope showed a little galena in crushed ankeritic carbonates and somewhat fractured quartz. The mineralization pinches and the fissure is practically barren along the greater part of the drift, with the exception of an 8-inch lens of sphalerite at 50 feet.

The northeasterly drift on the Cameron vein follows an irregular course, has a length of 170 feet, and two small crosscuts have been run from it. The fissure occupies about the full width of the working at the beginning of the drift, pinches gradually, and enters the west wall at 90 feet. There is a high, narrow stope about 30 feet in length at the beginning of the drift. A little lens of quartz in this area and a little pyrite in the fissure where it enters the wall of the working are all that can now be seen. Twenty feet beyond the point where the fissure enters the west wall the working turns through almost a right angle to the north, exposing a northerly trending fracture in highly altered greenstone. Twenty feet beyond the bend a crosscut running northeast exposes two small fissures which appear to be the continuation of the Cameron. The northerly trending fracture is probably the continuation of a well-defined shear exposed in the adit 95 feet beyond the Cameron vein. The greenstone is intensely altered about the intersection of this fracture with the Cameron.

The Bigelow vein, intersected by the adit 180 feet east of the Cameron vein, strikes 20 degrees and dips very steeply west. It is well defined where intersected by the adit and from 15 inches to 4 feet in width and carries a little zinc mineralization. The south drift is 130 feet long and follows the fissure to within 10 feet of the face where it disappears in the west wall. At 50 feet along this drift a raise goes to the surface, about 240 feet vertically above, with a slope of approximately 82 degrees east. It is inaccessible. There is a stope approximately 40 feet high between the adit and the raise. The vein in the back of the stope is narrow and has a maximum width of 2 feet. A specimen from the back of the drift

[1]Uglow, W. L.: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 103.

where the vein is 8 inches in width was examined under the reflecting microscope. In the hand specimen the vein appears to be almost wholly light resin-coloured sphalerite and it definitely veins the ankeritic carbonates. Under the microscope the sphalerite is seen to be fractured crosswise of the vein and the fractures are filled with calcite and quartz. A few grains of pyrite and small patches of galena are present. In one specimen a veinlet of galena in the sphalerite holds a small area of tetrahedrite.

For 50 feet beyond the raise, the fissure pinches and swells from 1 inch to 1 foot and contains practically no mineralization. At 50 feet a small stope 11 feet long and 18 feet high fails to show anything of interest.

The north drift shows the fissure to pinch rapidly to 3 to 5 inches within the first 30 feet and to turn abruptly into the west wall. For the next 30 feet an ill-defined fracture is followed. At the end of this stretch, a small, well-defined fissure coming from the south appears in the east wall and has been followed for 130 feet, the course of the drift changing to a little west of north. This fissure split at 90 feet and again at 120 feet and becomes indistinct. There is some alteration of the greenstone along the fissure, but no mineralization. The greenstone towards the end of the 130-foot section shows intense alteration and the drift turning easterly and ending on a southeast course follows an indistinct fracture which shows a sparkle of sulphide in 2 inches of quartz. This fracture is probably the continuation of the Cameron, it lies almost on the strike of the Cameron in the drifts on this adit level. The greenstone about this apparent intersection of the Cameron and the northerly trending Bigelow fissures is intensely altered.

An indefinite fracture in altered greenstone is intersected by the adit at 592 feet from the portal and has been drifted on for 85 feet to the south, exposing a little mineralization along the last 45 feet. This ground has been stoped up 30 feet and all that can now be seen is a small streak of zinc-lead mineralization up to 4 inches in width following the irregular fracture and dipping 43 degrees westerly.

A lower adit, 220 feet below the main adit, has been driven 130 feet, of which the first 60 are through overburden and broken ground and the last 70 feet in greenstone.

An older working on the property is a 90-foot adit 240 feet above the main adit and crossing it, in plan, about 60 feet east of the mouths of the drifts on the Bigelow vein. This upper adit runs northeast and along a fracture at first well defined but hard to follow in caving ground near the face. The adit is caving and a little copper stain in quartz is all that can now be seen. This adit with its crosscut is directly beneath two surface pits or shallow shafts which are inaccessible. A 24-foot prospect adit just east of the pits is in barren ground. The fracture exposed in the 90-foot adit is apparently the Bigelow. The top of the raise on the Bigelow from the main adit is 50 feet southwest from the portal of the 90-foot adit. These workings are evidently those of the Lone Prospector claim and are quite old.

The uppermost working is 45 feet vertically above and some distance easterly of the 24-foot prospect adit. It is a 40-foot prospect adit driven in shattered greenstone which has been extensively altered, perhaps in part by surface weathering. This working is believed to be on the old Iron Clad claim.

It is noticeable that the veins on the Queen Bess property occur in those parts of the fissures where alteration of the greenstone is confined to a narrow zone along the fissures. Where the alteration becomes more extensive, particularly about the intersection of fissures, the fissures become indistinct and the veins pinch out. The probable explanation is that when subsequent movement or opening of the fissures took place, accompanied by mineralizing solutions, the softer, altered rock failed to maintain the fissures, whereas the harder, unaltered greenstone did so accompanied by a brecciation of the narrow zone of ankeritic carbonates permitting the ascent of the mineralizing solutions and the formation of veins.

Some prospect workings at an elevation of 2,500 feet and about 1,500 feet south of the Upper Queen Bess workings are on the property of Mr. B. T. Foote of Auldgirth.

A prospect adit, 18 feet long, has been driven in a direction of 55 degrees in greenstone which shows alteration at and near the surface. The adit follows an ill-defined fissure showing carbonatization of the greenstone and dipping 35 degrees northwesterly. Some quartz and mineralization occur along the fissure. A specimen of the best material from the dump was polished and shows veinlets of sphalerite and quartz with a little galena and pyrite in ankeritic carbonates.

About 25 feet vertically above and to the southeast, are two open-cuts on the same shear which is better defined with nearly a foot of quartz in it but only a little sulphide.

FOGHORN

The Foghorn group, so far as known to the writer, consists of five claims owned by George Fennell and associates of Chu Chua. The property is on Foghorn mountain at elevations of 6,400 to 6,500 feet and can be reached by trails from Black Pool or Birch Island; the trails from the latter place being those now used.

Development consists of an adit and three shafts, all now inaccessible, and numerous pits and trenches.

The country rock exposed in the various workings and on the dumps is massive, light greenish grey, and schistose. It is probably a tongue from the Fennell batholith. Carbonatization of this rock is to be seen in several of the cuts.

The adit is at an elevation of 6,400 feet, on the south end of the summit of Foghorn mountain. It is completely caved. At the first shaft west and above the adit, there is, on the dump, a small pile of quartz, containing marmatite (black sphalerite high in iron) and a few specks of chalcopyrite. The second shaft north of and higher than the first has been sunk on a fracture striking 43 degrees with high dip to the northwest and showing a film of quartz containing specks of galena and pyrite. At the third shaft, still farther north, a small pile of quartz bearing galena, sphalerite, and pyrite, lies on the dump. Two of the numerous pits and trenches show small, barren quartz veins.

The property at a time when the workings were accessible was reported upon by W. M. Brewer.[1] He stated that he saw three narrow quartz veins carrying galena and some sphalerite and pyrite. The widest vein was

[1]Report of the Minister of Mines, B.C., 1915, pp. 220–221.

stated to have a maximum width of 14 inches and the other two veins were reported to vary in width from 6 to 12 inches. One of these veins had been opened by a long trench and about 25 tons of ore from it had been packed in bags for shipping. A sample of this sacked ore assayed: gold, trace; silver, 0·80 ounce a ton; lead, 78·7 per cent; zinc, 4·8 per cent.

On the north end of the summit of Foghorn mountain $\frac{3}{5}$ of a mile from the Foghorn adit, are some workings on a property owned by the late Axel Chidgrin (Chingrom).

The country rock is the same as at the Foghorn. An adit, 230 feet northwest of the cabin, has been driven 80 feet in a direction of 192 degrees. A small quartz vein containing galena, sphalerite, chalcopyrite, and pyrite is exposed where the adit enters bedrock 33 feet from the portal. This vein strikes approximately 55 degrees and dips 75 degrees southeast. The working was evidently driven to get under a pit from which float, similar to the vein material, was taken out. The float is evidently the glacially removed outcrop of the vein and has been transported only 80 feet. Two adits, 265 feet southeast of the cabin, have been driven in a search for the source of similar float, but are now caved. Other pieces of float were seen to the south and east of these workings. It is doubtful if any of the float has travelled more than a very short distance from its source. The float, apparently, was moved by the Pleistocene ice-sheet, the direction of movement of which was south.

Four-fifths of a mile east and south of the Foghorn adit, are workings on a property known as Kelly's. The workings consist of a caved adit and several open-cuts. Fragments of quartz carrying galena, sphalerite, and pyrite were found at most of the cuts. The well-defined walls and angular outlines presented by these pieces of vein material indicate a nearby source. The mineralization on Foghorn mountain, from what can be seen in the old workings, occurs in small, lenticular quartz-sulphide veins. The scarcity of outcrops and depth of overburden on the rounded summit topography makes prospecting and exploration a laborious and difficult task.

LYDIA

The Lydia property is at an elevation of 5,900 feet on the west side of Foghorn creek and is distant 7½ miles by trail from Birch Island.

The property was first described by W. M. Brewer in the Annual Report of the Minister of Mines for British Columbia for 1915. It consisted at that time of four claims owned by Geo. Fennell, Axel Chidgrin, and Alex. Dobson of Chu Chua, and on which a 30-foot drift adit had been driven 20 feet below the top of the bluff. By 1918 the property comprised fourteen claims and was being developed under option for New York interests by R. H. Stewart and P. W. Racey of Vancouver. This work was suspended in 1919 and the option relinquished.

The country rock is massive, light grey, and schistose. It has an argillaceous appearance, but carries some calcareous material. Under the microscope a thin section was seen to be composed of sericitic mica, quartz, calcite, chlorite, a little biotite, and some feldspar. The quartz occurs chiefly as large grains with the sericitic mica and chlorite flowing around them. The feldspar is chiefly in small grains, but also forms a few larger grains around which the micaceous minerals curve or flow. The rock appears to be a metamorphosed sediment.

The property has been developed by two main adits, three small prospect adits, and several trenches. The upper adit, at an elevation of 5,900 feet, follows an irregular course 440 feet long. This working for 226 feet from the adit mouth has been driven slightly south of west. Some quartz carrying pyrite and some pyrite disseminated in the country rock are visible for about 130 feet and for 96 feet, to where a small slip appears, some of the pyrite has been oxidized. From about 130 feet to 226 feet, only a little pyrite can be seen in the country rock. At 173 feet from the portal a small slip strikes 345 degrees, dips 50 degrees east, and shows a downthrow on the east side. At 226 feet from the portal, the working turns north and follows this direction for 71 feet, exposing a very little pyrite and quartz in the country rock. From a point 41 feet along this north course, the main working runs westerly and at this entrance a vertical slip striking 43 degrees is visible. The continuation of the main working for the first 56 feet runs west, exposing a little quartz and pyrite. Beyond this it turns to the south for 37 feet, exposing some quartz and a very little pyrite. At the end of this distance, the working again turns westerly and continues along this direction for 71 feet to the face, exposing considerable quartz and silicified country rock bearing some pyrite and chalcopyrite. The westerly trending courses of the adit closely follow the strike of the country rock which dips from 20 to 30 degrees to the north with some flatter rolls. Values in copper are reported to have extended from the portal to the slip at 96 feet.[1]

A lower level has been driven 230 feet below and to the north of the upper adit. This level intersects a granitic dyke, which outcrops 30 feet east of the portal of the upper adit and there strikes west of north. The lower adit driven along a westerly course intersected the dyke at 287 feet and passed out of it 55 feet farther on. Twenty-seven feet west of the dyke the working ends in two crosscuts, one running northerly for 77 feet and the other southerly for 186 feet. These crosscuts explore the ground west of the dyke. The country rock in these two drifts dips 23 degrees to 32 degrees northerly, about the same as in the upper adit, and, therefore, is the same set of beds as carry the mineralization in the upper adit, unless the angle of dip flattens in the stretch between the two levels and causes the beds of the upper adit to pass above the lower workings. No mineralization was encountered in the lower adit.

A 25-foot prospect adit has been driven north of and below the lower level, but revealed no mineralization. Two prospect adits 20 feet and 30 feet long, respectively, have been driven south of, and above, the entrance of the lower of the two main levels. The more southerly and higher exposed a barren quartz vein, 4 to 8 inches wide and striking westerly with high northerly dip.

A number of trenches above and also to the south of the upper adit fail to reveal any mineralization.

SHAMROCK

The Shamrock group, so far as known to the writer, includes several workings belonging to T. Montgomery and situated a half mile to a mile north of the Lydia on the west side of Foghorn creek.

[1]Davis, A. W.: Ann. Rept., Minister of Mines, B.C., 1923, p. 154.

The main working is on a trail at an elevation of 5,400 feet. It is an adit 150 feet long, ending in a 20-foot slope, and has been driven along a quartz vein which is well exposed on the surface. Where dipping 25 degrees to 30 degrees northerly, it outcrops southerly up the hillside for 100 feet vertically to where it is cut off by a granitic dyke.

The vein consists of a number of lenticular masses of quartz that follow the bedding of quartzose sediments. It is exposed throughout the length of the adit except where cut by the 20-foot granitic dyke 48 feet from the portal. The quartz contains some pyrite and has a maximum thickness of 4 feet. Surface sampling of this vein would have been sufficient to determine its worth.

A short adit, at the forks of a small creek to the south, is driven in dark grey schist. A small quartz vein is exposed at the portal and 15 feet to the north in the creek and its presence was apparently the reason for starting this working.

Another prospect adit 25 feet long has been started up the hillside to the south, on a quartz vein carrying a little pyrite.

MINNESOTA GIRL

The Minnesota Girl is located on the Foghorn Creek trail about 4 miles from Birch Island and is owned by J. W. Schlichter and associates of Birch Island.

The older workings on this property are about 250 feet above the trail where quartz stringers carrying galena, sphalerite, pyrite, and pyrrhotite occur in a greatly fractured contact phase of the granitic rock underlying the ridge on the east side of Foghorn creek. A sample from the upper dump taken by the Resident Mining Engineer of the district in 1923[1] assayed: gold, 0·02 ounce; silver, 4 ounces; lead, 1·5 per cent; zinc, 5 per cent. Several of the quartz stringers have been explored, but they are much too small to be mined separately and are too low in grade and too widely spaced to be mined collectively.

The more recent working is at trail level and is an adit driven 274 feet into the hillside along a direction of 78 degrees to get under the surface exposures. This adit is in metamorphosed, siliceous sediments for 166 feet to where the contact with the granitic rock is reached. A small quartz vein containing a little galena is visible in a 10-foot crosscut to the south on the granitic contact. Microscopic examination of granitic rock from the face of the adit shows that over half of it is ankeritic carbonate and the remainder plagioclase feldspar (albite-albite-oligoclase) and quartz with some calcite and pyrite. The rock is a contact phase of the aplitic granite intrusion referred to in the following description of the Smuggler property.

SMUGGLER

The Smuggler property is on the ridge on the east side of Foghorn creek between elevations of 3,500 and 4,200 feet and distant 3 miles by trail from Birch Island. The Smuggler was actively prospected by a Kamloops syndicate, in 1926 and early in 1927, for silver and lead. In 1929 test pits were sunk in a subsoil deposit of manganese just below the lowest working. A fluorite showing on top of a small knob on the ridge is well exposed, but no work has been done on it.

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

The workings on the silver-lead showings consist of three short adits and a few open-cuts.

The lowest adit, at 3,575 feet elevation and east of the cabins, was driven to explore a mass of quartz, that measures about 20 by 30 feet and contains some fine-grained galena, and is exposed a few feet to the west. The adit was driven 130 feet in an average direction of 226 degrees, in flat-lying, rolling, schistose, siliceous sediments with small lenses of quartz throughout. The quartz carries a little iron sulphide. Near the face of the adit, the schistose sediments contain considerable green chromium mica. Boulders of quartz occur in two open-cuts to the west.

One hundred feet higher and to the west are a short adit, a long open-cut, and a pit. The adit has been driven 55 feet in a direction of 199 degrees, in grey, siliceous, schistose sediments striking 345 degrees with low dip to the west. Small, irregular lenses of quartz, some of which carry a little galena, occur roughly following the bedding. One small lens of quartz at the portal cuts across the bedding. A few feet east of the adit is an open-cut 84 feet long in a direction of 112 degrees. A slip or small fault cuts across the open-cut 32 feet from the west end. From this slip easterly for 52 feet, a 2½-foot quartz vein is exposed in the south side, dipping about 25 degrees south and conforming in strike to the sediments. The north side of the cuts shows a little quartz and it appears that the cut has been made along the top of the bedded vein. Only a few specks of sulphide are discernible in the quartz. Between the adit and open-cut, a small pit exposes small masses of quartz in weathered rock. A small dump estimated by the writer to amount to about 10 tons has been reported to average: gold, trace; silver, 2·94 ounces; and lead, 9·1 per cent, but it is questionable if the average content could be determined by ordinary sampling methods. A specimen of the best-looking material shows watery quartz with cube and very fine-grained galena in milky quartz.

The highest adit is at an elevation of 3,755 feet and lies south of the lower workings. It follows an irregular course 150 feet long. Two crosscuts 50 and 20 feet long, respectively, have been run from it. The country rock is siliceous sediments, flat-lying with small rolls and slips and impregnated with pyrite. A little galena and pyrite occur in flat-lying lenses of quartz, the longest starting 30 feet from the portal and visible for 25 feet. The country rock is weathered for 30 feet from the portal. A little manganese oxide is displayed in surface material at the portal. A specimen of the best material on the dump shows quartz with fine-grained galena and coarser pyrite.

Near the top of the knob at 4,025 feet elevation, a short adit has been driven 230 degrees on a fissure dipping high to the northwest. A small lens of coarsely crystalline, white, green, and purple fluorite is exposed at the portal. Beyond this lens the fissure is filled with a little quartz carrying pyrite and stained with manganese oxide. This fissure cuts granitic rocks at their contact with the sediments which have been so soaked with granitic material that it is difficult to differentiate between the two classes of rock.

The manganese on the Smuggler property occurs below the lowest adit and also on the Foghorn Creek trail north of the Smuggler branch as a subsoil deposit of black oxide. The deposit below the adit lies where a slight flattening takes place in the steep slope of the ridge. A number of pits show the manganese to be very variable in grade. One pit may show as

much as 2 feet of clean oxide, whereas a pit 15 or 20 feet away may reveal only little oxide in the subsoil, or the oxide may occur as a cementing material in rock debris and constitute but a small percentage of the mass. The overburden varies from 1 to 3 feet in depth and second growth timber has sprung up everywhere.

At the second manganese occurrence, that is at the one on the Foghorn Creek trail, some of the pits show a fairly good grade of oxide with some calcareous material, but work to date indicates that the deposit is quite thin and very variable in grade. Only a few pits reveal possible commercial ore.

The Smuggler fluorspar showings are on top of the 4,200-foot knob just above and south of the workings. The deposit was staked in 1918 by A. G. McDonald, as agent for J. F. Gardner and E. H. Mansfield, and was examined the same year by R. P. D. Graham for the Munition Resources Commission of Canada.[1]

The formations exposed on top of the knob represent the upper contact of a granitic intrusion with, apparently, siliceous sediments soaked with igneous material and it is very difficult to differentiate between the igneous rock and the sediments. A sort of sheeting dips northwesterly at a low angle. Purple fluorspar is disseminated through an irregular zone of the sheeted rock and apparently the zone dips with the sheeting.

The main showing has a length of 250 feet northeasterly across the top of the knob, but fluorspar can be traced 300 feet southwesterly and 200 feet northeasterly, making a total length of outcrop of 750 feet. The main showing has a surface width of 25 feet at the southwest end; the width, 100 feet northeasterly, increases to 50 feet with traces of fluorite across further breadths of 100 feet on either side; and, at the northeast end, the width is about 50 feet with a decreasing content of fluorspar across a further breadth 40 feet northwesterly and traces for 200 feet southeasterly. A streak of fine-grained, dark purple fluorspar outcrops for 50 feet near the centre of the main showing and a few very small patches of fine-grained, white fluorspar outcrop near the southwest end.

The fluorspar in the main showing varies from a fine-grained, dark purple variety forming a large percentage of the rock mass, to a more coarsely crystalline variety in grains up to a quarter of an inch in diameter, disseminated in varying amounts through the rock. The main showing grades into rock carrying only an odd speck or two of purple fluorspar. Pyrite is disseminated through all of the fluorspar-bearing rock. The true thickness and depth of the deposit are unknown. The fluorspar-bearing zone appears to follow the sheeting in the rock, which dips flatly to the northwest; if so the thickness of the deposit would be only a fraction of the surface width.

A thin section from average grade fluorspar-bearing rock, in which the fluorspar occurs in disseminated form, shows the rock to be a crushed porphyry of aplitic (?) composition. The feldspar phenocrysts are rounded and crushed or bent and the rock exhibits a somewhat foliated structure. Fluorspar and celestite, which is not megascopically evident, are intimately intergrown and with the pyrite appear to have been introduced after the crystallization of the rock-forming minerals.

[1]Munition Resources Commission, Canada, 1920, pp. 49–52.

The following analysis by the laboratories of the Dept. of Mines, Ottawa, is of a carefully taken sample across 10 feet of the best-looking material at the northeast end of the main showing.

	Per cent
CaO	30·45
SrO	11·44
MgO	1·18
Fe_2O_3	2·94
Al_2O_3	6·82
Na_2O	5·21
K_2O	3·08
SO_3	16·13
Fl	18·58
SiO_2	12·10
	107·93
	7·82 Less O equivalent to Fl
	100·11

The fluorine calculated in terms of fluorspar (calcium fluoride) amounts to 37·99 per cent and the strontia calculated as celestite (strontium sulphate) to 20·27 per cent.

R. P. D. Graham sampled the high-grade, dark purple, fine-grained streak in 1918 and the following statements are from his report in the Munition Resources Commission, Canada, 1920.

"On analysis the fine-grained purple material was found to have a remarkable composition. It is in fact essentially a mixture of fluorite (calcium fluoride) and celestite (strontium sulphate) with minor quantities of lime, iron sulphide and oxide, alumina, silica, magnesia, manganese, etc., as impurities or present in associated minerals. The results of two partial analyses of this material are given below.

—	I	II
CaF_2	47·20	51·11
$SrSO_4$	32·30	26·29
$CaCO_3$	2·50	1·84
FeS_2	3·70	0·54
Fe_2O_3	.....	1·18
Al_2O_3	3·00	2·19
SiO_2	6·50	not det'd
MgO	present	present
MnO_2	.....	present
Undetermined	4·80	16·85
	100·00	100·00

Analysis I was made at the Ore Dressing and Metallurgical Laboratories of the Mines Branch, Department of Mines, Ottawa, on a sample composed of typical average specimens taken at short intervals along the whole length of the band.[1] Analysis II was made by me on the same material, after the removal of most of the pyrite by concentration. The inverse variation in the percentages of CaF_2 and $SrSO_4$ in the two analyses would indicate that the material contains both fluorite and celestite, together with minor quantities of other minerals such as quartz and aluminous silicates.

Examination of a thin section under the microscope bears out this view . . . . . .

The white material was found, on analysis, to be exceptionally pure, containing 96·12 per cent of CaF_2.[2]

[1]High-grade, dark purple, fine-grained streak.
[2]From fine-grained white patches of fluorspar.

Concentration Tests. The sample (10 pounds) of the fine-grained, purple material taken by Prof. Graham was subjected to concentration tests at the Ore Dressing and Metallurgical Laboratories of the Mines Branch, Department of Mines. The sample was crushed to 50 mesh and a small portion taken for analysis (*See* analysis I). It was found to contain 3·70 per cent of iron sulphide. Small tests were made by table concentration and flotation to remove these sulphides. Analysis showed 1·94 per cent of iron sulphide in the table product, and 1·07 per cent in the flotation product. Table concentration removed the coarse pyrite, but a percentage of the fine pyrite slimed and was carried over into the fluorite product. Flotation concentration removed the fine pyrite, but a percentage of the coarse pyrite was too heavy to float satisfactorily and remained in the fluorite product. A combination of table and flotation concentration should give satisfactory results.

Conclusions. The fine-grained, purple material is too impure to use as a flux or for purposes other than, possibly, the production of hydrofluoric acid. It is doubtful if such use could profitably be made of it. The celestite apparently cannot be removed by concentration. The coarser-grained material in the zone bordering the fine-grained band probably contains too low a percentage of fluorite and too much pyrite to be utilized. The white fluorite is of excellent quality but was only observed in a few small exposures. It is possible that further prospecting might reveal its presence in larger quantity."

Mr. Douglas B. Sterrett sampled the fluorspar in 1930 taking a 40-foot sample in a northwest-southeast direction, which is thought to represent about 25 feet in thickness.[1] About 5 pounds of the crushed sample was given to the writer for a check analysis which was made by the Deparment of Mines, Ottawa, returning 31 per cent fluorspar and 10·65 per cent celestite.

Two other occurrences of fluorspar were noted in the vicinity of the Smuggler: one of purple fluorspar and pyrite in a small prospect working at an elevation of 3,300 feet on the Foghorn Creek trail and the other at 3,000 feet elevation on the north slope of a 3,400-foot knob three-quarters of a mile northeast of the Smuggler.

The Smuggler fluorspar is fine grained and intimately associated with celestite, feldspar, and quartz, from which it has been impossible to separate it. Recently a flotation process has been developed for the recovery of fluorspar,[2] but the product is too fine grained for use as a flux, without some method of briquetting, off colour for the ceramic industry, and is limited to the aluminium industry. At Rosiclare, Illinois, where it has been used, a 40 per cent recovery yielding a 96 per cent CaF_2 product has been made from tailings containing 70 per cent CaF_2. Whether this process will separate fluorspar from celestite is unknown to the writer. Considering the much lower grade of the Smuggler fluorite this process if applicable does not appear to be economically possible at the present time.

The principal use of fluorspar is as a flux in the iron and steel industry, to a less extent in the aluminium industry, the ceramic industry, and in the manufacture of hydrofluoric acid. All of these uses require a high grade of fluorspar.

MILLAR'S PROSPECT

A prospect belonging to Mr. Millar of Birch Island is situated north and slightly east of the Smuggler at an elevation of 3,000 feet. It is reached by a branch trail, a little less than a mile in length, leaving the Foghorn Creek trail at an elevation of 2,620 feet.

[1]Personal communication.
[2]Mining and Metallurgy, New York, January, 1931.

An adit, 57 feet in length, driven into the hillside along a direction of 255 degrees, and an open-cut above it expose almost flat-lying, schistose, siliceous sediments into which considerable quartz has been injected in a very irregular manner. The quartz carries some pyrite, galena, sphalerite, molybdenite, and a little siderite. About 2½ feet of bedded quartz is exposed in the open-cut. The country rock is weathered to a depth of about 7 feet.

RED TOP

The Red Top group owned by W. E. Noble of Birch Island and J. Beaton of Vavenby is situated on the western end of the summit of mount McClennan at an elevation of 4,900 feet. The property is reached by way of the Mount McClennan forestry trail to a cabin at an elevation of 4,650 feet and then by a branch trail 2¼ miles long.

This group has been prospected by a number of open-cuts. The most westerly cut is 15 feet long across quartzites dipping 40 degrees north and is barren. Seventy feet due east is the north end of a cut that follows a lamprophyre dyke for 75 feet along a direction of 160 degrees. A little quartz carrying galena, sphalerite, and pyrite is exposed at one point along the side of the dyke and at this point there is also some sphalerite and pyrite in the quartzose sediments. Sixty feet east is the principal showing in a cut 50 feet long and exposing quartzites that strike 278 degrees and dip 42 degrees north. At 12 feet from the south end of the cut, sphalerite, galena, quartz, and pyrite are present in a zone that follows the bedding of the quartzite and is about 3 feet thick. Most of the mineralization is a very fine intergrowth of sphalerite and galena, for the most part replacing the quartzites.

Three hundred and eighty feet easterly along the strike of the quartzites, a 45-foot cut exposes a lens of quartz carrying some sphalerite and galena. The lens conforms with the attitudes of the quartzites, striking 285 degrees and dipping 43 degrees to the north. Sixty feet farther east, an 18-foot cut across quartzites, striking 295 degrees and dipping 45 degrees north, exposes a thin stringer of bedded quartz carrying very little sulphide. The next and last cut is 220 feet easterly, is 18 feet long, and exposes a little pyrite in the quartzites.

SNOW GROUP

The Snow group owned by W. E. Noble and J. Beaton is situated about 1 mile east of the Red Top workings at an elevation of 5,000 feet and immediately to the south of the Red Top trail.

An open-cut 115 feet long exposes an 18-inch lens of quartz and calcite with pyrite, sphalerite, and galena. The lens lies in and conforms with the bedding of quartzites and schistose platy quartzites which strike approximately 300 degrees and dip 14 degrees northeast. In the trench, a section, measuring 20 feet across the strike of the rocks, shows considerable oxidation apparently from the decomposition of pyrite. North of the long cut, a pit in drift and two open-cuts in quartzite are barren. Surface stripping just east of the northerly cut, or 80 feet from the north end of the long cut, exposes an irregular quartz vein up to 2 feet in width and containing pyrite, galena, and sphalerite. It dips flatly to the north in rough conformity with the bedding of the country rock. A number of

trenches and pits occur easterly from the long cut at intervals for 2,500 feet, but show little or no mineralization. The easternmost pits are beside the Red Top trail and one of them on the south side of the trail exposes a small, bedded quartz vein carrying pyrite.

SUNRISE

The Sunrise group includes the old Naomi claim and lies east of the Snow group. The workings are at an elevation of 4,870 feet on the side of the Forestry trail where it starts to climb to the summit of mount McClennan. They consist of three large open-cuts, a shaft, and two adits, all in quartzites. Massive pyrrhotite and pyrite occur in the form of a large, lenticular sheet or mass dipping slightly more steeply to the north than the almost flat-lying sediments.

The following quotations from reports by the Resident Engineer, A. W. Davis, in Annual Reports, Minister of Mines, British Columbia, for the years 1922 and 1924, indicate clearly the values found in the deposits. The present writer did not find the high-grade streak referred to in the 1924 report and it is possible that it has been taken out.

"The ore is siliceous, irony material lying in streaks conforming with the schist . . . . The following samples were taken from open-cuts 150 feet above tunnel:

(1) Upper 4·5 feet: gold, trace; silver, 1 ounce.
(2) Lower 5 feet: gold, trace; silver, 2·4 ounces.
(3) Picked sample from same cut showing streaks of black material: gold, 2·9 ounces; silver, 2 ounces.
(4) Along outcrops 600 feet east of tunnel: gold, trace; silver, 15 ounces.[1]

At the camp and near where the main workings are located a high-grade streak is exposed carrying grey copper, from which good values can be obtained. A sample taken last summer assayed: 4·6 ounces gold and 2·2 ounces silver, to the ton. This streak is very small and erratic; but following up and tracing it would appear to be the best method of developing the property."[2]

B.C. CLAIM

What is believed to be the B.C. claim is situated on Crossing (Galena) creek a short distance above the highway. Fine-grained magnetite and medium-grained pyrite occur in metamorphic rocks in proximity to a granitic intrusion at elevations of 2,200 and 2,930 feet. There are two prospect workings at elevations of 2,200 and 2,220 feet. Some placer gold is supposed to have been taken from this little creek[3].

LAST CHANCE

This property is on McCorvie creek, the first creek east of the Mount McClennan trail, and was not examined by the writer. It is described in the Annual Reports of the B.C. Minister of Mines for 1922 and 1923.

PLACER MINING

There is no record of placer mining having taken place within the district, but the Annual Reports of the B.C. Minister of Mines for 1899 and 1900 show that attempts were made to recover gold from the beds of North Thompson and Clearwater rivers. This was done in an attempt

[1]Davis, A. W.: Ann. Rept., Minister of Mines, B.C., 1922, p. 146.
[2]Davis, A. W.: Ann. Rept., Minister of Mines, B.C., 1924, p. 150.
[3]Ann. Rept., Minister of Mines, B.C., 1913.

to trace the source of fine gold found lower down the North Thompson and as a result Clearwater river was believed to have been the source of this material. In 1900 the Clearwater Placer Mining and Dredging Syndicate acquired several leases on the North Thompson and one on the Clearwater and put five men to work. Black sand samples sent to Baker and Company, of Newark, N.J., are reported to have returned 16 ounces gold and 124 ounces platinum to the ton of sample. The syndicate in 1901 bonded one of the dredging leases to George Gaunt of London, England, for six months for $50,000, but no further information concerning this deal is available. Evidently the ground was not productive, for there is no further record of placer mining operations.

MOLYBDENITE

A small showing of molybdenite lies just below the Clearwater road, 1½ miles from the main highway, on the south side of a little creek. The molybdenite and a little pyrite are in a quartz vein, 18 inches wide, cutting granodiorite close to its contact with graphitic schist and argillite. The vein strikes 70 degrees and dips 50 degrees southerly with a branch, a few feet long, striking more easterly. There are, also, one or two irregular lenses of quartz carrying molybdenite in the granodiorite. The sediments are south and east of the granodiorite.

A very little molybdenite was found in granitic rock at an elevation of 4,200 feet on the west side of Foghorn creek northwest of the Minnesota Girl adit that commences on the trail.

LIMESTONE

The only limestone found in any quantity close to transportation is in the large limestone belt crossing North Thompson valley near Vavenby just east of the map-area. An attempt, in a small way, was being made to quarry and burn this limestone. The kiln was constructed by driving into the limestone on the steep hillside, raising to the surface, and erecting a short stone stack above the raise.

CORBIN COAL FIELD, BRITISH COLUMBIA

By B. R. MacKay

CONTENTS

Illustrations

INTRODUCTION

The field season of 1930 was spent by the writer in a detailed investigation of the stratigraphy and structure of the Corbin coal field, British Columbia. This field is one of the smallest and at the same time one of the principal producing bituminous coal areas in southeastern British Columbia, and has gained prominence on account of the great original thickness of one of its coal seams and the remarkable concentration of coal in a small area that has occurred through intense folding and faulting of the measures. These are such that the deposit has been referred to at times as "the world's thickest coal seam" and as "a mountain of coal".

The determination of the number, thicknesses, and character of the seams present and the structure, extent, and geological relationship of the several deposits are of vital interest both to the operating company in its endeavour to evolve the most efficient method of mining these exceptionally thick deposits and to the Government in estimating the coal resources of the different fields. With the object of ascertaining these data the writer was assigned to geologically map and study the Corbin coal deposit.

The writer's thanks are due R. G. Crocker, General Manager, E. L. Warburton, Mine Manager, and F. W. Reger, Engineer of the Corbin Collieries, Limited, for assistance, office facilities, and data furnished the party in the course of its investigation. The writer's thanks are also due Messrs. H. N. Hainstock, H. C. Horwood, N. H. Fraser, and H. S. Fowler who were attached to the party as student assistants and who carried out their duties in a most efficient manner.

The Corbin Collieries, Limited, holdings comprise a block of twenty-four lots covering approximately 24 square miles of coal and forest lands, extending from a bend in the British Columbia-Alberta boundary line southward for a distance of 12 miles in a strip 2 to 3 miles in width and lying within 3 miles of the British Columbia-Alberta boundary line.

Most of the coal-bearing territory of this block, and that on which all development work to date has been done, is confined to Coal mountain which covers an area about 1 mile in width and 3 miles in length lying between the headwaters of Michel creek and its eastern branch known as Corbin creek. The middle of this field is 35 miles north of the International Boundary, 10 miles due south of Crowsnest station, and 3 miles west of the Alberta-British Columbia boundary.

The mining camp of Corbin lies at an elevation of 5,050 feet and is connected with the Canadian Pacific railway at McGillivray by a 12½-mile railway, the Eastern British Columbia railway, owned by Corbin Collieries, Limited. A government road from Crowsnest station on the Canadian Pacific railway leads up through Tent Mountain pass and over its summit into Michel Creek valley, whence it continues up Michel creek across the divide through Flathead pass at an elevation of 5,700 feet, down the valley of Squaw creek and Flathead river, and on to the International Boundary. Thirteen miles by road from Corbin is Flathead townsite, which was laid out as a coal mining camp in 1908, but of which only a few abandoned camp buildings now mark the spot.

A recently constructed automobile road runs for most of the way along the east side of Michel creek, connecting Corbin with the Crowsnest highway 2¼ miles below McGillivray. This road affords good motor communication with Fernie and the neighbouring coal camps of Crowsnest district, British Columbia and Alberta, and results in the Tent Mountain Pass road being seldom used.

Coal mountain lies between the headwaters of Michel creek and its most southern tributary, Corbin creek, being located in the heart of the Rocky mountains 3 miles west of the crest. The mountain rises from these broad, alluvial-floored valleys with a uniform slope of 20 degrees and terminates in a rounded, elongated crest which attains its maximum elevation of 6,830 feet, at a point 4,000 feet from the southern edge of the map-area, or 1¾ miles southeast of the junction of Michel and Corbin creeks. The lowest point in the area is on Michel creek at the northern border of the sheet. As this is 4,850 feet in elevation the maximum relief of the area is almost 2,000 feet. Upstream the relief gradually lessens, being reduced at the upper part of Corbin creek to slightly over 1,000 feet.

The gradient on Michel creek is about 100 feet in a mile and that of Corbin creek about 200 feet in a mile. Both streams are cutting their channels through the drift and remnants of at least three terraces may be observed in the lower part of the stream areas. The highest terrace is that on which part of Corbin is built at an elevation of 5,060 feet. Well-developed, alluvial fans have been built, at the mouths of the deeply incised tributary gullies, these being plainly apparent on the topographic map by the curved form of the countours.

The slopes of Coal mountain, and to a greater extent those on the opposite side of its two bordering valleys, are largely covered with a mantle of boulder clay, so that natural rock outcrops are relatively few and are confined mainly to the crest of the ridges, or to where the tributary streams and Michel creek have succeeded in cutting their channels through the drift into the underlying bedrock. On the northern slope of Middle mountain the thickness of the blanket of boulder clay is such as to

completely conceal the bedrock topography and to make impossible an accurate determination of the position of the coal seams or the boundaries between the geological formations. The great majority of the rock exposures are in grade cuttings along the mine trails and along the 6½-mile railway spur which runs from Corbin to No. 3 mine, and in the vicinity of the mine workings. The maximum depth of alluvium in the major valleys is estimated from the valley slope to range from over 200 feet below their junction to less than 100 feet at the head of the valleys.

Originally the entire area was covered with a mantle of spruce, fir, and poplar, but during the last twenty years a series of bush fires have destroyed most of the timber, leaving a stand of branchless tree trunks interspersed with second growth of jackpine, spruce, and brush. Small patches of unburned timber occur on the slopes of Coal mountain at the headwaters of Corbin and Michel creeks.

Mining of the deposits at Corbin began in 1908 when the Corbin Coal and Coke Company opened up their colliery. The progress in development has been given in the annual reports[1] of the Minister of Mines from that date up to the present. The total production up to the end of 1930 amounted to 2,304,773 short tons. Brief descriptions of the deposits based on these reports have been given by D. B. Dowling.[2] In 1913 a detailed geological investigation was made of Coal mountain, for the company, by F. C. Green, Consulting Engineer and Coal Geologist, Seattle. A map on a scale of 1 inch to 1,000 feet, with a contour interval of 100 feet, was compiled from the existing maps and data of the company's engineers and on it the approximate boundary of the coal-bearing rocks was indicated and a battery of structure sections of the principal coal seam drawn. The map and structure sections, although not claiming to be accurate, delineated the known coal deposits which were then under operation with sufficient precision, over most of the area, to be of considerable assistance to the company in planning their development work of mines Nos. 1 and 4 at the north end of Coal mountain, and especially of the open-pit workings at No. 3 mine on the west side of Coal mountain, together with the southward extension of these deposits. Green concluded that all of these deposits were segments of the same seam. At this time the economic possibilities of No. 6 deposit, which forms a disconnected body on the east side of Coal mountain and which is now the principal deposit under development, were not fully appreciated, the deposit being considered only as a shallow, stripping proposition. Much of the knowledge of this deposit has been obtained through recent mining development. In 1921 a private report on Coal mountain was made for the company by Van Court Warren, but this added little to the knowledge of the deposit; Van Court Warren interpreted Coal mountain as a fault block or "graben" of Kootenay coal-bearing and underlying Fernie sediments that had dropped down between Palæozoic limestones during the formation of the Rocky mountains, and he differed from Green in concluding that there are at least five thick coal seams in the measures corresponding to the different mines opened up. In 1923 R. Strachan[3] described the Corbin deposits along with other coal deposits of British Columbia. He gives the thickness of the seams at the

[1] Ann. Repts., Minister of Mines, B.C., 1908–1930.

[2] Dowling, D. B.: Geol. Surv., Canada, "Coalfields and Coal Resources of Canada", Mem. 59; "Coalfields of British Columbia", Mem. 69.

[3] Strachan, R.: "Coal Mining in British Columbia"; Trans. Can. Inst. Min. and Met., vol. XXVI, pp. 123–131 (1923).

six mines, which he refers to as six different seams, but states that the geological relationship of these deposits has not as yet been fully established. He puts the thickness of No. 6 seam at 400 feet. In 1924 E. L. Warburton[1], in a paper on "Wet Washing of Coal at Corbin," also points out that owing to the disturbed condition of the surrounding country and, therefore, the magnitude of the geological study involved, the number and relationship of the coal deposits have never been definitely worked out. He refers to No. 6 coal deposit as the "Mammoth bed" estimated to be over 450 feet thick from foot-wall to hanging-wall.

A more complete description of these unique coal deposits and method of preparation of coal for market at Corbin appears in the November, 1927, number of "Western Canada Coal Review."[2] In 1928 George Watkin Evans[3] published a short paper entitled "Mining World's Thickest Coal and Cleaning It" in which he gives the thickness of No. 6 deposit as 450 to 600 feet.

STRATIGRAPHY

GENERAL STATEMENT

The solid rock formations outcropping within the map-area range in age from Carboniferous to Lower Cretaceous embracing Mississippian, Pennsylvanian, possibly some Triassic, Jurassic, and Lower Cretaceous sediments; the first four mentioned being of marine origin and the last mentioned of continental or freshwater origin. All these rocks, and especially the upper and most incompetent formation, the Kootenay, have suffered intense folding, faulting, and crushing, being cut by strike and transverse faults of both the thrust and normal types with displacements along the faults measured in hundreds of feet. The bedrock is largely concealed by a mantle of Pleistocene boulder clay and Recent stream gravels, but sufficient exposures exist to reveal the lithological character of each of the formations present and to make possible the determination of the approximate thicknesses of each.

Table of Formations

	Age	Formation	Thickness	Lithological character
			Feet	
Palæozoic Mesozoic Quaternary	Pleistocene and Recent	.....	0–100	Glacial till and stratified, unconsolidated stream gravels and sand
				Erosional unconformity
	Lower Cretaceous	Kootenay.....	1,200	Sandstone, carbonaceous shale, thin lenses of conglomerate, and coal seams
	Jurassic.....	Fernie.....	2,800	Grey and brown clay shales, basal conglomerate
				Unconformity
	Carboniferous	Rocky Mountain quartzite.. (May include some Triassic)	960	Dolomite, quartzite, and chert
		Mississippian limestone.....	?	Fossiliferous limestone

[1]Warburton, E. L.: "Wet Washing of Coal at Corbin"; Trans. Can. Inst. Min. and Met., vol. XXVII, pp. 524–532 (1924).
[2]Warburton, E. L.: "Mining from a Mountain of Coal"; Western Canada Coal Review, vol. 10, No. 11, pp. 39–42 (1927).
[3]Evans, G. W.: "Mining World's Thickest Coal and Cleaning It"; Coal Age, vol. 33, No. 3, pp. 157–159 (1928)

PALÆOZOIC FORMATIONS

The lowermost Palæozoic rocks present consist of a thick series of light bluish grey limestone containing *Productus arcuatus* and other abundant marine species which place the strata as Mississippian in age. These sediments form the centre of the Flathead Range anticline, and skirt the eastern boundary of the area mapped. The upper part of the formation is seen in section in the walls of a prominent cirque a mile south of Corbin, but no determination of the thickness of the formation was made.

Overlying these fossiliferous limestones conformably is a series composed of dolomite, quartzite, and chert, the estimated thickness of which is 960 feet. No fossils were observed in these beds, but on the basis of their lithological character and stratigraphic position they are taken to represent the Rocky Mountain quartzite of Pennsylvanian age, although the uppermost beds of the series may prove to be of Triassic age. Near Crowsnest station, 10 miles to the north of Corbin, a 2- to 10-foot thick bed of dark grey to black, rock phosphate occurs at the junction of the Jurassic, and what is believed to be Triassic, beds. This bed has been opened at a number of widely separated points along the northern rim of Crowsnest basin and also at a point on the east side of Michel Creek valley 7 miles north of Corbin, but no evidence of its presence was observed at Corbin. The contact of the Palæozoic and Mesozoic beds is exposed at only one locality at Corbin, and here the coarse, conglomeratic character of the basal Mesozoic rocks suggests that if the phosphate bed of the underlying formation had been deposited, it was, in all probability, wholly removed by erosion prior to the deposition of the lowermost Mesozoic sediments.

FERNIE FORMATION

Jurassic sediments form the bedrock surface over most of Corbin map-area, occupying the broad valley of Michel and Corbin creeks and reaching over half-way up the western slope of Coal mountain. Owing to the paucity of outcrops no complete section of the Jurassic beds is obtainable, but sufficient exposures exist to indicate with fair certainty the varying lithological character of the sediments. The maximum thickness of the formation present, as obtained graphically in a series of sections taken across the area, is 2,800 feet.

The base of the Fernie at Corbin is marked by a bed of conglomerate which appears to be approximately 10 feet thick. It is composed of irregular fragments of dolomite, quartzite, and chert ranging in size from small pebbles to boulders several inches in diameter, all firmly cemented in a sandy matrix. This conglomerate outcrops at only one locality within Corbin map-area, on the crest of Corbin ridge 2,200 feet northeast of the townsite, so that its areal distribution and stratigraphic relation to the underlying quartzite could not be determined. The lowermost beds above the conglomerate observed in the area are probably separated from it by a stratigraphic interval of several hundred feet. These outcrop at the eastern edge of the map-area in the tributary gully that joins Corbin creek on the east at the south end of Corbin townsite. They consist of

light brown weathering, grey clay shales with a blocky fracture. A 10-foot thick horizon abounds in casts and moulds of belemnites. Near the mouth of this gully, and estimated to be approximately 600 feet stratigraphically higher in the series, the shales are light grey, thin bedded, and so compact and tenacious that it is difficult to make an impression on them with a handpick. On the west slope of Coal mountain at an elevation of 5,900 feet opposite the abandoned settlement of Twomile camp on the Flathead road 1,000 or more feet higher in the section, the shales take on a brownish grey colour and small, calcareous subspherical concretions appear. These concretions become conspicuously developed near the top of this brown, calcareous zone where in a 40-foot thick horizon they are so numerous that at the base of weathered slopes they may be gathered by the hundreds. They range in size from $\frac{1}{10}$ to 5 inches in diameter and occur in a dozen or more subspherical shapes. This concretionary zone was noted to occur at widely separated localities both on Coal mountain and on Taylor mountain on the west side of Michel creek and it should probably be considered as marking the top of the marine Fernie formation. Due, however, to its soft character, the horizon is extremely difficult to trace; consequently as defined by previous investigators, the boundary between the Fernie and overlying coal-bearing formation has been drawn approximately 250 feet higher up in the section at the base of a massive sandstone zone. The intervening beds consist of fine-grained, light grey to brown-weathering shale with thin lenses and beds of brown-weathering, grey, shaly sandstone. They record the transition from the estuarine conditions of the closing stage of the Jurassic to the freshwater sedimentation of the Lower Cretaceous.

A section of the passage beds measured on the slope of Taylor mountain on the west side of Michel creek opposite Coal mountain in descending order is as follows:

	Feet
Very fine-grained and bedded, light grey shale, weathering to a light brown	17·3
Interbedded black shale and light brown-weathering, grey, sandy shale ..	22·0
Bed of light brown-weathering, dark grey, calcareous sandstone, very fine-grained and bedded	1·0
Thin-bedded, light brown-weathering, grey, shaly sandstone with fine layers of black shale	16·0
Thin-bedded, hard, grey-black shale with fine layers of ironstone towards the bottom. These increase in number and thickness towards the top.	30·0
Very fine-bedded and fine-grained, brown-grey, shaly sandstone, silt-like..	42·0
Very fine-grained and bedded, brown-grey, shaly sandstone	58·0
Very fine-grained, light grey, sandy shale. Weathers brown and there are numerous massive beds 2 inches to 1 foot thick with finer bedded sandstone between	39·0
Brown-weathering, grey, very fine-grained, shaly sandstone	5·0
Black shale with numerous, small, 1-inch to 2-inch bands of light brown-weathering, grey sandstone	37·0
Very hard, fine-grained, dark grey sandstone, weathering light brown....	1·0
Thin-bedded, black shale with fine bands of brown-weathering shale. Contains rounded ironstone concretions	18·0
Thin-bedded, black shale with fine bands of brown-weathering shale. Contains rounded ironstone concretions	13·0
Thin, hard, finely bedded, black shale	29·8
Massive bands of shale	0·8
Thin-bedded, black, fissile shale with a few bands of lighter weathering massive shale 1 inch to 2 inches in thickness	58·0

KOOTENAY FORMATION

Overlying the Fernie formation conformably is a series of sandstones, with minor amounts of shales and coal seams. This series constitutes the coal-bearing measures designated, by G. M. Dawson, the Kootenay formation. They are confined largely to the crest and eastern slope of Coal mountain and form an elliptically shaped area 4,500 feet in maximum width and 2½ miles in length. Only the lowermost 1,200 feet of the formation has been preserved, and the paucity of outcrops prevents anything like a section being given. The formation, however, is well exposed on Taylor mountain on the west side of Michel creek opposite Coal mountain and a partial section measured from the basal sandstone upward gave a thickness of 1,854 feet. At Morrissey about 25 miles to the southwest, on the opposite side of the Crowsnest basin, a more complete section measured by James McEvoy gave a thickness of 4,736 feet.

By far the greatest part of the formation at Corbin consists of sandstones. These vary from fine-grained, shaly layers a few feet in thickness to massive, coarse-grained, crossbedded strata a hundred feet or more in thickness. Most of the sandstones are light grey, but some are dark and weather to a brown colour. In places thin beds and lenses of conglomerate were noted ranging up to 1½ feet in thickness with pebbles averaging ¼ inch in diameter and seldom exceeding ½ inch. The sandstone bed taken as marking the base of the formation has a thickness of over 150 feet. The shale beds vary from light grey, soft, sandy shale to dark grey to black carbonaceous shale. Some of the sandy shale has a high iron content which causes it to weather rusty brown. The carbonaceous shales abound in plant remains, including ferns, cycads, and conifers, and the assemblage indicates a Lower Cretaceous, Kootenay age.

Flora from the Kootenay Formation

A large and representative collection of the flora of the coal measures was made by the writer and examined by W. A. Bell, who reports as follows:

Locality 68. Collection obtained from rock dump at mine tipple, Corbin, B.C.

The following species were identified:

Cladophlebis ungeri ? (Dunker) Ward
Cladophlebis cf. *fischeri* Knowlton
Cladophlebis virginiensis Fontaine
Coniopteris sp.
Adiantum montanensis Knowlton
Ptilophyllum arcticum (Heer)
Podozamites lanceolatus (Lindley and Hutton) Fr. Braun
Nageiopsis longifolia Fontaine
Ginkgo lepida Heer
Czekanowskia sp.
Pityophyllum sp.

Remarks. The florule indicates a Kootenay age. *Cladophlebis virginiensis* Fontaine and *Ptilophyllum arcticum* Heer were most abundantly represented. *Ptilophyllum arcticum* (Heer) includes some forms that are indistinguishable from *Ptilophyllum boreale* (Heer), *Ptilophyllum acutipennis* (Heer), and *Ptilophyllum brevipennis* (Heer). It is probable, as

Seward noted, that these various species of Heer are not of specific rank. However, the majority of the specimens from Corbin are grouped about *Ptilophyllum arcticum* as a mean form and it is considered expedient at this time to recognize the fact.

Locality 69. Corbin map-area, from horizon about 15 feet above coal seam.

The following species are present:

Cladophlebis virginiensis Fontaine
Cladophlebis martiniana Dawson
Coniopteris sp.
Sphenopteris sp.
Ptilophyllum arcticum (Heer)
Dioonites buchianus (Ettingshausen) Bornemann
Czekanowskia sp.

Remarks. The assemblage indicates a Kootenay age.

The Kootenay formation at Corbin contains two important coal seams. The lowest of these, the Mammoth seam, has an original thickness varying from 15 to 180 feet, and is characterized by the presence of beds and lenses of carbonaceous shale, locally known as blackjack. The Upper seam has a thickness of 10 to 18 feet where observed, and lies approximately 400 feet stratigraphically above the lower or Mammoth seam. This seam is of somewhat poorer quality than the Mammoth seam. Both the Mammoth and Upper seams are believed to be represented in a section of the Kootenay formation exposed on Taylor mountain, the Mammoth seam being 43½ feet thick and the Upper seam being 24½ feet thick. There they lie 260 feet and 898 feet, respectively, above the base of the formation.

The section of Kootenay sediments as obtained on mount Taylor, given in descending order, is as follows:

Character	Thickness Feet
Dark grey, massive sandstone which weathers to a light grey	23·9
Heavy, dark grey, coarsely bedded sandstone, weathering light grey	26·9
Dark brown, chunky shale	18·7
Black, argillaceous, shaly sandstone	10·4
Massive, grey sandstone	18·7
Hard, dark brown sandstone, badly crumpled and overturned in places	35·0
Hard, grey, argillaceous sandstone weathered to a rusty orange colour	20·1
Brown shale	19·4
Brown-weathering, grey, shaly sandstone, almost slaty in texture	66·4
Black, blocky shale, weathering to a whitish grey	69·3
Dark grey, shaly sandstone, weathering to a rusty colour	9·7
Black shale, partly concealed	34·3
Dark, black, argillaceous shale	1·5
Light brown-weathering, grey, platy, shaly sandstone	12·7
Thin-bedded, platy, grey-weathering, dark grey, shaly sandstone	9·0
Light brown-weathering, platy, grey sandstone with thin layers of brown shale	28·9
Brown shale	30·3
Black, heavy, massive, shaly sandstone, argillaceous	8·0
Light brown-weathering sandstone, medium bedded, becoming massive at the top	17·5
Fine to coarse-grained, brown-weathering, grey sandstone	67·2
Light brown-weathering, coarse, brown-grey sandstone	31·0
Thin-bedded, platy, grey sandstone weathering light brown	18·2
Concealed	18·2
Concealed	10·8
Hard, black shale	49·0
Hard, dark grey, argillaceous shale weathering light grey	8·0

Character	Thickness Feet
Mostly concealed, but there is some dark brown shale showing and also some dark grey sandstone	37·0
Sandstone and shale. Partly concealed	39·0
Grey sandstone, weathering to a rusty red	28·1
Fine-grained, light brownish grey sandstone weathering to a brownish red	15·0
A coarse brown and black, grained sandstone, weathering reddish grey; rather platy and crossbedded	15·0
Coarse, dark grey sandstone, crossbedded and massive	14·0
Brown-weathering, thin-bedded, platy, hard grey sandstone becoming coarser towards the top	43·0
Hard, platy, thin-bedded, grey sandstone, weathering to a rusty red. Contains a few plant remains such as grasses	28·0
Carbonaceous shale, grading into a grey, shaly sandstone	3·4
Upper seam weathered coal	24·6
Black, carbonaceous shale	2·0
Fine-grained, thin-bedded, hard, shaly sandstone, grey, weathering brown, and is iron stained	4·1
Carbonaceous shale	6·8
Very poor *coal*, slickensided	3·4
Carbonaceous shale	1·3
Grey, shaly sandstone, very iron-stained and weathered to a rusty red. Contains a few ironstone lenses	6·2
Black shale, becoming brownish towards the top and is iron-stained	10·9
Very hard, black, fine-bedded shale, crisp. The upper beds of this portion of shale are carbonaceous and contain small bits of stems	55·4
Brown-weathering, thin-bedded, grey, shaly sandstone	1·3
Hard, platy, black shale	11·6
Brown-weathering, thin-bedded, grey, fine, shaly sandstone and interbedded shale	4·8
Very fine, fissile, iron-stained, brown shale	28·0
Thin-bedded, brown-weathering, grey, argillaceous shale	12·3
Fissile, brown shale	26·7
Dark grey, hard, shaly sandstone and shale, finely interbedded	11·6
Finely laminated, shaly, brown sandstone	5·4
Grey-weathering, brownish shale	9·6
Grey, shaly sandstone with a few shale layers	7·4
Grey-brown shale	28·0
Hard, grey, shaly sandstone	1·0
Brown shale	5·4
Brown, blocky shale	8·2
Thin-bedded, brown, shaly sandstone	6·8
Massive-bedded, grey-weathering, grey-brown sandstone	13·0
Interbedded sandstone and shale. Sandstone beds about 1 foot in thickness	8·7
Brown shale with some shaly sandstone layers	3·5
Fairly massive, grey weathering, fine-grained, grey sandstone	42·7
Light grey, fine-grained sandstone coarsely bedded and weathered to a very light grey, and is iron-stained in places	107·0
Very massive, dark grey sandstone	63·0
Dark brown shale	7·6
Grey sandstone, weathering brown	4·6
Brown shale	4·6
Brown-weathering sandstone	1·0
Dark, black, sandy shale	2·3
Reddish brown sandstone	1·0
Black shale	5·3
Very dark brown sandstone, weathered to a light brownish buff. Fine grained	3·2
Dark grey, pepper-and-salt textured sandstone weathering light grey	51·7
Dark grey, pepper-and-salt textured sandstone, weathering light grey with a 3-foot band of light brown, shaly sandstone about the centre	29·7
Very fine, laminated, grey sandstone with a 3-inch massive band 1 foot from the top	3·7
Coarse, grey-brown sandstone, weathering light grey with iron stainings	2·3
Brown, nodular, iron, concretionary shale, light grey in bottom 6 inches	2·0
Light brown, shaly sandstone with some black shale near the bottom. Weathers to a light brown. The upper 2 feet is of black, semi-carbonaceous shale	15·1
Carbonaceous shale	9·2
Concealed, probably shale	24·5
Black shale	6·0

Character	Thickness Feet
Mammoth seam:	
Bony *coal*	5·5
Good *coal*	3·7
Brown-weathering carbonaceous shale	4·2
Bony *coal*	8·8
Coal	20·8
Massive-bedded, dark grey, pepper-and-salt textured sandstone. Weathers to a light grey	39·5
Light brown-weathering, fine-grained, massive, brown-grey sandstone	3·0
Massive-bedded, brown sandstone with a few lenses of finer-bedded sandstone	33·1
Fine-grained, thin-bedded, light brown-weathering sandstone	7·0
Massive bed of brown-grey sandstone, fairly coarse grained	8·0
Thin-bedded, platy sandstone. Fine grained, dark grey to brown, weathering to a light grey and buff, slightly crossbedded	27·5
Dark grey to brown sandstone weathering to a light brown. Fine grained and crossbedded in places	4·0
Massive, dark grey, coarse-grained sandstone, weathering to a light grey	55·0
Finely bedded, blocky, grey sandstone, iron-stained to a bright orange	2·0
Finely bedded, blocky, grey sandstone weathering to a light grey	28·5
Fine and massive bedded, light grey sandstone	29·4
Massive, brown and grey sandstone, showing few or no bedding planes and weathering to a light grey	23·0
Total thickness	1,854·0

STRUCTURE

The coal measures form a tightly compressed and intricately folded and faulted synclinorium, 4,500 feet in maximum width, which is separated from Taylor Mountain coal basin, another erosion remnant 2 miles to the northwest, by a broad, folded, and faulted anticlinorium of Fernie shales. This anticlinorium consists of at least two anticlines, the axis of the intervening syncline being located on the crest of the hill 4,000 feet southwest of the junction of Michel and Corbin creeks. The axis of the most easterly of the anticlines of this anticlinorium lies approximately 4,000 feet east of the synclinal axis or 2,000 feet to the west of the crest of Coal mountain. Had the coal of this anticline not been eroded away its coal seams would now be approximately a half-mile above the bed of Michel creek.

The Coal Mountain synclinorium may be most simply described as composed of three pronounced synclinal folds ranging in maximum width from 1,000 to 1,500 feet and separated from one another by anticlinal zones, some of which are faulted and intricately crushed. The axes of these folds trend north 8 degrees east approximately paralleling Flathead Range anticline on the east and the Michel Creek anticline on the west. The synclinorium is of the abnormal type, with the axial planes of these three synclines diverging upwards; that of the western syncline being slightly inclined to the west, that of the central basin being almost vertical, and that of the eastern basin being inclined to the east. The Fernie sediments outcropping along Corbin creek dip 45 to 60 degrees west, but in the gully east of Corbin they are in part overturned to the west corresponding to the overturned attitude of the western limb of the Flathead Range anticline. The thickness of the Fernie beds lying between the Coal Mountain synclinorium and the Palæozoic anticline of Flathead range varies from 600 feet north of Corbin to 2,500 feet at the south end of the map-area and this variation is due to a progressively increasing part of the formation northward being cut out by strike faulting which occurred during

the elevation of the Rocky mountains. Most of the observed fault planes on the synclinorium and on the anticline to the west dip steeply to the west, but those on the east side of the synclinorium are interpreted as dipping steeply to the east, as this explains most simply the cutting out of the Fernie shales along Corbin Creek valley, and conforms with the overturned attitude of the western limb of the Flathead Palæozoic anticline.

The fault zone along Corbin Creek valley is thought to be one of the main zones along which movement has taken place. It is in alinement with the northwesterly-trending pronounced fault which marks the western border of the large area of Precambrian sediments lying to the east of Flathead river, and which has been traced for 30 miles north of the International Boundary (*See* Calgary Sheet, Map 204A). Although differing in direction of throw, and probably of later date than most of the thrust faults of the area, it is thought to join in depth the low angle fault plane which emerges 4 miles to the east at the base of the Rocky Mountain scarp, being the same plane on which Crowsnest monadnock 14 miles to the northeast is located. The abnormal and intensive folding and faulting which characterize the Coal Mountain synclinorium, as compared with the open basins of Taylor mountain and the main Crowsnest basin farther west, point to the proximity in depth of this underlying major low angle thrust fault.

In addition to this major fault zone Corbin area is cut by at least seven steeply dipping longitudinal faults lying to the west and paralleling the general structure of the area. Along the majority of these faults the beds on the west have overridden those on the east with an upward displacement of them measured in hundreds of feet.

Corbin area is also traversed by a later series of northwesterly-trending transverse faults which converge toward the junction of Michel and Corbin Creek valleys to continue northwesterly down Michel creek.

The axes of the three major synclines have been traced from the southern border of the map-area to the northern end of Coal mountain. The synclines may be conveniently designated as the western syncline, the central syncline, and the eastern syncline, the axes of which lie from 1,000 to 1,500 feet apart. The axis of the western syncline crosses the southern border of the map-area at a point 1,500 feet west of the crest of Coal mountain, and except for a few small offsets runs almost due north to beyond mine No. 3 open-cut. There it is offset by a transverse fault to the northwest for a distance of 500 feet. Thence it continues a northeasterly course for 2,000 feet to the crest of Coal mountain where it encounters another transverse fault. From this fault the synclinal axis trends almost true north passing about 200 feet west of No. 2 mine entry. In the southern and central parts of the map the syncline is shallow and open as indicated in No. 3 mine pit, but passing northward it becomes more highly compressed and modified by strike faults.

The central syncline consists of two troughs, the axes of which are difficult to trace. At the southern border of the map-area these troughs converge, and both lie to the west of the crest of Coal mountain. Four thousand feet to the north of the southern border of the map the axis of the western trough passes through the summit of Coal mountain, and from here it continues northward along the crest for half a mile where it is offset

a little to the northwest by a transverse fault. It is from here that the difficulty of tracing the trough arises, it being almost wholly obliterated by thrust faulting. It is thought to form the basin lying on the west of the tightly compressed, crushed, and faulted anticlinal zone on which is located mine No. 1. For most of the distance the eastern trough is concealed beneath boulder clay, but it is thought to be that on which No. 5 mine is located, and of which the eastern limb has been completely cut off by strike faulting.

The central syncline is separated from the western syncline by an anticlinal fold, the axis of which has also been traced along the west slope of Coal mountain from the southern border of the map northward to the east side of No. 3 open-cut, where it is also offset 300 feet to the northwest by a transverse fault to continue a half mile in a northeasterly direction across the crest of Coal mountain and down the eastern slope. Here it is again offset to the west and loses its identity in a pronounced strike fault which runs directly north passing about midway between No. 4 and No. 2 mines.

The eastern syncline forms a detached, canoe-shaped basin lying on the eastern slope of Coal mountain. It is more regular than either of the two former troughs, and its main modification consists of a slight offsetting of segments of the fold by three northwesterly-trending transverse faults. The axis of the basin lies within a few hundred feet of the crest of Coal mountain at the southern border of the map-area and disappears beneath the alluvium of Corbin Creek valley at a little over a thousand feet north of mine No. 6 entry. The form and structure of this basin are shown on the map and sections by the outcrop and attitude of the Mammoth coal seam. This syncline is separated from the central syncline in the southern part of the field by a double-crested, faulted anticline and on the northern part by an anticline and fault. Each of these basins will be described further in connexion with their respective coal deposits.

Due to the paucity of the outcrops, the five major transverse faults referred to above and indicated on the map and structure sections are based on relatively few clearly defined fault contacts. Their presence has been largely deduced during the compilation of the map in an attempt to interpret the observed field data in harmony with the most simple explanation of the varying attitudes of the beds, the offsetting of the axial lines of folds, and the abrupt termination of geological boundaries and coal seams. There is little doubt that numerous strike and transverse faults not shown on the map exist, and the structure of the area is doubtless even more complicated than indicated. For example, the initial factor in determining the course of Michel valley above Corbin Valley junction was doubtless a major northerly trending fault. Lacking other evidence of its existence, however, this fault has not been indicated on the battery of structure sections. All the transverse faults noted converge toward the junction of Michel and Corbin creeks and apparently continue a northwesterly course down Michel creek towards White Sulphur. This segment of Michel Creek valley doubtless coincides with one of the major diagonal faults of the district, being in alinement with the faults bordering the large Precambrian area lying to the east of Flathead river and north to the International Boundary.

The most westerly transverse fault indicated on the map and structure sections extends from the southern border of the map-area, at an elevation of 5,750 feet, 1,800 feet west of the crest of Coal mountain down its western slope in a direction north 10 degrees west. It passes through the gully at 5,900 feet, which separates the small knob from the main slope at the northern end of the upper railway switchback, crosses Opencut creek approximately 1,000 feet above its junction with Michel creek, and continues this course to near the junction of Michel and Corbin creeks where it curves slightly to the west to conform with the northwesterly course of this part of Michel Creek valley. Along this fault the beds on the west side have moved upward, but although it appears to be one of the most pronounced faults of the area, neither horizontal nor vertical displacement along the fault could be determined. A second transverse fault crosses the crest of Coal mountain 1,300 feet from the southern end of the map-area. It trends north 40 degrees west and merges into the first described fault where the lower railway spur crosses the small stream lying 500 feet southwest of Opencut creek. The existence of this fault is indicated by the abrupt termination and offsetting of axial lines of folds and strike faults, and the duplication of the Mammoth seam outcrop on the western limb of the central basin. The axial lines, faults, and coal seams on the northern side of this fault have moved relatively to the southeast with distances ranging up to 150 feet, and with a maximum upward displacement of the apices of folds of 100 feet. Another transverse fault crosses the crest of Coal mountain about midway between its north end on Corbin creek and the southern border of the map-area in a direction north 40 degrees west and intersects the lower mine railway spur 1,200 feet north of Opencut creek, and merges with the most westerly noted transverse fault near the junction of Michel and Corbin creeks. The presence of this fault is indicated by the abrupt offsetting of the Mammoth coal seams outcropping on the flanks of the eastern basin (No. 6 deposit) and the termination of the Mammoth coal seam on the west flank of the western basin (No. 3 deposit) 1,000 feet north of Opencut No. 3 mine and also the cutting off of the Upper seam on the east slope near the crest of Coal mountain. The axial lines, faults, and coal seams on the north side of this fault appear to have been offset 100 to 350 feet to the northwest, and the apices of folds on the north side appear to have dropped a maximum of 150 feet.

Evidence of a fourth transverse fault is to be seen in the gully a couple of hundred feet north of No. 6 mine entry and on the crest of Coal mountain at a point west 16 degrees north from this locality. On the west slope of Coal mountain this fault probably curves slightly to the north to merge into the main fault near the junction of Corbin and Michel creeks. Beyond the localities indicated the fault is deduced from either the termination or the offsetting of axial lines of folds and strike faults. Those on the north side of the fault on the east slope of Coal mountain appear to be offset approximately 200 feet to the northwest and this offsetting probably carries on to the west side of the mountain. The structure of the beds in the segment lying between the third and fourth mentioned, transverse faults, with the exception of that of the eastern major syncline, is far more complicated than is that of either of the adjacent fault wedges to the south or to the north, and as the outcrops are few the structure of the block as shown on the sections must necessarily be regarded as approximations only.

The existence of a transverse fault, trending in a direction north 65 degrees west beneath the alluvium of Corbin creek between Coal mountain and Middle mountain, is assumed mainly from the abrupt change in the course of Corbin valley cutting across the rock structure, and the offsetting of the axial lines and faults apparent when those of Middle mountain are projected southward into the area lying between No. 5 and No. 6 mines. Comparatively little data pertaining to the attitude of the beds, the geological boundaries, the existence of coal seams and axial lines of folds on Middle mountain to the west of Corbin were obtainable owing to its heavy mantle of boulder clay and the entire absence of any prospecting. Assuming that the correlation of the few axial lines observed to the north of Corbin valley with those on the south side is correct, those on the north side have a relative offset of approximately 200 feet to the west. The relative vertical displacement of the beds on opposite sides of the fault is even more indefinite, but from the increased southerly plunge of the folds on the north side of Corbin valley, and from their proximity to the overthrust Palæozoic beds from the east it is inferred that the beds on the north side of the fault have moved upward with respect to those on the south side.

ECONOMIC GEOLOGY

Coal is the only mineral of economic importance found within the Corbin map-area. The coal is of bituminous rank, and occurs in the Kootenay formation of Lower Cretaceous age. Owing to the complexity of the folding and faulting which characterizes the area and the veneer of boulder clay, alluvium, and talus which conceals most of the bedrock, the number, thicknesses, extent, and relationships of the several coal deposits have until recently remained unsolved, some investigators maintaining that each of the six mines was located on a different seam and others that all the mines were developing the same seam. The results of the past season's field work prove that two commercial seams are present in the formation at Corbin. These are designated as the Mammoth seam and the Upper seam, and lie 400 and 850 feet, respectively, above the base of the formation.

The Mammoth seam has a sandstone floor and a sandy shale roof, but in places a lens of carbonaceous shale, ranging up to 50 feet in thickness, separates the coal from the floor. The seam varies so greatly in thickness and purity within short distances that a description of it obtained at one locality is almost inapplicable to it at another. It ranges in original thickness from 25 to 180 feet and where severely folded it attains in some places a thickness of over 400 feet. Thin beds of soft, carbonaceous shale locally termed "blackjack" occur irregularly distributed within the seam itself.

The Upper seam has a sandstone roof and floor and is also characterized by the presence of partings of soft carbonaceous shale, of varying thicknesses. At the few localities at which it could be examined it had a total thickness varying from 10 to 18 feet.

The Mammoth seam is opened up at mines 1, 2, 3, 4, and 6 and the Upper seam at No. 5 mine which is still in the prospect stage. Unfortunately, little prospecting has been carried on by the Corbin Collieries,

Limited, away from the mines and over most of the map-area very little data could be obtained regarding the thicknesses of the seams, the presence of which was indicated by occasional small outcrops of coal or patches of coal bloom appearing through the veneer of boulder clay.

ANALYSES OF COAL

The coal of Corbin area is of bituminous rank and non-coking, and with a low sulphur content. Owing to the nature of the deposit a cross-section analysis of the seam is variable, bands of clean coal being interspersed with bands of impure coal containing varying percentages of bone, shale, and mineral impurities. These impurities give to the raw coal a rather high ash content, but this is greatly reduced in the preparation of the coal for market, as indicated in the last two analyses of the table. Most of the samples were taken according to Geological Survey procedure. The face of the coal seam was cleaned and a sample from a channel 4 inches wide and 1 inch deep taken completely across the seam omitting shale partings over 1 inch in thickness. The gross samples thus obtained were pulverized and quartered down at the mine to give 5-pound samples, which were sealed in air-tight galvanized-iron cans so that the original moisture content of the coal would be preserved until the samples were opened for analysis in the Fuel Testing Laboratories of the Department of Mines at Ottawa. The results of these analyses are given on the accompanying table.

Proximate Analyses of Bituminous Coal Samples from Corbin, B.C.

(Collected by B. R. MacKay, August 1930; or for him by officials of Corbin Collieries, Limited, December 31, 1930)

Lab. No.	Description and location of sample	Form of analysis	Moisture	Vol. mat.	Fixed carbon	Ash	S	Heating value calories	B.T.U.'s	F.R.	Coking properties
7769	Sample across Mammoth seam at No. 2 mine, 400 feet from mouth of tunnel, omitting shale layers, taken August 28, 1930	R	3·0	21·5	49·4	26·1	0·6	5,850	10,530	2·30	Fair
		D	.....	22·2	50·9	26·9	0·7	6,030	10,850		
7766	Sample across Mammoth seam at No. 4 mine, omitting shale bands taken August 29, 1930	R	2·1	23·3	60·4	14·2	0·2	7,000	12,600	2·60	Poor
		D	.....	23·8	61·7	14·5	0·2	7,150	12,870	2·60	"
8150	Sample across Mammoth seam at No. 4 mine taken December 31, 1930	R	1·2	25·8	57·0	16·0	0·2	6,840	12,310	2·20	Poor
		D	.....	26·1	57·7	16·2	0·2	6,920	12,460	2·20	"
7767	Sample at No. 6 mine across Mammoth seam 138 feet thick at Jordan Stripping, omitting shale layers over $\frac{1}{10}$ foot thick, taken August 28, 1930..	R	4·9	21·9	57·5	15·7	0·3	6,605	11,880	2·65	Poor
		D	.....	23·0	60·5	16·5	0·3	6,940	12,500	2·65	"
8152	No. 6 mine sample, taken December 31, 1930.....	R	3·1	22·5	55·9	18·5	0·2	6,330	11,390	2·50	Poor
		D	.....	23·2	57·7	19·1	0·2	6,535	11,760	2·50	"
7768	No. 5 mine, sample taken across Upper seam at face of workings August 29, 1930	R	3·2	21·3	48·6	26·9	0·3	5,725	10,310	2·30	Poor
		D	.....	22·0	50·2	27·8	0·3	5,920	10,650	2·30	"
8151	No. 5 mine sample, taken December 31, 1930.....	R	0·8	20·6	38·2	40·4	0·4	4,720	8,500	1·85	Poor
		D	.....	20·8	38·5	40·7	0·4	4,760	8,570		
7765	Average tipple sample No. 4 and 6 mines, taken August 15, 1930	R	2·7	22·7	58·5	16·1	0·2	6,790	12,220	2·60	Poor
		D	.....	23·3	60·2	16·5	0·2	6,980	12,570		"
8147	Birds-eye coal. $\frac{1}{4}$-inch slack, taken December 31, 1930	R	3·3	23·0	56·5	17·2	0·2	6,530	11,760	2·45	Poor
		D	.....	23·8	58·4	17·8	0·2	6,755	12,160		
8148	Washed coal taken December 31, 1930.....	R	1·3	24·0	63·0	11·7	0·3	7,250	13,060	2·65	Poor
		D	.....	24·3	63·9	11·8	0·3	7,345	13,220		
8149	Air-cleaned coal taken December 31, 1930.....	R	2·2	23·5	61·6	12·7	0·2	7,035	12,660	2·65	Poor
		D	.....	24·0	63·0	13·0	0·2	7,200	12,950		

R—As received. D—Air dried.

AREAL DISTRIBUTION OF COAL

The coal seams present on Coal mountain are the two lowest seams of the Kootenay series, and these are doubtless the same as occur on the two adjacent erosion remnants, Tent mountain lying to the northwest, and Taylor mountain lying to the west. On Tent mountain the seams are 45 feet and 12 feet in thickness, whereas on Taylor mountain they measure 43 and 24½ feet thick, and lie respectively 260 and 898 feet above the base of the formation.

The coal deposits of Coal mountain may be most conveniently grouped under the three major structural troughs previously referred to and which are shown by the configuration of the Mammoth seam on the geological map No. 2287 and on the accompanying battery of structure sections. These may be designated as the Western coal basin, the Central coal basin, and the Eastern coal basin.

WESTERN COAL BASIN

The Western coal basin as defined by the Mammoth seam has a maximum width of 1,000 feet and a length of 6,800 feet. It extends from the southern end of open-pit No. 3 mine on the south at an elevation of 7,850 feet to No. 2 mine at the northern end at an elevation of 5,350 feet. The trough is cut into three segments of almost equal length by two major transverse faults. The southern segment is a single, broad, shallow basin. The northern segment of the trough is much more compressed and cut by thrust faults. In the central segment the structure of the basin is complicated by folds and thrust faults and its form is more difficult to decipher, especially as nowhere within the segment could an outcrop of the Mammoth seam be actually located. Where indicated its position is inferred from the position and structure of the associated sediments and the movement of this segment with relation to the adjacent fault blocks on the north and south. In the northern segment in the vicinity of No. 2 mine the maximum thickness of the Mammoth seam, except where severely crushed, is placed at 100 feet, whereas at No. 3 mine the seam is 180 feet thick and has the following section:

Roof	Shale Feet
Coal	10
Shale	10
Coal	125
Shale	15
Coal	20
Floor	Sandstone

CENTRAL COAL BASIN

The Central coal basin is 1,500 feet in maximum width and 12,500 feet in length. It extends along the crest of Coal mountain from a little beyond the southern border of the map-area at an elevation of 7,500 feet, northward to opposite open-pit No. 3 mine, where it continues its straight course along the eastern slope to within a thousand feet of Corbin creek at an elevation of 5,200 feet. Throughout its length this basin consists

of two complementary troughs. These are clearly defined at the southern end where each is approximately 500 feet in width and separated by a strike fault. Traced northward the western trough can be easily followed along the crest, but the eastern trough, which lies on the eastern slope of Coal mountain, is largely concealed by boulder clay and is more greatly modified by strike faulting. At the northern end of Coal mountain the western subsidiary trough is almost obliterated, being crushed against the intervening anticlinal zone on which mine 1 is located, whereas the syncline on the east side of this anticline has its eastern limb apparently cut completely off by a strike fault that coincides with the axis of the syncline. The northward continuation of the western limb of this trough occurs on Middle mountain where both the Mammoth and Upper seams are represented. This Central basin has been cut into five approximately equal segments by the four northwesterly trending transverse faults each of which causes a slight offsetting of the coal seams. The structure of the central segment is so complicated by tight folds, overturned beds, and strike faults that the position and attitude of the Mammoth seam as shown must be regarded as only approximate. A more accurate determination of its position and attitude must await prospecting, drilling, or development work.

The western limb of the Central coal basin can be traced without any apparent break by occasional outcrops of the Mammoth seam along the western hillslope of Coal mountain from the upper end of No. 3 mine pit southward for a distance of 4,000 feet. Throughout this distance the seam has an average dip of 30 degrees east. At the southern border of claim 6997 the Mammoth seam is cut by one of the major transverse faults, and the outcrop on the south side of the fault is offset a distance of 300 feet to the northwest. From this fault the seam continues southward a distance of 1,500 feet where it forms the trough of a subsidiary fold, thence it continues its southward course with a dip of 40 degrees east for a distance of 1,200 feet to meet the axis of the western syncline of the Central basin. Passing around this it may be traced up the eastern limb of this syncline for a distance of 1,500 feet with dips varying from 40 degrees to 65 degrees west. There it appears to be cut off by the same northwesterly-trending transverse fault. Thirteen hundred feet farther south the Mammoth seam reappears on the western limb of an adjacent subsidiary syncline which apparently lies in faulted relationship with the previous trough with the intervening anticline cut completely out. The seam dips 45 degrees to 70 degrees east, and can be traced to beyond the southern border of the map-area.

At the southern border of the map this syncline is 400 feet in width and the Mammoth seam on its eastern limb outcrops on the crest of Coal mountain. It can be traced northward for a distance of approximately 2,000 feet where it, also, is cut off by the transverse fault. From here northward the position of the Mammoth coal seam on the intervening anticline and on the eastern limb of the basin has to be largely inferred. The intervening anticline is believed to continue northward to join with that on which No. 1 mine is located, whereas at the northern part of Coal mountain the eastern limb of the basin appears to be completely cut out by a strike fault passing close to the entry of No. 5 mine.

The Upper seam has its greatest extent in this, the Central coal basin. It forms a small, elliptically-shaped outcrop capping the highest point of Coal mountain and is thought to extend from a point 800 feet farther north along the flanks of the basin for a distance of 1,800 feet north to where it is offset 150 feet to the west by one of the major transverse faults. In the central segment only a few outcrops of the seam occur and the position and structure of the seam are largely inferred. In the adjacent segment to the north of the next transverse fault the upper seam forms the limb on which No. 5 mine is located, and in the segment north of Corbin creek it forms a shallow basin on the crest of Middle mountain.

The central basin as defined has been developed only at its northern end in mines No. 1 and No. 4 opened up on the Mammoth seam and mine No. 5 opened up on the Upper seam. A small prospect tunnel has also been opened up in the Mammoth seam at the head of Opencut creek, but no development work done.

EASTERN COAL BASIN

The eastern coal basin forms a detached, northward-plunging, canoe-shaped syncline 7,700 feet in length and 1,100 feet in maximum width. The northern end, at which No. 6 mine is located, is approximately 1,200 feet lower than the southern end. The eastern limb of the basin dips 45 degrees to 60 degrees west and the western limb is vertical to overturned with dips up to 70 degrees west. The basin is cut near its centre by a transverse fault, the segment on the north of which has been offset slightly to the west and displaced downward. A rotational strike fault with relatively slight displacement runs along the western limb of the basin between the outcrop of the coal seam and the centre of the fold. At the south end the beds on the west side have moved upwards, whereas on the north end these beds have moved relatively downwards. The coal seam has a thickness of 60 to 137 feet, but where severely folded and crushed is considerably thicker. It was failure to recognize the synclinal form of the deposit that led to the thickness of the coal seam being previously estimated at 600 feet, and the capping rock of the seam being interpreted as a rock intrusion.

The eastern coal basin is the most economically important of the deposits of Coal mountain, and to date less than one-fifth of the deposit has been developed, all development work being carried out at No. 6 mine on the northern end of the deposit.

Estimated Tonnage of Coal in Coal Mountain

In arriving at an estimate of the coal resources of Coal mountain little accurate data pertaining to the thickness of the seams at the different localities are available, but the thicknesses used in the calculations are believed to be very conservative. Thus an average thickness of 50 feet of commercial coal for the Mammoth seam and 10 feet for the Upper seam was employed in the calculations, although at most localities observed these thicknesses were greatly exceeded. Computations are based on an average specific gravity of the coal of 1·3, or an average weight of 80 pounds per cubic foot. In estimating the tonnages the areas of the several basins were plotted on co-ordinate paper on a scale of 1 inch to 800 feet.

The tonnages obtained are as follows.

Mammoth Seam

(1) Western coal basin, No. 3 mine basin

$$\frac{12 \times 800 \times 800 \times 50 \times 80}{2000} = 15{,}360{,}000 \text{ short tons}$$

(2) Central coal basin, No. 1 and No. 4 mines

$$\frac{33{\cdot}5 \times 800 \times 800 \times 50 \times 80}{2000} = 42{,}880{,}000 \text{ short tons}$$

(3) Eastern coal basin, No. 6 mine

$$\frac{16{\cdot}24 \times 800 \times 800 \times 50 \times 80}{2000} = 20{,}787{,}200 \text{ short tons}$$

Total of Mammoth seam.....79,027,200 short tons

Upper Seam

(1) Western coal basin

$$\frac{2 \times 800 \times 800 \times 10 \times 80}{2000} = 512{,}000 \text{ short tons}$$

(2) Central coal basin

$$\frac{8 \times 800 \times 800 \times 10 \times 80}{2000} = 2{,}048{,}000 \text{ short tons}$$

(3) Eastern coal basin = 0 short tons

Total for upper seam..... ..2,560,000 short tons

Total tonnage in Coal mountain, 81,587,200 short tons

Practically all of this tonnage is above tunnel level, but a considerable proportion of the tonnage will be unrecoverable due to the intense folding and faulting, the presence of mine fires, and the inaccessibility of certain segments of the seam.

ORIGIN OF COAL DEPOSITS

The coal seams at Corbin constitute the lowermost coal deposits of the Kootenay series, and are thought to be represented on the northern and western rims of Crowsnest basin by some of the lower seams present in the section at Michel, Coal Creek, and Morrissey. The seams at Corbin differ from those of the above-mentioned localities in exhibiting a remarkable variation in thickness and quality over comparatively short distances. This is especially true of the Mammoth seam which attains its greatest original thickness of 180 feet at No. 3 mine, and decreases in thickness to the north, east, and south. At No. 2 mine it is approximately 100 feet thick, at the north end of No. 6 mine it is 137 feet thick, and at the southern end of the deposit it attains to only a fraction of these thicknesses. The impurity of the seam is due largely to the presence in it of lenses and laminæ of soft carbonaceous and graphitic shale and to layers of hard, calcareous shale and impure coal locally termed "bone". In places these shale beds may be traced for hundreds of feet, whereas in other places they coalesce within short distances, completely surrounding lenses of pure coal. In most places the coal is separated from the sandstone by a lens of carbonaceous or calcareous shale ranging up to 8 feet in thickness.

The variability in the thickness and purity of the coal, the abnormal original thickness attained in the Mammoth seam, and the other features to be described below would suggest that the vegetation that formed the deposits at Corbin was, in part at least, accumulated by drift transport rather than wholly formed by growth "in situ".

At No. 2 and No. 6 mines there occur in the lower part of the Mammoth seam layers of at least a foot in thickness, consisting of alternating thin bands of dull and bright coal ranging from ½ to 2 inches in thickness. The dull bands contain a large percentage of calcium and magnesium carbonate, but the bright bands in section appear to be composed largely of clean, strong coal cut by numerous veinlets of calcite, which start at the top of the bright layer and cut through it normal to the bedding. Viewed in plan, these bright layers show a concretionary development of roughly circular calcareous bodies ranging up to 3 inches in diameter. These bodies are composed of a network of thin calcite veinlets ranging from microscopic dimensions up to $\frac{1}{20}$ inch in maximum thickness and which radiate from centres spaced 2 to 5 inches apart. Some have a star-like outline with five to twelve veinlets radiating from a central nucleus; others consist of numerous radiating veinlets joined by innumerable, closely-spaced, transverse veinlets forming a roughly circular, calcareous "honeycomb" bun-structure, whereas still others consist of a dense, central, shaly, circular zone ranging up to 2 inches in diameter with thirty-five or more veinlets radiating from the periphery into the coaly area. These interlock with veinlets radiating from adjacent centres and give to the coaly mass a regular, mesh-like appearance. Each of these masses is plano-convex in section with the flat side at the bottom and has a thickness corresponding to that of the bright layer of coal. Where exposed differential weathering causes the calcite veinlets and nuclei to stand out above the coaly matrix, forming dyke-like ribs in the resulting mushroom-top-like forms. They are thought to represent discoid calcareous concretions in different stages of development. The calcite forming the veinlets has doubtless been derived from the overlying, dull, impure coaly layers.

Another interesting feature connected with the Mammoth seam is the occurrence in it of clastic dykes, several of which are well exposed near the base of the seam at the upper or eastern side of the No. 3 mine basin. These clastic dykes consist of firmly cemented sandstone which shows jointing normal to the walls of the fissures. The dykes fall into two groups cutting through the seam at right angles to one another and normal to the bedding. The largest of the clastic dykes observed was traceable for a distance of 75 feet, and cut through the bedding for a distance of at least 15 feet. This dyke had a maximum width of 8 inches at the top and decreased gradually in thickness, branched in depth, and finally pinched out completely 2 feet above the foot-wall of the seam. The fissures were undoubtedly filled with sand derived from the overlying sediments, but whether it came from sandy lenses in the coal seam or from beds immediately overlying the coal seam could not be determined. They were apparently formed either during the formation of the peat bog or shortly after its burial. The fractures do not appear to bear any relationship to the more recent folding and faulting that has affected the coal deposits. Differential weathering causes the clastic dykes to stand out several inches to a foot or more above the surface of the coal.

MINING DEVELOPMENT AND COAL PREPARATION

The coal deposits of Corbin area have been under development continuously since 1908. Up to the present date six mines, designated by numbers corresponding to the sequence of their dates of initial operations (Plate II), have been opened up on Coal mountain. Of these mines Nos. 1, 2, 3, 4, and 6 are located on segments of the Mammoth seam, whereas mine No. 5 is on the Upper seam. Mines Nos. 1 and 4 are located on adjacent segments of tightly squeezed folds and hole into one another within a short distance of the entries of the two tunnels. The workings of these mines are so closely related that in describing the mining development they may be most conveniently considered together. With the exception of this and mine No. 5, the mines will be described in their regular sequence.

Mines No. 1 and No. 4

The segments of the Mammoth coal seam developed at No. 1 and No. 4 mines range in thickness from thin slivers up to pockets 250 feet across, and average over 100 feet thick. The folds in the coal seam, which are being developed, strike a little west of south and stand almost vertical, the coal rising in places from below the level of the lower tunnels at 5,070 feet, 500 to 750 feet vertically to the surface outcrop. The method of winning the coal followed at both these mines consists in driving the main tunnels and the counter tunnels lying 50 feet above from the outcrop along the seam and connecting them by raises spaced 100 to 200 feet apart. At about 1,000 feet in from the surface three main raises or shafts, 50 feet apart, were driven to the surface, hugging where possible one or other of the walls of the seam. These shafts were connected at intervals of 50 or 60 feet by levels, some of which were driven to the surface and others driven from the surface to intersect the vertical shafts. In addition to these shafts steeply inclined chutes were driven from one haulage way to the one immediately above. These chutes were timber-lined, and the coal, which had been caved into cars and transported to the nearest chute, was allowed to run down to the main entry. The levels ranged in length from a few hundred feet to a maximum of 2,100 feet in No. 1 mine, and 2,400 feet in No. 4 mine, the highest levels in each mine being the shortest and the main tunnels the longest. The excessive width and vertical attitude of the seam, combined with the soft nature of the coal, the friability of the enclosing wall-rock, the presence of huge tongues of rock either completely enclosed in the coal or projecting into the coal from the sides, permit of only a small fraction of the coal being economically won, and result in the formation of a gob which near the surface is subject to spontaneous combustion. As the workings advanced it was found that less and less of the higher coal could be extracted with safety, with the result that the developed area in both No. 1 and No. 4 mines took the form of triangular plates, the bases of which are the main level and the apices the points where the vertical shafts reached the surface.

Mining operations started in No. 1 mine in 1908. The lower tunnel was driven 2,100 feet along the seam and the seam was worked by a series

of ten levels spaced 50 feet vertically apart. In 1913 a bush fire caught on to the gob of the seam, and ate its way downward. Three months were spent in an unsuccessful attempt to extinguish the fire, whereupon the mine was sealed off and on June 3, 1914, abandoned.

Mining operations began in No. 4 mine in 1913 and this mine had been brought into production by the time No. 1 mine was abandoned. The seam here varies from 20 to 250 feet in thickness and averages well over 100 feet thick. In addition to the workings carried on from the main tunnel four levels known as the 300-, 400-, 500-, and 600-foot levels were driven into the coal from the hillslope, and the coal won from these workings was conveyed to the tipple by a surface incline tram. The vertical shafts were later raised at a point approximately 1,200 feet from the mine entry to intersect these levels and the seam finally blocked out by a series of seven levels. However, by September, 1917, fire from the 600-foot level of No. 1 mine had eaten through the coal into the east leg of the 600-foot level of No. 4 mine workings. An unsuccessful attempt was made to remove the burning coal which was located only a few hundred feet from the entry, after which this level was successfully sealed off by a cement stoping. Shortly afterwards fires broke out in the 400- and 500-foot levels, also on the east leg, and in 1918 work on these levels had to be abandoned. These were also sealed off by cement stopings, and since that date most of the coal has been obtained from the workings of the western limb of the No. 4 deposit. The coal is being won by what is known as the retreating caving system of mining, by which method cheap coal is being obtained at the expense of sacrificing a large tonnage of what should be recoverable coal, causing a corresponding shortening of the life of the mine. Recently the workings of No. 4 mine on a level have been extended through an 80-foot thick sandstone rib to tap the Mammoth seam on the eastern limb of the western coal basin. This limb is also tapped by the west workings of the 300-, 400-, and 500-foot levels of No. 4 mine. This is the same limb on which No. 2 mine is located, and it forms the eastern flank of the basin on which No. 3 mine is situated.

Mine No. 2

Work on No. 2 mine was started in 1908, but as yet the mine is still in the prospect stage. The tunnel has been driven along the seam from the outcrop at an elevation of 5,150 feet for a distance of only 900 feet, hugging a strike fault. At the mine entry the seam was only a foot in thickness, but at the face it is 18 feet thick. The workings from No. 4 mine tap into the continuation of the seam about 900 feet from the face of the workings where the seam has a rather uniform thickness of 80 to 100 feet, and as a consequence the development of this segment of the western coal basin will likely be continued from No. 4 mine outlets, rather than from continuing the driving of No. 2 tunnel.

Mine No. 3

This is an open pit located on the western syncline of Coal mountain at an elevation of 5,900-6,000 feet or 900 feet above the Eastern British Columbia railway at Corbin, with which it is connected by a standard gauge railway spur 6½ miles in length, which runs around the northern end of Coal mountain and gradually climbs up its western slope by a series of switchbacks (*See* Plate III A).

Stripping operations on this deposit, assisted by surface blasting, were begun in the summer of 1911, but were discontinued early in the winter on account of heavy downfall of snow which reached a depth of 6 to 8 feet. Underground operations were then started, but only a small tonnage of coal mined. At the same time the deposit was being prospected by diamond drilling, and by 1917 twenty-two bore-holes had been put down. Steam shovel excavation had been started immediately after the railway was completed in 1913 and in 1918 a contract to strip the southern part of the pit was let. Stripping operations continued with intermissions until 1921 when they were discontinued. No further work was done on the deposit until November, 1926, when, with the installation of a new cleaning plant, stripping operations were resumed under contract. Approximately 60,000 tons of coal were removed, but due to the excessively soft nature of the coal and the presence in the seam of numerous thin bands of soft, carbonaceous shale, which became intimately intermixed with the coal, the cost of cleaning the coal to the required ash content was found to be excessive and these operations were terminated. Since that date no work has been done on the deposit, the stripping plant has been dismantled, and the railway material is being requisitioned for replacement or other requirements in connexion with the operating mines.

Mine No. 6

Development work on No. 6 mine (*See* Plate III B) began in 1920, but did not get under headway until 1926 following the termination of operations on No. 3 mine (*See* Plate III A). Since that date the mine has been continuously operated and at present is the main producer of the camp. In 1920 two crosscut tunnels were started in the coal above the foot-wall where the coal outcropped at elevations of 5,390 and 5,456 feet, and were driven several hundred feet to the south along the east and west walls of the deposit. Later in the year a rock tunnel to intersect the coal was commenced at an elevation of 5,315 feet. From this point levels were carried to the southward along the walls, with counter levels and connecting crosscuts for ventilation. Upraises were then driven to the upper levels for lowering the coal. A chute system of working having been developed, work on the upper levels was discontinued until 1927, when, on account of an urgent demand for coal, the west sides of the 5,390 and 5,456-foot levels were blocked out for 1,000 feet to the south and the coal eventually caved. In 1925 a new rock tunnel was driven from tipple level at an elevation of 5,238 feet striking the coal seam at 360 feet from the surface, and from it a level known as the A level was carried in the coal. This level was later connected by upraises down which all coal mined in the upper level is brought. Most of the development work to date has been carried on in the 5,315-foot and A levels. The mine is worked by the room and pillar method, rooms being driven up the floor of the seam. This method has worked well on the eastern flank of the syncline where the seam dips 45 degrees to the west, but is not so applicable on the western limb where the seam is vertical or overturned. There the friable character of the capping rock, the soft nature of the coal, and the presence in the thick seam of a 10-foot thick bed of soft, carbonaceous shale result in the formation of large caves and a porous gob. In 1929 one of these gob areas took fire through spontaneous combustion and is still burning though sealed off.

To overcome such large losses in coal tonnage caused by such cavings and fires in the western limb of the syncline the company officials have recently devised a modified system of mining which they designate the slicing method. This system consists of blocking out the coal deposit in a series of panels leaving a 150-foot thick pillar of coal between each panel. In each panel from the 5,390-foot level three upraises, 50 feet apart, are being driven upward at an angle of 30 degrees to reach the surface outcrop. By employing this method the company officials estimate a recovery of 70 per cent of the coal as against a considerably smaller extraction obtained up to the present.

In 1927 an attempt was made to mine the outcrop coal by steam shovel operations carried on under contract. A considerable quantity of drift and weathered coal was removed, but only a relatively small tonnage of solid coal was recovered when operations ceased. At present cheap coal is being won by excavating this outcrop coal by hand-shovelling and passing it down mill-holes on chutes to the lower level where it is loaded into mine cars and transported to the tipple.

Mine No. 5

Mine No. 5 entry is 900 feet southeast of the mine tipple on the east slope of Coal mountain at an elevation of 5,300 feet. This mine is on the Upper seam. The tunnel was started in 1918 and driven 450 feet southwesterly through faulted ground where the coal seam becomes vertical and trends south 12 degrees west. Very little work has been done on the seam since 1921 and the mine is still in a prospect stage, the end of the tunnel being only 750 feet from the mine entry. The seam varies in thickness from thin stringers to pockets 70 feet in thickness. At the face of the tunnel the seam is 30 feet in thickness and the average thickness is about 18 feet. The seam is characterized by numerous thin partings of carbonaceous shale, which accounts for the high ash content appearing in the analysis.

The total output of the Corbin mines from commencement of operation in 1908 to the end of December, 1930, is as follows:

Year	Short tons	Year	Short tons	Year	Short tons
1908	3,683	1916	77,301	1924	29,817[1]
1909	68,113	1917	113,193[1]	1925	75,186
1910	142,074	1918	118,708	1926	84,658
1911	91,525[1]	1919	103,775[1]	1927	139,878
1912	136,935	1920	163,993	1928	178,927
1913	81,524	1921	73,386	1929	145,781
1914	83,230	1922	63,512[1]	1930	213,392
1915	62,543	1923	53,653	Total	2,304,773

The tonnage, produced from the several mines up to the end of 1930, was as follows:

	Short tons
Mine No. 1	368,007
No. 2	0
No. 3	409,016
No. 4	958,319
No. 5	4,402
No. 6	598,056

[1] Production reduced on account of strikes.

PREPARATION OF COAL FOR MARKET

The high ash content of the Corbin coal, due mainly to the presence in the seam of numerous, thin layers of soft, carbonaceous shale which in mining becomes intimately intermixed with the coal, combined with the soft nature of the coal, which permits of only a small percentage of lump coal, necessitates special preparation of this coal for market. To accomplish this the Corbin Collieries, Limited, have designed and installed at considerable expense an up-to-date cleaning plant. No attempt will be made to describe in detail the preparation of the coal, but a brief statement of the method is not amiss.

The coal received from the several mines is dumped into a large bin, from which it is fed by an apron conveyor over a shaking screen, which separates the mine run into three sizes: 4 inches or over; 4 inches to 1 inch; and less than 1 inch in diameter. The lump coal, i.e., that over 4 inches in diameter, is handpicked, the coal going direct to the mixing conveyor and the rock to the refuse bin. The material between 4 inches and 1 inch in diameter is elevated to a bin and fed over 600-A Elmore jig which separates the material into three products, coal, middlings, and refuse. The coal is elevated to a bin which leads into the mixing conveyor, whereas the middlings and refuse are conveyed to their separate bins, the middlings being either used locally or hauled with the refuse to the rock dump. The undersize from the Narcus screen, i.e., that less than 1 inch in diameter, is elevated and passes over vibrating screens which separate it into two sizes, that over $\frac{1}{4}$ inch in diameter and that under $\frac{1}{4}$ inch in diameter. The part over $\frac{1}{4}$ inch in diameter passes over an air separator which forms three products; coal that passes on to the mixing conveyor, and middlings and refuse that may be either sent to refuse bins or, if considered advisable, elevated and fed with the coarser coal into the Elmore jig for rewashing. The coaly material of less than $\frac{1}{4}$ inch in diameter is conveyed to Ruggles-Coles revolving heat driers which reduce the moisture in the coal to less than 1 per cent, thence it passes over vibrating screens which separate it into two grades, that over $\frac{1}{8}$ inch in diameter and that less than $\frac{1}{8}$ inch in diameter, both of which pass into their respective bins to be fed as required onto the mixing conveyor.

This thorough cleaning not only reduces the ash content of the coal, as may be seen by a comparison of the analyses of the prepared coal with that of the unprepared product, but permits of any desired mixing of the coals of various sizes and purity to meet commercial requirements.

The market for Corbin coal is largely confined to the Canadian Pacific railway, which runs through Crowsnest pass, and to the larger commercial centres in the neighbouring states of Washington and Oregon, principally Spokane. A small tonnage of the coal finds its way to centres in Alberta, Saskatchewan, and Manitoba. The coal is competing successfully against cleaner raw coal of the neighbouring coal fields, due to cheaper mining costs attributable mainly to the abnormal concentration of coal in the deposits.

DEEP BORINGS IN BRITISH COLUMBIA

By W. A. Johnston

(Chief, Division of Pleistocene Geology, Water Supply, and Borings)

The importance of obtaining dependable supplies of water, and the increasing necessity for providing information as to the probability of obtaining water from underground sources as the population of Canada increases both in numbers and density, have led to the formation of the Division of Pleistocene Geology, Water Supply, and Borings. The work of the Borings Division being so closely related to that of the new division it was considered advisable to include it in the newly formed division. The work that the Borings Division has been carrying on for over twenty years, involving the collection of samples and records from wells drilled for oil, gas, and water, will continue unaltered, however, and it is to be hoped that drillers of water wells will not fail to co-operate with the division in the work of compiling information as to subsurface conditions, both as regards the amount and kind of the water and the nature of the rocks passed through in the course of drilling. The division is in a particularly favourable position for the work of sample examination and identification as it maintains a laboratory specially designed and equipped for the purpose, and it has at command the advice of the field geologists in the work of rock identification and of the palæontologists for fossil identification. Bags for the collection of rock samples, and report forms, will gladly be forwarded on request and persons who intend to have water wells drilled are requested to advise the division so that arrangements may be made to obtain samples and records before the actual drilling commences.

In British Columbia drilling for oil and gas during 1930 was largely confined to the following areas.

Fraser Delta. Two wells were drilled for gas by the International Pipe Line Company on Lulu island, near Steveston. Considerable interest in the oil and gas possibilities of this area was shown in former years, due to the presence of gas seepages and to the proximity to the cities of Vancouver and New Westminster. Several wells were put down, but no commercial production was obtained. Geological conditions are fully described in Memoir 135 "Geology of Fraser River Delta".

Sage Creek. The Crow's Nest Oil Company's well, now called the Crow's Nest Glacier No. 1, has been drilled intermittently for several years and latest reports show it to be 3,260 feet deep. The B.C. Oil and Gas Company's No. 1 well is also located in this area.

Sumas Area. The International Pipe Line Company and the Sumas Gas and Oil Company both undertook drilling, operations being confined to section 22, township 19, range 5, east of the Coast meridian.

Cariboo District. The Cariboo Oil and Gas Company commenced drilling at Australian.

Dorr. The Pacific Petrol Products started drilling in Tobacco Plains area, the well being located in the town of Dorr.

Kelowna District. The Okanagan Oil and Gas Company have started drilling in this district on section 2, township 26.

Very little information was received as to water wells drilled either in British Columbia or Yukon. Climatic and topographical conditions in this area render the question of water supplies at depth of much less importance than in the Prairie Provinces.

Information as to the results of test drilling undertaken in the Greater Vancouver water district at First and Second narrows, Burrard inlet, False creek, Capilano canyon, and Capilano falls, Seymour intake, and Seymour Falls dam were forwarded by Mr. W. H. Powell, the engineer in charge. Mr. John Bennett of the Tulameen Coal Mines, Limited, Princeton, also forwarded a detailed section of the formations passed through by the slope of their No. 2 mine.

OTHER FIELD WORK

Geological

E. J. LEES. Mr. Lees, under supervision of W. E. Cockfield, continued topographical and geological mapping of Laberge 4-mile quadrangle (latitudes 61° to 62°, longitudes 134° to 136°), Yukon.

G. HANSON. Mr. Hanson concluded a detailed geological survey and investigation of the mineral deposits of Alice Arm area, B.C.

H. S. BOSTOCK. Mr. Bostock continued geological mapping of four 1-mile quadrangles in southern British Columbia (latitudes 49° to 49° 30′, longitudes 119° 30′ to 120° 30′).

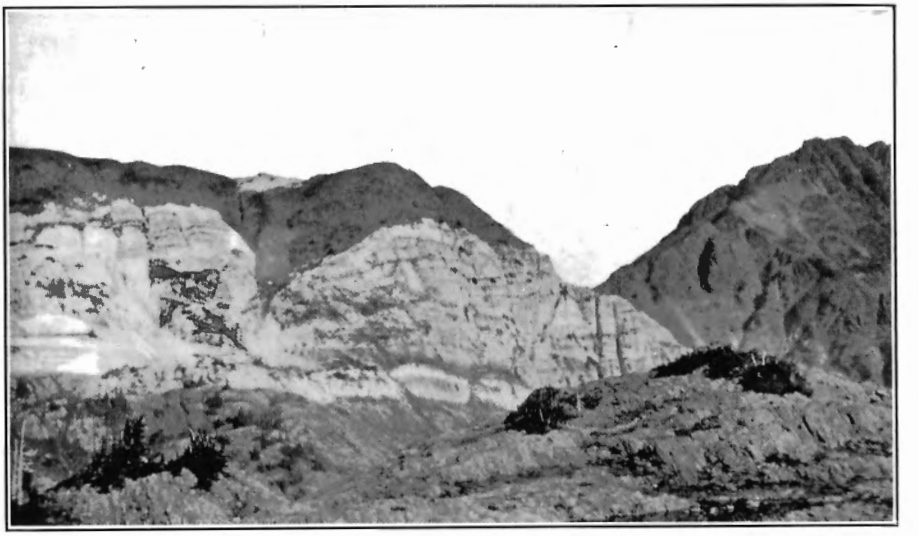
C. E. CAIRNES. Mr. Cairnes continued the detailed geological survey of Trinity 1-mile quadrangle (latitudes 50° 15′ to 50° 30′, longitudes 118° 30′ to 119°), British Columbia.

Topographical

R. BARTLETT. Mr. Bartlett made a topographical survey of Taku River 2-mile quadrangle (latitudes 58° 30′ to 59°, longitudes 133° to 134°), British Columbia.

S. M. STEEVES. Mr. Steeves completed the topographical survey of Salmo 1-mile quadrangle (latitudes 49° to 49° 15′, longitudes 117° to 117° 30′), and continued the topographical survey of Cranbrook 1-mile quadrangle (latitudes 49° 30′ to 49° 45′, longitudes 115° 30′ to 116°), British Columbia.

PLATE I

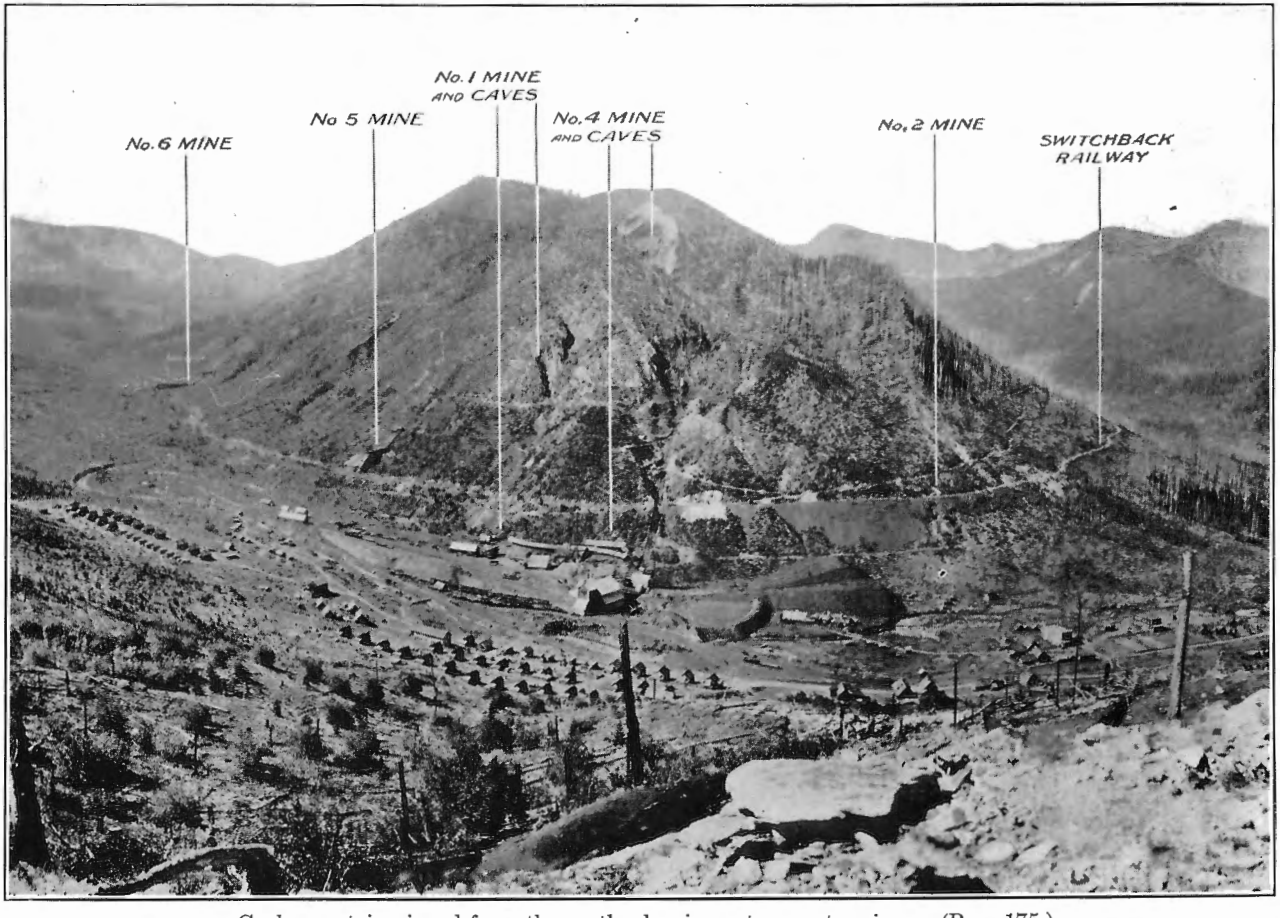


A. Fossiliferous Permian limestone (white) intruded by gabbro (dark grey above and below limestone); head of Marble creek, Strathcona park, Vancouver island. (Page 59.)

B. Looking northwest from head of Phillips creek, Strathcona park, Vancouver island: faulted Permian limestone (light grey) overlain by volcanics. (Page 60.)

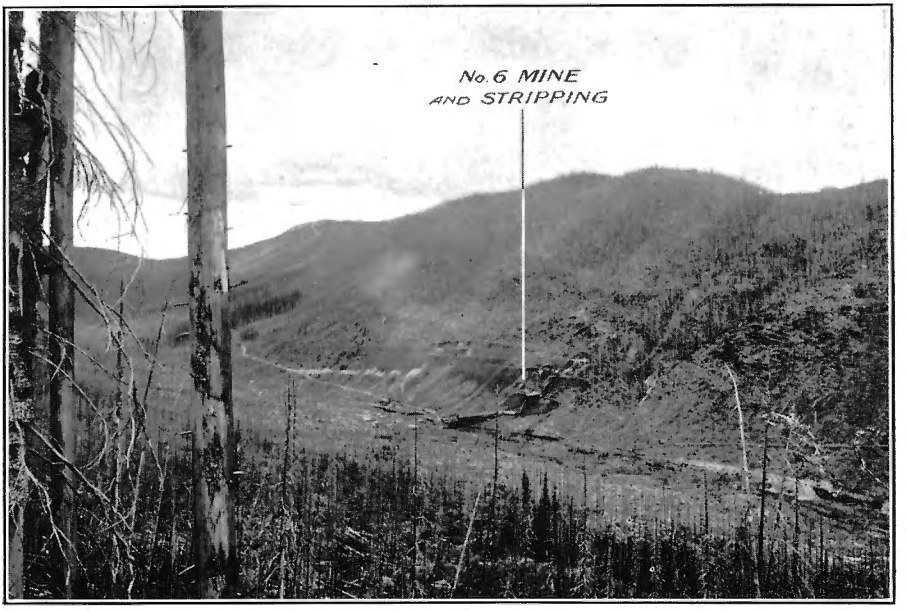
32786—13

32786—13½



Coal mountain viewed from the south, showing entrances to mines. (Page 175.)

A. No. 3 mine viewed from the west side of Michel creek. (Page 176.)



B. No. 6 mine viewed from the north. (Page 177.)

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.