CANADA

DEPARTMENT OF MINES

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

GEOLOGICAL SURVEY

W. H. Collins, Director

Summary Report, 1928, Part A

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OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

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SUMMARY REPORT, 1928, PART A

LITTLE SALMON AREA, YUKON

By W. E. Cockfield

CONTENTS

INTRODUCTION

Little Salmon area includes that part of Yukon territory drained by Little Salmon river. It lies between latitudes 62° and 62° 30′ and longitudes 133° and 135° 45′, being bounded on the west by Lewes river and on the east by Pelly river. The only settlement within the area is Little Salmon village, on Lewes river about 180 miles north of Whitehorse and 45 miles south of Carmacks. The river steamers of the White Pass and Yukon route pass Little Salmon village at regular intervals during the summer months. In the winter, the course of Little Salmon river is followed as a regular route between Ross River post and points on Lewes river. Thus the district has been known for a considerable time; but details as shown on existing maps proved to be incorrect. Little Salmon village at one time consisted of a trading post, an Anglican mission, and an Indian village, but it is now deserted for the greater part of the year.

Access to the area is afforded either by means of a foot trail or by boat using Little Salmon river as a route. The foot trail follows the course of the river fairly closely, but it was found to be in extremely poor condition and difficult to follow, as repeated bush fires had either caused it to become choked with windfall or in some cases had entirely obliterated it through the destruction of every vestige of vegetation. Considerable time had, therefore, to be devoted to cutting a trail suitable for use by pack animals, and at the close of the field season this trail was in fairly good condition from Little Salmon village to the upper canyon. Except in two instances, the trail is never very far from the river. About 2 miles from the head of the lower canyon the trail leaves the river for a distance of 4 miles, saving in this distance nearly 10 miles travel along the banks of the stream. Three miles below Little Salmon lake the trail follows up Bearfeed creek, and cutting through a pass in the hills, again enters the valley of Bearfeed creek which it follows to its head. At this point it climbs to the plateau surface and then drops to the valley of Drury creek, which it follows to

Little Salmon lake. This part of the trail adds nearly 10 miles to the distance to be travelled, but it would be impossible to secure a pack trail around the shores of Little Salmon lake. From the head of the lake to the upper canyon the trail is never very far from the river. Near the upper canyon it swings away from the river and crosses to Pelly river along a series of small lakes.

Little Salmon river itself offers a fair route into the district. It may be navigated by boats of shallow draught either by poling or with outboard motors for power. Except in the lower 10 miles the river presents few obstacles to navigation; this stretch of the river, however, known as the lower canyon, is swift throughout, with certain riffles of much faster water. The river is narrow and crooked, with numerous hairpin bends and overhanging trees or sweepers, and a large number of boulders and a few log jams add considerably to the difficulties of navigation. A boat of good power can ascend without great difficulty all but perhaps a few stretches of the fastest water. In low water the current in this stretch is much slacker, but lining would probably be necessary on some of the bars. From the head of the lower canyon for 3 miles upstream the current is still swift, but the river is much straighter so as to offer no great obstacles to navigation. Thirteen miles above the mouth there is a rapid. The channel is towards the left hand bank proceeding upstream. In high water the current at this rapid is probably swift enough to require lining, but in medium stages of water it can be ascended without difficulty. From the head of this rapid to the mouth of Bearfeed creek, i.e. 4 miles below Little Salmon lake, the current is much more sluggish, and the water is deep. A few riffles with fast water occur, but this stretch as a whole offers no difficulties to boats of good power. Four miles below Little Salmon lake a short rapid occurs and the channel is again towards the left bank proceeding upstream. Above this the river widens out to a lake-like expansion with a sluggish current, and with the bed of the stream overgrown with water grasses and weeds through which it is at times difficult to find a channel. The total distance from Little Salmon village to Little Salmon lake is 45 miles by river, and 28 miles by trail.

Little Salmon lake is 21 miles long and slightly over a mile wide. Almost throughout its length it is bordered by rocky shores and in some cases by rock cliffs which rise 15 to 20 feet above the water. The valley walls rise abruptly from the lake to a marked shoulder, whence they slope more gradually to the summits of the upland surface. From the experience gained during the season, which is confirmed to some extent by the Indians, it may be stated in general that the lake is not subject to the sudden and violent storms that are characteristic of the large lakes of southern Yukon, and there are probably few days during the summer when it would be unsafe to travel the lake in the small boats used for river work. In general it was found that windstorms usually died away at sundown.

Above the lake, Magundy river is reported to be navigable for about 20 miles in high water. The same point, however, may be reached in 7 or 8 miles by trail. This part of the river was not examined during the course of the work, save for a short distance above the lake, where the current was sufficiently slack in low water to allow a boat to be rowed against it. From 8 miles up the valley above the lake, Magundy river shoals rapidly, and there are numerous bars or riffles of fast water.

TOPOGRAPHY

Little Salmon area lies within the region known as Yukon plateau, which has so frequently been described that no lengthy description need here be given. In general it consists of broad, flat, gently undulating upland surfaces, separated by deeply cut valleys. The upland surface stands at 5,000 to 5,500 feet above sea-level. A number of isolated peaks and mountain ranges rise somewhat above the general level. Near the major valleys, the upland surface has been maturely dissected. This is true also in the case of Little Salmon area, in the vicinity of Lewes and Little Salmon valleys, which are usually fronted by low hills that do not rise above timber-line (4,500 feet). The elevation of the summits of these hills is, therefore, 1,000 feet below the plateau surface. When Little Salmon lake is reached, the character of the valley changes to a marked degree. The valley walls rise abruptly from the lake to a marked topographic unconformity, or shoulder, whence the slope is more gentle to the upland surface. Above the lake the hills still rise steeply from the valley, but the continuity of the plateau surface is interrupted by the Glenlyon range. To the north of Little Salmon valley is a second valley which occurs along the foot of Glenlyon range. This is occupied in part by Drury lake and Drury creek.

Little Salmon valley extends in a fairly straight line from Lewes to Pelly rivers. It is an old valley which is only occupied in part by Little Salmon river and its upper continuation, Magundy river. Near Pelly river, Magundy river enters this valley through a canyon after flowing parallel with Pelly river for some distance. Thirteen miles from Little Salmon village, Little Salmon river leaves this older valley to enter Lewes river through the lower canyon. This older valley with canyons above and below suggests changes in drainage following glaciation. The area has been, to a large extent, heavily glaciated. The exact extent of the ice was not determined, but it is probable that the greater part of the older valley referred to was occupied by ice. Many of the hills on the north side of the valley have a typical roches moutonées effect and 7 miles below Little Salmon lake a terminal moraine 3 miles long occupies the valley. Throughout its length from Little Salmon lake to the mouth, the river is bordered by high, gravel benches that represent in part glacial drift, and probably in part glaciofluvial accumulations, through which the river has cut to depths of 100 feet or more.

One feature of Little Salmon district that deserves attention is the difficulty of putting a road into the district should such be desired for mining operations. A road could be constructed without great difficulty as far as Little Salmon lake, although this would require a great deal of heavy grading work as a number of deeply cut gulches cross the high benches that a road would naturally follow. The cost of building a road around Little Salmon lake would be prohibitive, as a very great deal of rock-cutting would be entailed.

The timber of the area has been largely destroyed by repeated bush fires. Some stands of timber remain on the northern slope, that is, the southern side of the valley, where the ground as a rule is swampy, particularly along Little Salmon lake; but as a whole there is little green timber left in the area.

GENERAL GEOLOGY

The rocks of Little Salmon area include sedimentary, igneous, and metamorphic types. Of these the latter two types occupy the greater part of the area, the sediments occurring as a fringe along the western border and as isolated patches along the eastern border. For this reason, the lack of sedimentary horizon markers, the ages of the various rocks in the district are difficult to determine. In general the rock types found correspond closely with those of other districts in southern Yukon, and it may be stated at the outset that little new evidence with regard to ages of different formations was obtained. Perhaps the outstanding feature from a geological point of view was the discovery of fossils that may be classed with some assurance as Triassic. In southern Yukon fossils have been collected hitherto which were supposed to be Triassic, but the determinations were always doubtful. The fossils obtained last summer lead to the belief that the marine Triassic in southern Yukon is possibly much more widespread than has generally been supposed. The following table gives the formations present and their relative ages where known.

Table of Formations

	Recent and Pleistocene	Recent alluvium and glacial drift
Tertiary (?)..........	....	Quartz porphyry
	....	Granodiorite and related rocks
Mesozoic............	....	Andesite, tuff, and breccia
	Upper Triassic and, probably, Jurassic	Conglomerate, argillite
Palæozoic...........	Carboniferous (?) and, possibly, Triassic	Limestone
	Carboniferous and, or, Older...	Serpentine
Precambrian (?).......	....	Quartzite, mica schist, chlorite schist, and crystalline limestone

Schist Complex

The oldest rocks of the area are a group of metamorphic rocks, consisting of quartzite, mica schist, chlorite schist, and crystalline limestone. The quartzites are dark grey, green, mauve, or white, and as a rule are massively bedded, breaking up into large blocks which are a characteristic feature of the upland surface wherever these rocks occur. Close examination reveals an abundance of secondary mica, which gives to the rock a gneissoid appearance. Grey mica schist and greenish chlorite schist are interbedded with the quartzites. Where the mica schists are abundant they include beds or bands of crystalline limestone. These appear for the most part to be small, discontinuous lenses of impure limestone, which is in most cases dark brown or yellow due to staining with iron oxide. The schist group is well developed on both sides of Little Salmon lake and extends northward to Glenlyon mountains, and continues up the valley of Magundy river to Pelly river. In the part of the group exposed about the lower half of Little Salmon lake and on the hills to the north of it, quartzite and schist are most abundant, but passing up the lake and up Magundy valley, limestone bands become more prominent, until at a point 7 miles above the lake several hills, facing the valley, are composed entirely of limestone. Above this again there are several exposures of fairly thick limestones. This abundant development of limestone in the schist group has not been noted elsewhere in Yukon. A careful search was made over large areas of these limestones for fossils, without results, and it also became apparent that these larger developments of limestone were also interbedded with schist and, therefore, to be included in the schist group.

The structures of the schist group are exceedingly complicated and it would require much more detailed study than could be devoted to them to determine even the major features. Rapid changes of strike and direction of dip, combined with the prevailing steep dips, bear witness to intense and complex folding and probably faulting. No definite evidence as to the age of these rocks was obtained. They are undoubtedly older than the igneous rocks of the district, which cut them, and they have undoubtedly been subjected to folding and metamorphism that the older sedimentary rocks have escaped. For these reasons they are regarded as the oldest rocks of the area, and as investigations in other parts of Yukon have shown the schistose rocks there to be Precambrian, the schist group of Little Salmon area has also been classed in that era.

Serpentine

Only one small area of serpentine was noted in place, namely on the ridge south of Drury lake, but float in other parts of the area renders it fairly certain that there are other occurrences that were not found. It is a dense green to black rock with a greasy lustre, traversed in many cases by small veinlets of asbestos, which although of scientific interest are too small and insufficiently numerous to prove an economic source of that mineral. The relationship of the serpentine to the schist group was masked at its single occurrence by superficial accumulations; as it is, however, entirely surrounded by schist it seems probable that it represents a basic igneous intrusive since converted into serpentine. The specimens selected for examination proved to be wholly serpentine with veinlets of asbestos, and do not afford any clues as to the original character of the rock. This rock is similar to the "Gold Series" of Atlin district, which may be considered Palæozoic and possibly Carboniferous. On the other hand it might be correlated with the "Moosehide diabase" of Klondike district, the age of which is uncertain. Cairnes classes certain pyroxenites and peridotites of Wheaton district as Devonian, but as evidence of age is distinctly lacking in Little Salmon district, the serpentine has been classed as Palæozoic, Carboniferous, or older.

Limestone

Limestone occurs in patches and bands in the andesite of the lower canyon of Little Salmon river, and at a few points above the canyon. These bands are seldom more than 500 feet wide, and as they are partly covered it is in many cases difficult to trace individual bands. The bedding is in most cases obscure, and difficult or impossible to detect. One prominent band crosses Little Salmon river near the head of the lower canyon, appearing as a series of outcrops that give the appearance of belonging to the same band. This is in part a fault breccia, recemented with calcite. The limestone is grey, compact, and largely, if not wholly, recrystallized. A careful search of what was assumed to be a single band of limestone resulted in the discovery of only two fossils, which were submitted to E. M. Kindle and F. H. McLearn for identification. One of these, Mr. Kindle reports, "belongs to the Zaphrentid group of genera, possible *Hapsiphyllum*, and affords satisfactory evidence of the Palæozoic age of the formation represented. Until more evidence is presented I would advise referring the beds represented to the Carboniferous as a provisional disposition of them". The second coral was determined to be not a Palæozoic form. Mr. McLearn reports it to be too poor for identification; it may be *Isastrea* with a Mesozoic correlation. These corals were obtained some distance apart on what was believed to be the same band of limestone; but as the outcrops are not continuous and with the evidence of faulting previously cited, it would appear that there are two limestones, one of Carboniferous(?) age and the other of Triassic(?) age. As these cannot be separated in the field without adequate faunal evidence they are grouped on the map under one pattern as Palæozoic limestone, but it should be remembered that Mesozoic limestone probably is also present.

Conglomerate and Argillite

The rocks of this group compose the hill facing Lewes river north of Little Salmon village, and continue up the northern bank of Little Salmon river nearly to the head of the lower canyon. Exposures are not numerous except along the summits of the hills and on the benches of the river. The conglomerates were found along the lower part of the river and as they have been traced continuously from one of the type areas, namely Carmacks area, along the banks of Lewes river, they are unhesitatingly classed with the Laberge beds. The conglomerates are massively bedded with cobbles and boulders of granite, andesite, and rocks of the schist group embedded in a tuffaceous matrix. The bedding is best seen from a distance; close at hand it is quite obscure. Towards the upper end of the lower canyon a few exposures of black to dark grey argillite were noted, which have been jointed and sheared so that the bedding is indistinguishable. Fossils were obtained from one of these outcrops. These were determined by Mr. McLearn to be flattened and fragmentary specimens of *Pseudomonotis subcircularis* (?), with a probable correlation with upper Noric of the Upper Triassic. The age of the Laberge beds has been determined in Whitehorse district to be Lower Jurassic to lower Middle Jurassic; with the probability of a somewhat greater range. It seems apparent that the argillites found in Little Salmon area do not, therefore, belong in the Laberge beds, but constitute an underlying formation. Occasional fossils that were believed to be Triassic forms have been heretofore found in southern Yukon, in all cases in limestone, but always the poor state of preservation precluded a definite age determination. It would now appear to be fairly definitely established that marine Triassic does occur in southern Yukon, and if the previous somewhat indefinite determinations be accepted the marine Triassic is much more widespread in southern Yukon than was formerly believed to be the case. It is also possible that some marine Triassic has been included with the Laberge beds in other sections. Detailed studies will probably be necessary at a number of points before the succession can be established. For mapping purposes the Triassic and Jurassic have been included under the one pattern on Map 227A accompanying this report.

Andesite, Tuff, and Breccia

A large area in the lower part of Little Salmon valley is floored with andesites, andesite tuff, and breccia. These rocks exhibit a variety of colours, usually red or green, and they vary greatly in texture. Some are aphanitic, others are porphyritic, and still others amygdaloidal, with the amygdules filled with quartz, calcite, or more rarely zeolites. The tuffaceous phases resemble greatly the matrix of the conglomerate of the Laberge beds, and phases of the latter, where pebbles are absent, cannot be distinguished from the tuffs here included. The andesites, however, are in part at least younger than the Laberge beds, for it has been found, where they have been studied in detail, that they cut the Laberge beds. No new evidence on this point was obtained in Little Salmon area. The andesites here described are probably in part intrusive and in part extrusive. Remnants of Carboniferous or Triassic limestone occur in them and elsewhere it has been found that some of them cut the Laberge beds and in turn are cut by granitic intrusions of the Coast Range batholith. They may thus be partly contemporaneous with the Laberge beds and partly later and may be referred to the Jurassic.

Granodiorite

These are grey to pink rocks, of a granitic habit, usually coarse in grain, with feldspar crystals in many cases up to 1 inch or 2 inches in length. They resemble closely in lithological characters the intrusives of the Coast Range batholith, and also granitic intrusives which occur at many places throughout the plateau. In Little Salmon area several small bodies of these intrusives occur in the vicinity of Little Salmon lake. The main occurrence, however, is in Glenlyon range. Only a small part of the western contact of these intrusives of Glenlyon range was examined during the field season, but from work that has already been done by McConnell on Pelly river, and from what could be seen from the hills facing Glenlyon range, these mountains are apparently underlain by granitic intrusives throughout their length, and in reality form a batholith at least 75 miles long, stretching from near the junction of Pelly and MacMillan rivers to Little Salmon river, and possibly extending farther both northwest and southeast than indicated by the present known limits. This body has a maximum width of 16 miles and narrows rapidly towards the northwest. It has a northwesterly trend, thus corresponding to the trend of the major structural features of Yukon. It is proposed to call this body the Glenlyon batholith. It crosses Magundy river at one point where it has a width of about 4 miles, but its southeastern extent from the valley could not be seen. The age of these bodies of granitic intrusives which occur within the plateau region has never been satisfactorily determined. They have usually been correlated with the Coast Range intrusives, but definite evidence as to their age is lacking. In Little Salmon area they cut andesites which are believed to be, in part at least, more recent than Lower Jurassic. Consequently they may be considered as related to the Coast Range batholith, i. e. Upper Jurassic, or they may possibly be younger, extending into the Cretaceous.

Quartz Porphyry

Rocks of this type are not abundant in Little Salmon area. One small body was found cutting schist close to the margin of the granitic intrusives, and a few dykes cutting andesite occur near the margin of one of the smaller granitic masses. Typically these are light yellow to brown rocks with a fine-grained matrix with phenocrysts of quartz, and occasional crystals of feldspar. These are the youngest consolidated rocks of the area. Elsewhere similar rocks have been classed as Tertiary, and as no new evidence has been obtained they are also in this report referred to that era.

Overlying all the consolidated rock formations is a mantle of alluvium and glacial drift. This consists of soil, talus, rock debris, silt, sand, gravel, boulder clay, and volcanic ash. The accumulations in the valleys are thickest, and where their thickness is such as to render it difficult or impossible to inspect the underlying bedrock by ordinary prospecting methods, they have been mapped. On the upland surface and hillsides numbers of rock exposures permit of making an estimate of the type of rock underlying the soil covering. The accumulations in the valley bottoms are in places at least 100 feet thick, as the rivers have exposed sections of this thickness of these unconsolidated materials, without cutting through to bedrock.

ECONOMIC GEOLOGY

So far as is known to the writer there are no claims in good standing in Little Salmon area. Although the area has been travelled to a considerable extent by both white men and Indians, it would appear to have received very little attention from the prospector. The reasons for this are not apparent. The country at the present time is undoubtedly difficult to travel owing to the large amount of windfall, but this condition did not always exist, and the ease with which central points in the district may be reached by water, overcomes the difficulty to some extent. The fact that the district has furnished a winter, rather than a summer, route, may possibly in some measure account for the lack of prospecting. The only deposit brought to the attention of the writer was an occurrence of silver-lead ore, which has been known for a long time to the Indians who travel through the district. Another deposit of silver-lead ore is reported to occur to the south of the area mapped, but definite information with regard to this could not be secured.

The occurrence shown to the writer by the Indians lies about 7 miles from the head of Little Salmon lake, near the head of the first large creek entering Magundy river from the north. There is no trail to the deposit, which, however, lies close to a route used by the Indians while hunting between Little Salmon lake and Pelly river. The mineral showings occur in a line of small cliffs at the pass near the head of the creek.

The country rock in the vicinity consists of schist with a small intrusion of quartz porphyry. Owing to poor exposures the form of this intrusion could not be ascertained. There are a number of showings, none of which is well exposed, being mostly covered with talus from the cliffs. The best exposure consisted of a vein cutting schist having a strike of south 80 degrees east and a dip of about 45 degrees to the southwest. The vein could be traced up the cliffs from the talus below for a length of about 80 feet; the part exposed in the cliff face being probably the narrowest part of the vein. At the top of the cliffs it had a width of 6 inches; at the base the width was judged to be about 2 feet. On the flat above the top of the cliff the vein was covered by overburden so that it could not be told whether the vein continued or pinched out immediately. No float was found on this flat. The mineralization consists of galena and zinc blende with siderite, quartz, chalcopyrite, and pyrite. At the widest part of the vein noted, there was 2 to 6 inches of more or less massive galena along the foot-wall of the vein, followed by about 10 inches of disseminated galena. The remainder of the vein was apparently barren. On the cliff face a seam of about 2 inches of galena occurred at the foot-wall, with occasional small masses of galena elsewhere in the vein. A sample was cut across the best mineralized showing that could be found; including only those parts showing some galena mineralization. This sample had a width of one foot and assayed[1] as follows:

Gold	none
Silver	23·53 ozs. per ton
Lead	48·76 per cent
Zinc	1·60 "

A second showing occurs about 25 feet southwest of the first. This is apparently in the form of a lens having a maximum width of 6 feet and an estimated length of about 40 feet. The galena mineralization is apparently much more scanty than in the first showing. The minerals noted in place were quartz, siderite, and zinc blende, but float from this lens showed some black manganese oxide, pyrite, and galena, demonstrating that these minerals do occur.

The intrusion of quartz porphyry occurs below these showings. Below this again, near the creek level, are a number of occurrences of iron oxide, carrying pyrite and chalcopyrite. The amount of overburden in this vicinity precluded the securing of definite data with regard to these.

A considerable amount of work would have to be done on these deposits before a clear idea of their character and extent could be obtained. From what can be seen at present, the writer would judge that the individual occurrences are quite small and the assay taken shows that they do not carry any considerable amounts of silver. It may be taken that unless

[1] Assay by Mines Branch, Dept. of Mines, Ottawa.

deposits of much greater size than indicated by those seen are discovered, attempts at mining would not be justified, as the cost of putting a road into the district for mining purposes would be considerable. The deposits are of interest, however, in indicating that mineralization has taken place in Little Salmon area, and that this mineralization lies near the border of the Glenlyon batholith. This batholith, as already pointed out, extends from Little Salmon river to near the junction of Pelly and Macmillan rivers; and it may possibly extend farther southeast and northwest beyond its present known limits. Its eastern border lies along Pelly river for a large part of this distance and is consequently easy of access; its western border is more difficult to reach and extends in part along Drury lake where the batholith is widest. Towards its northern end the batholith apparently narrows, so that both borders may be readily reached from Pelly river. The schists to the south of Drury lake, i.e. along the contact of the granodiorite, hold numerous quartz veins. Where examined these proved to be barren of sulphides.

With regard to placer gold, the areas bordering the batholith might be classed as reasonably favourable, were it not for other factors which tend to destroy the value of deposits of this type. As already pointed out parts of Little Salmon area have been intensely glaciated, and these are the very parts in which placer deposits most likely might have formed. This glaciation would not only tend to destroy concentrations of gold in the form of placers, but would also tend to bring any remnants beneath a deep layer of glacial drift. Consequently the region cannot be looked upon as favourable to deposits of this type.

Coal

The rocks of the Laberge beds contain coal at many points in Yukon. A narrow fringe of these rocks occurs on Lewes river and a few isolated outcrops occur near Pelly river. Owing to the lack of definite horizon markers, it is impossible to say whether the coal-bearing horizons are present or not.

SECOND PRELIMINARY REPORT ON STIKINE RIVER AREA, BRITISH COLUMBIA

By F. A. Kerr

CONTENTS

INTRODUCTION

Since preparation of a final report on Stikine River area will require considerable time it has been deemed advisable to issue in advance a brief synopsis primarily designed for the prospector. The chief purpose is to point out those areas that are likely to be most fruitful and also to indicate the best methods of reaching and travelling through the sections designated. The first preliminary report on this area for 1926[1] gives considerable general information and a detailed description of the Devils Elbow deposits, which will not be repeated here.

Means of Travel and Accessibility of Various Sections of the Map-area

As indicated in the report of 1926 ready access can be gained during the open season to any point along Stikine river between its mouth and Telegraph Creek by established means of transportation. The river is swift and dangerous, and except for men skilled in navigating such waters, the regular passenger and freight boats afford the only sensible means of travel. Small boats can be navigated down river by skilled rivermen with ease, but to move against the current is a slow and difficult process and in most cases the amount of time lost and the dangers involved nullify anything gained. However, for some work a small boat may be necessary. The more or less standard type of craft that has been developed after much study on the part of boat-builders and operators is undoubtedly the most suitable for general use. It is flat-bottomed and shovel-nosed, with considerable beam. The length varies according to the need, though 24 feet is in general the most appropriate. Such boats can best be procured at Wrangel or on the river. Since time is, in most cases, of value the boat should be powered with an outboard motor. Ordinarily an engine of about 8 horsepower is the most satisfactory; it will drive the boat at sufficient

[1] Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1926, pt. A.

speed to ascend, without assistance, all the rapids ordinarily encountered and at the same time not overpower the boat so as to make navigation unduly dangerous.

The regular passenger and freight boats will stop at almost any point along the main river channel, but the river has many distributaries (sloughs) and it is sometimes impossible to land on the mainland at or near the exact point which it may be desired to reach. As a rule the mouths of tributary streams form the best base from which to start operations. When approaching the river for the purpose of taking passage on one of the boats, it is essential to pick some point where the main channel is close to the valley wall, otherwise there may be intervening waterways which will be a serious hindrance to progress and, in any case, the valley flats are covered with a dense, matted jungle through which travel is extremely difficult.

From Telegraph Creek south to Shakes creek it is possible to use horses to some extent since there are a few trails on the lower wooded slopes, and above timber-line the surface over large areas is not too rugged to permit of travel by this means. As far south as Little canyon, dogs were used in the present undertaking to very great advantage as packers. In this section of the map-area a good dog can go almost anywhere, though, in the lowlands, it may be necessary to follow the crude trails of the trappers. A dog will carry up to 50 pounds, and with very little assistance and proper treatment has staying power superior to a man. His load, of course, is all gain except for a small quantity of emergency rations, since his equipment is of negligible weight, and the rather abundant game affords his complete food supply. Throughout the rest of the map-area, under present conditions, back-packing is the only feasible means of transporting supplies.

There are few well-defined routes of travel in the area. In general, besides the established trails, there are two courses that it is best to pursue; either proceed directly to timber-line, which is usually at about 4,500 feet, and travel the open spaces above this; or follow the streams. The latter course, however, is suitable only in wide, glaciated valleys where the streams have not cut deeply into the glaciated surface.

From a point opposite Glenora a road and trail along which horses can be used afford access to a large area between First South Fork river and Glacier river (one mile below the mouth of Shakes creek). This section can also be reached by the trail along the east bank of First South Fork river.

A trail, now in very bad shape because of much fallen timber, commences at the road-crossing of Fourmile creek (6½ miles below Telegraph Creek) and leads to the headwaters of the same stream. This area, as well as that farther south, is somewhat more accessible from Glenora or from Shakesville by a trail to the junction of the two branches of Brewery creek, thence up the ridge between these and along the West fork. Two other routes are: one from the telegraph trail north of Telegraph creek, up a tributary of Tahltan river; and the other by trail from Shakesville up Shakes creek to Shakes lake at its source. The latter route is also the best for reaching the headwaters of North Fork river which joins Clearwater river 7 miles above its mouth, and a large area tributary thereto. The mountain between Shakes creek and the lower part of North Fork river can be reached by a side trail.

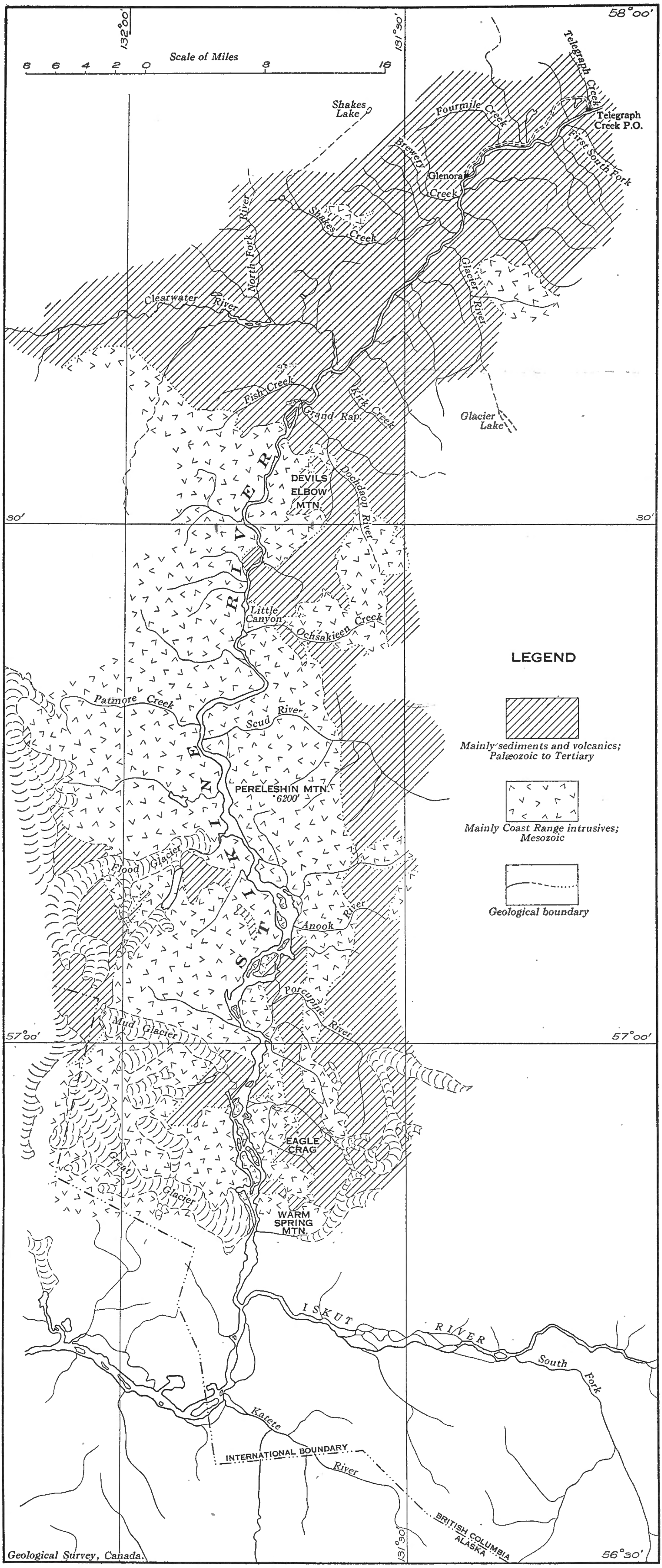

Figure 1. Lower Stikine River area, Cassiar district, B.C.

Ready ingress to Glacier lake at the head of Glacier creek has been made possible by the construction of a trail suitable for pack horses, from near the mouth of Pritchard creek 4½ miles south of the mouth of Glacier creek. A trail from the mouth of a creek 2 miles up river from the mouth of Clearwater river, up the mountain to timber-line and thence around the southern slope affords entry to a large upland area extending towards Glacier creek.

During the greater part of the summer Clearwater river can be navigated by powered boats, with considerable danger, to a point about 12 miles or so above its mouth and at high water probably as far again. By use of a motor supplemented by lining over riffles it is possible to take a well-loaded standard boat to this point at almost any stage of water and possibly beyond for a distance, said to be 10 miles, to Clearwater lake at the head of the river. In this way considerable quantities of supplies can be laid down anywhere along the valley without serious difficulties or excessive expense. From Clearwater landing to the west side of North Fork river, a fair road used by motor trucks provides a safer means of transportation as far as it goes. From the end of the road trails continue to several points; to the mouth of North Fork river; for some distance up Clearwater valley; along a creek joining the North Fork on the west side, one-half mile south of end of road; and a short distance up North Fork valley; so that a large area in this vicinity is readily accessible. A good bridge crosses North Fork river, so that the road could be extended to the west for many miles without much more expense than that necessary for clearing and the construction of bridges over tributary streams. The valley of the river joining, from the south, Clearwater river 3 miles above the mouth of North Fork river, can be more easily traversed on its east side. For 6 or 7 miles above its junction with the Clearwater the best route would seem to lie on the relatively gentle slope at 500 to 1,000 feet above the river, through heavy timber where travelling is probably fairly good and trail construction should not be difficult. Above this first stretch, where the river flows in a canyon, the valley floor is wide with extensive gravel bars and should for many miles furnish no serious travel obstacles. The valleys of the two larger tributaries of Clearwater river, coming from the south and next above the tributary just described, are somewhat similar and should offer fair routes. Clearwater valley, therefore, forms a main traffic artery for a large area of rugged mountainous country. From the mouth of the Clearwater a trail up the ridge to the west is a means of entry to the highlands at the head of Fish creek, though a somewhat more direct way is over the ridge opposite the mouth of Dochdaon river.

A good trail leads east up Kirk creek which enters the Stikine, from the east, one mile above mouth of Clearwater river. Another trail from the mouth of Kirk creek runs to and up the next tributary to the north. The trail from Jackson at the mouth of Dochdaon river, south to the claims on Devils Elbow mountain, is well maintained. From this mountain it is possible to drop down into the valley on the east side and, from it, by traversing a low pass to reach the wide, glaciated valley of upper Dochdaon river and the mountains about its head. A more difficult route is offered by a blazed line commencing on the east side of Stikine river, at the mouth of the second creek $3\frac{1}{2}$ miles above Little canyon. It leads to and across a low pass east of the mountain northeast of the mouth of the creek. A branch line follows the creek to its head. From just below Little canyon, a trail follows Ochsakieen creek for about 8 miles.

Scud river can be navigated for about 17 miles by powered boats, with some lining, and considerable difficulty and danger. The river along the lower 25 miles spreads into many channels over a wide gravel bottom and probably under no conditions is good for navigation, though it is probable that with considerable lining, for which the gravel bars are well adapted, fairly heavily loaded boats could be taken at least 25 miles (possibly much farther) upstream. Since the Scud flows nearly due west and has many wide, glaciated, tributary valleys it affords a means of easy entry into an extensive, largely unknown area.

Travel on the south side of Patmore creek for many miles is fairly good since there are extensive gravel bars and a more or less continuous bear trail.

The valley of the larger creek, coming from the east about 2 miles north of the mouth of Anuk[1] river, gives access to several large mountains and, by a low pass at its head, to a deep, timbered valley which probably drains to the Scud. It is said that by a pass in this general vicinity Indians travelled regularly by well-timbered valleys from the Stikine to the Iskut, reaching the latter at a point above the canyon. Those familiar with the story are of the opinion that Anuk valley was the route for leaving the Stikine. The supposition that a fairly easy route to the headwaters of Iskut river from this general vicinity does exist is not at all unreasonable. One of the largest tributaries of the Iskut has its source in the same area as the Scud. Other tributaries of the Iskut below this creek probably have the same southeast trend and head up just east of Anuk river. Further, since the ice movement in this area was in general southward, unusually low north-south passes are common, so that the probability is very great that at least one such exists between the Stikine and upper Iskut drainage systems. This is an extremely important consideration, since it is feasible to reach upper Iskut river by a fairly good route from Stewart and if a road or railway were constructed to this point, a new means of entry to the great area between Scud, Stikine, and Iskut rivers would be afforded.

Anuk river, for a short distance above its mouth, flows through a canyon in the base of a narrow valley and, therefore, is not easily traversed; its drainage area will, therefore, be difficult to explore.

Porcupine river is similar to the Scud, but being somewhat smaller does not appear to be easily navigable, though it is probable that boats could be tracked upstream for 10 or 12 miles. Travel by foot would seem to be better on the south side, since the two large tributaries from the north may be serious obstacles. A short distance above the foot of the glacier, a low pass leads northeast to the valley of a tributary from the east. By means of this pass the canyon at the mouth of the tributary is avoided. The valley of the tributary is low, wide, well wooded, and extends far northeast.

South of Porcupine river to the Iskut the tributary valleys are occupied by glaciers at no great distance from the Stikine, and the streams from these, except that flowing along the south base of Warm Spring mountain,

[1] Anook on Figure 1.

are small and for the most part flow in valleys that present serious difficulties to the traveller. The long ridges in this section afford by far the best travelling, though that of Eagle Crag is somewhat of an exception to this rule. For a considerable part of the area on the west side of the river no detailed description of routes has been given, since it is unlikely that there will be much desire at present to travel there. In general the glaciers or valley flats offer the best courses to pursue in this section.

Climate

Stikine River area extends from the heart of one physiographic province well into another, and its climate, therefore, shows considerable diversity. In the Coast range as far up river as Little canyon, precipitation is heavy throughout the year, and as a consequence accumulation of snow is very great. Summer is considerably advanced before much of the area above timber-line is denuded of its blanket of snow and it would seem inadvisable to attempt general prospecting in this section before June, though work on discovered properties might well be started in April. During May, June, July, and August weather conditions are the most favourable for working. September weather is very uncertain and there is usually considerable rain. After October 1, snow settles on the peaks and gradually works down the slopes. Precipitation is said to be heaviest between the International Boundary and Flood glacier and, of course, is greater in the mountains than in the valleys.

Up river from this zone, precipitation decreases until the minimum is reached at Telegraph Creek. Whereas in the central part of the range the snow accumulation during the winter may amount to 20 feet, at Jackson at the mouth of Dochdaon river it is reported to be about 6 feet and at Telegraph Creek probably somewhat less. The mountains north and west of Jackson are comparatively free of snow much earlier than those near the axis of the range. Prospecting could be commenced early in May and from that time until the middle of October conditions are very favourable for travel and work. There is little rain during the summer and snow does not begin to stand below timber-line until well on into October. Despite the small general precipitation there are, because of the fairly high mountains in this section which attract somewhat more rain and snow, few places where sufficient water for ordinary purposes cannot be found.

Water Conditions on Stikine River

During the winter Stikine river generally freezes from Telegraph Creek to near salt water, though on rare occasions the winters are so mild that open spots occur where the current is particularly swift. As a rule the freezing has progressed far enough by the first of January to permit of travel on the river. The ice usually goes out between the middle of April and the middle of May. The water then is at a very low stage and the bars of the river, being only shallowly covered, make navigation difficult, and sometimes, particularly if very cold weather continues, the regular boats are delayed several days. With the rise of temperature toward summer, the river rises and during June is very high, generally reaching the maximum in the latter half of the month. In July and August water is maintained at a high stage and the largest boat at present on the river can navigate to Telegraph Creek with little difficulty. In September the supply of water generally decreases fairly rapidly, so that shortly after the middle of the month it has reached a very low stage, when navigation by the regular river boats is difficult. However, this period, if it comes at all, is usually short, for late September rains raise the level, and navigation is fair until about the middle of October when with increased cold the precipitation assumes the form of snow and the river-level is lowered. For one to two months after this the river is navigable by small boats.

The river drains a very large area and its vagarities are pronounced. Storms may cause precipitation in one part of the area, thus raising only certain tributaries; and sections may be subjected to excessive sunshine, causing increased melting, whereas others protected by clouds are relatively cool. During the greater part of the summer the main river is not subjected to rapid changes in level, though in the autumn when it is low, a rise of 6 feet in one night has been known to occur in narrow sections after a heavy rain. On rare occasions (possibly once in ten or more years), the lake on Flood glacier breaks loose and a tremendous amount of water, suddenly released, carries everything before it and undoubtedly would seriously menace any craft on the river below this point. The outbreaks are reported to occur late in the summer. There is no way to predict their coming nor is there much warning, but such catastrophes are so rare as not to be a consideration for the ordinary river service.

The high water in the spring is a menace mainly because at extreme stages it loads the river with numerous drift trees and other debris. With care a boat can, in most places, easily steer a course to avoid these. In Little canyon the river is confined in a narrow gorge and the water is driven through with tremendous force, developing many powerful boilers and eddies. Under these conditions navigation at best is difficult and with the added menace of much drift becomes unsafe. This condition has seldom obtained sufficiently long in recent years to cause important delays.

During the autumn, winter, and spring, tributary streams contribute a very small load of silt, the water becomes clear and is able to pick up material from its own channel to be transported farther down river. At this time the stream becomes confined to definite channels which are fairly well cleaned out. Most of the soft sand-bars in the channel are removed, but gravel bars, owing to the decreased force of the water, remain unaffected. With the coming of high water so much more material is carried from the very swift tributaries into the comparatively slow-flowing Stikine that it is unable to carry the load and throughout begins to aggrade its channel; bars are built up wherever the water is slack; the river is greatly constricted opposite stream mouths; and changes its channel considerably, especially in the lower reaches where the material is relatively fine and easily moved. These and concomitant factors contribute greatly to the difficulty of navigation. With the falling of the river-level in the late summer and autumn and the consequently decreased carrying capacity, new bars appear to tax the boatman. Low-water stages, though offering many stretches in which the current is relatively slow, afford in general the poorest and most dangerous navigation conditions. In the lower reaches, snags and sand-bars are numerous; in the upper section gravel bars, riffles, and boulders menace even the most experienced voyageur.

Water conditions on Clearwater river do not follow exactly those on the Stikine. High stages of water may come much later since they derive a large part of their supply from glaciers. Hence a spell of hot weather at any time will very considerably increase the quantity of water. Also, autumn rains, because of the heavy precipitation in the mountains which the Clearwater drains, affect the river considerably more than the main river. Low water comes somewhat earlier. Scud river has the same changes of water conditions as the Clearwater, though their periodicity may not conform. In general the tributaries are subject to much more rapid and greater changes than the main river. Those from glaciers show, especially in hot weather, a marked daily variation which is not apparent on the main river. To the traveller this is an important consideration, since a stream that can be forded in the morning may be quite impassable by evening. Furthermore, conditions for navigation on either the Scud or the Clearwater may be favourable one day and by the next be adverse.

Vegetation

Due to the diversity of climate, vegetation is fairly definitely of two types. In the wet belt below Little canyon the river flats are a veritable jungle; large cottonwood trees stand out above a tangled mass of willows, cranberry bushes, and devil's clubs. The lower slopes wherever conditions are favourable are heavily clothed with a mature forest of spruce, balsam, and hemlock. Travel through this is as a rule easy. Where the trees are sparse or absent there is generally a thick underbrush of alders or devil's clubs which greatly impede progress. In many places, however, where the slopes are steep, the rock is entirely bare. Gullies and protected spots where the snow accumulates and lingers are generally fairly free of vegetation and afford the best routes for ascent. Timber-line throughout the wet belt is low, probably averaging about 3,500 feet, though in localities favourable to growth it extends up to 4,500 feet.

Above Little canyon the vegetation somewhat resembles that of the dry belt. The valley flats are slightly more open than in the lower part of the river. On northerly slopes that are protected from the sun the vegetation differs only slightly from that in the wet belt, but elsewhere there are fewer trees; pines, birches, and poplars are present and in places are the most abundant types. Underbrush is less luxuriant and in general virgin forests are open and park-like. Unfortunately, there are few sections which have not been burnt over in the last fifty years and as a consequence there is much fallen timber and secondary growth which seriously obstruct passage. Steep southern slopes such as those along the north side of Clearwater valley are in many places practically barren except for the more hardy shrubs. Timber-line in general is about 4,500 feet, though in favoured positions it extends to 5,000 feet.

GAME AND FISH

On the west side of the river from 7 miles north of Little canyon and on the east side north of Scud river, goats are abundant above timber-line. South of Patmore creek on the west side they are very rare. Moose are fairly plentiful north of Clearwater river, but to the south they are rare. Sheep are found in the northeastern part of the area. Bear are fairly numerous everywhere.

In the late summer and autumn, salmon are abundant in the main river and many of the tributary streams. Cut-throat trout and dolly-varden can be caught in the river and are abundant in some of the streams north of Clearwater river.

GENERAL GEOLOGY

The map-area is essentially a strip along the eastern contact of the Coast Range batholith. The rocks are divisible into two main groups, the intrusives which make up the batholith, and the non-intrusives. The latter group consists of pre-Permian metamorphosed sediments with some volcanics, Permian limestone, Triassic and Jurassic volcanics with some sediments, Cretaceous conglomerate capped by volcanics of the same age, Eocene volcanics with interbedded shales, sandstones, and conglomerates, and Pleistocene flows. The group naturally presents an extreme range in character of materials, both because of wide lithological differences in the original rocks and because of a greatly varying degree of metamorphism. The batholith in the map-area also presents great heterogeneity, since it is composite and the various intrusives show considerable inherent diversity as well as modifications due to their influence on one another.

NON-INTRUSIVES

Pre-Permian

The pre-Permian rocks are found throughout the map-area in more or less discontinuous masses. Generally they occur at the contact of the batholith and lie between it and the Permian limestone or the Mesozoic volcanics, though in the northeastern part of the area there is a large mass some distance from the batholith. They are in the main metamorphosed sediments. Dark grey is the dominating colour, though green is also fairly prevalent. In general, schists, slates, and quartzites predominate, with lesser quantities of calcareous materials and volcanics. They are, as a rule, well bedded and by this characteristic can in most cases be distinguished from the other formations. As exposed in different parts of the area the pre-Permian series exhibit diverse assemblages of materials. On Stikine river below Grand rapids there is a considerable thickness exposed which is highly calcareous and differs from the overlying Permian limestone mainly in being somewhat more argillaceous and darker in colour; the rocks are mainly light to dark grey, highly calcareous schists or schistose limestone. The argillaceous content has been metamorphosed to micaceous minerals, whereas the carbonates are mainly crystalline, though in some places these two have been altered, especially near the contact with the batholith. Between Scud river and the mountain at the head of Ochsakieen creek there appears to be an even greater thickness of calcareous beds; otherwise this type of material is unimportant. On the southeastern slope of Devils Elbow mountain, in what appears to be a lower series than that just below Grand rapids, the calcareous element is practically absent, and quartzites predominate, with some slates and schists. However, in most places the two latter types of rock are the most abundant. Rarely; pre-Permian rocks show a character not greatly different from that of some of the Jurassic and Triassic materials, being made up largely of altered igneous rocks. Some of the clearly volcanic materials, however, show more metamorphism than is common in the younger series. In many places the true character of the rocks cannot be so easily indicated since metamorphism, deformation, and intermingling of intrusives have created heterogeneous complexes which are not readily deciphered.

Permian

The Permian limestone when present forms a relatively narrow band between the older Palæozoic sediments and the younger Mesozoic volcanics. The latter generally lie to the north or east. Owing to the fact that a pronounced unconformity occurs between the Palæozoic and Mesozoic rocks, the limestone is in many cases entirely absent. Because of this and the complexity of structure the individual masses have great irregularity in shape and size. They occur throughout the area and are most extensive on Clearwater river, on Stikine river near Grand rapids, in the vicinity of the head of Ochsakieen creek, east of Pereleshin mountain, in a roof pendant north of Patmore creek, and in a broad north-south band lying some distance east of the map-area and crossing Anuk river.

The Permian limestone is a fairly uniform light grey and as a consequence stands out prominently against the other rocks except where it is in contact with the lighter phases of the batholith. In the main the material appears to be a fairly pure limestone, now largely crystalline. In places, notably near the batholith, it shows some beautiful marbled and coarsely crystalline phases. Some of these are pure white, whereas others show irregular tinting and variegated effects common to much marble used for decorative purposes. In part the limestone is well bedded with individual strata from a fraction of an inch to a foot in thickness. Elsewhere it is massive and gives no clue as to the direction of bedding. Practically everywhere it is intensely folded, and much broken and fractured. White chert or silicified beds are fairly common in the series and in general appearance very closely resemble the limestone. A somewhat darker grey chert is distributed in irregular masses in some sections.

The structure of the Palæozoic sediments, which is most clearly brought out by the distribution of the Permian limestone, seems to indicate that these strata were first intensely folded with axes trending northeast and southwest. Some of the folds thus developed were very close, especially in the vicinity of the Clearwater-Stikine River junction. Secondly, there was folding with a northwest-southeast trend which developed an anticline in the batholithic area so that the cross folds there are now turned up and truncated in a manner that leaves a pattern crudely suggestive of a frill.

Triassic, Jurassic, and Lower Cretaceous

Overlying the Permian limestone is a great thickness of volcanics, which includes a series of Triassic age, another of Jurassic, and possibly some early Cretaceous. Since they are not readily divisible into their various groups, the description of the distribution of the individual members would serve little purpose in a preliminary report such as this. North of Clearwater river, and north and east of Devils Elbow mountain, with the exception of sections already noted and others that will be noted, Mesozoic volcanics occupy almost all the area of non-intrusives. Other smaller masses occur throughout the southern part of the map-area.

The Triassic volcanics rest upon Palæozoic rocks of different ages with, in most places, no conglomerate intervening. As is usual in materials of this type they show a great heterogeneity. Green is the predominating colour; dark greys are common, and red, purple, black, and light greys are present. There are also various colour combinations and mottlings. Diversity in texture is equally marked, ranging from that of coarse-grained, igneous rocks through the different types of extrusives to that of argillites and slates. Coarse breccias, agglomerates, and conglomerates are fairly common. A great part of the series is made up of massive flows, some of which show well-defined bolster structure. Associated with them are masses of well-bedded tuffs which in places are of little thickness and limited length, being more or less lenticular in shape. Elsewhere the thickness is considerable and the same group of strata may be observed over a distance of many miles. In the lower part of the series north of Clearwater river there is a considerable thickness of weirdly coloured, green, grey, and purple, well-bedded quartzites with some argillites. Elsewhere there are black and dark grey argillites, slates, and schists, with, in places, a high calcareous content. Limestone occurs throughout the series associated with a great variety of materials, though the total amount is very small. In the volcanics there are bedded lenses of a few to several hundred feet in length; small concretions are scattered through great thicknesses, giving an appearance suggestive of conglomerate; a calcareous content is fairly common in many of the clastics. In the sediments there are fairly pure limestone beds as well as many that are definitely calcareous.

Separation of the Triassic and Jurassic volcanics cannot be made except by working out the structure and tracing the unconformity between the two series or by the discovery and determination of fossils. The base of the younger series is in many localities marked by conglomerate. West of the Stikine, opposite Pritchard creek, this basal member is exceptionally extensive, thick and coarse, and contains a large percentage of granitic boulders. Stratigraphically above this in many places there is a series of calcareous sediments including some fossiliferous limestone. With the exception of a thick member of bedded jasper, the rocks of Jurassic age resemble very closely those of the previous period. Early Cretaceous volcanics may be present, but as yet have not been differentiated.

The Mesozoic volcanics so far referred to are for the most part greatly deformed and in many places show close, possibly isoclinal, folds. Metamorphism is also extensive, but much less intense than in the older Palæozoic rocks.

Upper Cretaceous

From First South Fork river to Fourmile creek and on the tops of the mountains opposite the mouth of the Clearwater, strata of Upper Cretaceous age occur. This series rests with a marked unconformity on the older complex. On one of the mountains it is made up essentially of conglomerate, which throughout has many beds with well-rounded boulders ranging up to one foot in diameter. The materials that constitute them are largely igneous. Eastward the sediments become finer in texture and on First South Fork river conglomerates with pebbles up to one inch in diameter predominate. Interbedded with these are thin beds of sandstone. Both types of material are light grey. The pebbles of the conglomerate are well rounded and the matrix is mainly fairly fine grains of quartz. The sandstones are similar to the matrix and rarely are fine grained. On a mountain opposite the mouth of the Clearwater, the thickness of the series exceeds 2,000 feet, whereas on First South Fork river there is not much more than 100 feet exposed. The strata everywhere are practically horizontal in marked contrast to the underlying rocks. The relative positions of the various masses suggest a general dip east or northeast. On the top of one mountain opposite the Clearwater the sediments are capped by a thin layer of volcanics which, owing to its position, is of very limited extent.

Eocene

Eocene rocks occur along the river just north of Shakes creek. The base of the series is marked by a very coarse conglomerate made up largely of the underlying volcanics. Above this there is exposed in one place about 100 feet of fine conglomerate, sandstone, and shale. These are interbedded, the first mentioned predominating and the last occurring only as a few thin beds. They, too, are made up largely of materials from the underlying volcanics, and may be in part tuffaceous. Near the mouth of the first large creek from the east, north of Glacier creek, some highly carbonaceous sandstone is exposed. This almost assumes the aspect of coal and is said to be sufficiently combustible to use in a forge. A few inches of this material appear in a bed of grey sandstone which is mainly quartz. The sediments are overlain by a number of lava flows interbedded with tuffs. The whole series is considerably deformed. Beds opposite the mouth of the creek mentioned above are vertical and at no place were they found to be even nearly horizontal. They have been subjected to considerable faulting, probably accompanied by some tilting of the blocks, but whether this is the cause of all the deformation is not clear. They may also have been somewhat folded. They appear to be much more deformed than the Upper Cretaceous rocks.

Tuya Lavas

The horizontal lavas that cover a large part of the Interior plateau, and their associated cinder cones, have previously been described. A few small areas occur along the river for $2\frac{1}{2}$ miles below Telegraph Creek. They represent, probably, remnants of what was once a complete filling of the river valley between these two points. Just above Shakes creek there are two other small masses. These may have been part of the flows as near Telegraph Creek. They are undeformed and lie directly across faults that cut all the other rocks.

INTRUSIVES

Intrusive rocks occupy in general the western section of the map-area. They constitute a part of the great Coast Range batholith which extends along the coast throughout British Columbia and southern Alaska.

In the map-area the contact between the intrusives and non-intrusives cannot be indicated by a single well-defined line. In many places it is marked by a zone in which from east to west there is a gradual increase in the percentage of igneous rock from an insignificant quantity to practically the entire content. Within the batholith there are numerous roof pendants, whereas east of the main contact both within and beyond the area mapped there are many small intrusive masses that are closely related to the main body.

The batholith in Stikine River area is composite in that it was developed during several intrusive periods rather than one. Because of this it shows a considerable diversity of character in various sections and cannot well be described as a whole. In the north, between Clearwater river and a point about 4 miles north of Patmore creek, the mass, with the exception of an irregular and discontinuous border, the product of an earlier intrusive period, is of fairly uniform character. The rock here is a granite, is light brown, and mainly very coarse grained. Orthoclase, oligoclase, and quartz occur in about equal proportions, with orthoclase predominating only sightly over oligoclase. Ferromagnesian minerals have only a very small representation. This phase of the batholith is the most acid noted. From the mountain south of Patmore creek to the Great glacier on the west side of the river there is another large area of fairly uniform material. This is light grey, medium to coarse grained, and granodiorite in composition. The irregular and discontinuous fringe bordering these two areas to the east and the section between them show a pronounced heterogeneity of materials. Two or more distinct intrusive phases other than those mentioned above seem to be represented. The rocks range in colour from light grey to black, in texture from coarse to dense, and in composition from granodiorite to basic phases which show very little, if any, feldspar. In places they exhibit considerable metamorphism and the original character is often entirely masked. Shearing and fracturing are pronounced in some sections. At the contact in places, notably in the vicinity of the Devils Elbow claims, alteration of both the intrusives and non-intrusives has proceeded to such an extent that it is often difficult to differentiate the two.

The satellites to the east of the main batholith exhibit a diversity of character. Generally each shows some marked similarity to one of the phases of the main mass.

The effect of the intrusions on the adjacent rock is markedly diverse with different phases of the batholith and with various sections of the same phase, even on one type of rock. Of course the variety of materials greatly increases the number of modifications. The changes brought about range all the way from those that are not perceptible, to the development of entirely new materials which offer little clue as to their original character.

The composite nature of the batholith clearly indicates that its development took place over a long period of time. Granitic masses cut Palæozoic sediments and Triassic volcanics, and dykes that may have originated with such masses penetrate even Upper Cretaceous sediments. The basal member of the Jurassic series contains an abundance of granitic boulders, clearly indicating that part of the batholith had been developed and unroofed before that period. Although there may have been intrusives of even Palæozoic age in this section, it is believed that development of the Coast Range batholith proper began early in the Triassic and continued throughout the greater part of the Mesozoic era. Possibly dying phases of this igneous activity may have contributed in some small way at even later periods. In the map-area it has been possible to separate the batholith into sections that are clearly of markedly different ages, but there does not appear to be any systematic arrangement of these sections.

ECONOMIC GEOLOGY

The greater part of the map-area lies within what may be called the eastern contact zone of the Coast Range batholith. This zone has long been regarded as favourable for the occurrence of mineral deposits and has already produced well-known mining camps such as Portland Canal, Alice Arm, and Atlin. On the basis of the general geology there seems to be no apparent reason why Stikine River area should not have potentialities as great as any other section.

Mineralization throughout this zone has been in general attributed to the intrusions that developed the batholith. In the map-area the extensive Devils Elbow deposits[1] and others of a similar nature have been definitely traced to one of the earliest phases of intrusion. There is considerable additional evidence which suggests that mineralization was extensively associated with this phase. What is thought to be the latest intrusive body—the light brown, granite mass—does not in general show much evidence of associated mineralization, though in some places it contains seemingly related pyrite veins. However, it is believed that the contacts observed are by nature unsuitable for showing signs of mineralization; therefore, even slight manifestations may be favourable.

Though definite evidence has not been forthcoming, there is much to suggest that other intrusive periods were also productive of mineralization. The significance of these observations is twofold; first, it stands to reason that since there has been more than one intrusive period and consequently more than one mineralizing period, potentialities are greater than if the batholith were simple; secondly, the fact that the batholith itself has been re-intruded by each later phase makes potential mineral bearers of all the parts so affected.

Of the intruded rocks, limestone is undoubtedly the most favourable for the reception of mineral deposits, but equally valuable occurrences may be found in any other type of material. The known deposits and other evidences of mineralization have been noted in a great variety of rocks.

[1] Kerr, F. A.: Geol. Surv., Canada, Sum. Rept. 1926, pt. A

Few discoveries have been made in the area, which is not surprising since very little prospecting has been done. In 1873 and during the following years the Cassiar gold rush attracted many prospectors to northern British Columbia, but practically all of these passed through the map-area without pausing to do any work. The Stikine and the tributaries in the vicinity of Telegraph Creek were tested for placer deposits and some of the bars of the main river were very productive for a short period. Following 1898 there was another rush of prospectors up the Stikine, but they all had their eyes fixed on the distant Klondike. There is nothing to indicate that either of these influxes induced any extensive search for minerals in this area. All important streams have undoubtedly been tested for placer gold and some desultory hard-rock prospecting has been done in the areas immediately south of Telegraph Creek, but there is ample evidence to show that the work done in any section was not adequate to give a fair idea of its possibilities. However, there have been sufficient discoveries to support clearly the contention that mineralization does occur over an extensive area. Furthermore, during the field operations of the present work many evidences of this mineralization, both in situ and in float, were observed throughout the area.

The important discoveries include the following types of deposits: silver-lead-zinc with some copper (chalcopyrite); copper (mainly bornite); copper (chalcopyrite) with pyrrhotite; copper (tetrahedrite); free milling gold and placer gold. Small veins have been observed of chalcopyrite, of pyrite, and of arsenopyrite—the latter two with gold and silver values. Also small deposits of magnetite and of hematite have been noted. Float specimens suggest still other types of deposits.

The most important known deposit in the map-area at the present time is one of placer gold at the mouth of the canyon on North Fork river, owned by Captain Sydney Barrington and associates. During the last two years a very well-planned program of drilling has been carried out. The results have been sufficiently encouraging to warrant a continuation of the explorations. Since the working of this ground will involve considerable difficulties, profitable operations will be largely dependent on securing suitable equipment and maintaining efficient management. The properties had already produced over $20,000 worth of gold from hand operations. The gravel was removed from among boulders in pits which undoubtedly required much labour, yet the undertaking is reported to have been profitable.

The deposits on North Fork river owe their origin to a peculiar set of circumstances. Probably many streams in this area had considerable gold concentrations previous to the Pleistocene period, but with the advent of glaciation the ice removed the concentrates and scattered them far and wide. In North Fork River area, however, most of the ice from the upper section moved through Shakes Creek valley, so that a part of the North Fork valley between Spann creek and the mouth of the canyon was not subjected, during the glacial period, to the same intense scouring and cleaning-out process as others. Hence gold that accumulated during the preglacial and interglacial periods, especially that in the canyon, was not disturbed. The post-glacial activity of the river waters has removed to some extent the old accumulations and has carried them downstream beyond the canyon. The natural tendency there, since the gradient and water velocity were somewhat less, was for the gold to be dropped not far below the canyon and to work its way down into the gravel, which is of considerable thickness. If this theory is correct, the best values should be obtained near the canyon and there should be a general decrease with an increase of distance from it, which seems to be the case. Clearwater valley, which North Fork river enters just a short distance below the canyon, has been extensively glaciated, so that any accumulations found there are derived from a reconcentration of glacial drift or brought in by North Fork river and in either case are not likely to be very great. The decrease in gradient toward the Clearwater and the presence of a thick, unconsolidated channel base would militate greatly against the gold being transferred far from the canyon, though the current certainly is sufficiently strong to move considerable fine, and some fairly coarse, gold.

The possibilities of finding other placer gold deposits in the map-area are not very good. Other locations where the preglacial or interglacial accumulations were preserved probably do exist, but their location would be difficult and for the average prospector the time that might be spent in searching for such localities is not warranted by the possibilities.

The Devils Elbow deposits have already been described[1], since then, however, the Apex property south of these claims has been visited. The mineralization is of somewhat the same character as that of the other claims. The intrusive, however, was not observed and is believed to be at some depth below the exposures. The mineralization with associated altered limestone represents an irregular patchwork across the face of a fairly large cliff exposure. It appears as though the country rocks had been irregularly broken and solutions passing along the fractures and bedding planes caused mineralization. The rock so affected, in section across the face has a net-like arrangement. Though the rock is in this way rather intimately mineralized and though fine specimens can be picked from many points, it is doubtful whether the material as a whole is sufficiently rich to be of value, and owing to the irregular distribution of the richer portions in small masses they could not be mined separately. However, since in other sections mineralization increases toward the contact, and since the exposures on this property may be at some distance from the intrusive, it is possible that valuable deposits may occur nearby.

New showings have been discovered in this general area during the last two years, which further emphasizes the widespread mineralization described in the previous report.

At Kirk's mine (August claim) on the western slope of the mountain drained by Kirk creek, an adit has been driven into the hill and turned in the shape of a horseshoe to tap a deposit exposed in a steep gully. The rocks here are green Triassic volcanics. On the surface there are two or three separate mineralized zones of lenticular shape. None is much over 200 feet in length with a maximum width of about 15 feet. Mineralization seems to have taken place along fractures in sheared or shattered zones.

[1]Op. cit.

The most important minerals are bornite and chalcopyrite, which in exposed parts are mainly altered to malachite. Assays in general average about 2 per cent copper with some gold and silver.

The Mountain Goat claim at some distance to the northeast shows much the same type of mineralization. The zone is said to be narrow, but fairly long.

Other deposits examined are not of sufficient importance to warrant description in a brief report of this type.

CONCLUSIONS

No lode deposit has so far been discovered or brought to a stage of development that clearly indicates a prospective future value, though certainly some of the known deposits have possibilities. There is much that augurs well for the district as a whole, and it seems to present a great extent of territory that warrants careful prospecting. Included in this category is practically the whole area of non-intrusives mapped, and much beyond. The least favourable section is that immediately adjacent to Telegraph Creek, which may lie too far beyond the batholith to have been penetrated by mineralizing solutions.

Roughly, the average width of the most favourable zone from the main contact eastward or northeastward is probably about 25 miles, though from point to point with varying conditions this factor undoubtedly changes considerably. Which sections of this zone offer the greatest possibilities it is difficult to say, though in general calcareous sediments afford the best country rock. Furthermore, areas containing a fair number of satellites and a variety of intrusives (since this may indicate several intrusive periods and consequently several mineralizing periods), would seem to be preferable. Prospecting already done has been more extensive in the area east of North Fork river and north of Clearwater and Dochdaon rivers. Coincidentally, this is the section that conforms least with the conditions described above as being the most favourable, yet, though its possibilities have been only scratched, some results have been obtained.

Roof pendants are favourable for mineralization. Mineral specimens are somewhat abundant in the morainal material of the glaciers which come from the large pendant in the southwestern part of the map-area. However, this mass is relatively inaccessible and the evidence of mineralization does not seem to be sufficient to warrant prospecting there at present. In the northwestern part of the area, however, conditions are ameliorated and roof pendants there should not be overlooked.

The above delineated sections seem to offer by far the best opportunities and afford sufficient area to keep many prospectors occupied for some time. The variety of known mineral occurrences and the composite character of the batholith indicate clearly that a great diversity of deposits may be expected, and prospectors should keep in mind that any one deposit they see is not necessarily representative of the next one they may encounter.

MINERAL DEPOSITS OF ALICE ARM DISTRICT, BRITISH COLUMBIA

By George Hanson

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INTRODUCTION

Alice arm is the eastern branch of Observatory inlet which is on the northern coast of British Columbia between Portland canal and Nass river. The village of Alice Arm is at the head of the inlet of the same name. It is about 600 miles up the coast from Vancouver, about 100 miles north of Prince Rupert, and 18 miles east of Anyox. The town of Anyox is at the junction of the two arms of Observatory inlet and was built by Granby Consolidated Mining, Smelting, and Power Company who at that place operate a mine, mill, and smelter.

Regular coastwise steamship service exists between Anyox and Alice Arm and points to the north and south, and a regular tri-weekly motor boat service is maintained between Anyox and Alice Arm.

The field work on which this report is based occupied July and August, 1928. The object in visiting Alice Arm was to study the geology and mineral deposits of the district. This investigation will be continued in 1929 when the geology will be studied in greater detail.

Geological reconnaissance has been carried out in the vicinity of Alice Arm [1] and detailed geology has been done on upper Kitsault river.[2] The mineral deposits have been described from year to year in the Annual Reports of the Minister of Mines of British Columbia.

The writer was assisted in the field by Mr. A. E. Goranson. The writer is indebted to Mr. R. Bartlett, Topographic Division, Geological Survey, Mr. F. Butterfield, B.C.L.S., of Victoria, B.C., Mr. and Mrs. R. F. McGinnis, Mr. A. Davidson, Mr. M. Peterson, and others, of Alice Arm, B.C., for hospitality and information.

[1] Hanson, George: Geol. Surv., Canada, Sum. Rept. 1923, pt. A, pp. 29–45; 1922, pt. A, pp. 35–50.
Turnbull, J. M.: Ann. Rept., Minister of Mines, B.C., 1916, pp. 53–84.
McConnell, R. G.: Geol. Surv., Canada, Mem. 32, pp. 81–94 (1913).
McEvoy, J. E.: Geol. Surv., Canada, Ann. Rept., 1893, pt. A, p. 13.
[2] Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, pp. 7–21.

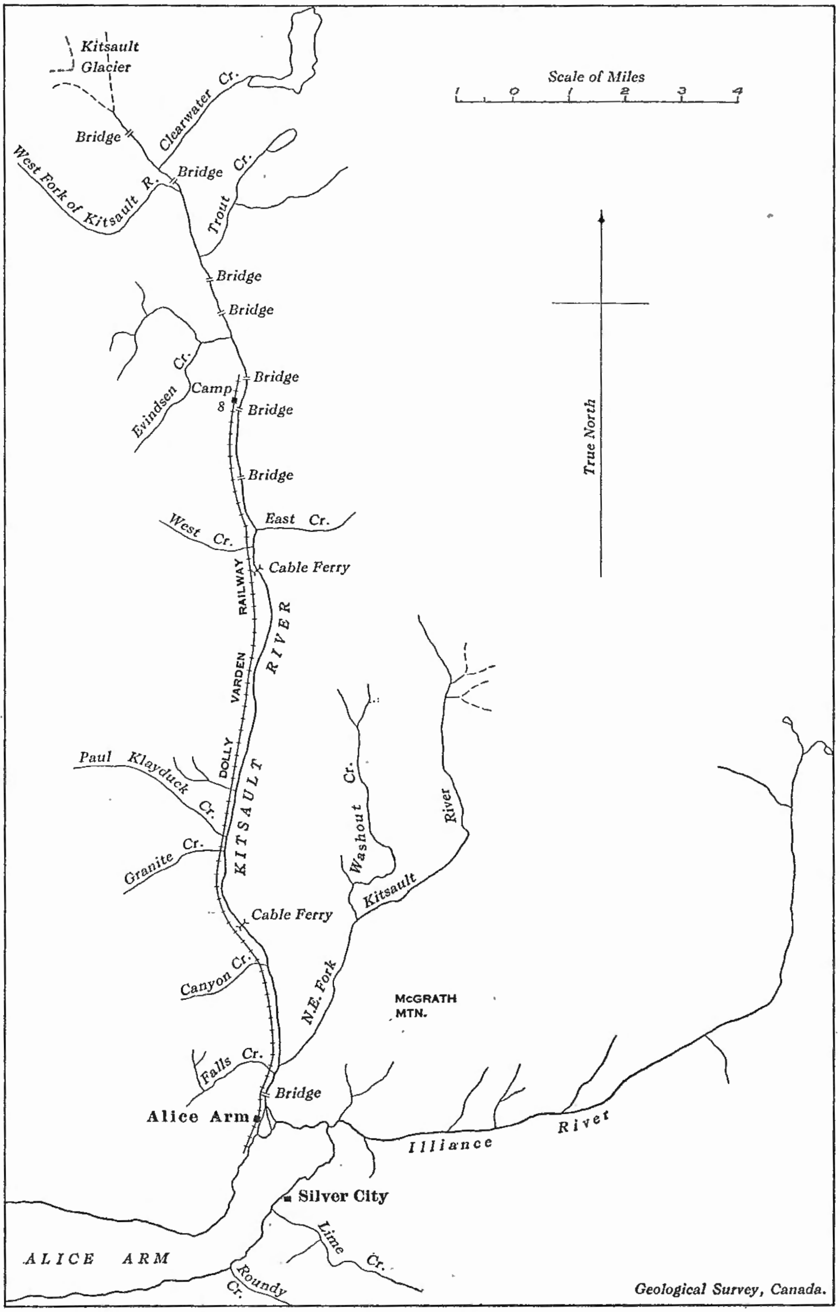

Figure 2. Sketch map of Alice Arm district, B.C.

The village of Alice Arm is on a flat area, at the head of Alice arm, hemmed in on three sides by precipitous mountain slopes. On the fourth side is the sea. The flat is 4 square miles in area and consists of delta material carried down into Alice arm by three streams which enter at its head.

The streams entering the head of Alice arm are Illiance, Northeast Fork Kitsault, and Kitsault rivers. The Kitsault is the largest and is a short mountain stream heading in Kitsault glacier 25 miles north of Alice arm. The stream is rapid and has cut steep canyons in the harder rock formations over which it runs. Northeast Fork Kitsault river is now a tributary of Kitsault river and enters it on Alice Arm flat. Before the delta had grown to its present proportions, however, the Northeast Fork Kitsault was a separate stream. It is glacially fed and flows south about 5 miles and then southwest about 7 miles to its mouth. Illiance river is about 16 miles long and flows south about 6 miles and then west 10 miles to the head of Alice arm. Although to some extent glacially fed the Illiance is in most seasons of the year a fairly clear stream.

The mountains north and south of Alice arm are high, rugged, and covered locally with glaciers. East of Alice arm the country is more subdued and plateau-like and between Alice arm and Nass river is a plateau about 2,200 feet above sea-level.

The mountain slopes below an elevation of 3,000 feet, and the river valleys are densely wooded with hemlock and a heavy growth of underbrush. The flat at the head of Alice arm was covered with a beautiful stand of hemlock and spruce timber until 1923 when all available timber was logged off.

There is very little to record about the history of Alice arm prior to 1900. Observatory inlet was named by Capt. Vancouver in 1793. Alice arm was named in 1869 after Alice, wife of the Rev. Robt. Tomlinson, who was in charge of the Church Missionary Society Mission at Kincolith. In an attempt to find a good trail route from the coast into the northern interior of British Columbia, the Provincial government in 1874 sent an expedition into Alice arm to search for a feasible route to Nass river. This expedition, strange to say, failed to find the low pass to Nass river. During the last part at least of the nineteenth century and the early part of the twentieth century Indians lived at Alice arm for at least part of the year. It is not likely that they selected Alice arm as a place to fish as the Illiance is the only stream there that salmon ascend and it is only a small stream. The Indians had overland routes between Nass river and Alice arm and they probably made extended trips to Alice arm to hunt mountain goats. An Indian reserve was set aside at Alice arm, but in recent years no Indians have occupied it. The reserve was returned to the Government in 1928 and in that year it was subdivided into lots of varying size.

Mineral claims were staked in Observatory inlet in 1900. The Hidden Creek group of claims, which is the nucleus of the Granby Consolidated Mining, Smelting, and Power Company's mine at Anyox, was staked in 1901. The Roundy group and other mineral claims at Alice Arm were staked at about the same time. As the valleys tributary to Alice arm are steep-sided and heavily wooded, they were ascended only by arduous labour before trails were built, and the early stakings were, therefore, near the shores of Alice arm. Any area so far from regular routes as Observatory inlet must develop very slowly unless some economic resource of outstanding importance is discovered. The Hidden Creek group of claims proved to be of outstanding importance, and the value of this property became known in about 1910. In this year, also, mining began at the head of Portland canal, and interest in the general area became quite active. The discoveries at Anyox and Stewart led to the establishment of regular steamship communication with southern points. More prospectors entered Alice arm and prospecting was extended up the valleys. In 1914 the smelter at Anyox was completed and mining began on a scale of 1,500 to 2,000 tons of ore a day. Shortly after this, active development was begun at the Dolly Varden mine on Kitsault river.

The Dolly Varden mine was situated 17 miles from Alice arm and transportation of ore and supplies became a problem of considerable moment. High-grade ore was discovered and those in control of the mine considered it advisable to build a narrow gauge railway from tide water up Kitsault valley to the base of the mountain on which the mine was situated. The contract for building the railway was let to the Taylor Engineering Company on a cost plus 10 per cent basis. The cost proved to be considerably greater than had been estimated and as the Dolly Varden Mining Company was unable to pay, the mine was taken over by the Taylor Engineering Company. This company commenced shipments of ore from the mine in 1919 and ceased operations in 1921 after mining 35,000 tons of ore containing 1,300,000 ounces of silver.

In the meantime and since that time, prospecting and development have gone on at Alice arm, and mining in a small way has been carried out on the higher grade ore-bodies. A concentrating mill was completed at the Toric mine on Kitsault river in 1928 and in that year mining was begun at this mine. This and other active development suggest that the future growth and development of Alice arm will be somewhat like that of Stewart since 1916, the Canadian mining centre at the head of Portland canal. Good trunk trails exist up Illiance and Northeast Fork Kitsault rivers, and a railway and trail up Kitsault river. Branch trails give access to all of the mining properties.

MINERAL DEPOSITS

The area is on the eastern border of the Coast Range batholith and the mineral deposits are part of the interior belt of mineralization which forms a fringe along the eastern contact of the batholith for most of its length. An hiatus occurs in the belt at Nass river where no mineral deposits are known. Alice arm is at the southern end of that part of the belt that extends northward and that includes the mineral deposits of Portland canal, Unuk and Stikine rivers, and Atlin.

The mineral deposits of Alice Arm district can be classified under five headings:

(1) Molybdenite deposits
(2) High-grade silver-bearing veins in argillite
(3) Silver-lead deposits in volcanic rocks
(4) Sphalerite deposits
(5) Chalcopyrite deposits

No molybdenite deposits are described in this report.

The high-grade silver-bearing veins in argillite are quartz veins 6 feet or less in width, which are mineralized with primary silver minerals. The silver-lead deposits in volcanic rocks are vein-like, usually much wider than 6 feet, consist of quartz, barite, and country rock, and are mineralized with silver-bearing galena and tetrahedrite. Owing to secondary enrichment some of the deposits of this type contain rich silver ore.

The sphalerite deposits are vein-like and consist of quartz, calcite, country rock, and resin-coloured sphalerite. The deposits vary considerably in size and are usually in sedimentary rocks.

The chalcopyrite deposits are vein-like and consist of quartz, country rock, and chalcopyrite. The deposits are mostly in volcanic rocks. In many respects they closely resemble the sphalerite deposits and may be closely related to them in origin.

The deposits have not yet been studied sufficiently to enable the writer to formulate any satisfactory theory to account for the various distinct types of mineral deposits.

WOLF MINE[1]

The Wolf mineral claim is on the mountain slope north of the village of Alice Arm. The known ore deposits and the mine workings are at the base of the mountain near the mouth of Falls creek, less than a hundred yards from the Dolly Varden railway.

The claim was staked by J. E. Stark many years ago. Mr. Stark discovered narrow, high-grade, silver-bearing veins and explored them by means of open-cuts. In 1925 the claim was bonded by J. Fiva also of Alice Arm and in that year underground development was begun and ore was shipped. In 1926 and 1927 Mr. Fiva continued developing the mine and in 1927 made a second shipment of ore.

The country rock in the vicinity of the Wolf mine is argillite and sandy and argillaceous quartzite, intruded by many lamprophyre and diorite dykes. The sedimentary rocks lie in gentle, open folds and in the mine itself they strike north and dip about 20 degrees west. Most of the dykes are vertical and strike north 30 to 40 degrees east.

The mineral deposits consist of three narrow silver-bearing quartz veins lying parallel with the enclosing strata and structurally about 100 feet apart. The central vein is exposed by open-cuts for a distance of 160 feet. Underground work on this vein has proved a strike length of 220 feet and a dip length of 70 feet. The other two veins have been explored on the surface only and are known to be at least 100 feet long. The veins vary in width from a few inches to several feet, but in general are about a foot wide.

In the northern part of the underground workings, the central vein is divided into two branches which may reach the surface as two separate veins. A narrow lamprophyre dyke usually less than a foot wide accompanies and intrudes the vein or its lower branch. In a few places the vein consists of closely spaced gashes of quartz in a zone several feet wide. In most places it is a single vein a few inches to several feet wide. Small stringers of quartz branch from the vein. Veins or stringers less than 6 inches wide do not appear to be of commercial grade. The vein is cut by many lamprophyre dykes 1 to 6 feet wide and by a diorite dyke 30

[1] Ann. Rept., Minister of Mines, B.C., 1925, p. 74; 1926, p. 79; 1927, pp. 70, 1.

feet wide. All of the dykes except the one associated with the vein strike north 30 to 40 degrees east and two of them offset the vein several feet.

The vein consists of white quartz containing rock fragments and bands and disseminations of silver-bearing sulphides. The sulphides are chiefly in bands along the foot-wall of the vein. These bands of sulphide are up to 8 inches thick and consist of rich silver ore. The metallic minerals are chiefly pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, ruby silver, and native silver. The gangue is quartz containing some ankerite, calcite, and barite.

The veins have been formed along fractures which followed the strike a•d dip of the enclosing rocks. The angular rock inclusions show that the vein matter did not simply penetrate between beds but entered a fractured zone. James states that the best ore occurs along the vein walls where the argillite has been sheared to a graphitic gouge or a fine, broken schist.[1]

The three veins have been developed by surface open-cuts and the central vein by a tunnel consisting of 140 feet of crosscut and 250 feet of drift. A raise connects with the vein outcrop 40 feet above the drift, and small stopes have been opened up. A 17-ton shipment of ore in 1925 yielded 3 ounces gold, 2,212 ounces silver, and 583 pounds lead. A 28-ton shipment in 1927 yielded 4 ounces gold, and 2,051 ounces silver. The 1925 shipment was in two lots. The one consisting of carefully sorted ore assayed $5.40 in gold and 306·4 ounces silver per ton. The lower grade lot assayed $2.20 in gold and 80 ounces silver per ton.

It has been stated that the central vein splits into two branches and that small quartz stringers also branch from the vein. In systematic underground development it would probably be advisable, therefore, to explore at right angles to the vein by means of crosscuts or diamond drills in order to determine whether any of the branch stringers contain ore. Branch veins are most likely to be of commercial grade where they are in fractured or sheared zones. Overburden is locally quite thick, timber and underbrush interfere greatly with surface prospecting, but where surface trenching can be done to advantage it should be the best and cheapest method of looking for ore-shoots in the veins. When surface work cannot be done to advantage, the veins showing commercial ore on the surface should be followed by drifts. The veins will probably not be both wide and rich at any one place. The best ore-shoots will perhaps be only one foot or so wide. The veins may possibly yield a profit to a few individuals, but do not warrent large-scale development and are rather small for company operation.

ESPERANZA MINES, LIMITED[2]

The holdings of Esperanza Mines, Limited, which consist of the Esperanza group of three mineral claims are on the west side of Kitsault river about a mile from Alice Arm. The mine workings extend from 450 feet to 660 feet above sea-level. A good horse trail has been built from the railway to the mine.

[1] Ann. Rept., Minister of Mines, B.C., 1927, p. 71.
[2] Ann. Rept., Minister of Mines, B.C., 1927, p. 78; 1926, p. 79; 1925, p. 74; 1924, p. 53; 1923, p. 55; 1922, pp. 55, 56; 1921, p. 48; 1920, p. 47; 1919, p. 50; 1918, p. 56; 1916, pp. 60–62; 1911, pp. 70, 71.
Dolmage, Victor: Geol. Surv., Canada, Sum. Rept. 1922, pt. A, pp. 31, 32.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1922, pt. A, pp. 46–47.
McConnell, R. G.: Geol. Surv., Canada, Mem. 32, pp. 92, 93 (1914).

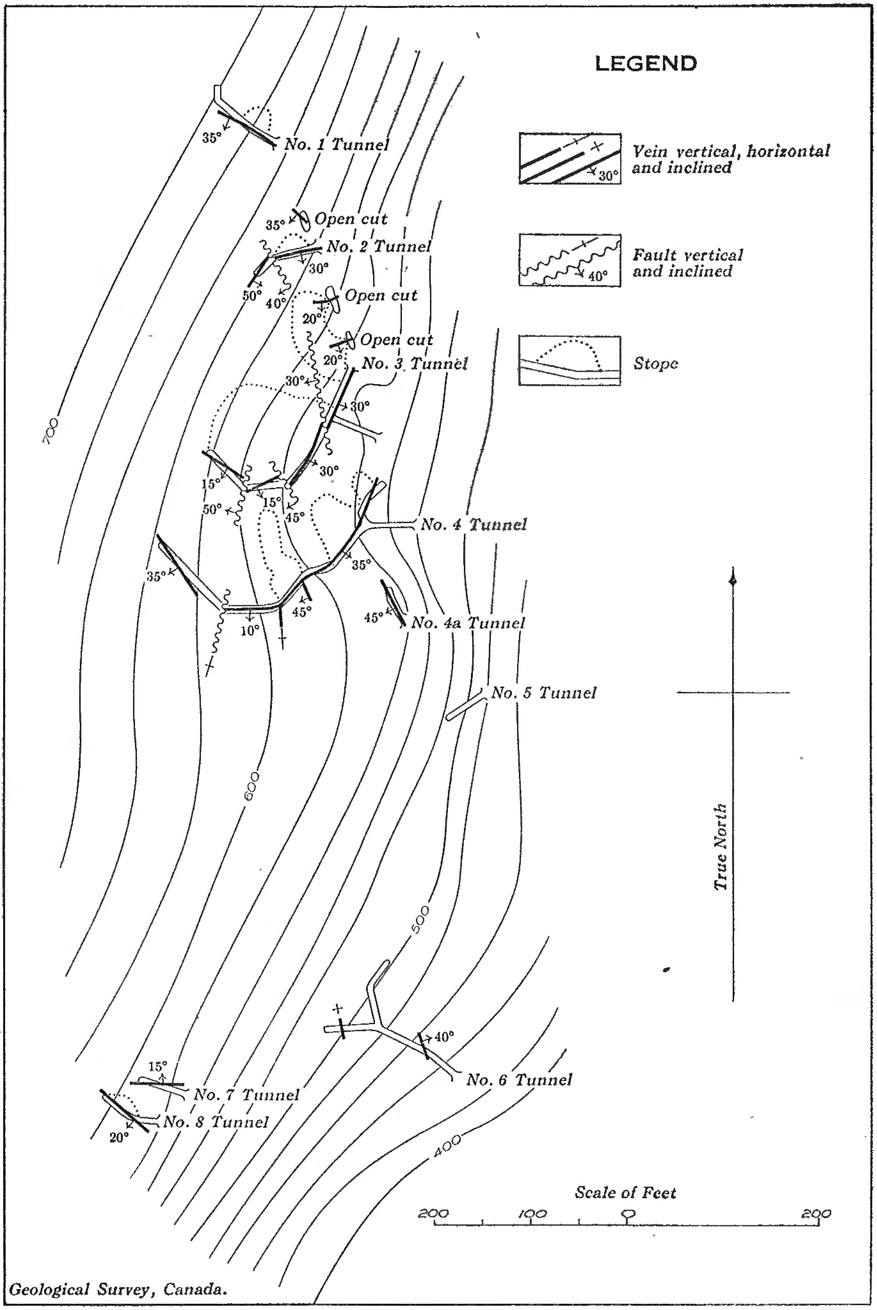

Figure 3. Plan of workings of Esperanza mine, B.C.

The mineral claims of the Esperanza group were among the first staked at Alice Arm. The group was first known as the Roundy group after R. Roundy who staked the claims. It was later known as Alderbarab group, the name of one of the claims of the group, and still later as Black Bear group after the Black Bear claim of the group. Small shipments of ore were made in the early years of the property, particularly by E. Morrison in 1911, who then had the property under bond from Mr. Roundy. About 1916 the property was acquired by Salinas Brothers and has since been known as the Esperanza group. Salinas Brothers carried on mining until 1921, when they sold the property to Mr. Elge who in turn disposed of it in 1922 to a syndicate of Anyox men. This syndicate began mining under the management of J. Peacock, but since 1923 under the management of Mr. Fraser. In 1927 Esperanza Mines, Limited, was organized and took over the Esperanza group of claims. Mr. Fraser is the present manager.

The country rock in the vicinity of the Esperanza mine is argillite intruded by narrow lamprophyre dykes. The sedimentary rocks lie in gentle northwesterly striking folds. The dykes strike northeast. The rocks have been faulted by pre-mineral and post-mineral faults.

The strata exposed in the northern five tunnels (Figure 3) strike northwest and dip southwest at angles of 20 to 50 degrees. South of this, at No. 6 tunnel, the rocks dip northeast. West of No. 6 tunnel, at Nos. 7 and 8 tunnels, the rocks again dip southwest. A synclinal axis passes, therefore, between No. 6 tunnel and the tunnels farther north, and an anticlinal axis lies between No. 6 tunnel and those farther west. Practically all of the ore so far mined has come from tunnels No. 1 to 4 where the rocks dip southwest.

The mineral deposits are silver-bearing quartz veins which contain, as well, lead and copper minerals. Scheelite is present in the veins, but so far tungsten has not been extracted from the ore.[1]

The main ore-body is a quartz vein which for the most part lies in a fault fracture. The fault fracture is curved and strikes from southwest to west and finally northwest, in which direction it coincides in strike and dip with the country rock and tends to lose its identity. The fault fractures dip southeast and south and the strata dip southwest. The vein that occupies the fault fracture and its apparent extension along the sedimentary beds is, then, in the form of a southerly plunging anticline. The vein is in some places as much as 6 feet thick, but in most of the stopes is 1 to 3 feet thick. It has its greatest proved length in No. 4 tunnel, where it is 320 feet long. Its dip length is known to be greater than 500 feet. The vein anticline is complicated somewhat by normal faults of small throw. Some of them follow the bedding planes of the argillite and in these cases the western side of the faults has been downthrown 2 to 12 feet. Other faults, striking approximately north at the axis of the anticline, apparently fault the vein in the same direction. That part of the curving fault making an angle with the strata is not a single fracture but is occasionally branched. In some places, also, the fracture changes direction suddenly to follow the bedding planes for a few feet and then abruptly changes back to its original strike. The vein follows all these

[1] Ann. Rept., Minister of Mines, B.C., 1924, p. 53.

changes of direction. Where the vein lies parallel to the bedding on the western limb of the vein anticline it is chiefly parallel to the beds, but at some places it crosscuts the bedding at low angles.

Several quartz veins 1 to 6 feet wide join the main ore-bearing vein. One of these branch veins has been exposed in tunnel No. 4A. It lies parallel to the enclosing rocks. Four other quartz veins are exposed in tunnels Nos. 6, 7, and 8, several hundred feet south of the most southerly exposure of the main vein. The two veins in tunnels Nos. 7 and 8 are exposed for a distance of 50 feet in each case. They are 1 to 3 feet wide and are ore-bearing. No connexion has been established between these two veins, but they may be parts of a single vein. Two bed veins 1 to 2 feet wide are exposed in No. 6 tunnel.

The metallic minerals in the veins are arsenopyrite, pyrrhotite, pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, ruby silver, native silver, probably polybasite, and other silver minerals. The gangue minerals are chiefly quartz and ankerite. The paragenesis has been discussed by Dolmage[1]. The ore in many places occurs in bands of almost solid sulphide, which lie commonly at the hanging-wall of the vein. In some places the ore minerals are disseminated through the whole width of the vein. Goranson states that the best ore is in the narrow part of the vein where gouge is plentiful, and that carbonaceous matter may have been important in precipitating the silver sulphides.[2] Work done after Mr. Goranson saw the property shows that most of the stopes are along the anticlinal axis of the vein. The vein matter appears to be entirely of primary origin and has been formed by filling a curving fault fracture.

The veins occur on the easterly slope of the mountain west of Kitsault river. The main vein strikes west and dips south. The outcrop of this vein trends slightly west of north, so that from south to north the outcrop inclines uphill. The angle between the line of outcrop and the horizontal is approximately the dip of the vein. The vein has been developed by tunnels driven westward along its strike.

The most northerly tunnel or No. 1 tunnel follows the vein northwestward for about 60 feet. The vein is here a bed vein 1 to 3 feet wide, consisting mainly of quartz. Some ore has been stoped from this tunnel.

No. 2 tunnel is 120 feet south-southeast of No. 1 tunnel and is a drift 70 feet long driven southwest along the vein which here occupies the fault fracture. A post-vein fault striking northwest and dipping southwest parallel to the strata has offset the vein in this tunnel a distance of 4 feet. The vein is 1 to 2 feet wide and dips south to southeast 20 to 50 degrees. Some ore has been stoped from this tunnel. Between Nos. 1 and 2 tunnels an open-cut exposes the vein which there is a bed vein dipping southwest.

No. 3 tunnel has two portals, one 130 feet and the other 200 feet south-southeast of No. 2 tunnel. Between No. 2 and No. 3 tunnels two open-cuts expose the vein which is there along the fault fracture. It strikes west and dips south 25 degrees. A stope 20 feet long along the strike and 100 feet long along the dip extends from this tunnel up to the two open-cuts above. In this stope a northwesterly striking fault along the bedding of the rocks has downthrown the southwestern side 2 feet. From its more northerly portal No. 3 tunnel is a curving drift following

[1] Dolmage, Victor: Geol. Surv., Canada, Sum. Rept. 1922, pt. A, p. 32.
[2] Hanson, George: Geol. Surv., Canada, Sum. Rept. 1922, pt. A. p. 47.

the vein southwest and west along the fault and northwest along the strata a total distance of 250 feet. Above this tunnel most of the vein has been stoped in an area 200 feet along the strike and 100 feet along the dip. This large stope is along the axis of the vein anticline. The dip along the axis of the anticline is in some places as low as 10 degrees. The vein is as much as 6 feet thick locally, but is in most places only 2 or 3 feet thick. Several faults striking north offset the vein in the tunnel. In all cases the western side has been downthrown and the individual throws are less than 12 feet. The other portal is lower than the tunnel level. From the lower portal a crosscut has been driven northwest for 20 feet where it encounters the vein. From this point a raise follows the vein to the tunnel.

No. 4 tunnel is 100 feet south-southeast of the more southerly portal of No. 3 tunnel. The tunnel commences as a crosscut driven west for 60 feet, where it encounters the vein in the fault fracture. From this point the tunnel is a curving drift for 320 feet along the vein, curving from southwest to west and to northwest. Several stopes exist above that part of the vein striking northeast. The vein is in general less than 3 feet wide. Two branch veins join the main vein on this level, both from the south. The more easterly is 2 feet wide and is a bed vein dipping west. The other is 6 feet wide and is a vertical vein in a fault zone. Both are quartz veins with very little sulphide.

No. 4A tunnel 80 feet south of No. 4 tunnel is a drift 40 feet long on a bed vein 2 feet wide striking north-northwest and dipping west. It is perhaps the same bed vein as that noted in No. 4A tunnel.

No. 5 tunnel is 120 feet southeast of No. 4A tunnel. It is 50 feet long and does not expose any ore.

No. 6 tunnel is 480 feet south of No. 4A tunnel. It is 240 feet long and crosscuts two quartz veins. The first strikes northwest, is 2 feet wide, and dips northeast. The other is near the face of the tunnel and lies nearly horizontal, dipping into the floor of the tunnel to east and west. Both veins are bed veins.

No. 7 tunnel is 280 feet west of No. 6 tunnel. It is a drift 50 feet long on a quartz vein 1 to 3 feet wide striking northwest and dipping gently northeast.

No. 8 tunnel is 40 feet southwest of No. 7 tunnel and is a drift 60 feet long on a quartz vein striking northwest and dipping southwest. Both the veins in tunnels Nos. 7 and 8 are bed veins and may be parts of a single vein. Ore has been stoped from No. 8 tunnel.

The grade of the ore can be seen from the following tabulated record of ore shipments. It must be borne in mind that the ore that is shipped is first sorted. Some parts of the vein such as bands of solid sulphide locally present on the hanging-wall side of the vein consist of very high-grade silver ore, and if this material can be broken down without too much quartz admixture it is shipped without sorting.

Year	Tons of ore mined	Gold	Silver	Copper	Lead
		Ounces	Ounces	Lbs.	Lbs.
1911	61	7	7,140	....	....
1918	13	3	2,700	....	....
1920	18	4	3,788	....	....
1922	231	22	12,128	404	1,285
1923	141	20	11,107	514	640
1924	232	28	17,501	434	334
1925	156	11	8,086	....	1,170
1926	54	10	5,735	....	528
1927	7	2	720	....	105
Totals	913	107	68,905	1,352	4,062

Good ore was stoped along the axis of the vein anticline in No. 3 tunnel. This ore anticline is somewhat disturbed between tunnels Nos. 3 and 4. Some ore has been mined between these tunnels, but probably good ore still remains. Above the upper stope of No. 3 tunnel the ore anticline has not been explored. This could perhaps be done best from No. 2 tunnel or from the open-cut just below. Search should also be made for the anticline farther up the hill along the strike of its axis. Below No. 4 tunnel perhaps the best place to explore for downward continuation of the ore-body would be by driving northwest from No. 5 tunnel. The rocks from No. 5 tunnel north strike northwest and dip southwest. At No. 6 tunnel, however, although the strike is the same the dip is northeast. A synclinal axis striking northwest passes, therefore, between Nos. 5 and 6 tunnels. The anticlinal ore-body will almost certainly be considerably modified in shape if it continues south to the change in dip of the sediments. For this reason exploration from No. 6 tunnel might not find the ore-body known in the tunnels to the north. The ore-bodies of Nos. 7 and 8 tunnels should be explored further.

Systematic sampling would show whether the vein could be mined as a whole and milled with profit. Even if the vein show a good grade of milling ore, enough ore should be blocked out to make its milling a profitable enterprise before a mill is built.

ALICE GROUP[1]

The Alice group of four mineral claims adjoins the Lone Maid claim on the north. The group is west of Kitsault river about 2 miles from Alice Arm. A trail extends from the Esperanza mine to the Alice group.

The country rock is argillite with bands of argillaceous quartzite striking northwest and dipping southwest at moderate to steep angles. The rocks have been intruded by narrow lamprophyre dykes striking northeast.

The mineral deposit is a quartz vein varying in width from a few inches to 3 feet. It is a bed vein, that is, it lies parallel to the strata, and it has been traced along the surface for 1,500 feet northwestward

[1] Ann. Rept., Minister of Mines, B.C., 1925, p. 74; 1923, p. 56; 1922, p. 56; 1916, p. 62

from the southern boundary of the group. The metallic minerals in the vein are pyrite, sphalerite, and galena. The minerals appear to be contemporaneous in time of deposition.

The vein has been explored by several open-cuts and four short tunnels. The lowest tunnel, a short distance north of the southern boundary of the property, has been driven southwest as a crosscut along a lamprophyre dyke for 30 feet, at which point it encounters the vein. A drift then follows the vein northwest for 55 feet. Above the tunnel an open-cut on the vein discloses high-grade silver ore. The vein in the tunnel, however, is not of commercial grade. About 500 feet northwest two open-cuts expose the vein, which there consists of barren quartz. About 1,000 feet farther northwest are three short tunnels totalling 125 feet in length. They have been driven northwest along the vein. The vein appears to consist of barren quartz. Open-cuts exist farther northwest which may or may not be on the Alice group and expose similar vein matter.

The vein on the Alice group may be the northward extension of the one exposed in No. 1 tunnel Esperanza mine. As it is a bed vein and as it is not covered with much overburden it is easy to trace and expose by open-cuts. In view of the fact that good silver ore occurs in the vein in Esperanza mine and that silver minerals do occur in the vein on the Alice group, the vein should be explored further by means of surface strippings. The surface should be done to search for ore-shoots. If none is found tunnels should not be driven.

LONE MAID CLAIMS[1]

The Lone Maid mineral claim is on the west side of Kitsault river somewhat over a mile from Alice Arm. It adjoins the Esperanza group on the north. The trail to the Alice group crosses the Lone Maid claim.

The country rock on the claim is argillite striking northwest and dipping steeply southwest.

The known mineral deposit on the claim is a quartz-calcite vein. It strikes northeast, dips steeply northwest, is 1 to 5 feet wide, and has been traced for a distance of 75 feet. The sulphide mineralization is meagre in quantity. The sulphides are pyrite, pyrrhotite, chalcopyrite, sphalerite, and galena. A tunnel has been driven 75 feet southwestward along the vein and from a point 55 feet from the portal a crosscut has been driven northwestward for 95 feet along the strike of the country rock. No vein matter exists in the crosscut part of the tunnel.

The vein on the Alice group to the north may be the northward continuation of the vein in the upper tunnel of the Esperanza mine and if so will pass through the Lone Maid claim. In any case the northward continuation of the Esperanza vein should be sought. An attempt should also be made to trace the Lone Maid vein up the hill and down toward Kitsault river. Exploration should consist of surface work until ore is found worthy of underground development. Although no commercial ore is known at present on the Lone Maid claim, thorough prospecting is recommended.

[1] Ann. Rept., Minister of Mines, B.C., 1923, p. 56; 1922, p. 56; 1916, p. 62.

LA ROSE MINE[1]

The La Rose mine is on the eastern slope of Haystack mountain west of Kitsault river, and about 8 miles from Alice Arm. The mine workings are about 1,800 feet above the Dolly Varden railway and can be reached from the railway by means of a good horse trail.

The property was worked in a small way by its prospector owners, who made small shipments of ore in 1918 and 1919. In 1920 the Alice Arm La Rose Mining Company, Limited, was formed to operate the mine, and commenced active development in 1925. Ore was shipped in 1926 and 1927, but the property was again idle in 1928.

The country rock consists of argillite and tuffaceous sandstone cut by lamprophyre dykes which also cut the ore deposits. The sediments strike northwest and dip northeast.

The ore deposit is a vein occupying a narrow shear zone striking north and dipping steeply east. The surface expression of the shear zone is a well-marked bench or shallow gully along the hillside. The gully, however, contains deep drift, so the vein is difficult to trace. The vein has been opened up by a crosscut tunnel which cuts it 160 feet below the outcrop, by drifts from the tunnel, and by a raise that follows the vein from the tunnel to the surface. The vein has not been traced beyond the limits of the underground workings. It is a few inches to 3 feet wide and consists of quartz and the metallic minerals arsenopyrite, pyrite, chalcopyrite, pyrrhotite, sphalerite, galena, tetrahedrite, native silver, and probably silver sulphides. The shoots of ore so far discovered are small. Other veins are known, but were not examined by the writer.

The following is a list of the ore shipments from the La Rose mine .

Year	Tons of ore	Gold	Silver	Lead
		Ounces	Ounces	Lbs.
1918	11	1	1,543	....
1919	22	3	6,157	....
1926	42	10	7,111	2,348
1927	4	1	768	340
Totals	79	15	15,579	2,688

The ore-bearing vein should be traced as cheaply as possible, in order to prospect the vein and to locate and outline ore-shoots. Unless this prospecting discovers ore likely to be of a persistent nature no elaborate scheme of underground work should be started, but the ore found should be extracted as cheaply as possible.

SILVER CHORD GROUP[2]

The Silver Chord group of four mineral claims is at the north end of McGrath mountain, on Northeast Fork Kitsault river about 7 miles from Alice Arm. The cabins and underground workings are about 1,200 feet above sea-level and about 200 feet above the main Northeast Fork trail.

[1] Ann. Rept., Minister of Mines, B.C., 1926, p. 79; 1925, pp. 74, 75; 1923, p. 57; 1919, pp. 50, 51; 1918, pp. 56, 57; 1916, p. 63.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1922, pt. A, p. 46.
[2] Ann. Rept., Minister of Mines, B.C., 1927, pp. 73, 74; 1926, pp. 29-81.

The group is controlled by Kitsault Eagle Mining Company, Limited, which company under the management of Mr. McMorris has done all of the mining development on the property.

The country rock consists of argillite and argillaceous quartzite striking north. The rocks are probably folded into open anticlines and synclines. Narrow lamprophyre dykes cut the sediments.

The known mineral deposits on the group are two sphalerite-bearing quartz veins striking north and dipping steeply.

One of these a short distance above the cabins strikes north and is approximately vertical. The short tunnel driven on the vein shows that the width is variable and the sulphide mineralization is extremely sporadic. One small body of sphalerite ore about 3 feet wide was exposed where the vein outcropped. This shoot proved to be 10 feet long. The tunnel in only 50 feet long, but does not expose any more sphalerite mineralization in the vein. The quartz vein varies from a few inches to several feet in width and may have been formed by replacement.

Another vein striking north and dipping steeply west is exposed a few hundred feet west of the one above the cabins. This vein is at least 500 feet long. It consists of quartz-calcite gashes and stringers, making a total width of 1 to 25 feet. A narrow minette (lamprophyre) dyke accompanies the vein either lying within it or along one or the other wall. Where the vein is widest it consists in general of about 20 per cent vein matter and 80 per cent rock. Where it is only a few feet wide it may be mainly vein matter. Pyrite, galena, and sphalerite are present in slight amount. The vein has been deposited along a shear zone which, where widest, was penetrated by vein stringers and, where narrowest, was filled usually by a single vein. The age relationship between the dyke and the vein is not known. Later than both dyke and vein is parallel shearing intense enough to change locally the argillaceous wall-rock into graphite schist, and to alter locally the dyke beyond easy recognition.

The vein above the cabins has been explored by a tunnel 50 feet long. The other vein has been developed by two tunnels one 100 feet above the other. Both tunnels have been driven south along the vein. The lower tunnel is 480 feet long and has short crosscuts totalling about 200 feet. The upper tunnel 140 feet farther south is 220 feet long.

The vein appears to be very low grade and underground work should not be continued unless sampling proves the presence of commercial ore.

BILLY MAC GROUP [1]

The Billy Mac group of six mineral claims is at an elevation of 2,200 feet on the southern slope of McGrath mountain. The group adjoins the Standard group on the south and the Highland group on the east. The main McGrath Mountain trail crosses the property.

The country rock consists of argillaceous and calcareous sediments striking north.

Sphalerite associated with quartz and calcite is exposed in a dozen open-cuts and short tunnels, but so far the separate showings have not been linked into definite veins or zones of known size, shape, or attitude. One body only is known to be tabular and has been traced for 200 feet. It strikes northeast and dips southeast about 30 degrees. It is 20 feet thick

[1] Ann. Rept., Minister of Mines, B.C., 1927, p. 73.

and may be the result of replacement in a crushed zone or along a particular stratum. The lower 5 feet of the body consists of quartz well mineralized with sphalerite. The upper part of the body is largely calcite and contains many inclusions of country rock.

About 300 feet northeast of this deposit are two other exposures of vein matter. They are on opposite sides of a creek and may be parts of a mineral body lying nearly horizontal. The mineralization consists of quartz, calcite, and sphalerite. About 200 feet northwest of these showings are five open-cuts exposing quartz and calcite mineralized with sphalerite. The shape and attitude of these deposits could not be made out. About 150 feet northwest of the vein-like body is a line of open-cuts trending northeast. These cuts may be along a single mineral body. Individual showings in these open-cuts are up to 8 feet wide and consist of quartz, calcite, sphalerite, and country rock inclusions.

The mineral bodies are not well enough exposed to show their mode of origin. They may have been formed along particular beds, or along fracture zones. They have been formed chiefly by replacement.

Sphalerite is the only known mineral of possible commercial importance on the property. No ore is known nor is likely to be discovered of other than milling grade. Because of this large ore-bodies must be exposed before mining can begin. Attention should be directed, therefore, to tracing the better mineral bodies so that there will be no doubt of their continuity and attitude. When this is done, if the showings then exposed warrant further work such work can be planned intelligently.

HIGHLAND GROUP [1]

The Highland group of six mineral claims is on the southern slope of McGrath mountain. The group adjoins the Billy Mac group on the west.

At least two roughly parallel mineral zones are known on the property in a country rock of argillite. One strikes northeast and has been traced imperfectly by five open-cuts for a distance of 400 feet. It is a sheared and shattered zone 20 feet wide in some places, containing irregular bodies of quartz, calcite, and sphalerite. The best vein matter consists of rock fragments cemented by quartz, calcite, and sphalerite.

About 300 feet northwest is another parallel mineral deposit. This deposit lies in a clearly defined fault zone. The mineral deposit occurs as lenticular and irregular bodies within the fault zone. The bodies contain quartz, calcite, sphalerite, and a little pyrite and galena. This mineral zone is in a steep-walled canyon and is difficult to examine.

Because only low-grade ore is likely to be found in these mineral zones prospecting should be confined to the tracing out of deposits to show their size and attitude. Sampling should then be done to decide whether the bodies there outlined merit development on a scale adequate for milling operations.

SUNRISE GROUP [2]

The Sunrise group of eight claims occupies part of the southern slope and part of the flat top of McGrath mountain. The McGrath Mountain trail formerly ended at the Standard group which adjoins the Sunrise group on the south, but was extended in 1928 to the Sunrise group.

[1] Ann. Rept., Minister of Mines, B.C., 1927, pp. 72, 73.
[2] Ann. Rept., Minister of Mines, B.C., 1927, pp. 71, 72; 1926, p. 78; 1923, p. 61; 1918, pp. 68, 69.

The Sunrise group of claims includes the former Silver Band group of four mineral claims and four additional mineral claims. The regrouping under the name Sunrise group took place in 1926. The property is part of the holdings of the Kitsault Eagle Mining Company, Limited, and development has been done under the management of Mr. McMorris.

The country rock consists of argillite and associated coarser-grained sediments striking north. Several narrow lamprophyre dykes occur and one large dyke or elongated stock of augite porphyrite. The mineral deposits occur in the argillite in fractured and brecciated zones and also as clear-cut veins.

Many open-cuts have been made on the mineral showings, but the development, although it exposes many mineral deposits, fails to prove any connexion or continuity between the scattered showings. The veins strike north and have steep dips. They are 1 to 6 feet wide and contain quartz with some calcite and sphalerite. Wider deposits up to 20 feet wide, formed probably in brecciated zones, consist of quartz, calcite, and sphalerite, and fragments of country rock. One of these bodies appears to be flat-lying, another appears to dip north about 30 degrees. It is likely that faults with small throw are numerous and that this is one reason why correlation of the mineral showings is difficult. The material exposed in some of the open-cuts would be good zinc ore if present in sufficient quantity.

The owners believe that the larger mineral showings are two roughly parallel deposits striking north about 800 feet apart and that the more easterly one is joined at right angles by a cross or branch vein. The writer does not believe that this condition is proved and would suggest that enough surface work be done to prove the attitude of the deposits before elaborate underground development is begun. Because the deposits are large and well mineralized they warrant extensive development.

CHANCE GROUP [1]

The Chance group of six mineral claims is north of Trout creek which flows into Kitsault river 19 miles from Alice Arm. The Trout Creek trail, which branches off the main Kitsault trail at the mouth of Trout creek, passes by the Chance cabins.

The property has been held for over ten years and prior to 1923 was known as the Last Chance group and consisted then of four mineral claims. It was bonded in 1919 by H. B. Price who did some diamond drilling. Clothier reports that the horizontal drill holes were encouraging, but that the down-holes to prove the ore-body at depth failed to locate it.[2] The diamond drilling was all done from a single station. Since 1921 the owner has been working intermittently on a crosscut tunnel.

Several mineral showings exist on the property, but only the principal ones were visited. These are two parallel brecciated zones mineralized with copper, lead, and silver minerals. The two deposits are about 100 feet apart. They strike north 75 degrees east and are approximately vertical. They are exposed in four open-cuts and if they extend between the end open-cuts they are at least 700 feet long. The length is, however, not proved. The more northerly deposit is 18 feet wide in one open-cut and the other one is about 12 feet wide.

[1] Ann. Rept., Minister of Mines, B.C., 1923, p. 59; 1922, p. 61; 1921, p. 51; 1920, p. 49; 1919, p. 56; 1918, p. 62. Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 19.
[2] Ann. Rept., Minister of Mines, B.C., 1923, p. 59.

The deposits consist of brecciated volcanic rock cemented and replaced by quartz, jasper, barite, calcite, pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite. Oxidation has resulted in thin crusts of azurite and slight accumulation of black, crumbly material resembling manganese oxides. The more northerly deposit where 18 feet wide contains much tetrahedrite and picked specimens assay well in silver. The more southerly deposit does not appear to be so well mineralized as the other one, but picked samples return high silver assays.

The deposits were apparently formed by replacement and filling along brecciated zones. The width of the deposits is likely to be variable, but the length should be ample for ordinary mining operations. One open-cut exposes a width of 18 feet of ore and the ore-shoot here indicated merits a good deal of development. In reaching for other shoots open-cuts should be placed rather close together, as ore-shoots may be short and might otherwise be missed. Because of the possibility of developing a considerable quantity of commercial ore this property is worthy of careful attention by mining companies.

CLIMAX GROUP[1]

The Climax group of two mineral claims is on the north side of Trout creek adjoining the Moose and Silver Horde groups of claims. The workings are about half a mile from Kitsault river and 19 miles from Alice Arm. A branch of the main Trout Creek trail gives access to the property.

The mineral deposit is a siliceous body 20 to 30 feet wide in fine-grained volcanic rocks. It has been formed apparently by replacement and filling along a crushed and brecciated zone. Where it is exposed in a tunnel about 80 feet long it is 24 feet wide, strikes south 70 degrees east, and is vertical. Clothier states that this deposit is the eastward continuation of the one present on the Moose group of claims.[2]

The deposit consists chiefly of quartz and silicified country rock, but contains also some calcite, jasper, and barite and is mineralized with pyrite, marcasite, sphalerite, galena, and tetrahedrite. The sulphides are not plentiful and the whole deposit seems rather low grade. Narrow bands of galena containing tetrahedrite and good values in silver occur locally in the deposit. A peculiarity in the mineralization is the presence of rounded pellets of marcasite.

The deposit has not been opened up to any conclusive extent and because of its size and mineralization warrants further development.

SILVER HORDE GROUP[3]

The Silver Horde group of four mineral claims is on Trout creek and adjoins the Wolf group on the north. The claims are on the east side of Kitsault river 19 miles from Alice Arm and are reached by means of the Trout Creek trail.

The early work done on the property consisted of surface trenching which was done in an attempt to find the northward extension of deposits known on the Wolf group. One or more of the early discovered mineral showings were explored by diamond drill by the Granby Consolidated

[1] Ann. Rept., Minister of Mines, B.C., 1926, p. 83; 1925, p. 76; 1923, p. 60; 1922, pp. 60, 61; 1919, p. 55; 1918, p. 61.
[2] Ann. Rept., Minister of Mines, B.C., 1922, pp. 60, 61.
[3] Ann. Rept., Minister of Mines, B.C., 1926, p. 84; 1924, p. 55; 1922, p. 60; 1918, p. 61; 1916, p. 79.

Mining, Smelting, and Power Company in 1917. The results of the drilling were not published, but apparently they were unsatisfactory. Later work has been done on other mineral deposits on the group.

Only one mineral deposit in the group was visited by the writer. It occurs in a country rock of fine-grained tuffs and was formed probably by filling and replacement in a brecciated zone. It is 2 to 10 feet wide and has been traced for 100 feet. It strikes northeast and dips 70 degrees southeast. It consists of quartz and country rock and the metallic minerals pyrite, marcasite, and galena. A fault is the boundary at the lower end of the deposit and this fault was encountered in a tunnel below, but the mineral deposit beyond the fault was not located underground.

The property warrants further surface development.

TORIC MINE[1]

The Toric mine is on the east bank of Kitsault River canyon, about 17 miles from Alice Arm. Access to the mine is furnished by the Dolly Varden railway which extends from Alice Arm to Camp 8, and from this point by a skid road which extends to the mine.

The Toric group of four mineral claims was explored by prospect owners for many years, and they demonstrated the presence of a fairly large low-grade mineral deposit containing shoots of high-grade silver ore. In 1924 the property was taken under option by the Consolidated Homestake Mining and Development Company, Limited, who commenced a more ambitious program of underground development. The name of the company was changed in 1927 to Toric Mines, Limited. The company development has been done under the management of A. C. H. Gerhardi. The company completed construction in 1928 of a mill capable of milling 50 tons of ore per day. Operation of the mill began in the late summer of 1928.

The country rock in the vicinity of the mine consists of massive breccias and lava flows.

The mineral deposit is exposed best in the tunnel driven by the Toric Mines, Limited. This tunnel is 1,100 feet long, including all crosscuts and drifts, and proves a deposit 280 feet long and 80 to 120 feet wide at this level. No underground development has been done above or below this tunnel. The surface mineral showings are not well exposed, as a good deal of surface drift is present. The surface showings, however, exhibit only moderate sized deposits less than 20 feet wide. On the surface the strike appears to be south 70 degrees east and the dip about 50 degrees north. In the tunnel about 150 feet below the outcrop the deposit strikes east and both walls dip 45 degrees north. The deposit as exhibited in the tunnel contains several large horses of country rock and it is possible that the so-called walls of the surface showings are merely horses of rock and that the deposit is wide at the surface also. In one or two places in the tunnel about midway between the hanging-wall and the foot-wall of the deposit, contacts between the deposit and horses of country rock suggest that in these places the deposit lies in a horizontal attitude. If the deposit is of the shape suggested, dipping 45 degrees at both walls and

[1] Ann. Rept., Minister of Mines, B.C., 1927, pp. 75, 76; 1926, p. 84; 1925, pp. 76-78; 1924, p. 55; 1923, p. 60; 1922, pp. 59, 60; 1921, pp. 53, 54; 1919, p. 54; 1918, p. 58; 1916, pp. 78, 79.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 15.

horizontal in the central part, its thickness is much less and is not related to the width indicated in the tunnel. Small faults are present and offset the deposit slightly, but they have probably not had any influence in making the deposit appear to be wider than it actually is. If further work is done on the surface it will probably disclose wider deposits than were indicated in the old surface open-cuts.

The deposit in the tunnel is typically a coarse-grained mixture, perhaps intergrowth of barite, jasper, hematite, quartz, and ankerite. This material holds fragments of country rock and contains a small amount of pyrite and galena. At least one shoot of high-grade silver ore is known in the deposit. It occurs near the hanging-wall side of the deposit and consists of quartz mineralized with pyrite, galena, native silver, and perhaps other silver-bearing minerals.

The surface mineral deposit is similar to that in the tunnel, except that it appears to contain more hematite. The surface showings have been described rather fully by Clothier.[1]

The deposit has been formed apparently by filling and replacement in a brecciated zone. The structure of the enclosing rocks is not evident, but the deposit may be parallel to the beds of volcanic rock. The native silver seen on the surface and in the tunnel occurs as flakes which are simply a filling in small cracks, and appears to be of secondary origin. Judging from the depth to which native silver extended at the Dolly Varden mine in the same district, it can not be expected to extend much more than 200 feet below the outcrops at the Toric mine.

The mineral deposit at the Toric mine is quite large and if the deposit is rich enough to be mined as a whole, the mine should operate for many years.

MUSKATEER GROUP[2]

The Muskateer group of five mineral claims is on the eastern bank of Kitsault river about three-quarters of a mile north of the Toric and about 20 miles from Alice Arm. The Kitsault River trail passes just below the cabins and workings.

Two mineral deposits are present on the property both in massive volcanic rocks. The main deposit is exposed in open-cuts and a tunnel. It is 15 feet or more wide and has been traced for a distance of 250 feet. The deposit is vertical and it strikes south 60 degrees east. It consists of quartz, barite, jasper, pyrite, sphalerite, chalcopyrite, and galena, and in general appearance closely resembles the Toric deposit. In the tunnel the wall-rock is slightly mineralized with sulphides and contains jasper, quartz, and barite, as far as 25 feet from the wall of the mineral deposit. The deposit is locally well mineralized with galena and the shoots thus indicated if of a moderate size would constitute good milling ore. At one place on the surface a specimen was obtained that contained numerous rock fragments and one fragment of pyrite-galena ore, the whole being cemented with nicely crystallized quartz. This may be due to local surface brecciation and does not necessarily indicate a general post-ore movement.

[1] Ann. Rept., Minister of Mines, B.C., 1925, pp. 76-78.
[2] Ann. Rept., Minister of Mines, B.C., 1922, p. 60; 1920, pp. 47, 48; 1919, p. 55; 1918, p. 60; 1916, p. 79. Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 18.

The other deposit imperfectly traced by open-cuts appears to strike north. The most northerly open-cut is about 200 feet south of the deposit just described. The two deposits are very similar in mineralization.

Both deposits were apparently formed by filling and replacement in a brecciated zone. Although the deposits are low grade they are worthy of further development work.

BASIN GROUP[1]

The Basin group of six mineral claims is on the grassy upland slopes at timber-line on the divide between Goat and East creeks. Both creeks enter Kitsault river from the east, Goat creek at Camp 8, 16 miles from Alice Arm, and East creek at a point 11 miles from Alice Arm. The property can be reached by means of a horse trail which ascends East creek or by a foot trail up Goat creek. There is no bridge across Kitsault river at East creek so horses must ford the stream. A cable ferry suitable for pedestrians has been constructed across Kitsault river 10 miles from Alice Arm, and a good bridge has been built at Camp 8.

The country rock consists of argillaceous sediments and volcanic breccias.

Several mineral deposits exist on the property. One deposit, consisting of quartz, pyrite, chalcopyrite, tetrahedrite, and sheared rock, is up to 20 feet wide and appears to be hundreds of feet long. The deposit strikes northeast. It is probably a replacement along a sheared zone. Another deposit is a clean-cut quartz-calcite vein 15 feet or more wide and probably more than half a mile long. This vein is apparently barren. Another deposit is in a flat-lying shear zone and consists of quartz, pyrite, arsenopyrite, chalcopyrite, and tetrahedrite. The exposed ore-shoot in this case is very small, being only 1 foot wide and 15 feet long, but it consists of very high-grade silver ore.

The property is on the outskirts of the district and has because of this received very little attention. The deposits, particularly the large shear zone deposit, should be explored farther by open-cuts. If such development exposes silver ore, even though present only in small shoots, the deposit should be rather thoroughly explored.

TIGER GROUP[2]

The Tiger group of three mineral claims is located a short distance above the Toric mine. The workings and camp buildings are about a quarter of a mile east of Kitsault river 17 miles from Alice Arm. Although this property is so close to Kitsault river and although it has been under active development for a long time only a foot-trail connects it with Kitsault River trail.

The property was staked in 1916 and consisted then of two claims. In the next two years it was explored rather thoroughly by means of open-cuts. The property was bonded in 1919 by H. B. Price who drove a tunnel and did some diamond drilling, but relinquished his option. In 1926 a

[1] Ann. Rept., Minister of Mines, B.C., 1924, p. 54.
[2] Ann. Rept., Minister of Mines, B.C., 1927, p. 76; 1926, p. 84; 1922, p. 60; 1919, pp. 54, 55; 1918, pp. 59, 60; 1916, p. 80.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 18.

fractional claim was added to the group and in later years a lower tunnel has been driven and a third tunnel commenced.

The country rock consists of hard, dense, volcanic tuffs cut by several narrow lamprophyre dykes.

The mineral deposit is a quartz vein 4 to 18 feet wide which has been traced on the surface for 300 feet. The vein strikes north 30 degrees east and dips steeply northwest. As the hillside slopes southwestward the vein outcrop inclines up hill from south to north. A transverse fault 60 feet from the north end of the vein offsets the vein 30 feet. Another parallel fault 20 feet farther north has apparently offset the vein 40 feet.

The vein contains calcite as well as quartz and is mineralized with pyrite, sphalerite, galena, ruby silver, and native silver. Locally the vein contains good silver ore and the surface exposures of the northern part of the vein are probably of milling grade. The southern part of the vein is not well exposed on the surface, but a crosscut tunnel at this part of the vein exposes 6 feet of vein matter containing pyrite, sphalerite, galena, ruby silver, and native silver. Ruby silver and native silver occur in the top tunnel 130 feet below the surface and in No. 2 tunnel about 80 feet below the surface. These minerals are also present at the surface.

The surface open-cuts show the width, length, and strike of the vein. The diamond drilling was done from points downhill from the vein and the holes were pointed southeast at right angles to the vein. Eight or nine drill holes approximately parallel in direction explore a length of about 300 feet along the strike of the vein. The upper tunnel was driven south-eastward under the faulted part of the vein. The face of the tunnel is about 150 feet below the outcrop. The next or No. 2 tunnel is 115 feet lower and about 300 feet southwest of the upper one. It has been driven east for 96 feet. A third or No. 3 tunnel has been commenced about 150 feet below and 175 feet southwest of No. 2 tunnel.

It is highly desirable that development be continued on the Tiger group as there seems to be a good chance of proving sufficient tonnage for profitable milling.

WOLF GROUP[1]

The Wolf group of four mineral claims is east of Kitsault river just south of Trout creek. The distance from Alice Arm is about 19 miles. Kitsault River trail crosses the claims.

The group of claims was staked in 1916 and was sold to the Dolly Varden Mining Company the same year. This company immediately commenced active development of the known mineral deposits and by means of many open-cuts, 5,000 feet of diamond drilling and 80 feet of tunnelling proved mineral deposits of considerable size. The property has not been under development since 1916. In 1919 the properties of the Dolly Varden Mining Company were taken over by the Taylor Engineering Company. In 1922 the mine holdings of the Taylor Engineering Company were acquired by George Wingfield through mortgage foreclosure. Mr. Wingfield and other creditors incorporated the Northern Mining Properties, Limited, to take over the mining properties acquired.

[1]Ann. Rept., Minister of Mines, B.C., 1920, p. 48; 1919, p. 55; 1918, pp. 57, 61; 1916, p. 77.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 18.

Four mineral deposits are known on the property in a country rock of tuffs and breccias. The hillside slopes westward at a fairly steep angle and as the deposits strike roughly northeast the outcrops incline uphill from southwest to northeast. The deposits are large quartz veins varying from 4 to 50 feet in width.

No. 1 vein has been explored by seven open-cuts, a short tunnel, and seventeen diamond drill holes. It strikes north 70 degrees east and dips steeply north. It is 10 to 50 feet wide and has been traced for a distance of 400 feet between the elevations of 1,450 and 1,775 feet. The vein consists of quartz containing a good deal of pyrite and some galena and sphalerite.

No. 2 vein is 250 feet west of No. 1 vein. It is 25 feet or less in width and strikes north 20 degrees east. It has been traced for 260 feet between the elevations 1,240 and 1,340 feet by means of five open-cuts. Four diamond drill holes have been drilled to test this vein. The vein matter seems a little lower grade than that in No. 1 vein and it also contains spherules of marcasite. The most southerly exposure of No. 3 vein is 500 feet north of the west end of No. 1 vein. The vein is 20 feet or less wide and has been traced for 300 feet between the elevations of 1,510 and 1,710 feet. It has been developed by eight open-cuts and thirteen diamond drill holes. The vein matter is very similar to that of No. 1 vein, but on the whole appears to be of lower grade. The vein strikes north 20 degrees east and is in line with No. 2 vein. No. 2 and No. 3 veins may be parts of a single vein with an unexplored gap 300 feet long in the middle.

No. 4 vein is parallel to No. 3 vein and lies 150 feet west of it. It has been traced for 150 feet by means of five open-cuts. The vein is 15 feet or less in width and is similar in general character to No. 3 vein except that it contains occasional blades of barite.

The veins were apparently formed by filling and replacement along fracture zones.

The records obtained during the development of the Wolf property should show conclusively whether or not the deposits could be mined with profit. This property has outstanding potential merit.

VANGUARD GROUP[1]

The Vanguard group of four mineral claims is 3,000 feet above sea-level in the area between Kitsault river and West Fork Kitsault river. The property is 22 miles from Alice Arm. A good horse trail branches off Kitsault River trail and crosses the Vanguard claims.

The country rock is dark grey, volcanic tuff and breccia. The contact with a formation of argillite lies a few hundred feet northeast of the mineral showings.

Several mineral deposits are known on the Vanguard group, all containing copper minerals and holding as well values in gold and silver. The chief mineral deposit in the group is approximately parallel to the contact between the volcanic and sedimentary rocks. It is 15 feet or less in width and has been traced on the surface for 750 feet. The deposit strikes north 60 degrees west and dips steeply southwest. The outcrop

[1] Ann. Rept., Minister of Mines, B.C., 1927, p. 77; 1926, pp. 82, 83; 1923, p. 57; 1922, p. 57; 1919, p. 56; 1918, pp. 65, 66; 1916, p. 83.
Hanson, George: Geol. Surv., Canada, Sum. Rept. 1921, pt. A, p. 20.

inclines uphill from southeast to northwest and its upper exposed end is 275 feet above the lower end. The deposit is well mineralized with pyrite and chalcopyrite. Quartz, calcite, and barite are present, but the gangue material is probably chiefly country rock. On the whole the deposit is vein-like, but locally it consists of country rock containing many narrow stringers of chalcopyrite with heterogeneous strikes and dips.

A good shoot of ore is exposed on the surface about midway between the top and bottom open-cuts. It is 3 to 12 feet wide and 200 feet or more in length.

Two crosscut tunnels have been driven under this deposit. The deposit was encountered about 50 feet below the surface in the upper tunnel and was drifted on for 50 feet. Good chalcopyrite ore occurs only at the end of the drift and as this is some distance northwest of the lower end of the ore-shoot on the surface it would suggest that the ore-shoot plunges northwestward. The deposit was encountered 185 feet below the surface in the lower tunnel and was followed northwest by a drift 85 feet long. The end of the drift is 225 feet below the surface. In this tunnel the ore-body is locally 15 feet wide and contains several bands up to 2 feet wide of good copper ore.

The rocks in the lower tunnel are distinctly sheared and the shearing is parallel to the ore-body. Several ribs of quartz lying parallel with the shearing occur in the crosscut part of the tunnel and suggest that mineral deposits may exist there parallel to the one under development.

Several hundred feet south of the chief mineral deposit two open-cuts expose chalcopyrite, but the strike and dip of the deposit are not indicated. About 150 feet below these cuts and 300 feet east another open-cut exposes a chalcopyrite deposit of unknown strike. A tunnel driven below this open-cut encounters a pyrite-chalcopyrite deposit, of unknown strike.

The width and strike of the mineral deposits south of the main deposit should be proved in the cheapest way possible, so that future underground work can be done to the best advantage. The mineral deposits on the Vanguard group warrant a good deal of development and are recommended to the attention of mining companies.

TOPLEY MAP-AREA, BRITISH COLUMBIA

By George Hanson and T. C. Phemister

CONTENTS

Illustration

INTRODUCTION

The village of Topley is on the Canadian National railway, 285 miles west of Prince George and midway between Prince George and Prince Rupert. The area with which this report is immediately concerned stretches from Topley on the south, northwards about 12 miles; the width of the map-area is also 12 miles. The area was mapped geologically during the summer of 1928 with the aid of the topographic survey made during the previous year by Mr. MacDonald. During the work valuable assistance was rendered by Mr. A. E. Goranson and Mr. N. Freshwater.

The district has been the scene of considerable prospecting for some time past. Since the discovery of the Topley Richfield property by Mr. Taylor, in June 1926, this activity has grown until at the present time there is little unstaked ground in the neighbourhood. The only other prospect comparable in size and development with Topley Richfield group is the one about one mile to the southwest known as the Golden Eagle group. These two prospects are about 8 miles north of Topley and can easily be reached by road from that village.

The area is easy of access, the Canadian National railway and the highway from Hazelton to Prince George running along its southern boundary. From Topley a wagon road runs northwards through the area and continues to Babine lake. The northern section is in very poor condition, but the southerly part as far north as the branch road to the Topley-Richfield mine has been widened and greatly improved. The country is well provided with trails over most of which pack horses can be taken.

The only previous geological studies carried out in this district are those by Mr. D. Lay, published in the Annual Reports of the Minister of Mines, British Columbia. His detailed descriptions were of great assistance to the writers in the field. A careful study of the rocks met at the Topley Richfield mine was made also by Professor J. Turnbull of the University of British Columbia.

The writers' thanks are due to Mr. F. H. Taylor, general manager of the Topley Richfield Mining Company, for many courtesies, and to the prospectors in the field during the season, for the unselfish manner in which they gave of their experience and assistance.

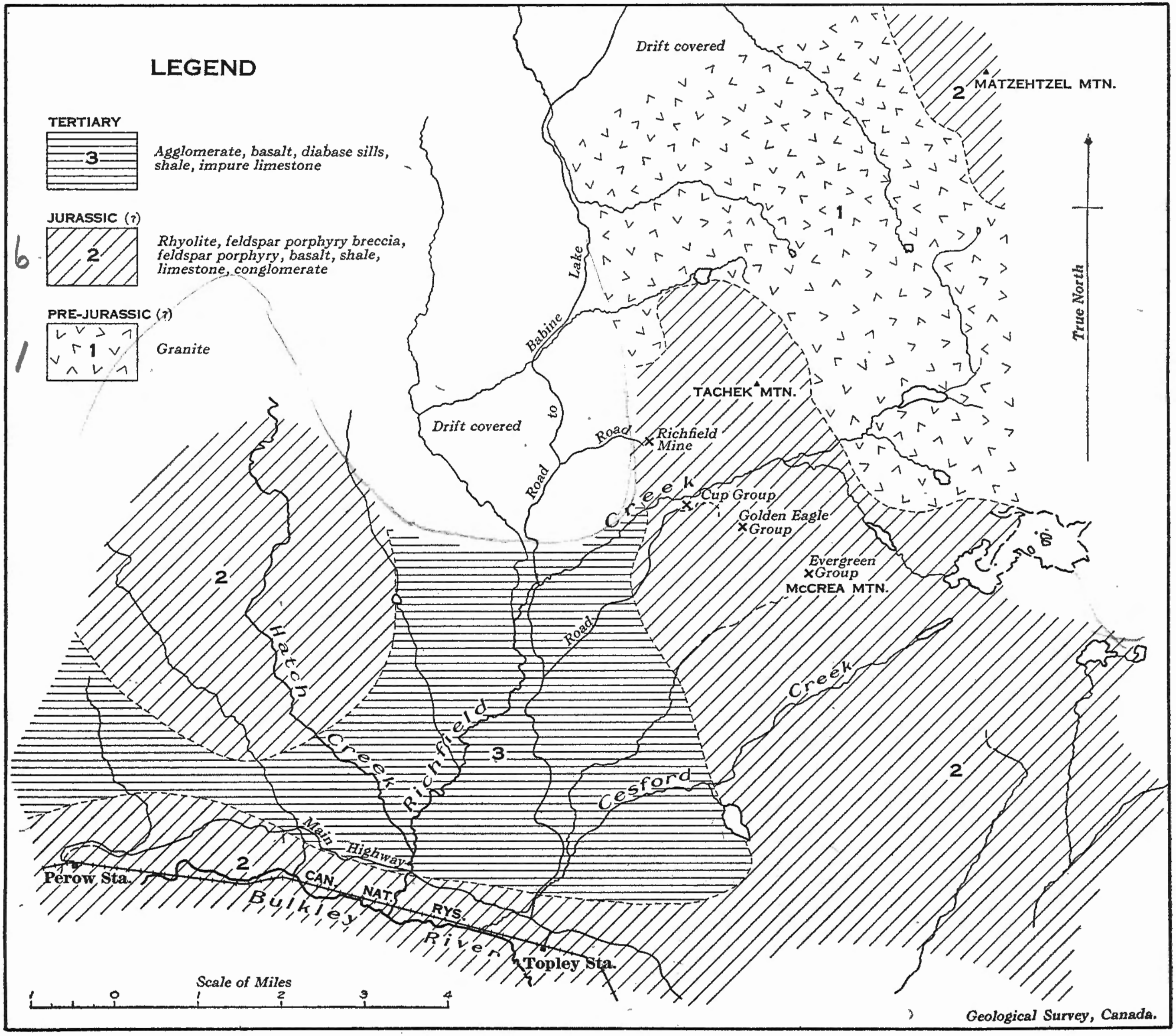

Figure 4. Topley area, Coast district, B.C.

PHYSICAL FEATURES

Topley area lies just to the west of Nechako plateau. The map-area may be divided into three topographic divisions: (1) Bulkley valley; (2) a broad valley running northwards towards Babine lake; and (3) the mountainous country to the east. Of these three divisions the first is the least conspicuous. Bulkley river here is not far from its source and, therefore, has not developed a valley at all comparable in width with that farther northwest. Prior to the location of the river in its present course there was formed a considerable thickness of sand, gravel, clay, and silt in a valley bounded by the high ground just to the south of Topley and by Tachick[1] and McCrea mountains to the northeast. In the drift sections exposed, boulder clay occurs with sands, gravels, and silts. The gravels above the boulder clay were, in many cases, derived from the latter. The boulder clay beds occur at various horizons in any one section and throughout the valley irregular patches of boulder clay pass into gravel and sand beds. Small glaciers, therefore, must have been present in the valley and before their final disappearance they probably advanced and retreated locally more than once, leaving behind them the beds of boulder clay now found at different horizons in the drift. The glacial agency, however, though important, has not been the most important factor in the formation of these drift deposits which, on the whole, consist dominantly of coarse gravels and sands. In places these show distinct bedding, but the bedded materials in many cases grade into very coarse, bouldery material lacking any signs of bedding, occurring in lens-shaped patches which pass into finer gravel and into sand beds. Examples of such relations can be seen in the cuttings in the main road, both east and west of Topley. It appears, therefore, that these deposits were formed, on the whole, by rapid, perhaps torrential streams coming from the high ground and depositing their sediment in a series of fans spread over the floor of the valley. If this were the case, there probably would be local quieter pools in which the finer sediment would settle, giving silt and clay beds. Such quiet waters would likely be only temporary and in the lowest part of the valley. This was probably a little north of the present river and there are found the largest developments of silt and clay beds. The best examples are: (1) about half a mile southeast of Topley, where an arm of the Bulkley has cut through banded silts and clays which form a steep bank about 50 feet high; and (2) on the main road about a quarter of a mile east of the bridge over Johnny David creek, where the road runs through banded, whitish silts which in dry weather give rise to a very fine white dust. Some silts and clays occur elsewhere, but nowhere occupy areas as large as those mentioned.

After the filling of this valley, the streams from the hills ran in shallow troughs in the drift and these troughs are still to be seen along most of the present creeks. The best examples are along Byman and Ailport creeks at the western and eastern edges of the area respectively. There, stretching on either side of the gorges of the present creeks, are broad, shallow valleys cut below a terrace-level that seems to mark the old top of the sediments. This terrace-level is about 2,800 feet, rising a little towards the hills. The same phenomenon can be seen along Richfield creek, although there it is not so well marked. Looking down the canyon

[1]Tachek on Figure 4.

of Richfield creek one can distinguish at the top of the canyon proper a gentle slope up to the general level of the terrace-level. If the profile of this slope be completed, one realizes that here also a broad, shallow valley existed prior to the formation of the present stream bed. We can, therefore, picture Bulkley valley at this stage as a broad valley filled with sediments, with a flat surface sloping gradually up towards the high lands to the northeast. Shallowly scooped into this surface were creeks probably sluggish and probably draining westwards along the axis of the valley. Following this stage, the streams were given great erosive power which resulted in their cutting down into the mantle of drift and, on the sides of the old valley, through that mantle into the solid rocks beneath. Owing to their greatly enhanced erosive power they were able to cut deeply into the solid rock, making narrow, steep-sided gorges of which Richfield Creek canyon is the best example. The increased westerly drainage gave the present Bulkley River valley. The river runs close to the southern side of the old valley and has formed its trough between the high ground southwards and the main mass of sediment to the north, so that some rock is exposed on its southern bank. The depth to which it cut into the sediment of the old valley is indicated by the high bluff on its southern bank just east of Perow station. Here a section of 80 to 90 feet of sand, gravel, and clay rises very steeply from the river. This thickness seems to be nearly the total thickness of the sediments at this point, for both to the west and east there are small exposures of rock in the stream bed.

In the case of Richfield creek, a tributary flowing from the north, the stream has cut a canyon through Tertiary volcanic rocks and has done so by pot-hole erosion. In the deepest part of the canyon there are some splendid examples of this process, the walls of the gorge in many cases sloping upwards and inwards from some large pot-holes now broken through. At the falls the water rushes down from one pot-hole to another. Higher up the stream where it has cut into the well-jointed Jurassic rocks, pot-hole action has been less and erosion has been determined more by joints, the steep walls of the creek in some cases being simply joint-planes from which the rock has slipped off in great blocks now lying in the bed of the creek. In the case of Ailport creek, another tributary from the north, no pot-holes developed. The creek runs along the eastern contact of a dyke. The rock on the eastern side of the dyke has been greatly shattered and it is in this material that the stream has cut its course.

The broad valley running northwards to Babine lake is one of the most important physiographic features of the area, but unfortunately little data can be acquired as to the character of the deposits forming its floor, since practically all of the valley is covered with vegetation. The only exposures found were in the banks of Hatch creek about 2 miles from the source of that stream, and if any conclusion may be drawn from this occurrence it would be that the floor of the valley consists of rock covered only by a thin layer of sediment. No sections of drift were found, but the occurrence of ridges of gravel and boulders was noted.

In the mountainous eastern country of the map-area there are two mountain ridges. These have the forms of roughly parallel arcs, convex towards the southwest. The more northerly and higher of the ridges contains Matzehtzel mountain (5,700 feet). Only part of this ridge comes into the map-area. Except for the peak of Matzehtzel mountain, the contours of this ridge are smooth. Only at the summit are there rocky eminences and these are neither high nor steep. The more southerly and westerly ridge contains as its highest point Tachick mountain (5,400 feet) with McCrea mountain (4,800 feet) to the south. The ridge becomes lower where it swings round to the east, the elevation there being 4,500 feet. Tachick mountain stands up as a squarish block with steep, rocky faces on all four sides. Towards the base the slope becomes much gentler as a rule. The mode of retreat of the face of the mountain has been mainly by the breaking off of blocks isolated by the intersection of joint-planes. Some of these joint-planes are practically vertical and some are inclined at small angles. Joint-planes with similar directions appear to prevail throughout the rocks of the mountain. Near the base, the breaking up of the rock by formation of joint-blocks and their removal will not be the dominant process, but it is higher on the mountain. Hence, the sharp change from the more gradual lower slopes to the precipitous, blocky contours of the main part of the mountain as found on the east, south, and west faces. The northern side, however, rises in a remarkably steep face with only a very short, gentler, lower slope. The reason for this departure from the normal is that beneath the main, jointed formation of the mountain, are sedimentary beds which at the contact have tended to weather away rapidly, thus undermining the formation above.

McCrea mountain presents characters similar to those of Tachick mountain, but differs in having a greater area at the top and in the character of its peaks. The latter stand out much more sharply than do the highest points on Tachick mountain. This difference is due to a difference in the character of the rock. The broad area of the top of McCrea mountain is much dissected by small valleys. The lower peak, to the southeast, presents a much more even surface than do those of Tachick and McCrea mountains. It is considerably lower than both of these and the rock of which it is composed also differs.

Between these two curved ridges of Tachick mountain and Matzehtzel mountain lies a stretch of low ground which drops to the west and northwest to the valley that strikes towards Babine lake. In the middle of this low ground, in its northern section, there is a low ridge that also sweeps round to the northwest. The contours of this ridge are very smooth and suggest a maturer topography than found elsewhere in the area.

Parts of two drainage systems occur within the map-area. All the creeks in the extreme northern part flow towards Babine lake and thence by Babine river to the Skeena. All the creeks south of this northerly section flow southwards to Bulkley river which flows westwards along the southern edge of the map-area. No well-defined watershed separates the two drainage systems, but only low, flat, swampy ground from which the dip of the surface to either north or south is scarcely appreciable. The high ground where one would expect to find watersheds did not exercise much control over the distribution of the drainage system. Thus, one section of Richfield creek, the largest creek in the area, has its sources in small lakes in the low ground between Matzehtzel mountain and Tachick mountain and cuts across the Tachick Mountain-McCrea Mountain range. The creek just to the north of Tachick mountain also comes from the same low ground. The effect of Tachick mountain is simply to deflect the stream a little to the north before it joins the main, southerly drainage into the Bulkley. In a similar way McCrea mountain has deflected the drainage from Nez lake northwards to where it joins with Richfield creek to flow south. As will be shown later, it is believed that underlying the area is a great mass of granitic rock, the surface of which seems to dip to the south in the main part of this area. Tachick Mountain and Matzehtzel Mountain ranges are residual masses of a later formation that has elsewhere been removed, revealing this older surface. It is on this resuscitated, older surface that the sources of the present creeks are mostly found.

GENERAL GEOLOGY

There are two great drawbacks to a complete understanding of the geology of this district. In the first place, the exposures are few, practically only one-tenth of the total area of the map-area showing rock outcrops. Of course, even in the drift-covered areas, there are small, isolated exposures, but since the rocks are dominantly igneous and show marked and rapid variations, the value of these small outcrops is not so great as it would be if the formations were of more uniform character. In any case, these small, isolated exposures are of very little value so far as elucidation of structure is concerned. It is in this matter of structure that the second difficulty arises, for, the formations being practically all igneous, there are no sedimentary horizons that can be followed and the degree of folding thereby determined. The main igneous formation over practically the whole of its extent shows absolutely no trace of bedding. The dominantly igneous character of the rocks presents the further difficulty of a lack of fossil evidence as to the age of these rocks, although elsewhere, igneous rocks probably of the same age as the presumably Jurassic rocks of the map-area do contain fossils.

The age classification of the rocks of Topley area is based on a comparison of the rocks met there with the formations of known age in nearby areas and on the general distribution of these formations in this part of British Columbia. Dawson at an early date carried out reconnaissance studies in the vicinity of François lake about 35 miles south of Topley. He distinguished a great series of porphyritic rocks with breccias and agglomerates, the Porphyrite group, overlain by vesicular, basaltic lavas of Tertiary age. A little to the southwest these Porphyrite rocks have later been shown to be Jurassic. About 50 miles east of Topley map-area, reconnaissance mapping has been carried out by Camsell in the stretch between Stuart and Takla lakes. There the oldest rocks are Carboniferous and are dominantly sediments. The younger formation may be Cretaceous and consists of an upper sedimentary and a lower volcanic series. The volcanic series consists of andesites, tuffs, breccias, and some rhyolites. It is overlain by Tertiary volcanic rocks. Intruding the Carboniferous, but antedating the other formations, there is a granite whose age could only be stated as "Triassic or Jurassic." No rocks of the Porphyrite group occur there. Thirty miles to the northwest of Topley more detailed geological mapping has been carried out by Hanson in Driftwood Creek district, Babine mountains. The most widespread formation is the Hazelton group which is considered to be the equivalent of the Porphyrite group of Dawson and is of Jurassic age. It is divided into three subdivisions, a lower volcanic division, a middle sedimentary division, and an upper volcanic division. The latest phase of these Hazelton rocks is a set of rhyolite and quartz-porphyry intrusions. These were followed by a series of diorite and quartz-diorite stocks and dykes which are the only other pre-Pleistocene rocks of the district, though Cretaceous sediments are found in immediately adjacent areas.

About 45 miles due west of Topley, mapping of the Telkwa River area has been carried out by Leach. In this area Lower Cretaceous sediments overlie rocks of the Porphyrite group and in the extreme west the crystalline rocks of the Coast Range occur. The rocks of the Porphyrite group are here all of igneous character.

Within Topley area the oldest formation observed lies in the low land between Tachick and Matzehtzel mountains. The rock belongs to the granite family. It forms the surface on which the rocks of the two mountains rest as great blocks and this surface dips south and perhaps also west. Although the exposed extent of the surface within the area studied is not large, its presence suggests that prior to the formation of the Jurassic rocks there must have been a considerable interval during which the land was planed down and the batholithic rocks unroofed. On this surface the first deposits formed in Topley area were a series of tuffs, shales, and limestones with some conglomeratic beds. These are exposed in only two places: (1) at the northern end of Tachick mountain, the better outcrop; and (2) a thin, poorly exposed layer of breccia-conglomerate at the southeastern end of the same mountain. Their deposition was followed by that of a great volcanic series, the sequence and character of which varied from place to place. The variation is so great that it is difficult to express it in a summary fashion, but this much may be said: to the northeast only a thin layer of feldspar porphyry breccia was formed. Southwards the first of the volcanic rocks over the greater part of the area consists of very fine-grained, reddish and purplish andesitic material much of which is porphyritic with white plagioclase and, in some cases, pink orthoclase crystals. Overlying this in Tachick mountain is a great thickness of massive feldspar-porphyry breccia which continues southwards to McCrea mountain. South from the latter mountain the rocks change to amygdaloidal basalts and to the southeast to fine-grained, purplish, porphyritic rocks which in places approach rhyolites in composition. The latest phase of the volcanism was an irregular injection of rhyolite dykes and the formation of irregular bodies of banded rhyolite and rhyolite breccias. These bodies reach their greatest development on Matzehtzel mountain where they make up practically the whole mass of the mountain. They also form the southeastern side of McCrea mountain and are the rocks of its southern peaks. After the formation of these volcanic rocks Topley area was subjected to erosional processes which carved its surface into configurations not much different from those of the present day. The highlands of the present Matzehtzel-Tachick-McCrea Mountain area were formed and a large basin developed to the south. In this basin there was formed first a series of Tertiary shales and sandstones whose distribution indicates that the deepest part of this basin was somewhat to the north of the present Bulkley river. On top of these sediments was ejected Tertiary basalt flows and agglomeratic rocks, all of which are extremely vesicular. These rocks lap up around the bases of Tachick and McCrea mountains and in Richfield Creek canyon have a slight dip towards the mountains.

Table of Formations

Age	Character of rocks, etc.	Greatest thickness
		Feet
Recent	Sands, gravels, boulder clays, silts, and clays	200
Tertiary	Vesicular, basaltic rocks with diabase sills and dykes probably of same age	400
	Shales and sandstones	50
Jurassic (?)	Dykes and flows of rhyolite and rhyolite breccia	1,000
	Feldspar-porphyry breccia, etc	1,200
	Shales, limestones, conglomerates, and breccias, with some volcanic material	300
Pre-Jurassic (?)	Granitic rocks	

DESCRIPTION OF FORMATIONS

Pre-Jurassic Granitic Rocks

These rocks occur in the low ground between Tachick and Matzehtzel mountains and outcrops were also noted north of Nez lake. They form, therefore, an arcuate outcrop bounded on the north, south, and southwest by overlying Jurassic volcanic rocks. Within this area of outcrop, however, there are, locally, small exposures of the Jurassic porphyritic rocks. It is noteworthy that such rocks in many cases occur on small knolls at about the same elevation as the base of the volcanic rocks of the mountains. Since none of the exposures has any depth it was impossible to be sure, however, that faulting had not been operative in determining their presence.

In hand specimen the granitic rocks vary considerably. Three varieties can be distinguished: (1) pink and white granite, (2) white granite, (3) grey granite. The most prevalent type, the pink granite, is a coarse, porphyritic, gneissose rock consisting of white feldspar, pink feldspar, quartz, biotite, and hornblende. The pink feldspar characteristically forms large euhedral crystals which have crystallized prior to the development of the gneissose structure, for they show all degrees of attempted alinement with the grain of the rock. Carlsbad twinning is frequently present in them and in this respect they are quite distinct from the white feldspar crystals which with quartz form the base of the rock. Although the pink feldspar crystals have been turned in the direction of the gneissosity of the rock they do not show any signs of fracturing or crushing, so that we must conceive that they were so oriented while the rest of the mass was liquid. The best exposures of this type are on the small hill about 2 miles north of the northern end of Tachick mountain. There the gneissosity strikes 35 degrees west of north, but the dip could not be determined. At this locality the pink feldspar crystals attain dimensions of $2\frac{1}{2}$ and $1\frac{1}{2}$ inches and many show a peripheral zone of somewhat different appearance. Cutting across the gneissose structure in this locality are quartz and pink feldspar, pegmatite veins, the largest vein observed being 9 inches wide. In the pegmatite veins the largest piece of pure, pink feldspar seen was about 3 by 2 inches. Similar pink and grey granite occurs also at the southeastern end of Tachick mountain underlying the formation of the mountain. There the gneissosity strikes 80 degrees east of north. Quartz and quartz-pink feldspar veins are present, but reach only 2 inches in width. Throughout the area underlain by the granitic rocks this coarse type is dominant, but with the exception of the two localities mentioned the gneissic structure is either absent or is irregularly developed.

The white granite is a departure from the prevailing rock type due to the absence of the porphyritic character, the rock becoming even and usually also finer grained. All gradations from the normal variety are found. In these non-porphyritic rocks very little pink feldspar is present. Such rocks show no trace of gneissose structure.

The third variety into which the second grades, is the grey granite. It is much duller than the two varieties mentioned above, the quartz content is smaller, and all the feldspar is a dirty white, greenish shade. In grain it is similar to the white granite and no porphyritic modifications were found. The third variety grades into the second, but nowhere was seen to directly grade into the first variety.

Within the granitic rocks there are many inclusions of rocks of various types. In size they vary from small fragments about 6 by 3 inches to masses certainly greater than 12 by 12 feet. From a study of hand specimens it would appear that the original material of these inclusions has been volcanic. They are now completely recrystallized and in some cases have received material from the granitic rocks. Some are hornblende and mica schists, whereas others have no alinement of prismatic or flaky minerals and are hornfelsic in character. These hornfelses, in hand specimen, appear to consist of abundant, heterogeneously arranged hornblende prisms and pinkish feldspar crystals. In practically every case thin, irregular stringers of granitic matter traverse the rock.

In many of the exposures, especially those of the coarse, pink and white granite, thin, irregular stringers of epidote are present. Spots of epidote are also scattered irregularly throughout the rock mass.

Evidence of Age. There can be no doubt that these granitic rocks are the oldest present. The evidence on which this conclusion is based is as follows.

Granite boulders occur in conglomerate, and pink feldspar similar to that in the granite occurs in a breccia overlying the granite at the base of the volcanic rocks.

Fragments of the granitic rocks also occur in the overlying volcanics which are probably of Jurassic age. The best exposures of this relationship are at the base of Matzehtzel mountain. There, in the low ground, amongst the timber and in the creek beds, are many exposures of pink and white granite and these exposures continue to the base of the mountain.

The first sign of the presence of a new formation is an abundance of large boulders of porphyrite breccia, all of which contain subangular fragments, of varying size, of the granite on which the boulders now rest. The porphyrite breccia is then met in place and the distance between the last exposure of granite and the first of porphyrite breccia is not more than 40 yards. In the last exposure of granite the rock shows no variation from the normal, coarse, pink and white type of this part of the area and no xenoliths occur. The fragments of granitic rock in the porphyrite breccia are identical with the granitic rock beneath and vary from very small up to boulders about 9 by 6 inches. The porphyrite breccia forms only a thin, irregular strip in this part of the area and the dominant formation is rhyolitic. In the lower exposures of the rhyolitic member, fragments of pink and white granite are also abundant.

Although specially searched for, no veins or dykes of granite were found traversing the Jurassic rocks. Since the presence of such minor intrusions is considered by prospectors to indicate favourable conditions for ore deposition, search for them has not been confined to geologists, but so far as the writers are aware no prospector has yet found a stringer from the granitic rocks penetrating the Jurassic rocks. It may, therefore, be taken as proved that such intrusions are absent. It seems that the most logical conclusion is that the granite is the older formation.

The granitic rocks show, in places, well-developed primary gneissose structures. Considering the origin of such structures one would expect that their strike would parallel the contact with the rocks into which the granite has been injected. The only place where this test could be applied was at the southeastern end of Tachick mountain. There, at the base of the mountain, gneissose pink and white granite occurs and its contact with the overlying formation can be located within a range of about 100 feet and runs approximately north and south. The direction of the gneissosity, however, strikes 80 degrees east of north, so that there is a marked obliquity between it and the contact. In the locality where the gneissic structure is best seen and most regularly developed, i.e., about 2 miles north of Tachick mountain, the strike of the structure is 35 degrees west of north. There is no conformity between this direction and any contact between the two formations.

Within the granitic rocks large inclusions occur and these inclusions have in all cases been greatly metamorphosed. It is to be expected, therefore, that the roof of the granite would also show considerable metamorphism. Nowhere was rock seen immediately on top of the granite, but at the north end of Tachick mountain the sediments, amongst which are limestones, are exposed down to an elevation about 200 feet above the granitic rock surface, and show no trace of thermal metamorphism.

The granitic intrusion probably took place under conditions of some lateral stress in the earth's crust. The Jurassic rocks, however, show no evidence of folding, but appear to be relatively undisturbed, so that it is improbable that they were the country rock into which the batholith was injected. The position of the outcrop of the granitic rocks with respect to the topography shows that the Jurassic rocks have been stripped off the surface of the granite and it is considered to be probable that this granitic surface underlies the whole area. The boundaries of the granitic and Jurassic formations are not determined by faults, since signs of faulting are absent.

In the general area between Hazelton and Dawson's type area of the Porphyrite group wherever the Porphyrite rocks are intruded by granitic bodies, the granitic masses stand up, usually as peaks overlooking the Porphyrite rocks. Nowhere do they occur in low ground with the Porphyrite rocks forming mountains above them. The reversal of this relation in Topley area indicates some different relationship between the granite and the Porphyrite formations and suggests that the most satisfactory explanation is that the granite is older than the Jurassic rocks of the area and that the latter formed on its surface, from which, in places, they have since been stripped.

Jurassic Rocks

In the group of rocks classed as Jurassic, three divisions are distinguished: (1) a basal series consisting of sediments; (2) overlying this conformably, so far as can be judged, a great thickness of volcanic fragmental rocks referred to in the present report as the porphyrite breccia series; and (3) rhyolitic rocks cutting the porphyrite breccia.

Basal Sediments. All the exposures of the basal sediments are on Tachick mountain on the northern and southeastern ends. The better exposure is at the northern end, but even there the outcrops are few. This end of the mountain is precipitous down to an elevation of about 4,500 feet. At this elevation, timber begins and here also are the first outcrops of the sedimentary beds. The upper beds of the sediments have weathered more rapidly than the overlying rocks, so that some undercutting of the cliffs occurs. The upper contact of the sediments can be traced along the face of the mountain, but falls eastwards, so that it is ultimately lost in the timbered land. All the sedimentary beds are covered by timber and the only exposures are on ledges within the forest. By stripping the moss in likely places other outcrops are obtained.

The exposures at the southeastern end of Tachick mountain are few and it is evident that the sedimentary layer must have thinned considerably within the length of the mountain, because here the distance between the porphyrite breccia of the mountain and the granitic rocks is not over 50 feet at the most.

The sedimentary rocks are tuffs, shales, conglomerates, and limestones. The tuffs are dense rocks, breaking in many cases with a conchoidal fracture. Their hardness is about 5 and in some cases this is the only indication that they are not limestones. They are pale grey to bluish grey and on the surface in many places they are bleached white through a depth of about 1 mm. Extremely delicate banding is present in some of the outcrops, but the banding is not continuous. The bands vary in thickness from 2 millimetres to leaf-like laminæ. Specks of pyrite are present, but are by no means abundant. The shales are bluish to purplish and probably contain a considerable amount of volcanic material. Pyrite is present and the rock weathers to a rusty mass that may readily be mistaken for gossan. Only small, isolated exposures of the conglomerates were found. In a band near the top of the series, the average grain size is about 2 millimetres. Farther down are exposures of a bed with pebbles of granitic rock similar to that to the north and about 4 inches in greatest dimension.

The component fragments of the conglomerates are subangular, rarely rounded. Quartz is the most abundant constituent. Calcite is present in the matrix. Breccias of similar characters were met in two places: (1) at the southeastern end of Tachick mountain where all the exposures are of this material; and (2) about 300 yards south of the small creek at the northern end of the mountain about $\frac{3}{4}$ mile from where it leaves the lake. The base of this breccia is light coloured. The larger and most conspicuous fragments are of a dark green rock that effervesces slightly with acid, and holds pseudomorphs after feldspar; it is probable that the fragments are altered volcanic rocks. The other quantitatively important components of the breccia are quartz and feldspar. The feldspar is of both the pink and the greenish white varieties and it is probable that along with the quartz they have been directly derived from the granitic rocks beneath. Much calcite is present, disseminated throughout the matrix. The situations of the exposures of this rock make it seem probable that the rock is very close to, if not actually at, the base of the sedimentary series. The limestone is impure and fine-grained. The only good exposure is below a peculiar trachytic, feldspar-porphyry on the lower slopes of the northwestern end of Tachick mountain. There the rock is cut by many irregularly distributed calcite veins, varying in width from mere leaves up to 4 inches. Crystals of pyrite abound; these are probably not due to hydrothermal agencies.

Porphyrite Breccia Series. This series consists of a great variety of rocks which for convenience of description may be placed into four groups. These are: (1) porphyrite breccias; (2) epidotized porphyrite breccias; (3) purplish volcanic rocks; and (4) greenish basalts and diabases.

The porphyrite breccias are the most abundant rocks of the series. They form, practically, the whole of Tachick mountain and all but the southwestern end of McCrea mountain. They occur also at the eastern end of a mountain to the southeast where they are cut through by Ailport creek. The fragments in these breccias vary greatly in size. The largest seen were 3 feet square in section and from these there are all variations down to fragments about half an inch square. The rocks vary from dark grey to purple, green, and white. In places there is a difference in colour between the fragments and the matrix, but no regular relationship was found. On weathered surfaces the breccias are much lighter in colour and, indeed, from a distance look somewhat like granitic rocks. The breccia character is beautifully exhibited on the weathered surfaces and can be more easily studied there than on a freshly broken surface. There is not, in every case, a sharp boundary between the fragments and the matrix, but instead, in many instances, the fragments are accretions of the crystalline material of the matrix into which there is a continuous gradation. In other cases, a part of the boundary of a fragment is sharp, whereas the rest of the boundary is of the transitional type. Between these two types of fragments and fragments whose whole boundary is sharply defined, there are all gradations and the materials of the matrix and of the fragments are essentially the same. These relations indicate that the breccia character was due to the aggregation of crystalline material in parts of the cooling magma. In the matrix, flow lines around the fragments occur in many cases and, throughout the mass, well-banded, somewhat rhyolitic-looking material forms short bands that fade out into more normal rock. The directions of these bands appear to be unrelated. The flow lines and the irregular distribution of bands of the rhyolite-like material indicate that the magma was viscous at the time of its crystallization and was subjected to movements. These movements and the viscous condition gave rise to the brecciated appearance.

In the typical porphyrite breccia there is no sign of vesicularity. The rock is characteristically dense and compact, with the base of the fragments and of the matrix fine to medium-grained. The rock types met in fragments and matrix are diorites, porphyritic rocks in which the dominant phenocrysts are soda-lime feldspar. The diorites hold remarkably few dark minerals. In the porphyrite varieties, which are the most abundant, the dark minerals, hornblende and augite, are also present as phenocrysts. No quartz is to be seen in hand specimen.

Porphyrite is not limited to the breccias, but occurs also as an unbrecciated rock. Such material is found on the northeastern side of the mountain west of Ailport lake and also northwards towards Nez and Ailport lakes. It occurs also in some exposures in the lower ground of the area, but its areal distribution there cannot be determined on account of the drift, although from its distribution it would appear as if it were below the porphyrite breccia. At the northern end of Tachick mountain a variety of the porphyrite occurs beneath the main formation of the mountain. It consists of remarkably white plagioclase crystals about a quarter of an inch in length, in many cases in radiating intergrowths, set in a very fine-grained, purple matrix in which a few small crystals of hornblende also occur. At higher elevations fragments of this rock occur in the porphyrite breccia. Normally only one kind of feldspar is to be observed in the porphyrites, but about half-way up Hatch creek, a little to the east of that stream, in addition to the whitish plagioclase, there are also large crystals of pink orthoclase. These orthoclase crystals attain dimensions of as much as 1 inch by ½ inch and seem to be of a different generation from the much smaller, plagioclase crystals, for whereas the latter show perfectly sharp boundaries against the matrix, the orthoclase crystals have been much corroded and in some cases are mere ghosts of their former selves. The plagioclase crystals in one or two cases appear to have replaced orthoclase crystals. Quartz and mica are also present in this rock and probably it approaches a type intermediate between the latites and the dacites.

Much of the porphyrite breccia has undergone alteration to epidote. This alteration is displayed practically throughout the whole of the formation, but is especially pronounced on the western exposures of these rocks on Tachick mountain and southwards to McCrea mountain. The epidote occurs in various ways. It is present frequently as numerous, thin veins of irregular distribution. The boundaries of the veins are, in some cases, sharp, but in just as many instances the epidote has spread outwards into the porphyrite so that there is no distinct boundary between vein and rock. The thickest vein seen was 9 inches wide and occurred just west of the Cup group on Richfield creek. In the middle of the veins there are many open spaces lined with quartz and calcite, but not sulphides so far as was observed. The formation of the veins must have taken place after the rock in which they are now found had become sufficiently rigid to yield by fracture, but the epidotization process may have been effective before complete solidification of the porphyrites as a whole, for the peripheries of many of the fragments of the breccia are completely altered to epidote, whereas the matrix in which they lie shows no sign of the alteration in hand specimen. This relation may indicate that these fragments were acted upon by the altering agent prior to their final cementing in the breccia. The process of alteration of the fragments has been carried to completion in many cases and all gradations occur from fragments altered only along a narrow peripheral zone to others completely changed to epidote—at least so far as can be ascertained from examination of hand specimens. Within such completely altered fragments there are, in many cases, vugs, and some of these vugs are lined with crystals of epidote, quartz, and calcite.

At the top and at the bottom of the porphyrite series occur volcanic rocks of considerable variety, but all are reddish purple and of very fine grain. At the northern end of Tachick mountain, underlying the main formation of the mountain and immediately overlying the sediments, there are rocks of this class. The lowest member has patchy texture due to some parts showing many small phenocrysts and other parts none. There are no sharp boundaries between these patches. Upwards this material gives place to the already described more porphyritic rock with phenocrysts up to about one millimetre in length. Above this occurs the porphyrite with very white plagioclase crystals and purple base.

The purple volcanic rocks which occur at the top of the series, above the porphyrite breccia, are different from those at the bottom and probably represent more rapidly chilled varieties of the porphyrite breccia. The upper development shows rhyolitic tendencies and many of the rocks are banded and have their feldspar crystals arranged with their longer dimensions roughly parallel to the direction of the banding. In the field, in places, they appear like flagstones, showing dip and strike like sedimentary rocks. The dips observed seem to indicate that the inclination of the flows varies irregularly from place to place. Since, however, none dips at very high angles it is probable that the formation as a whole is comparatively flat.

An important variety of these purple volcanic rocks is a markedly amygdaloidal and vesicular rock. It is in considerable abundance in the gorge of Ailport creek where it passes in places into a breccia, with a very irregular concentration of phenocrysts relative to base in different parts of the rock. As in the porphyrite breccia of Tachick mountain, some fragments have sharp boundaries and others have poorly defined boundaries or lack them. Similar amygdaloidal and vesicular basalts occur on the eastern part of the mountain between Cesford and Ailport creeks.

On the southwestern and middle parts of the mountain between Cesford and Ailport creeks there occurs a series of greenish rocks, some of which have the texture of basalts and some that of diabases. Their relations to the other rocks of the mountain could not be accurately determined, but they appear to be of the same general age as the purplish volcanic rocks described above, for the latter pass into them without any marked unconformity such as is found elsewhere between the Jurassic and Tertiary volcanics and, furthermore, on the southwestern side of the mountain, rhyolite cuts these rocks. These greenish rocks, moreover, are much more altered than any of the Tertiary and the majority of the basalts are amygdaloidal, whereas the basalts of Richfield creek, etc., are typically vesicular. The filling of the amygdules consists of quartz and calcite and in the majority of cases calcite is widespread throughout the rock, due to alteration of the primary minerals. Thin veins of calcite are also present. At the southwestern side of the mountain between Cesford and Ailport creeks the best examples of the developments of the diabasic texture are found. There, on the lower slopes of the hill, the rock becomes very coarse and in places is best described as a gabbro-diabase. Within it are segregations of extremely coarse material, one of the best examples seen being a roughly triangular segregation about 8 inches by 9 inches by 12 inches. Within it the plagioclase crystals are, on an average, about 1 inch by ¼ inch, and are arranged in a criss-cross manner. The rock at this point is much veined by epidote and also by thin, white veins of saussurite substance.

Rhyolite Series. These rocks make up practically the whole of the part of Matzehtzel mountain that is included in the map-area, and stretch eastwards from this point. They occur also on the southwestern corner of McCrea mountain, and dykes and irregular intrusions of rocks of this group are found throughout other parts of both McCrea and the mountain between Cesford and Ailport creeks. It is difficult to determine exactly how these rocks occur, whether they are flows, dykes, sills, or more irregular intrusions. At some places on the southwestern part of McCrea mountain distinct dykes of rhyolite occur, but in most exposures the rhyolite appears to be a flow breccia of irregular thickness and distribution. On Matzehtzel mountain some of the banding of the rhyolite is almost vertical, suggesting dyke-like bodies.

Amongst these rhyolite rocks there is great variety. The types met are: (1) light-coloured rhyolites with practically no phenocrysts; (2) very well-banded, pink rhyolite; (3) dense, black, structureless rhyolite; (4) porphyritic rhyolite, the phenocrysts being practically all feldspar with occasionally some hornblende; (5) flow breccias with angular fragments of rhyolite in a rhyolite matrix that flows around the fragments, the rhyolite of matrix and fragments is in some cases porphyritic; (6) undirected rhyolite breccias with angular fragments of pink and black rhyolite in rhyolite matrix. In all these types epidote occurs as small cavity-fillings, or as irregular stringers, or as alteration products of feldspar. The latter mineral is practically always altered and appears white, pink, or green. In the rhyolite porphyrites the matrix is coarser than in the non-porphyritic variety and in some extreme cases is almost identical with some of the finer phases of the porphyrites of the area.

Correlation and Age. No fossils were found in these rocks. They agree in characters with the Jurassic, Hazelton, or Porphyrite rocks. A comparison with those of proved Jurassic age in Driftwood Creek area emphasizes the probable correctness of the view that the Topley rocks also are Jurassic. In Driftwood Creek area Hanson distinguishes four divisions of these Jurassic rocks; a lower volcanic, a sedimentary, an upper volcanic, and a rhyolite division. In the upper volcanic division the base consists of amygdaloidal lavas or tuffs and tuffaceous sediments. Breccias occur and in the eastern part of the area there are crystalline, feldspathic porphyries several hundred feet thick, which are interpreted as sills. These rocks agree in general characters with the Topley porphyrite series. Rhyolite flows occur in Driftwood Creek area and in Topley area the close of this phase of the igneous activity was also marked by the injection of rhyolite material. It thus seems that the Topley rocks were contemporaneous with the upper volcanic and rhyolitic divisions of Driftwood Creek district.

Tertiary Rocks

Practically all these rocks occur in the lower areas in a basin that coincides in general with the present Bulkley valley. On Matzehtzel mountain, however, at an elevation of 5,000 feet, a small patch of volcanic rock was found overlying and enclosing fragments of the porphyrite breccia, so that we must consider that though the accumulation of the Tertiary volcanic rocks was in the depressions, their source was, in some cases at least, at greater elevations.

At the base of the Tertiary rocks are sediments which are nowhere well exposed and are best developed on Byman creek. There, about three-fourths of a mile north of the road crossing, the creek passes into a gorge which has been the locus of faulting that strikes roughly north-south. There has been considerable dragging of the beds into the fault-plane, so that no reliable estimate of their thickness can be made. The rock consists of impure limestones, black shales, and intercalated volcanic rocks which are now almost completely altered to dark green chloritic products. In these beds there has been evidently considerable disturbance, part of which may possibly be due to the accumulation above them of the great thickness of volcanic material. There has, also, been a great deal of alteration of solution and of reprecipitation. These processes have been facilitated by the fracturing of the beds, but they have probably been due mainly to the movement of ground water along this plane of unconformity. One of the effects of these processes has been the formation of many calcite veins in both the impure limestones and shales. These veins, since some contain pyrite, are apt to be mistaken for valuable mineral veins, but their mode of origin makes it improbable that they will contain any values. A much veined rock of this series is found also on Richfield creek, about one-fourth of a mile north of the road-crossing. Here practically the whole of the originally calcareous rock has been broken across by veins and cavities filled by crusts of calcite. It is improbable that these basal Tertiary sediments are anywhere thicker than about 50 feet.

The volcanic rocks, which make up by far the greater thickness of the Tertiary material, are exposed in a splendid section in the canyon of Richfield creek. The rock types are feldspar-porphyry flows with very coarse crystals of labradorite, agglomerates, columnar basalts, and vesicular basalts. These rocks, on the whole, dip gently northeast and this dip is probably due to their formation on the sloping sides of the basin. They are cut by dykes and sills of fresh diabase. All the material of the agglomerates and basalt flows is vesicular. The degree of vesicularity varies considerably and the more vesicular varieties weather more rapidly than the less vesicular types. In some cases the fragments of the agglomerates are spherical masses up to 20 feet in diameter. These are practically glassy on their periphery, with vesicles elongated circumferentially. Inwards the mass becomes somewhat more vesicular, but is always markedly less so than the matrix. The latter in most cases is almost a pumice and, therefore, weathers very rapidly. In the weathered rock faces in the canyon of Richfield creek, south and north of the falls, the large, spherical masses stand out like great carbuncles in a mass that below shows signs of stratification. Some of the apparent stratification is due to alternation of flows of different vesicularity.

The greatest thickness of these volcanic rocks is about 400 feet.

Age and Correlation. There are three principal reasons for placing these rocks in the Tertiary: (1) They overlie unconformably the Jurassic rocks; (2) they are lithologically similar to the Tertiary rocks to the south; and, (3) they occupy a structural position similar to the Tertiary rocks to the south, i.e., they fill valleys not much different in location and extent from those of the present day and are overlain by drift of glacial origin.

STRUCTURE

Lack of exposures makes an accurate determination of the structure of the area impossible. Enough data have been acquired, however, to establish the more important facts concerning the structure. (1) The granitic rocks in the low ground between Tachick and Matzehtzel mountains underlie the Jurassic rocks of these mountains. (2) The Jurassic rocks dip gently northwards on Tachick mountain. (3) The porphyrite breccia is cut and overlain by the rocks of the rhyolitic series. (4) The Tertiary sediments and lavas lie in basins in the Jurassic rocks, these basins not being very much different in location and in outline from those of the present day. (5) Faulting has occurred along the western base of Tachick mountain in lines running about magnetic north.

The precise contours of the granite surface beneath the Jurassic rocks are unknown and it is not known to what extent, if any, folding or faulting has affected the Jurassic and pre-Jurassic rocks. However, since the granitic rocks occur at both the northern and southeastern ends of Tachick mountain and do not reappear to the south, it seems reasonable to assume that the granite surface dips gently southwards and that, moreover, folding and faulting have not much influenced the distribution of the rocks. The degree of faulting on the western base of Tachick mountain could not be ascertained, but it may be in part responsible for the presence of the granitic rocks at the lower part of the northwestern corner of the mountain. This faulting appears to continue southwards, for, on Richfield creek, the most westerly exposure of the porphyrite breccia shows evidence of considerable shearing. Evidence of faulting is also to be found in the rocks on Ailport, Hatch, and Byman creeks. The faulting in these creeks does not, however, appear to be of any great displacement and certainly has not exerted any marked influence on the distribution of the formations.

The area is regarded as being close to the eastern limit of the Jurassic rocks. The low ground between Tachick and Matzehtzel mountains is a "window" in which we see the rocks of the basement which here consists of granitic material. This surface dips gently southwards. All reports dealing with the Jurassic rocks immediately to the east of the Coast range speak of them as being of great thickness and as nowhere having their base exposed. Dawson estimated their thickness at 10,000 feet in the country south of François lake and Marshall has recently given even a greater thickness to the group in the area immediately adjacent to the Coast range. Next to the Coast range these Porphyrite rocks have been subjected to considerable folding. Topley area was apparently too remote from the focus of these movements to suffer any marked distortion, and its Jurassic rocks probably dip uniformly westwards and southwards. Denudation in pre-Tertiary time produced a basin in the southern section of the area and here first some sediments and then a great thickness of volcanic rocks were formed in Tertiary time. In late Tertiary, or post-Tertiary, minor faulting occurred.

ECONOMIC GEOLOGY

GENERAL STATEMENT

All the mineral deposits are veins and replacement deposits and, so far as present prospecting has shown, are confined entirely to Jurassic rocks. In considering this statement, however, it must be kept in mind that practically all the best outcrops of the district consist of these Jurassic rocks, these being the formation of the mountains. Although there are abundant smaller outcrops of the granite, yet the exposures occur in heavily timbered land in which prospecting is difficult. In the granite outside of the map-area two cases of cupriferous staining were reported to the writers, but no primary copper sulphide was seen. In the Tertiary volcanic rocks, in their best exposures in Richfield Creek canyon, no signs of mineralization were observed and since it is probable that practically the whole thickness of the formation is visible in this gorge, the suggestion is that the ore-bodies were formed in pre-Tertiary time. In the sediments at the base of the Tertiary, especially in the impure limestones, pyrite occurs, in some cases quite abundantly, as for example in the lower parts of Byman creek. Such occurrences, however, are probably to be referred to reduction of iron sulphates by carbonaceous matter under atmospheric conditions and not to hydrothermal agencies. No values in precious metals are to be expected in such cases.

So far, mining activity in the district has not gone beyond the prospecting stage. One of the great difficulties with the ore-bodies so far found has been the determinations of their extent in a horizontal direction. The ore-bodies occur near the base of the mountains and are covered by a mantle of drift the thickness of which varies rapidly and irregularly. At the Topley Richfield mine the drift is locally as much as 50 feet thick. From investigation of the surface it is practically impossible to come to any reliable conclusion as to the detailed structure in the vicinity of the prospects and perhaps the cheapest method of obtaining reliable information is by the use of the diamond drill. Up to the present, this method of attack has been employed only at the Topley Richfield group.

MINERALOGY

Classified according to mineral content, three types of deposits can be distinguished. These are: (1) Replacement deposits and veins containing pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite, with a quartz and calcite gangue. Gold and silver values occur with these deposits. (2) Veins containing specularite, with quartz and epidote gangue and in some cases with some pyrite and chalcopyrite. These contain little or no values in gold or silver, so far as work up to the present has shown. (3) Veins containing galena and chalcopyrite with barite and carbonate gangue. There is not yet sufficient reliable data to hand to make possible a generalization on the precious metals content of this type of vein.

None of the minerals presents characters meriting special mention, except perhaps the sphalerite. This mineral shows a variety of shades from almost colourless through green to greenish brown and brown. A crystal from the Golden Eagle group shows a peripheral zone of emerald green and a core of the colour of amber. The form of the crystal is determined mainly by dodecahedral cleavage planes, but a tetrahedral face is present. The lustre on the cleavage surfaces is adamantine, whereas the tetrahedral face is much duller.

The country rock of the first of these types is always the porphyrite breccia and the deposits appear to occur only in the areas where the rocks of this series show pronounced epidotization. Thus the Topley Richfield mine, and the workings of the Cup and Golden Eagle groups, are located in porphyrite breccia which shows epidotization in a marked degree. Indeed the belt of porphyrite breccia stretching between these three properties shows the greatest development of epidote found in the area mapped. It should be noted, however, that there is no direct relation between the degree of epidotization at any point and the abundance of mineral, i.e., although the veins occur in the area of greatest epidotization yet within that area the greatest mineralization and the greatest development of epidote do not go hand in hand. Furthermore, there is no evidence of epidote having been formed with the minerals in the veins, so that there does not appear to be any reason for assuming any direct genetic relationship between the phenomena of epidotization and of mineralization. The veins of this type have usually sharp walls and vary in width from a fraction of an inch to about 8 feet. Information as to their length and depth is as yet scanty, but one vein in the Topley Richfield mine is known to be as much as 300 feet long. The larger veins are usually banded. The bands are due to: (a) presence of different minerals in the various bands, and (b) remnants of altered wall-rock, these remnants being parallel to the walls of the vein. The irregular characters of the boundaries of these included fragments of the walls indicate that replacement has been operative in determining their isolation within the vein. Fissure filling has also been a mode of mineral formation, for we find an abundance of crystal-lined cavities within the veins and some of the banding also is obviously due to the formation of a coating of one mineral, the crystals of which have projected into the open space, and then the deposition of a layer of another mineral on top of this crust. The formation of these larger veins appears, therefore, to have taken place along a fracture zone within which there were many small fissures between the individual fractures. These fissures were filled wholly or in part by crusts of minerals and the rock between fracture planes was replaced in varying degree.

The replacement deposits are tabular and vein-like, but although they are the more important mineral deposits at the Topley Richfield mine and have consequently been explored by underground workings, very little is known yet about their age or mode of origin. It is not known whether the loci of the replacing solutions were fractures, beds, or shear zones. Individual replacement deposits are known to be as much as 50 feet long and 6 feet thick, but as they have been developed on only one level their depth is not known. From the evidence so far collected it seems possible that though an individual replacement deposit may not persist for any great distance along the strike, yet its place may be taken by another adjacent one, so that an *en échellon* arrangement is suggested.

The veins of type (2), specularite with or without pyrite and chalcopyrite, in a gangue of quartz and epidote, occur either within the rhyolite or in the sheared and altered porphyrite breccia immediately adjacent to it. In some cases, as on the northwestern end of the mountain between Cesford and Ailport creeks, blocks of porphyrite breccia have been isolated by the intrusion of the rhyolite and within these blocks, hematite-quartz-epidote veins, with in some cases, chalcopyrite, occur. So far the only prospects in this type of vein have been located on McCrea mountain. Matzehtzel mountain, where the rhyolite series is best developed, either shows no such mineralization or prospecting has not been sufficiently intensive to bring it to light. This type of mineralization is present in small, irregular veins, usually of very small width, and in some occurrences they form knots from which veinlets stretch into the surrounding rock.

The only veins with barite gangue (type 3) so far located have been in the porphyrite breccia, one about the middle of McCrea mountain and the other at the eastern end of the mountain between Cesford and Ailport creeks. In the latter case the porphyrite breccia is of a much more open type than that of Tachick mountain, but it is doubtful if this fact has any relation to the special type of gangue here found.

Metasomatic Processes

Attention has been drawn by previous observers to the alteration of the rock associated with the main mineralization in this area and a laboratory study of the altered material has been made by Mr. V. Dolmage of the Geological Survey. The results of this study have been written up in the Annual Report of the Minister of Mines, British Columbia, 1926, pages 139, 140. The following partial chemical analyses of three samples of altered rock at the Topley Richfield mine, by the Bureau of Mines, British Columbia, are taken from page 140 of the above-mentioned report.

—	Per cent	Per cent	Per cent
Gold	trace	....	trace
Silver	trace	....	0·4
SiO_2	44·4	63·2	50·8
Al_2O_3	2·3	2·0	1·0
Fe_2O_3	7·1	9·7	8·0
$CaCO_3$	20·4	11·8	17·0
$MgCO_3$	17·5	5·1	15·3

The minerals in the altered rock are chiefly quartz, calcite, and dolomite. Since the characters of the unaltered rock had not been fully determined at the time of these studies it was not possible to trace the course of the alteration. Although no further chemical analyses are yet to hand, a little fuller explanation of the phenomenon is possible and is attempted below.

In general it may be said that mineralization in the porphyrite breccia occurs only in areas exhibiting this particular, yet to be described, type of rock alteration. Thus all the veins of Topley Richfield group occur in a section of the porphyrite breccia that is intersected by zones of alteration, and the same holds true for the veins at the Golden Eagle group and elsewhere. The alteration in these areas appears to have taken place laterally from small cracks which are now in some cases filled with calcite. These cracks may or may not contain sulphides, for though mineralization occurs only in areas that show rock alteration, yet within these areas the mineralization does not follow the alteration in detail. This point has been mentioned by Mr. Lay and by Professor Turnbull in the case of the mineralization at Topley Richfield mine and the same feature can be observed at other prospects. The relation, therefore, between the mineralization and the alteration is of somewhat the same type as that between the former and the epidotization of the porphyrite breccia mentioned above. There is this difference, however, that the areas of this type of alteration are more local than those of epidotization which is on a much larger scale. The mineralization, therefore, bears a closer general relation to the rock alteration than to epidotization.

The boundaries between altered and unaltered porphyrite breccia are remarkably sharp. This relation is well shown in specimens from the Topley Richfield area. In them typical porphyrite breccia, to all outward appearance quite unaltered, is separated, in many cases, by a knife-like boundary, from material so completely transformed that no trace of even the original texture remains. A similar relation is to be observed in the case of the wall-rock of some of the veins, as, for example, the east vein at Topley Richfield mine which in the exposure is about 3 feet in width. The zone of alteration bordering the vein cannot exceed about 6 inches and the rock beyond is apparently normal porphyrite breccia.

In the least altered phase, the base of the rock consists of a greenish chlorite, white mica, calcite, and quartz. All the crystals are minute. The feldspar phenocrysts have undergone practically complete alteration to white mica, calcite, and quartz, which occur as exceedingly fine-grained aggregates with boundaries representing those of the original feldspar crystals. The ferromagnesian phenocrysts are completely altered to chlorite pseudomorphs. There is no evidence that the alteration has proceeded from small cracks. The agents affecting the alteration, perhaps mainly water and carbon dioxide, must have permeated the rock, but, on the other hand, the products of the reactions remained in the place where the reaction took place. The original texture of the rock has, therefore, not been destroyed and in hand specimens the shapes of the original individual crystals have been preserved and the breccia character of the rock is still apparent. The rock as a whole, however, has become much softer due to the formation of softer minerals and the extremely fine-grained character of the alteration product.

In another phase the alteration, even more intense, is to white mica, and there is a partial loss of the original textural characters. The ferromagnesian minerals are completely altered to chlorite and serpentine pseudomorphs. In the groundmass, along with the white mica, are long prisms of colourless amphibole arranged in criss-cross fashion. Some calcite, serpentine, and quartz are present. Narrow veins of calcite and of quartz are visible, though they are scarcely to be perceived in hand specimens. The rock is usually whitish to greenish, and, on cursory examination, shows no signs of its original characters. A closer inspection, however, reveals small, rectangular areas which differ slightly in colour from the rest of the rock. These are the now wholly altered feldspar phenocrysts. The rock also presents a blotched appearance and this is all that remains of the original breccia character. That any trace of this primary structure remains at all is due to the fact that some of the original fragments were very high in feldspar phenocrysts, so that, in the alteration, they have given a patch somewhat lighter in colour than the rest of the rock. In still more highly altered material even this feature has disappeared and the rock is entirely without sign of its original character. It is an aggregate of white mica, calcite, serpentine, chlorite, colourless amphibole, and quartz. Under the microscope the serpentine and chlorite can be seen aggregated here and there, such aggregations probably representing former ferromagnesian minerals, but, on the whole, no trace of the original crystals remains. Microscopic veins of calcite and of quartz are numerous. Many similar veins are also visible in hand specimens and due to these veins, many of which are open in the centre, the rock is much more open textured than in any of the other phases of the alteration. There has been considerable introduction of new material, principally calcite with some quartz and a little sulphide.

In the less altered material, the dominant process seems to have been one of alteration of the material already present. In the more advanced stages of the alteration of the rock there has been an ever increasing addition of material. The materials introduced, carbonate and silica, become more and more the important components of the system, until finally there results a replacement of the rock by carbonate and silica. This is a dense, whitish to light brown, rock with a somewhat conchoidal fracture and with, in some cases, the lustre and appearance of flint. It is, however, easily scratched with the knife and effervesces with acid. Cubes of pyrite are present and thin veins of compact calcite traverse it.

Though, for purposes of description, these phases of the alteration have been described as though they were quite distinct, it must be remembered that in the field all variations, from completely altered to fresh porphyrite, occur and, in some cases, in most confusing relationships. In the Topley Richfield mine the rock alteration has been further complicated by later shearing which broke up and brought together in perplexing relationships, completely altered rock, black sheared porphyrite, and fragments of quartz veins.

Origin of the Mineral Deposits

The origin of the mineral deposits has not been established. It has been stated that the chief mineral deposits occur in porphyrite breccia in an area that shows considerable epidotization. If, however, the epidotization is related to a late stage in the consolidation of the porphyrite breccia its relation to much later mineral deposits must be remote, in which case the association of mineral deposit and epidotized areas is fortuitous.

It is probable that a strong fracture fault or shear zone existed at the Topley Richfield deposit prior to its deposition and if so this suggests that the area as a whole was consolidated prior to the fracturing. The parallelism of several veins, e.g., those on the Golden Eagle and Box groups, suggests for their pre-ore fractures a common regional origin which also suggests that the area as a whole was consolidated prior to mineral deposition.

It seems, therefore, that the source of the ore is intrusive rock younger than the porphyrite breccia. This intrusive may be represented by the rhyolite, which occurs in the area, or it may be still younger and if so does not outcrop in the area.

The veins of type 2 show such a close relation to the rhyolite that there seems little doubt that they have been derived from that magma. In some cases their form suggests that they are segregations from the rhyolite, since they form small, irregular masses completely enclosed by that rock.

Oxidation, Etc.

In the deposits examined the oxidized zone is of very small depth, and in some cases is practically absent. The minerals found are iron hydroxide, malachite, azurite, and, in one case, a few small crystals of chalcanthite. The evidence so far available indicates that very little if any secondary enrichment is to be expected. Below the shallow oxidized zone, the minerals of the veins appear quite unaltered and of primary generation.

DESCRIPTION OF PROPERTIES

TOPLEY RICHFIELD MINE[1]

The Richfield group of mineral claims is north of Richfield creek at the base of Tachick mountain 8 miles from Topley. A good automobile road connects the property with the Canadian National railway and the Hazelton-Vancouver highway at Topley.

The claims were staked in June, 1920, by F. H. Taylor and Wesley Banta and were known then as the Red Top group. The property was taken under option by the Standard Silver Lead Mining Company who did some 700 feet of underground work before relinquishing the option in July, 1927. In the autumn of 1927 Mr. Taylor organized the Topley Richfield Mining Company, Limited, to develop the property, which then became known as the Richfield group of claims or the Topley Richfield mine. Mr. Taylor is the general manager at the mine and since commencing operations late in 1927 has maintained continuous underground development.

The country rock at the mine consists of fragmental volcanic rocks referred to in this report as porphyrite breccia. Because glacial drift is thick and plentiful, bedrock can be seen practically only in the mine workings. The rock is strongly sheared locally and near the mineral

[1] Ann. Rept., Minister of Mines, B.C., 1927, pp. 140-147; 1926, pp. 121, 122, 138-143.

deposits is intensely altered to a soft rock consisting chiefly of magnesium and calcium carbonates. This alteration product is known locally as "topleyite" and has been discussed in preceding pages.

One zone of post-ore shearing is so far known. It is exposed by the mine workings and lies chiefly west of the mineral deposits, but also includes them in some places. The sheared zone has not been completely crosscut, but it is more than 75 feet wide. The sheared rock is a fissile, soft, chlorite schist. Some shearing probably took place prior to mineral deposition and some, if not all, certainly took place later. Fragments of altered wall-rock and of ore in the shear zone adjacent to the ore-body show clearly that some of the shearing took place after the ore was deposited.

Two mineral deposits occur on the Richfield group and are known locally as the "North vein" and the "East vein". All of the underground work except diamond drilling has been done on the "North vein."

The "East vein" is about 370 feet east of the most northerly known point on the "North vein". It strikes north and dips 65 degrees west. Open-cuts prove a length of 100 feet and a width of 3 feet. This is a clear-cut vein occupying a single fissure. It is roughly banded in that one of the constituents, tetrahedrite, is commonly present in narrow bands a quarter of an inch or more wide. The vein consists of quartz and the sulphides, pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite. The pyrite is disseminated through the quartz. Sphalerite is fairly abundant and is in most places of a normal resin colour, but is in some places yellowish green. Chalcopyrite is not so plentiful as sphalerite. Galena is fairly abundant and has been rendered gneissic by post-ore earth movements. Tetrahedrite is fairly abundant and commonly occurs in fine bands. Two diamond drill holes drilled to intersect the "East vein" showed narrow mineral deposits slightly below commercial grade from 100 to 200 feet below the surface. These, although not commercial, contain 0·6 to 0·2 ounce of gold and from 1 to 4 ounces of silver per ton. It is not known whether these deposits are to be correlated with the vein sought. A crosscut has been driven east 400 feet from the workings on the "North vein" to intersect the "East vein". This crosscut about 150 feet below the outcrop of the "East vein" exposes some half a dozen clear-cut quartz sulphide stringers up to 6 inches wide, but although it had gone beyond the point where the "East vein" was expected, it had not encountered any larger veins that could be correlated with the "East vein" at the time of the writer's visit in early September, 1928. Further development will be necessary to prove the value of this vein.

The "North vein" has been developed by two shafts, by some 2,000 feet of drifts and crosscuts, and by several diamond drill holes below the level of the drifts. A shaft sunk on the discovery outcrop of the deposit follows it downward about 70 feet on a dip of about 50 degrees. Drifts were driven north and south from the shaft, and later the second shaft was sunk for purposes of ventilation. The drifts about 50 feet below the collar of the discovery shaft extend south 100 feet and north 750 feet. Crosscuts have been driven east at distances of 60, 220, and 570 feet north of the shaft, the one at 570 feet being the one driven to cut the "East vein". Crosscuts to the west are at the shaft, and at distances of 100, 140, and 400 feet north of the shaft. The ground rises to the north, so that at the beginning of the "East vein crosscut" the drift is 100 feet below the surface.

The development has shown that the "North vein" is not a single mineral deposit, but consists of veins and replacement deposits. The northern part of the workings expose a definite quartz sulphide vein striking north 30 degrees east and dipping 45 degrees west. The vein is 280 feet long and 3 to 12 feet wide. It consists essentially of quartz and pyrite and where exposed in the workings is below commercial grade. About 220 feet north of the shaft, near the south end of the quartz-pyrite vein first mentioned, a horizontal quartz sulphide vein has been followed east for 100 feet. South of the shaft a drift driven south for 100 feet encounters two vein-like replacement deposits each several feet wide and about 5 feet apart. They strike north 30 degrees east and dip 45 degrees to 10 degrees west. They may be faulted portions of a single deposit. In any case the deposits appear to enter the east wall of the drift and the northward continuation should pass east of the shaft. Another definite vein is exposed in the crosscut to the east, 60 feet north of the shaft. The strike of this vein is about north 30 degrees east and the dip is vertical. Between the shaft and the flat vein 220 feet farther north are at least three tabular replacement deposits, each several feet thick and 2 to 6 feet apart. They strike roughly north 30 degrees east and dip at varying angles west. The southward continuation of these deposits should pass west of the shaft. These deposits are folded and broken. Diamond drill holes drilled from the surface to explore the "North vein" at depths ranging from 100 feet to 400 feet had at the time of the writer's visit failed to locate any ore-body that can be definitely correlated with deposits in the mine workings, although they did penetrate several mineral bodies. This condition is not to be wondered at, as the deposits are very irregular and until they are followed downward for some distance along the dip very little can be known of their probable location at greater depth. According to a report by J. M. Turnbull, consulting engineer for the company, issued in January, 1929, further diamond drilling has been done from underground stations with the result that commercial ore has been found in several places below the drift level.

The deposits, particularly the replacement deposits, appear to be rather short. Faults are numerous and it is quite possible that a solution of all the fault problems would indicate one or more fairly regular deposits. Shearing has also broken the deposits. It is likely, however, that several replacement deposits occur which are perhaps lenticular in shape.

The replacement deposits are dark in colour, in general darker than the enclosing rock. The material of the deposits is hard and consists of quartz and calcite or dolomite and the sulphides pyrite, arsenopyrite, sphalerite, chalcopyrite, galena, and tetrahedrite. The sulphides are fairly uniformly distributed through the gangue. From microscopic study of polished specimens of replacement ore it can be seen that pyrite, arsenopyrite, and quartz were deposited first. These early minerals were crushed and fractured and at this time and later came sphalerite and chalcopyrite. Clearly later than the narrow crushed zones in the early minerals are galena and tetrahedrite. Still later earth movements are indicated by gneissic galena. Later still the whole deposit was fractured and the fractures filled with a carbonate which is chiefly dolomite.

As development work in the area is so far not extensive and as surface rock exposures are infrequent the extent and nature of the locus of the ore solutions causing the ore deposits at the Topley Richfield are not known. It is possible that prior to ore deposition a shear or fracture zone of considerable extent existed striking north 30 degrees east and that the deposits of the Topley Richfield mine were formed in this zone.

GOLDEN EAGLE GROUP[1]

The Golden Eagle group of claims is on Richfield creek 7½ miles from Topley. The property is controlled by a company known as Topley Silver, Limited.

The mineral deposit is in fragmental volcanic rocks and consists of a narrow, quartz-sulphide vein. It is a few inches to 2 feet wide and has been traced for 300 feet along the strike by open-cuts and three shafts. It strikes northwest and dips 35 degrees northeast. Two of the shafts were full of water at the time of the writer's visit and the vein in them could not be examined. In the deepest shaft, 90 feet deep, the wall-rock has been altered to a light-coloured rock for a distance of 2 feet from the vein. The alteration has been effected by the introduction of sericite, calcite, chlorite, and pyrite. The vein consists of quartz mineralized with pyrite, sphalerite, chalcopyrite, galena, tetrahedrite, and probably polyargyrite. It contains for the whole depth of the shaft a band of sulphide 4 inches or more thick on its hanging-wall side. The vein is drusy and holds well-formed crystals of quartz and sphalerite. A peculiarity of the mineralization is the colour of the sphalerite which is a pale or yellowish green. The vein contains rather high-grade silver ore and for this reason, even though it is narrow, is worthy of considerable development.

CUP GROUP[2]

The Cup group of three mineral claims is on Richfield creek about 7 miles from Topley.

Some development was done on the property in 1924 by Frank Chettleburgh of Telkwa, B.C., who in that year held an option on the claims. In 1927 further work was done by the Topley Consolidated Mining and Development Company, Limited. In 1927 this company went into liquidation and the property reverted to the original owner.

The mineral deposit consists of one or more quartz-sulphide veins lying in fragmental volcanic rocks. The veins are practically horizontal and outcrop in the canyon of Richfield creek. The outcrops have been broken into by open-cuts and by five short tunnels and in this way vein outcrops have been traced for a quarter of a mile. The veins exposed in the various tunnels are similar in general appearance and may be parts of a single vein.

The veins vary in width from a few inches to 4 feet and consist of quartz mineralized with pyrite, sphalerite, chalcopyrite, and galena. Assays show that the vein matter contains half an ounce or less of silver per unit of lead.[3] Sulphide mineralization is in general rather sparse, but small local shoots of sulphide occur where the vein consists chiefly of galena.

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[1] Ann. Rept., Minister of Mines, B.C., 1927, p. 148.
[2] Ann. Rept., Minister of Mines, B.C., 1927, pp. 147, 148; 1924, p. 98.
[3] Ann. Rept., Minister of Mines, B.C., 1927, p. 148; 1924, p. 98.

BOX GROUP[1]

The Box group of four mineral claims adjoins the Golden Eagle group and is on Richfield creek about 7½ miles from Topley.

The mineral deposits are veins in a country rock of feldspar porphyry-breccia. The wall-rocks are whiter close to the veins than farther away, the colour being due, probably, to sericite and calcite. Two veins are known. They strike northwest and dip steeply northeast. The veins are 1 to 4 feet wide and one of them has been traced by open-cuts for a distance of 300 feet. They contain pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite, in a quartz gangue. The galena and tetrahedrite are silver bearing. Mr. Lay cites one assay which shows that locally at least the vein matter contains 2 ounces of silver per unit of lead.[2] An attempt should be made to trace the veins farther along the surface.

EVERGREEN GROUP

The Evergreen group of mineral claims are on McCrea mountain about 6½ miles from Topley.

Two veins are known on the property. They occur in volcanic rocks; are about 500 feet apart, are roughly parallel, and strike north. Each vein has been traced by open-cuts, trenches, and shallow shafts for 300 feet. The veins are a few inches to 3 feet wide and consist of quartz, barite, calcite, and specularite, and a little pyrite, sphalerite, and chalcopyrite. No ore of commercial importance has yet been found.

MCCREA AND KYLLING CLAIMS[3]

Several mineral claims staked by Messrs. Kylling and McCrea of Topley are on the south side of Cesford creek about 4½ miles from Topley.

The country rock is of rhyolite and rhyolite breccia. An oblong body of diabase 150 feet wide also occurs in the vicinity, but its relationship to the rhyolite is not clear. Open-cuts have been made in the rhyolite which in some places contains disseminated pyrite, chalcopyrite, specularite, and chlorite. The material is too low grade to be ore. The diabase is commonly amygdaloidal, contains a great deal of epidote, and in several places contains narrow veins of quartz and specularite.

HAVEN'S CLAIMS

Mr. Haven has explored the contact between the feldspar-porphyry breccia and the underlying sedimentary material at the northern end of Tachick mountain. A cut about 5 feet wide and exposing a face of rock about 6 feet high has been made, but so far no reliable signs of any mineralization have been discovered. The reddish weathering of the formation at this point is due to the presence of a shaly bed which crumbles easily under the action of the water seeping down from the mountain.

[1] Ann. Rept., Minister of Mines, B.C., 1927, pp. 148, 149.
[2] Ann. Rept., Minister of Mines, B.C., 1927, p. 148.
[3] Ann. Rept., Minister of Mines, B.C., 1926, p. 144.

CLAIMS AT THE NORTHWEST CORNER OF TACHICK MOUNTAIN

On the lower slopes, at the northwest corner of Tachick mountain, the granite is exposed on a small knoll. Between it and the feldspar-porphyry breccia there are irregular patches of limestone, which contain pyrite. Claims have been staked here, but it is probable that the pyrite is not to be referred to ore-forming agencies, but rather to the action of hydrogen sulphide generated locally in the adjacent material at the time of its formation. Considerable prospecting has also been carried out on the granite which contains some irregular quartz veins. The latter are segregations from the granite and if similar to those met elsewhere in the area will probably not carry any mineral values.

WATSON'S PROSPECTS

These are about the middle of the mountain between Cesford and Ailport creeks, one at the top of the mountain and one at the base. The former consists of a very narrow zone of sheared feldspar-porphyry impregnated with pyrite. The strike of the mineralization runs about north-south. Some copper staining is present and specularite occurs which would seem to relate the mineralization to that found at the western end of the mountain on the McCrea and Kylling claims. Rhyolite intrudes the feldspar-porphyry a little to the north. The mineralization at the base of the mountain also occurs in feldspar-porphyry. The rock is greyish green and contains many veinlets of epidote. There is a considerable zone of oxidized rock, and the main zone of the rock, which may contain ore, runs about 5 degrees south of west. The mineralization observed consists of quartz, pyrite, and chalcopyrite.

The operations at both of these prospects consist of shallow pits.

AILPORT'S PROSPECT

The claims staked by Mr. Ailport are on the eastern side of the gorge of Ailport creek. The rock is of the feldspar porphyry-breccia type, but has been greatly broken by faulting. This zone of faulting has determined the course of Ailport creek and can be followed southwards towards Six-mile creek which is just to the south of the map-area. Within the faulted zone are many calcite veins of varying width. The veins cross one another and all dip steeply either to the west or east. Green cupriferous staining occurs in many of them. The vein opened up by Mr. Ailport strikes 10 degrees east of north and dips about 80 degrees east. It is about 12 inches wide and there are thinner parallel veins in the wall-rock. The gangue minerals are barite and calcite. Though cupriferous staining occurs, sulphides are rare; only a little chalcopyrite and one or two specks of galena were observed. At the time of the writer's visit, however, very little development had been carried out, and it was practically only the outcrop that could be seen.

JOHNNY DAVID'S PROPERTY

Johnny David's property is situated about 3 miles north of the main road, in a small gully about a quarter of a mile east of the eastern fork of Johnny David creek. Although practically all the surrounding country is drift covered, rock is exposed in the sides of this gully and at the time of the visit a continuous exposure of the rock was being made by a stripping about 180 feet in length running along the side of the gully which runs about 60 degrees east of north. This stripping shows a zone of sheared and altered feldspar-porphyry. The zone is traversed by bands of completely altered and mineralized rock, these bands run about 55 degrees or so west of north and dip about 60 degrees to the west. The best bands are at the western end of the stripping and there vary in thickness from mere stringers to about 6 inches. In the middle of the stripping there is a band of comparatively unaltered rock containing only a little sulphide, towards the eastern end the alteration again becomes complete though the amount of sulphide is very small. The sulphide present is chalcopyrite. The gangue is mostly carbonate with a little quartz.

East of the workings the rock is much less altered and is feldspar-porphyry breccia. The same rock is met in the small gorge of the east fork of Johnny David creek and also farther west in the gorge of Johnny David creek. In many of the exposures there are zones where alteration to carbonate material has been complete and where pyrite occurs. No signs of a heavy mineralization were, however, encountered.

CLAIMS ON BYMAN CREEK

On Byman creek about a mile north of the main road, openings have been made in the rock-walls of the gorge. This gorge is along a zone of faulting which has involved sandstones, shales, and volcanic rocks believed to be at the base of the Tertiary series. The rocks are thoroughly broken and have been extensively veined by calcite probably derived from the calcareous rocks. The veins here and there contain some pyrite. Prospecting has been done on them, but it is most improbable that veins so formed will carry any values in gold and silver.

LUCKY SUNDAY GROUP [1]

About 500 yards east of Perow station on the southern bank of Bulkley river a small rock exposure 100 feet or so in length emerges from the drift which covers practically all of this area. On the eastern part of the exposure the rock is feldspar porphyry breccia. The rest of the exposure consists of streaked white and black material, the white being quartz and calcite, the black altered rock. The quartz and calcite bands are very thin and all strike about 10 degrees west of north and dip about 70 degrees west. A little pyrite and a few grains of chalcopyrite were identified in some of the bands, but no signs of a heavier mineralization were seen.

[1] Ann. Rept., Minister of Mines, B.C., 1927, p. 149.

GUN CREEK MAP-AREA, BRITISH COLUMBIA

By V. Dolmage

CONTENTS

Illustrations

INTRODUCTION

Gun Creek map-area embraces about 550 square miles, is roughly square in outline, and derives its name from Gun creek, a large stream which follows a southwest course diagonally through the southern half of the area and joins Bridge river a few miles to the south. The area is about 100 miles north of Vancouver. The intersection of longitude 123 degrees and latitude 5]1 degrees is centrally situated within the area. It may be convenient y reached from Vancouver via the Pacific Great Eastern railway to Bridge River station on Seton lake and thence by motor road up Bridge River valley to near the mouth of Gun creek where the Gun Creek trail branches to the northwest leading diagonally through the area, over Warner pass, and down Taseko valley. From here, trails lead north to the Chilcotin road, which joins the Pacific Great Eastern railway at Williams Lake, which is 120 miles beyond Bridge River station. The northern part of the area is more easily reached by this longer but lower route, particularly during a considerable part of the season when Warner pass is filled with snow. Several good trails branch from the Gun Creek trail to various parts of the district, and much of the area northeast of Gun creek is so open that horses may be taken to almost any part.

During the three months spent in the field, the entire area was mapped topographically and geologically on a scale of 2 miles to the inch. The topographical mapping was greatly facilitated by an excellent triangulation net established in 1925 by Mr. John Davidson of the British Columbia Department of Lands. Six of his triangulation stations on well-chosen peaks and marked by large, well-constructed cairns, lie within the area, and several others within short range of it. The writer was assisted in the field by A. H. Lang, H. C. Horwood, and C. S. M. Camsell. All the topographical mapping was done by Mr. Horwood.

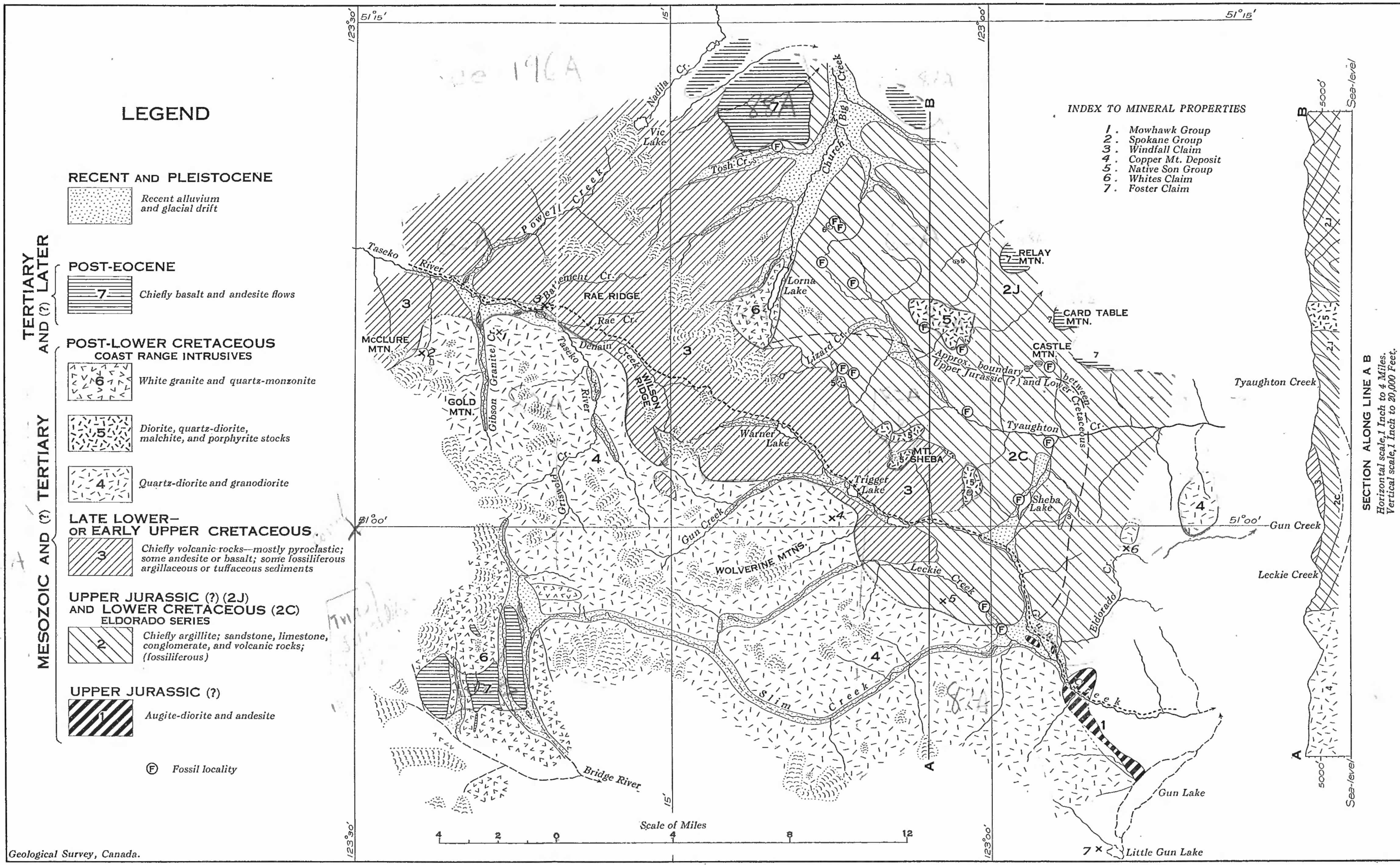

Figure 5. Gun Creek area, Lillooet district, B.C.

Parts of the area had been previously mapped by Bateman[1], Camsell[2], and MacKenzie[3]; Bridge River area adjoining on the south was mapped by Drysdale[4] and McCann[5]; and Dawson's[6] classical Kamloops area lies only a few miles to the southeast. In 1911 Camsell[7] spent 8 days in a quick reconnaissance of Bridge river and Cadwallader creek. In 1912 Bateman made a reconnaissance through Gun Creek area and beyond to Chilko lake and published a brief but clear description of the geology bordering the route travelled. In 1918 Camsell returned to the region to investigate the copper deposits west of Trigger lake; his report contained a description of the geology of the general region. In 1920 J. D. MacKenzie made a thorough examination of the limonite deposits of Taseko valley and mapped in detail an area of about 35 square miles. Later in the season he made a reconnaissance survey up Gun creek, across by Spruce lake to Tyaughton creek, and thence east to Fraser river. His report includes a small-scale geological map of the route.

CHARACTER OF THE DISTRICT

Mountains

The area lies along the eastern margin of the Coast range of British Columbia, and, except for a very small section in the extreme northern part which reaches to the edge of the Interior Plateau, the whole area is extremely mountainous. The peaks and ridges rise from 7,000 to 10,000 feet; some of the deeper valleys are cut down to an elevation of 3,000 feet, giving in places a maximum relief of 7,000 feet. Three types of mountains can be distinguished by well-defined characteristics depending largely on their geological structure. West and south of Gun creek are the high, rugged, granitic mountains of the Coast Range proper, occupied by many great glaciers and extended snow-fields. Between Gun and Tyaughton creeks is a range of almost equally lofty but much less rugged mountains. These have smoothly rounded slopes, composed of soft, crumbling sediments, culminating in sharp pinnacle-like peaks composed of porphyry intrusions and mainly occupied on their northern slope by one or two glaciers the perpendicular cirque walls of which accentuate the spire-like sharpness of these somewhat isolated peaks. Sheba, with her twin nipples rising abruptly above full rounded slopes to an elevation of over 8,000 feet, is the most conspicuous of these mountains and is the best known landmark of the entire region. East of Tyaughton the mountains are composed of the same soft sediment and have similarly rounded slopes, but instead of culminating in sharp pinnacles of porphyry they are topped by small remnants of flat-lying basalt flows that give them mesa-like outlines. The most prominent as well as the most beautiful of these are Card Table and Castle mountains, shown in Plates I and II.

[1] Bateman, A. M.: Geol. Surv., Canada, Sum. Rept. 1912, pp. 180–210.
[2] Camsell, Charles: Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 25.
[3] MacKenzie, J. D.: Geol. Surv., Canada, Sum. Rept. 1920, pt. A.
[4] Drysdale, C. W.: Geol. Surv., Canada, Sum. Rept. 1915, pp. 75–85; 1916, pp. 45–53.
[5] McCann, W. S.: Geol. Surv., Canada, Mem. 130.
[6] Dawson, G.M.: Geol. Surv., Canada, Ann. Rept. 1894, pt. B.
[7] Camsell, Charles: Geol. Surv., Canada, Sum. Rept. 1911, pp. 111–115.

Valleys

The valleys, particularly those of the western part, have been extensively modified and enlarged by valley glaciers to which their present configurations are almost entirely due. Their dimensions are out of proportion to the size of the streams that now occupy them. They have broad, sweeping curves, flat but locally irregular bottoms with many lakes and post-glacial canyons cut through glacial debris and into the solid bedrock in places to a depth of 50 feet. The sides of the valleys are made up of series of faceted spurs alternating with hanging tributary valleys. In many places long, graceful talus slopes reach from lofty, perpendicular cliffs down to the flat floor of the valley. The larger valleys terminate in large, open basins above timber-line and have great stretches of open, grassy slopes such as those at the head of the Bridge, shown in Plate I B.

Drainage

The southern part of the area is drained by Gun and Tyaughton creeks, both of which are tributaries of Bridge river; the northern half is drained by Church (Big) creek and Taseko river, both of which discharge into the Chilcotin which enters Fraser river 40 miles south of Williams lake.

Immediately northeast of the area the mountains dip down to the level stretches of the Interior Plateaux of British Columbia, which in this general region are largely covered by basalt flows.

GEOLOGY

The outstanding geological feature of Gun Creek area is the eastern contact of the Coast Range batholith, which runs through the central part of the area from northwest to southeast. West of this contact the area is occupied almost entirely by the rocks composing the batholith, quartz-diorite and granodiorite; to the northeast of this contact the area is underlain largely by two formations, in the north the Cretaceous volcanics and in the south the Lower Cretaceous sediments known as the Eldorado series. The remaining formations, some younger and others older, occupy relatively small areas and are of correspondingly small importance.

BRIDGE RIVER SERIES

The oldest formation of this general region is known as the Bridge River series. It occupies a wide belt of country stretching to the southeast through Bridge River map-area and beyond Fraser river, where it forms part of the Cache Creek series, as defined by Dawson, which is of Carboniferous age. The Bridge River series adjoins, but does not extend into, Gun Creek map-area and lies just east of the body of augite diorite shown on the map to extend from Gun lake to Gun creek. This series consists mainly of thin-bedded, contorted quartzites interleaved with thin layers of schistose argillaceous material, but includes also considerable volcanic material, now in the form of greenstone, and a few short, thick lenses of limestone.

AUGITE-DIORITE STOCKS

The oldest formation shown on the accompanying map is the body of augite diorite that extends from Gun lake to Gun creek. The boundary of the map was extended to include this body of rock because of its probable economic importance. All the gold-quartz veins of Cadwallader Creek area, which lies only a few miles south of Gun lake, occur within this rock. Figure 5 shows two other very small bodies of this or similar rock in Gun Creek valley near the mouths of Leckie and Eldorado creeks. The rock is black to dark green and is very irregular in grain, varying abruptly from fine to medium within short distances. It consists primarily of augite, plagioclase, hornblende, and orthoclase, but small amounts of chlorite, zoisite, sericite, and calcite are present as alteration products, and smaller amounts of magnetite and titanite as accessory minerals.

The augite diorite is intensely fractured and veined by quartz. The fractures are short, straight, usually less than one-quarter inch in width, and filled with quartz. They conform closely to two main directions, striking northeast and northwest respectively. In Cadwallader mining district a few of these veins are 3 to 6 feet wide and contain valuable amounts of gold associated with small quantities of arsenopyrite. Some of these ore veins follow the northwest strike, whereas others follow the northeast. No veins of ore have as yet been found in the augite diorite of Gun Creek area.

The stocks of augite diorite cut rocks of Triassic age in Bridge River area, but their relations to the younger rocks have not been determined. They are thought to be late Jurassic.

ELDORADO SERIES

A large section in the northeastern part of Gun Creek area is underlain by a thick series of steeply folded sediments, well known in the adjoining map-area as the Eldorado series. In Gun Creek district they occupy virtually all the area east of Church (Big) creek, northeast of Sheba mountain, and north of Gun creek. To the west these rocks pass beneath the Cretaceous volcanics, to the southwest they are cut off by the Coast Range batholith, and to the east they are covered by extensive flows of Miocene lavas.

The beds composing the Eldorado series consist mainly of argillite, but many beds of sandstone, conglomerate, and lenses of limestone as well as a few layers of volcanic material are also present. The upper and lower horizons contain very little else than argillite with some fine sandstones. In the central part of the formation is a well-defined zone to which almost all the conglomerates, limestones, and volcanic material are confined, but which also contains much argillaceous material. In the upper horizons are several sandy layers thickly crowded with fossils, mainly of various species of *Aucella*. In the argillites, in places, ammonites are fairly plentiful and in ~~the~~ limestone lenses, particularly those near Castle mountain, are several species of corals and gasteropods.

The conglomerates are both fine and coarse, but the latter predominate greatly. They consist mainly of well-rounded pebbles up to 6 inches in diameter and average over 3 inches. These pebbles are composed of chert, quartzite, limestone, argillite, and volcanic material cemented in a fine matrix of the same materials but very small in amount. In most beds the chert pebbles predominate, but limestone pebbles are always abundant and entirely constitute some of the conglomerates. A striking feature of one of these beds of conglomerate is the great size and angularity of some of the limestone fragments. Large pieces up to 4 feet in length with sharp angular corners and re-entrant angles were observed. Angular fragments of argillite also are present and mixed with these large numbers of rounded pebbles of limestone and chert. The chert pebbles can be easily identified as having come from the Bridge River series and the rounded pebbles of limestone probably also came from the same series. One of these was found to contain fossils of *Bryozoa*, one of which, though not well preserved, strongly resembles *Fenestella*. The angular fragments of limestone and shale appear to have originated in the nearby beds of argillite and limestone, probably as the result of some sudden change in slope due to some movement that occurred before they were solidified. The conglomerates have been carefully described by MacKenzie.[1] The thickness of the formation is at least 20,000 feet.

The beds of the Eldorado series are steeply, and in places intricately, folded and over considerable areas are nearly vertical. In general, however, they conform to a large synclinal fold the axis of which strikes and plunges fairly steeply towards the west from a point a few miles east of Castle mountain. This syncline is indicated by the trend of the well-defined zone which includes the limestone and conglomerate lenses. To the northeast of this fold, in the neighbourhood of the head of Tyaughton creek, the dips are reversed, indicating anticlinal axis in this vicinity.

To the west, the Eldorado sediments pass under the Cretaceous volcanics. In Gun Creek valley and at the head of Lizard valley the two formations are conformable. Along the summit of Sheba ridge the contact is well exposed, but the mutual relations of the two formations are not so simple. In general the volcanic series is less steeply folded than the much more incompetent sediments. In the vicinity of the contact the latter are sheared and buckled against the volcanic rocks and in places stand at higher elevations than those required by the normal dip of the contact. Also a considerable part of this contact is occupied by the porphyry stocks which form the sharp peak of this ridge. The greater intensity of the folding in the sediments may be accounted for by their greater incompetency.

The relation of the Eldorado series to the Coast Range batholith is clearly an intrusive one and considerable metamorphism is in evidence. In Leckie creek a highly fossiliferous bed near the contact is largely converted to epidote and garnet and many of the fossils are replaced by pyrite and pyrrhotite. To the east the Eldorado series is overlain unconformably by extensive flows of basalt of Miocene age. Only a few small remnants of this lava extend into the map-area and cap some of the mountains in the vicinity of Relay creek.

A number of fossil localities were found in the region occupied by Eldorado series and a fairly large number of species collected, but the age determinations are based largely on species of *Aucella*. The fossils

[1] MacKenzie, J. D.: Geol. Surv., Canada, Sum. Rept. 1920, pt. A, p. 75.

were studied by F. H. McLearn of the Geological Survey who reports that the fossils from localities lying stratigraphically above the zone of conglomerate and limestone lenses are of Upper Knoxville, and, therefore, Lower Cretaceous age; that those from localities close to this zone are either Upper Jurassic or Cretaceous; and that collections from four localities stratigraphically below this zone are probably Lower Knoxville which is now believed to be Upper Jurassic. From these observations it seems very probable that the Eldorado series ranges in age from Upper Jurassic to Lower Cretaceous. A. M. Bateman[1] found fossils in this same series of sediments which contained Upper Knoxville species of *Aucella*, but he does not specify the localities.

CRETACEOUS VOLCANICS

About one-third of the area is occupied by a thick series of fresh-appearing and only slightly folded volcanic rocks which overlie, for the most part conformably, the Eldorado sediments. They outcrop in the northwestern part of the area and are particularly well developed in the mountains north of Taseko valley. They consist mainly of explosive ejecta with smaller amounts of lava in the form of thick, massive flows. Both the lava and the pyroclastic material are andesitic or basaltic in composition and porphyritic in texture. The lavas are dark green to black, whereas the fragmental material is often bright green or purple, and in some beds the two colours are nicely blended. The fragments composing the pyroclastic materials consist entirely of porphyritic andesite and basalt which do not differ greatly in composition from one another, and are like the lava of the flows and the finer matrix in which they are enclosed. No fragments of foreign material could be found in any of the beds. The clastic material is coarsest in its southern part where the fragments average about 2 or 3 inches in diameter and are mostly well rounded. A well-marked bedding is everywhere evident and the structure is thereby easily seen. In the lower part of the formation are several layers of black, argillaceous and tuffaceous sediments, in places thickly crowded with plant remains. Near Battlement creek one of the tuff beds, 50 to 60 feet thick, has been silicified to a marked degree for several miles. The silicification is almost complete, but the replacement of the original component fragments is so perfect that their outlines are still clearly visible. Many small cavities lined with small, clear crystals of quartz are abundant throughout the bed. Pyrite in the form of well-developed pyritohedrons, averaging a quarter of an inch in diameter, is sparingly disseminated throughout this bed. In one section, near the mouth of Battlement creek, are white quartz porphyry dykes and several veins consisting mainly of tourmaline, but with much quartz and rutile. One of these veins, though only a few inches wide, contains surprising quantities of easily visible gold.

Several hundred feet higher on Rae ridge is a similarly altered and pyritized bed of much finer tuff which can be traced along the ridge for nearly 4 miles. Owing to the porosity of the bed, the large content of pyrite, and the angle at which the bed intersects the mountain sides, large quantities of surface waters have been able to percolate through it, remove

[1] Geol. Surv., Canada, Sum. Rept. 1912, pp. 192–193.

much of the pyrite, and deposit its iron content in Battlement, Rae, and Feo valleys in the form of limonite beds of considerable extent. On Wilson ridge and McClure mountain similar pyritiferous deposits have yielded even larger beds of limonite. These have been fully tested and described by J. D. MacKenzie.[1] The thickness of the formation must be in places over 10,000 feet.

As previously stated, these volcanic rocks overlie the Eldorado sediments in places conformably. They are only gently folded and, except the above-mentioned altered beds, the rocks are decidedly fresh. They are intruded by dykes and apophyses of granodiorite, all of which probably, and most of which certainly, belong to the Coast Range batholith which occupies immense areas immediately to the south and west.

The intrusive relation of the Coast Range batholith to these rocks was definitely determined in several localities and is particularly well shown on Wilson ridge, McClure mountain in Taseko valley above Battlement creek, and at the head of Denain creek. In none of these localities has the comparatively low dips of the tuff beds been disturbed. Dykes and apophyses are numerous and metamorphism in places is pronounced.

These volcanic rocks are also pierced by a stock of white granite near Lorna lake in which rises the main branch of Church (Big) creek. This granite is correlated on lithological grounds with the white granite about the head of Bridge river. To the north and east the tuffs are overlain unconformably by Tertiary basalts.

From the carbonaceous beds of this formation and from three different localities collections of plant fossils were taken. One of these collections was sent to Dr. Edward W. Berry of Johns Hopkins University who reported that the material was too poorly preserved for a positive determination of any of the plants, but that the fossils strongly indicated the age of the beds to be pre-Tertiary and post-Lower Cretaceous. He remarks further "Insofar as the indefinite character of the fossils permits a tentative opinion I should say that the horizon is early Upper Cretaceous and perhaps not very different from that of the Upper Blairmore east of the mountains. It might be late Lower Cretaceous, but the evidence is slightly more favourable to the preceding opinion." Collections made in 1928 from what appear to be the same beds in the lower part of Powell creek, about 3 miles from the above locality, were examined by W. A. Bell of the Geological Survey, who found, among much poorly preserved material, fragments of two fern species, *Microtaenia variabilis* Knowlton and *Tapeinidium? undulatum* (Hall) Knowlton. From the presence of these ferns Mr. Bell concludes that the horizon is probably of Colorado or Montana age, both of which are early Upper Cretaceous. These determinations, together with the facts that the series overlies Lower Cretaceous rocks and that the beds are intruded by the Coast Range batholith, leave little doubt that these beds are early Upper or late Lower Cretaceous. The relations of the series to the Eldorado series and the Coast Range batholith rather favour the late Lower Cretaceous age.

[1] Geol. Surv., Canada, Sum. Rept. 1920, pt. A, p. 42 *et seq.*

COAST RANGE INTRUSIVES

Quartz, Diorite, and Granodiorite

Almost the entire area south of Gun creek and Taseko river is occupied by quartz diorite and granodiorite, which area is part of the huge mass known as the Coast Range batholith. The two rock types are composed essentially of quartz, plagioclase, hornblende, biotite, and orthoclase, and differ only in respect to their content of orthoclase and biotite, and the proportions of these minerals vary in such a way as to form gradations between the two rock types. A few pegmatitic segregations in Gun Creek region are characterized by the presence of conspicuous amounts of tourmaline with the usual quartz, orthoclase, albite, and biotite.

The Coast Range batholith is the principal source of the metalliferous deposits of the region and is actually the host of several large, low-grade segregations of copper minerals. These deposits occur along the margin of the batholith where the granitic rocks have been rendered porous either by fracturing, as in the case of three of the deposits situated in Taseko River country, or as the result of the development of a peculiar orbicular structure, as in the case of the so-called Copper Mountain deposit situated a few miles west of Trigger lake (*See* pages 88-93).

The age of this great batholith has long been a contentious problem, but the mass of evidence bearing on it has been growing steadily. In the region under review the batholithic rocks were found intruding Lower Cretaceous beds which had previously been folded into a perpendicular posture. Also, they were found to intrude the Cretaceous volcanics which overlie the sediments and which are shown by structural and palæobotanical evidence to be of late Lower or early Upper Cretaceous age. Similar evidence was found in adjoining areas, so that it can be definitely stated that a very large part of the batholith is post-Lower Cretaceous. What formerly seemed to be conflicting evidence is now explained by the fact that the batholith is composite in structure and made up of intrusions of magma similar in composition but different in age. Because of this complexity of the batholith in other localities and of its post-Lower Cretaceous age in this area, a section 12 miles in width was explored in search of a contact with an older part of the batholith. Instead, however, a younger granite was discovered occupying a large area about the headwaters of Bridge river. This granite intrudes the post-Lower Cretaceous batholithic rocks which form the margin of the batholith in this area, and is, therefore, regarded as of late Upper Cretaceous or Tertiary age.

PORPHYRY STOCKS

A short distance east of the batholith the Cretaceous sediments and volcanics are cut by many sills and stocks of various kinds of light-coloured porphyries, some of the larger of which are indicated on Figure 5, east and west of Tyaughton creek. The majority of these porphyries are coarse-grained, light grey diorites consisting of large phenocrysts of andesine and smaller ones of hornblende crowded together in a matrix of the same minerals plus small amounts of magnetite. Some of these porphyries have abundant quartz phenocrysts and are similar in composition to a quartz diorite. Others of the porphyry stocks occurring along Sheba ridge are very light in colour and have a dense groundmass enclosing needle-like phenocrysts of black, lustrous hornblende averaging less than one-quarter of an inch in length. The white groundmass consists of andesine, hornblende, and a little quartz. These dense porphyries may be referred to as malachites. One of the larger of these stocks situated at the east end of Sheba ridge a few miles from Sheba (Spruce) lake has been altered over the greater part of its outcrop by solutions which have removed the hornblende phenocrysts and coloured the rock from white to dull red. The rocks are also intensely fissile, breaking, under frost or other weathering agents, into thin sheets less than one-quarter inch thick and sometimes several square yards in area. The fissility is parallel to the contacts of the intrusion, but is highly developed throughout the stock. In one locality a fault has intersected this fissile material, producing the peculiar effect shown in Plate II A.

The large porphyry intrusion east of Tyaughton creek is of the quartz diorite-porphyrite type. It contains a large amount of pyrite and all along its contacts a considerable amount of pyrite has been introduced into the surrounding rocks. Almost all the streams that cross the contacts of this intrusion yield small amounts of gold from their gravels and it is possible that this is a product of the mineralization that surrounds the stock.

The age of these porphyries is not determined beyond the fact that they cut the Cretaceous sediments and volcanics as well as the batholith itself. They are a persistent feature throughout the eastern contact of the batholith and are believed to be related to it in both time and origin.

THE YOUNGER GRANITE

Near the headwaters of Bridge river, a large body of white granite intrudes, and is, therefore, younger than the main body of the Coast Range batholith. The eastern contact of this granite was traced in a north-south direction for 6 miles and could be seen to extend much farther in both directions. Its western contact lies beyond the limits of the area mapped and was not observed. A smaller stock, 3 miles in diameter, of what appears to be the same granite, was found south of Lorna lake at the head of Church (Big) creek. Near Gold hill at the head of Gibson (Granite) creek a large number of cream-coloured quartz porphyry dykes strike south towards the granite at the head of Bridge river and are probably off-shoots from it.

This granite consists of about 40 per cent quartz, 40 per cent albite-oligoclase (Ab $_{80}$-A$_{n20}$), 5 per cent orthoclase, and 15 per cent biotite, and is, therefore, more properly a soda granite. It differs from the Coast Range batholith in the larger amount of quartz, more acid plagioclase, less hornblende, and more biotite, resulting in a much higher colour, by which the two formations can be easily distinguished even when viewed from a distance.

Considerable mineralization was observed along the eastern contact of the granite and, near the eastward projecting apophysis shown on Figure 5, several bodies of vein quartz carry pyrite and chalcopyrite.

One of these veins is 12 feet in width, where observed. The region was recommended to the prospectors of the district as a favourable one and later a promising discovery of copper ore was made.

The age of this granite is thought to be late Upper Cretaceous or Tertiary.

TERTIARY AND LATER LAVAS

East and north of Gun Creek map-area are extensive flows of basalt, flat lying and resting unconformably on all the other formations. Small remnants of these lavas cap some of the high mountains east of Tyaughton creek and on both sides of Church (Big) creek, large areas of basalt flows are present.

These volcanic flows are as a rule highly vesicular and consist almost entirely of dark brownish or black basalt, often having large glassy phenocrysts of labradorite. In one locality gas-formed cavities over a foot in diameter were observed. In a few places, such as on Castle mountain, thin layers of tuff occur between the flows, one of which was reddish grey in colour. No coarse breccias are found in the formation. They are undoubtedly of Tertiary age and have been classified as Oligocene, Miocene, or more recent.

In the basin at the head of Bridge river the white granites which underlie that region are capped by fairly large areas of exceedingly fresh flows of andesite and basalt porphyry. The flows are thin and have a pronounced columnar jointing. The surface has been scoured by glaciers, but is almost entirely free from drift or other glacial debris. The lavas are exceedingly fresh and as the glaciation of their surfaces is almost certainly due to recent alpine glaciers it is probable these lavas, like those on mount Garibaldi to the south and on Lady and Price islands to the west, are of Pleistocene or post-Pleistocene age.

ECONOMIC GEOLOGY

There are no producing mines in Gun Creek area, but there are several promising copper and gold deposits, some of which had they been more accessible would probably be much nearer the producing stage than they are at present. The Cadwallader Creek section of Bridge River area, only a few miles to the south, has long been an intermittent producer of gold and has recently, through the successful development of the Pioneer mine, become a steady producer. The success of this operation has stimulated new interest in the adjoining properties, several of which have been consolidated under one management and are now being tested on a large scale.

The most important deposits of Gun Creek area are four low-grade copper-gold deposits, situated in the Coast Range batholith along its contact. A higher grade copper deposit was discovered during the season, at the head of Bridge river. There are two gold deposits, the Native Son on a small tributary entering Leckie creek from the west, and the Taylor property on Battlement creek, a tributary of Taseko river.

TRIGGER LAKE COPPER DEPOSIT

Of the copper deposits the best known is a few miles west of Trigger lake and is usually referred to as the "Copper Mountain deposit", an unfortunate name, as there are two other more important and better known "Copper mountains" in British Columbia. The Trigger Lake deposit (as it is now called) has been known for a number of years and during the war attracted the attention of several large copper-producing companies. In 1918 it was fully described by Charles Camsell[1], since when little or no work has been done on the property. The deposit is 3 miles almost due west of and 900 feet higher than Trigger lake, which is on the Gun Creek trail 30 miles northwest of the Bridge River motor road. Geologically it is situated in the Coast Range batholith at its contact with the Cretaceous volcanics, the latter being intensely metamorphosed and, owing to the oxidation of much pyrite, deeply weathered. The details of the geology surrounding the deposit are clearly shown on the map accompanying Camsell's report. Lying between the volcanic rocks and the batholith is a large mass of diorite porphyrite 1,200 feet wide. The adjoining batholith and Cretaceous volcanics are cut also by many feldspar and quartz-feldspar porphyry dykes, lighter in colour, coarser in grain, and much smaller than the diorite porphyrite. Some of these smaller dykes contain a few small, disseminated grains of pyrite. The mineralized part of the batholith is a normal granodiorite composed of fresh andesine, hornblende, biotite, orthoclase, and magnetite. Excepting where surface oxidation has been effective the granodiorite is remarkably fresh, even though impregnated with considerable amounts of chalcopyrite. Where surface waters have oxidized the sulphides the feldspars have been intensely kaolinized and much limonite has been deposited. The segregation of the ore minerals in this particular part of the batholith seems to be dependent on the development of peculiar orbicular structure. The granodiorite occurs as nodules or "pillows" from 10 to 18 inches in diameter, having well-formed, smooth surfaces, but no visible internal radical or concentric texture. The interiors of the nodules consist of normal massive granodiorite similar to that of adjoining, non-orbicular parts of the batholith. The internodular portions are made up of miarolitic granodiorite together with quartz and chalcopyrite. The miarolitic cavities are lined with well-formed crystals of quartz, orthoclase, laumontite, and chalcopyrite. Some of the internodular spaces are completely filled with quartz and sulphide which appear like shells enclosing the nodules, and in several cases there were parts of two concentrically arranged quartz shells separated by a layer of normal granodiorite an inch or less in thickness.

In places there is considerable chalcopyrite disseminated in the quartz, and occasionally blebs of this copper mineral up to 3 inches in diameter. Chalcopyrite is also sparsely disseminated in the marginal portions of the nodules. Small amounts of pyrite are associated with the chalcopyrite. No gold or silver minerals have been observed in the sulphides, though assays show these metals to be present in small amounts.

The section of the batholith affected by this structure and mineralization, so far exposed, is 800 feet wide and extends for 1,800 feet up the steep slopes of the mountain. Outside this zone are several smaller areas

[1] Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 25.

containing sparse mineralization. Owing to the size of the area mineralized, as well as the sparseness and irregularity of the mineralization, it is difficult to make reliable estimates of the copper content. Samples of nearly pure chalcopyrite have been found to contain as much as 67·2 ounces of silver per ton and 31·5 per cent copper. A sample taken across 6 feet of what appeared to be a typical section of the ore showed traces of silver and gold and 0·5 per cent copper. Undoubtedly the deposit is exceedingly low grade, averaging less than 1 per cent in copper. The downward extension of the ore along the contact is possible and if even ordinary depths were attained the dimensions of the mineralized body would be indeed great, but taking into consideration the situation of the deposit and its low copper content, it is unlikely that even a very large body could be profitably mined under present conditions. No features were observed which indicate any probability that higher grade material may or may not be discovered at depth, though it is possible that where samples have been taken the grade has been slightly lowered by leaching.

In Taseko valley three similar deposits of copper are being developed, one by E. J. Taylor and the other two by the Consolidated Mining and Smelting Company. All three deposits occur in the quartz diorite of the Coast Range batholith, not far from its contact with the Cretaceous volcanics. All three deposits consist of sparse disseminations of chalcopyrite in the quartz diorite, either where it has been fractured or where it has had a miarolitic tendency.

On Taylor's deposit, when visited by the writer in August, a large amount of open-cutting had exposed considerable areas. It is situated on the south shore of Taseko river, a few hundred yards above the mouth of Battlement creek. The mineralization was first exposed by extensive cuts on the bank of the river. A few hundred yards south of the river, and separated from it by a gentle rise, is a large muskeg extending south to the foot of the steep slopes of the valley. On the low rise between the river and the muskeg, a trench 6 feet deep exposed mineralized quartz diorite. Other trenches at close intervals along a line striking north of the river exposed similar mineralization over a length of 130 feet.

The mineralization is confined to the batholith but adjacent to its contact, which is exposed on the opposite side of the creek. The overlying tuffs dip gently to the north at angles of 20 degrees to 30 degrees and the contact appears to follow the same dip for some distance at least. The mineralized quartz diorite has been intensely altered. The feldspars are sericitized, the hornblendes have completely disappeared, and the rock has a decided porosity, the small cavities being lined with perfectly formed crystals of quartz and pyrite. Both pyrite and chalcopyrite, together with small amounts of molybdenite, are disseminated throughout the rock.

In all the pits the rock has been attacked by surface waters that have removed much of the sulphide, leaving considerable limonite. No fracturing or shearing can be detected and for this reason the trend of the ore cannot be deduced. The mineralization may be confined to irregular patches lying beneath the tuffs and now exposed by erosion, or it may trend in a southwest direction towards the Mother Lode and Mohawk deposits $1\frac{1}{2}$ miles distant. In the latter deposit a pronounced fracture zone strikes northeast towards Taylor's showings.

This deposit also is low grade. A sample taken by the writer along the 130 feet exposed in the pits was found to contain 0·03 ounce of silver per ton and 0·35 per cent copper. This material, however, was considerably oxidized and leached. Owing to the nature of the workings at the time of the examination it was not possible to obtain a sample of unleached material. A specimen obtained from a large boulder found in excavating one of the trenches was not leached in its interior parts and contained much more chalcopyrite than the samples from the trenches. Traces of gold are found in most of the samples; gold is present in small amounts in the other deposits of this class and in the Mother Lode can be panned from the oxidized outcrops. A very rich, but small, gold-bearing vein was found in the tuffs a short distance above the granite contact on the adjoining Windfall claim, where rich alluvial ground was also found. All these facts suggest the possibility of finding small but appreciable amounts of gold in this copper property which would aid greatly in its development. It is obvious, however, that the hope for this deposit lies in the chance of proving immense tonnages of low-grade material.

Of the two deposits being developed by the Consolidated Mining and Smelting Company, the Mother Lode-Mohawk is the nearer to Taylor's. It is situated at an elevation of 6,500 feet on the spur between Gibson (Granite) creek and Taseko river and is about 1½ miles south 40 degrees west from Taylor's showings. It is conveniently reached by a good trail which branches from the main Taseko Lake trail near the mouth of Gibson (Granite) creek, where the elevation is less than 5,500 feet. This deposit has been previously described by the writer.[1]

The only formation near this deposit is the Coast Range batholith. The contact with the tuffs lies in the bottom of Taseko valley one mile to the north, but it is probable from what is known of the strike and dip of this contact that the tuffs formerly extended up the slope of the mountain and overlaid this deposit for only a short distance.

The mineralization is confined to two wide fracture zones in the quartz diorite. The lower is the better defined and has been the more fully explored. It is about 100 feet wide, strikes in a northeast direction, and is bounded on either side by fairly definite walls that dip at nearly vertical angles to the southeast. Owing to the steep slope of the outcrop its explored width is greater than 100 feet and it can be traced along the strike for several hundred feet. Within this zone of fracture the rock is cut by a close network of quartz veins varying in width from ¼ to 2 inches, but averaging not more than ½ inch. These are partly filled by quartz, leaving many small cavities lined with quartz crystals. Chalcopyrite associated with very small amounts of pyrite, zincblende, and galena is present in the veinlets and is also, to a greater extent, disseminated through the adjoining portions of the quartz diorite. Small amounts of tourmaline and rutile are also present in the veinlets. The rock minerals have been slightly sericitized, but are, on the whole, notably fresh.

In addition to the natural exposures, several cuts have been made in the fracture zone and, at the time of the writer's visit, a crosscut tunnel was being driven into the ore zone 100 feet vertically below the outcrop. Later in the season this tunnel reached the mineralized zone and was

[1] Geol. Surv., Canada, Sum. Rept. 1924, pt. A.

driven a considerable distance into it, proving the same widths and values as on the outcrop. A sample taken by the writer in 1924 contained traces of gold and silver and 0·5 per cent copper. The values obtained in the tunnel are reported to be slightly higher. Occasional samples taken from the deposit contain as much as one-half ounce of gold to the ton.

The second fracture zone on this property, formerly known as the Mother Lode, is situated above the one just described, at an elevation of 7,000 feet. It is similar to the lower zone, but is very poorly exposed and little work has been done on it. A peculiar feature of both these zones, and particularly the upper one, is that good gold values can be panned from the oxidized surface exposures. As no work of any consequence has been done on this zone since 1924, it was not revisited.

The other deposit being developed by the Consolidated Mining and Smelting Company is known as the Spokane and is situated in a cirque at the head of McClure creek. The contact between the quartz diorite and the overlying tuffs is a quarter of a mile to the west on the slopes of McClure mountain.

The deposit consists of an irregularly shaped area several hundred feet in length and of unknown width, in which the quartz diorite is fractured and cut by small veins of quartz containing many open cavities. A small amount of chalcopyrite is present in the quartz stringers, but a much larger amount is present in the quartz diorite. The fractures are of such a nature and so many of them are void, that it is difficult to distinguish between bedrock and the many large blocks of quartz diorite strewn about the cirque. The values in the deposit are conceded to be higher on the average than those from any of the other deposits. A large number of trenches and open-cuts exposed mineralized material, some of which might be classed as ore, but the work was not successful either in proving a workable body of ore or in throwing much light on the shape, attitude, or future possibilities of the deposit.

Another deposit of this general type, but differing in one or two respects, was examined. This, the Phair property, is situated on Roebottom creek a quarter of a mile above the trail that leads up Gibson (Granite) creek. It occurs in quartz diorite but differs from the other deposits in that the ore minerals are confined to two well-defined shear zones, that is, zones in which the great bulk of the fractures are parallel, or nearly so, to one another and to the walls of the zone on which they are confined, as contrasted with the above-mentioned fracture zones in which the veins strike in widely divergent directions. The fracture zones contain many open cavities, whereas the shear zones have none and the quartz veins are replacements rather than fillings.

The lower shear zone is 16 feet wide and is exposed on both sides of the creek, proving a length of at least 100 feet and indicating a much greater length. It strikes north 20 degress to 25 degrees east and dips 75 degrees to 85 degrees to the southeast. The quartz diorite is altered to sericite and chlorite and is cut by numerous parallel quartz stringers. The quartz and altered rock contain much disseminated pyrite and chalcopyrite. The upper zone, a few hundred feet farther up the creek, is 20 feet wide and is also exposed on both sides of the creek. It strikes north 25 degrees east and dips steeply to the southeast. The other features of this zone are similar to those of the lower zone. A sample taken by the writer across the upper zone assayed a trace of gold, 0·14 ounce of silver per ton, and 0·41 per cent copper. It is probable that there are sections of this zone that carry higher values.

During the season a discovery of copper ore was made by a prospector named Griswold in a hitherto unexplored section of the map-area about the head of Bridge river. The deposit, situated in a small canyon near the northern end of the most easterly of the three large areas of lava shown in the southwest corner of Figure 5, is at the contact between the younger granite and the quartz diorite of the Coast Range batholith. As the discovery was made after the mapping of this section had been completed it was not visited by the writer. However, specimens collected by Mr. Griswold have been examined, one of which was about one foot in length. The specimens consist entirely of chalcopyrite and quartz in such proportions that the copper content would appear to run over 10 per cent and probably as high as 15 per cent. The Griswold showing is easily accessible; it is not more than 40 miles from the Bridge River road and can be reached by a trail following an easy grade of Bridge river. When the hydroelectric project now being carried out by the British Columbia Electric Railway Company is completed a considerable part of this section of Bridge river will be converted by a dam into a long, navigable lake, which will facilitate communication between the Griswold showing and the road, and cheap power will be available for transportation, mining, and treatment operations. In view of these advantages, as well as the fact that the mineralized margin of the younger granite has been mapped, this newly discovered mineralized area appears to be worthy of attention. The stock of similar granite at the head of Church (Big) creek appears from a distance to have some mineralization about its margin and it also might be worth investigation. One small deposit has already been discovered just north of this stock and is being held by George Mears of Hanceville.

A deposit of arsenic-gold ore, the Native Son, on the headwaters of a small creek which joins Leckie creek 3 miles above its mouth, is owned by Joe Russell of Lillooet and was for a time under bond to A. B. Trites of Vancouver. The deposit has been described by M. E. Hurst.[1] The showings are in the canyon of a small hanging valley just where it is intercepted by the steeper slope of Leckie valley at an elevation of 6,000 feet above sea-level and 1,000 feet above Leckie creek. The veins are exposed in four tunnels, three large open-cuts, as well as in several small outcrops that are scattered along the canyon for a distance of 600 feet. The majority of the exposures, however, are grouped within a distance of 200 feet.

The veins are enclosed in the beds of the Eldorado formation about half a mile north of the batholith. The sediments are folded, faulted, metamorphosed, and cut by several dykes of quartz diorite and one of basalt. The beds now consist mainly of biotite, quartz, sericite, and epidote, their original character being completely obliterated. Owing to metamorphism and faulting the detailed structure of the beds was not worked out. The batholith at this part of its contact is abnormally high in orthoclase and over an area of several square miles has a composition close to that of a granite.

[1] Geol. Surv., Canada, Econ. Geol. Ser. No. 4, p. 82.

The deposit is made up of a number of lenses of solid arsenopyrite up to 5 feet in width arranged somewhat promiscuously in a zone of sparse mineralization 25 feet wide. The zone, poorly defined with irregular mineralization, appears to have a general strike in a north 20 degrees east direction and to dip nearly vertically. A section measured across the farthest south showing, which appears to be the richest part of the vein, showed that it consists of 5 feet of solid arsenopyrite, 5 feet of disseminated arsenopyrite, and 1 foot of solid arsenopyrite. A sample taken across this section contained 0·06 ounce of gold to the ton. The ore zone exposed in a tunnel 60 feet to the north consists of 25 feet of disseminated arsenopyrite. A sample of pure arsenopyrite taken by Hurst contained 0·03 ounce of gold and 0·07 ounce of silver to the ton. The owner, Mr. Russell, claims that the higher gold values are obtained from the disseminated ore and the above assays bear this out.

GEOLOGICAL RECONNAISSANCE IN SLOCAN AND UPPER ARROW LAKES AREA, KOOTENAY DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes

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Illustration

INTRODUCTION

Nearly eight weeks of the 1928 field season were spent in a reconnaissance survey of areas lying between and adjacent to Upper Arrow and Slocan lakes, Kootenay district, British Columbia. The object of this work was, partly, to extend geological mapping from Slocan district into the Upper Arrow Lake country where, it was hoped, some connecting link or links might, eventually, be established with previously explored areas lying still farther north and west. Field work, too, included an examination of mineral occurrences and mining possibilities within the area investigated, special attention being directed to mapping the extension of the Slocan series from its metalliferous sections in Slocan district. Attempts were also made to differentiate the several bodies of granitic rocks appearing within the limits of the map-area.

Field work was facilitated by the kindly co-operation of business men and government officials of the district and by officers and employees of the branch line of the Canadian Pacific railway operating between Kaslo and Nakusp. During the field season the writer was ably assisted by Messrs. J. A. C. Harkness and J. S. Stevenson.

The area dealt with in the present report (*See* Map 232A) embraces portions of both the Selkirk and Columbia mountain systems separated from one another by the prominent Columbia River valley here occupied by Arrow lakes. Within the map-area, the Selkirk system includes parts of two distinct mountain groups represented by Lardeau (northern Slocan) mountains to the northeast and Valhalla mountains to the southwest of the transverse valley followed by the Canadian Pacific railway between Rosebery and Nakusp. This valley follows the general northwesterly trend of deformation of the underlying sedimentary and volcanic formations and is continued for at least some distance west of Upper Arrow lake. Elevations in the area range from 1,395 feet, the water-level of Upper Arrow lake (July 13, 1926), to over 8,000 feet at the summits of Big Sister and Rugged peaks in the northern Valhalla mountains. The area is timbered to a height of 6,000 feet or more above sea-level, but the luxuriance of vegetation depends partly on the character of the underlying rocks and partly on the time that has lapsed since several parts of the area have been swept by forest fires.

MINING

The area as a whole has witnessed comparatively little mining activity. Rosebery, on Slocan lake, is situated near the northwestern limit of the well-known silver and silver-lead district commonly referred to as "Slocan." Some mineralization of essentially similar character, though as yet producing no outstanding mines, is included in the southwestern corner of the map-area, in the vicinity of Mineral City. Some mining activity has also been recently experienced in the extreme northwest corner of the area where the "Big Ledge," referred to at considerable length in a subsequent report,[1] has been subjected to further exploration.

LUMBERING

The chief industry is lumbering, the forests adjacent to the principal waterways providing excellent stands of a variety of trees, of which white pine is commercially most important and is succeeded, in order, by fir, hemlock, tamarack, and cedar.

AGRICULTURE

Farming ranks second among the industries in the vicinity of Arrow lakes, the bench lands bordering their shores affording wide areas of arable lands. Serious and sustained attempts at fruit growing have, as a result of difficulties in marketing, not met with the success that the excellent character of the product would seem to warrant.

GEOLOGY

The bedrock geology of the area (*See* Map 232A) embraces an assemblage of formations extending from Precambrian to Tertiary (?). The bedrock over wide areas is mantled by heavy accumulations of drift; in such areas, outcrops of underlying rocks are rarely seen and are encountered only by chance.

The sequence, general character, and mutual relations of the several formations are briefly expressed in the following table.

[1] This volume, pp. 109–118.

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PRECAMBRIAN

The term Precambrian has been applied to a series or group of highly metamorphosed rocks embracing a variety of crystalline schists interbedded with massive, light-coloured quartzite, crystalline limestone, greenstone, and paragneisses.

The *crystalline schists* are, in general, medium to coarse-grained rocks distinguished by their lustrous appearance and schistose structure. Light and dark coloured micas, quartz, and feldspar are the abundant mineral constituents, but in many cases the surfaces are knotted or lumpy from the development of meta-crystals of such minerals as staurolite, scapolite, and garnet. Red garnets are particularly abundant in some beds and commonly reach one-quarter inch or more in diameter. The *quartzites* are light-coloured, massive, well-bedded rocks in which there is commonly quite an abundant development of biotite and garnet. The *limestone* beds are coarsely crystalline, white rocks carrying more or less quartz which so weathers as to form a rough surface. Small flakes of graphite are commonly present and other secondary minerals include garnet, diopside, and epidote. The *paragneisses* appear as a gradational phase between the crystalline schists and the associated gneissic intrusives of the Nelson batholith and they represent a more or less completely digested product of the older rocks. Quartz, orthoclase, plagioclase, biotite, muscovite, diopside, olivine, apatite, sericite, kaolinite, sphene, graphite, and sulphides are among the minerals recognized in microscopic studies of these rocks. A belt of *greenstone schist,* several hundred feet wide, crosses Upper Arrow lake to the south of St. Leon and Pingston creeks. This greenstone has the appearance of an altered volcanic rock. It is overlain by granular, quartz-biotite schists carrying, in places, large crystals of feldspar and what appear to be deformed and altered rock fragments as well as occasional well-rounded pebbles of quartzite.

The general structure of the Precambrian rocks lends strength to the view that they are separated by a great unconformity from succeeding sedimentary and volcanic formations. Their average dip is low as compared with that of later formations and their strike does not everywhere conform with the northwesterly trend of deformation of the younger rocks. The structure is anticlinal across Upper Arrow lake in the vicinity of Pingston and St. Leon creeks. This structure plunges to the south, reappearing in exposures along the west shore of the lake north of Nakusp. Farther south the structure is broadly dome-shaped, the apex coinciding approximately with the summit of the ridge running north from Saddle mountain. In the trough formed between the plunging anticline and the dome, the northwest-trending belt of the Slocan series of sediments and volcanic rocks lies unconformably.

The age of these older rocks is referred tentatively to the late Precambrian on the basis of lithical similarity with rocks of that age appearing along the shores of Kootenay lake and extending northerly and northwesterly into Lardeau country. Their high degree of metamorphism as contrasted with that of later sedimentary and volcanic rocks in the area and their apparent unconformable relations with these rocks are contributing reasons for assigning them to this early period of geological history.

In mapping the Precambrian rocks only those areas underlain mostly or entirely by these rocks are shown. Intervening areas occupied by the Nelson pegmatite-gneiss complex contain, however, an abundance of inclusions of Precambrian rocks. These inclusions are particularly abundant in zones varying up to one-half mile or more in width bordering those areas mapped as Precambrian.

KASLO SERIES

The oldest members of the group of sedimentary and volcanic rocks overlying the Precambrian measures within the map-area are those of Kaslo series. This series, as here developed, is composed chiefly of massive, fine-grained, green, andesitic volcanic rocks and associated dioritic intrusives. In places these rocks are altered to dark green serpentine.

The considerable area of Kalso series appearing in the basin of Wilson creek forms part of a wide belt extending southeasterly to the vicinity of Kaslo creek in Slocan district. To the northwest its continuity is interrupted by the Kuskanax batholith. To the south and southwest, the Kaslo series underlies slaty sediments of the Slocan series. The exact contact was nowhere observed, although it was located approximately at a number of points. The nature of this contact has, however, been interpreted from close study in areas farther to the southeast, as disconformable, in that a short period of time seems to have lapsed between this period of volcanism and the deposition of Slocan series.

SLOCAN SERIES

The Slocan series is represented by a great thickness of sedimentary and volcanic rocks forming a belt several miles in width extending northwesterly across the area. The sedimentary members form the greater part of the series. They include a variety of rock types comprising slate, argillite, quartzite, limestone beds, and tuffaceous sediments, the latter grading into the distinctly volcanic members of the series. Under the microscope the more arenaceous beds are seen to be composed chiefly of quartz grains of nearly uniform size held together in an argillaceous or calcareous groundmass which, in general, constitutes a minor proportion of the rock. A few feldspar grains are generally present. Under the influence of thermal metamorphism, as in the vicinity of batholithic intrusives, other minerals, including, in most cases, an abundance of shreds and small flakes of reddish brown biotite, may form. Muscovite or sericite shreds may also be present and meta-crystals of andalusite are sometimes abundant. The *tuffaceous sediments* are difficult to distinguish in the field and, in fact, appear to grade on the one hand into the arenaceous beds, just described, and, on the other, into beds of waterlain tuffs included with the volcanic members of the Slocan series. Under the microscope the groundmass of the tuffaceous sediments generally constitutes a large proportion of the slide and is rather indeterminate in composition. Crystals or grains of feldspar are generally scattered in conspicuous numbers through this groundmass, but quartz grains are comparatively scarce. Rock fragments may also abound and many of them seem from their fine texture and extensive alteration to chlorite to be of volcanic origin. More or less calcite is present. In some cases it appears to be an original constituent, whereas in others it occurs as an alteration product replacing crystals of feldspar and other constituents of the rock. The character of this group suggests a different origin for the detritus composing it, from that of the material forming the more typically sedimentary strata. That this origin may be related to vulcanism and to an accumulation of pyroclastic materials is suggested not only by the composition of these "tuffaceous sediments", but by their apparent gradation into beds which are distinctly pyroclastic and are included with the volcanic members of Slocan series.

A number of *limestone* beds were noted in the Slocan series. These are most abundant towards the northeasterly flank of the belt. They are typically light to dark grey, rather flaggy, fine-grained to semi-crystalline rocks. Occasional fragments of poorly preserved fossils were observed in these beds in Wilson Creek basin and on the summits northeast of the head of Slocan lake.

The distinctly volcanic members include one prominent lava flow of augite andesite averaging, in those sections where it was observed, several hundred feet in thickness. This andesite is notably vesicular, and some of the vesicles are filled with calcite and others with chlorite. This texture and the presence, also, of numerous, well-formed, dark green phenocrysts of augite in an otherwise fine-grained groundmass, give a characteristic appearance to the rock. The flow appears to lie at or near the base of a series of waterlain tuffs and breccias intercalated with tuffaceous and argillaceous beds. All members except the breccias are difficult to distinguish in the hand specimen from sedimentary members of Slocan series. Under the microscope the tuffs show a groundmass of ashy appearance, through which are scattered abundant crystals of feldspar and fragments of volcanic rock. Very little quartz is in evidence and there are generally crystals of mafic minerals. More or less chloritic material also suggests the presence of altered mafic constituents. Other minerals observed in these tuffs include muscovite, calcite, epidote, and sulphides. The *breccias* are readily recognizable as such in the hand specimen, being made up of an assortment of angular fragments of volcanic rock and crystals of feldspar and pyroxene in a fine groundmass. The breccias vary from green to purple and otherwise bear a close lithological resemblance to members of the Nicola formation of south-central British Columbia. Under the microscope the groundmass of these breccias is distinctly ashy in appearance. Through it fragments of lava and crystals of both pyroxene and feldspar are abundant, but there is little or no quartz.

The general structure of the Slocan series is apparently synclinal. A greater proportion of slate and limestone beds occur on the northeast flank than on the opposite limb of the syncline where there is a gradation into more massive and less calcareous types. The major structure is complicated by much folding and faulting and on the whole by steeper dips than those obtaining in the underlying Precambrian formations.

Determination of the outcrop area of the Slocan series was regarded as having some economic significance, in that this series farther to the southeast is the host to most of the more important silver-lead and silver-lead-zinc properties of Slocan. Within the present area, however, the series seems on the whole poorly mineralized, a feature not attributable to change in the character of the members of the series, but rather to differences in the batholithic intrusives invading it.

The age of Slocan series as determined from fossil collections obtained in Slocan district to the southeast of the present area is probably Triassic. The distinctly volcanic members of the series are very similar to areas of "Rossland Volcanics" appearing in the vicinity of Mineral City as mapped on the West Kootenay map-sheet. Within the present area these volcanic rocks are apparently interbedded with the Slocan series and their age consequently is referred to the Triassic.

POST-TRIASSIC INTRUSIVES

The term "Post-Triassic Intrusives" includes the entire assemblage of batholithic and allied minor intrusives of Kootenay district. Within the present area these intrusives include representatives of two batholiths possessing not only distinctive lithological characters, but which, it is believed, were intruded at different times. For the older and much more extensively developed batholith the name "Nelson", commonly employed in geological literature pertaining to Kootenay district, is applied. The later more locally developed batholith is assigned a new name, "Kuskanax", by reason of its typical exposure in the basin of Kuskanax creek and the fact that this creek cuts entirely across it.

Nelson Batholith

In the present area, the Nelson batholith is subdivided into three members known as, respectively, the Nelson gabbro-gneiss, Nelson granite, and Nelson pegmatite-gneiss-complex. Of these members the first is nowhere observed in contact with either of the others, so that its relations could not be directly established. There is evidence, however, of a gradational contact between the other two members, though elsewhere their individual characteristics are well shown.

Nelson Gabbro-Gneiss. This gneiss forms a narrow, dyke-like body along the contact of the Kuskanax batholith with the Slocan series west of Kuskanax creek. Where it reaches Upper Arrow lake, this gneiss widens to a maximum width of about 1½ miles. It is a medium-grained, greenish rock carrying a somewhat greater percentage of mafic than salic constituents. The former include an abundance of dark green amphibole (hornblende), a small proportion of biotite, and a conspicuous development of epidote. The chief salic constituent is plagioclase feldspar. A little quartz is also present. In structure the rock is notably foliated as a result of deformation. Along shear zones, alteration to chloritic materials is far advanced. Accessory minerals include a variable but always noticeable dissemination of iron sulphides.

The position of this intrusive along the southern flank of the Kuskanax batholith was at first thought to indicate that it was a basic border phase of that batholith. Observation, however, showed that this contact was sharply defined, that the Kuskanax batholith cuts the gneiss, and that the latter is distinctly more deformed and quite different in mineral composition from members of the Kuskanax batholith. On the other hand the extent of this deformation and, in some degrees, the similarity in mineral composition of this gabbro-gneiss with gneissic members of Nelson granite, seemed to allow a more satisfactory correlation with the Nelson than with the Kuskanax batholith. The relatively basic composition was taken to imply that the rock is an early phase of Nelson batholithic intrusion.

Nelson Granite. The Nelson granite is exposed as a tongue-shaped mass crossing Slocan lake from northwest to southeast in the vicinity of Rosebery. A considerable area of this intrusive also appears to the west of the narrows between Upper and Lower Arrow lakes and may, in fact, be continuous with the belt crossing Slocan lake.

The Nelson granite is typically a medium to coarse-grained rock in which large crystals of orthoclase (in some cases microcline) are conspicuously distributed, lending the whole a characteristic porphyritic appearance. In composition the rock may be classified as granite, though varying locally to granodiorite and quartz diorite. The essential minerals are quartz, orthoclase, microcline, and plagioclase. Both hornblende and biotite are present in variable but, generally, quite minor proportions. Occasionally a little muscovite is observed and is characteristic of gradational phases between Nelson granite and the Nelson pegmatite-gneiss complex. Microcline is generally less abundant than orthoclase. Plagioclase is mostly albite or albite-oligoclase, but varies to oligoclase-andesine in the quartz diorite rocks.

In its general structure, the Nelson granite is massive, but in places it possesses a notably crushed and foliated appearance as a result of deformation. This latter feature is, however, not common within the area covered by this report.

The Nelson granite is economically important in that to it is ascribed the extensive mineralization of Slocan district. In Slocan district not only have the overlying members of the Slocan series been impregnated by metalliferous solutions, but the granite itself is the host of numerous ore deposits. This important feature is not lacking in the present area where most of such mineralization as has been observed occurs either within or adjacent to outcrop areas of this granite.

Nelson Pegmatite-Gneiss Complex. This complex occupies a greater area than any other formation within the map-area. It is remarkable, however, that in spite of its wide distribution and the great lithical dissimilarity of its two members the complex, as a whole, is readily distinguished from other granitic rocks in the area. Some difficulty was experienced in assigning a boundary between this complex and the Nelson granite, as these two members of Nelson batholith grade into each other across a zone that in places both within and without the limits of the present area varies up to half a mile or more in width.

The pegmatite-gneiss complex, as its name implies, represents an assemblage of two distinctive rock types—one resembling a pegmatitic granite and the other distinguished in general by a gneissic or banded structure. These two types are so intimately associated as to preclude effective separate mapping. The pegmatitic member is characteristically a coarse-grained rock of irregular texture in which quartz, plagioclase, orthoclase, and muscovite are the essential minerals. Quartz is abundant and commonly possesses a rather smoky appearance. The feldspars are white to creamy-yellow and crystals of them vary markedly in size. Muscovite is common, occurring both in small flakes and in thick books up to one-half inch or more in diameter. Biotite may also be present, but generally in minor proportion to white mica. Red garnets were also observed. A thin section from one of these rocks was examined under the microscope and found to possess a rather curious appearance. Plagioclase was more abundant than orthoclase and was finely twinned, with, in many crystals, the albite lamellæ disappearing before reaching the edges of the crystal. Pegmatitic intergrowths were common. Quartz was abundant and but little strained. Rounded grains of quartz were observed within larger feldspar crystals and quartz was grown to or enclosed in quartz without, in some cases, at least, optical continuity. Sericite appeared to be a common secondary mineral.

The other phase of this complex is, in general, easily distinguished by its gneissic appearance, greater uniformity in texture, and finer grain. In many places it was observed to be intruded by narrow, irregular tongues of the pegmatitic granite, although other contacts again appeared more gradational in character.

The gneiss is typically a medium-grained, grey rock of uniform texture and possesses, in general, a gneissic or finely banded structure. In some places this structure is barely recognizable if present at all, and at such localities the rock has a massive, fresh appearance. Every gradation, however, exists between the more massive and the distinctly gneissic types. Other features, too, serve to correlate them. Both are characterized by the presence locally of red garnets occurring either individually or in streaks or clusters. Both types, too, show, here and there, a rather vuggy or pseudomiarolitic texture in which small cavities contain clusters of amethyst quartz, calcite crystals, limonite, pseudomorphs after pyrite, and clusters of black tourmaline crystals.

Under the microscope the members of the gneissic phase of the complex have a rather granular appearance suggesting recrystallization and a derivation, at least in part, from pre-existing rocks. Quartz is an abundant mineral and is but slightly strained. Plagioclase is generally more abundant than orthoclase, and microcline is rare or absent. Both biotite and muscovite are commonly present and sericite occurs as a secondary mineral. A little hornblende was noted in one specimen. Micropegmatitic intergrowths are common, but perthite is comparatively rare. Accessory minerals include sphene, magnetite, iron oxides, chlorite, kaolinite, red garnet, and sulphides. The composition of these gneissic rocks ranges from binary granite to quartz monzonite.

In mapping the pegmatite-gneiss complex, considerable difficulty was experienced in separating it from areas of included Precambrian rocks with which the members of the complex are everywhere associated. The abundance of these inclusions and the observation that their contacts with gneissic members of the pegmatite-gneiss complex are not sharply defined, make it not only difficult to draw any definite boundaries, but also, over considerable areas, raise the question as to whether the underlying rock should be mapped as older rock or as the pegmatite-gneiss complex. More detailed work over areas occupied by this complex would undoubtedly result in more accurate mapping of the several components. In the present case, areas were mapped as pegmatite-gneiss complex where members of this complex are dominant or where observations were not taken in sufficient detail to warrant differentiation of older included materials.

The peculiar features of Nelson pegmatite-gneiss complex, its relations with the Nelson granite and with the Precambrian rocks, afford probably the most interesting and important problem in the area.

The following explanation is offered tentatively as applying to the area under present consideration as well as to other areas in the vicinity of Kootenay and Slocan lakes where similar geological conditions have been observed and studied.

Summarizing what has been covered in preceding paragraphs, the facts seem to be as follows:

(1) The Nelson pegmatite-gneiss complex forms part of the Nelson batholith as field evidence points to a gradation, across a zone of considerable width, from typical Nelson granite to pegmatite-gneiss complex.

(2) Areas underlain by this complex are coincident with areas in which numerous inclusions of Precambrian rocks are found.

(3) The larger bodies of Precambrian rocks are always highly metamorphosed and bordering members have in certain instances been traced along their strike to where they apparently pass into gneissic equivalents of the pegmatite-gneiss complex.

(4) The pegmatite phase of the complex was, at a number of places, observed to cut the gneiss. Other contacts appeared more gradational, but no instances of the gneiss intruding the pegmatite were noted.

(5) Mineralization is, in general, weak in the members of the pegmatite-gneiss complex, whereas it is abundantly present and often of commercial importance in the Nelson granite.

(6) The gneiss of the complex is, characteristically, a rock of fresh, recrystallized appearance which rarely, either in the hand specimen or under the microscope, shows evidence of any considerable deformation.

The conclusion based on the above facts is that the pegmatite-gneiss complex is, in essence, a deep-seated contact phase of the Nelson batholith with Precambrian rocks. This conclusion implies that prior to the intrusion of this batholith the entire areas under consideration were underlain by great thicknesses of Precambrian rocks, which, in turn, were overlain by heavy deposits of late Palæozoic and early Mesozoic sedimentary and volcanic rocks. The incursion of the Nelson batholith was doubtlessly accompanied by more or less deformation of the overlying rocks, resulting in the development of, at least, broadly folded structures. In working its way towards the surface, the Nelson batholith everywhere encountered and was forced to penetrate the Precambrian rocks before reaching the later formations. The Precambrian rocks were thus the first to be affected by the advancing batholith and by reason of their comparatively great depth below the surface were longest subjected to the agencies of thermal and hydrothermal metamorphism released by the batholith. It is consequently to be expected that these Precambrian rocks should everywhere exhibit a greater degree of metamorphism than the overlying formations. It is also natural to suppose that the batholithic intrusives in working their way through the Precambrian rocks should not only affect them strongly, but in varying degrees, according to the composition of these older rocks. The more quartzitic beds seem to have best retained their original characters, whereas the argillaceous and limy strata show all degrees of metamorphism from schistose types which, though greatly altered, are nevertheless clearly recognizable as older rocks, to banded paragneisses igneous alike in appearance and composition. Localities were noted where a single stratum could be traced along its strike from a rock definitely pre-batholithic in age to a banded gneissic rock the equivalent in appearance and composition of the gneiss of the pegmatite-gneiss complex. In fact the field evidence in general supports the view that the banded structure so characteristic of the gneiss might be attributed to conformity with bedding lamellæ of completely assimilated older rocks.

The pegmatite member of the complex, in common with pegmatites in general, probably represents a late phase of differentiation of the batholith. It is abundantly associated with the gneiss and also with inclusions of Precambrian rocks, but has not been observed within the main areas of Nelson granite or Slocan series. It appears that, for some reason or other, the pegmatitic intrusives did not extend as far towards the surface as the Nelson granite and did not, in effect, reach the strata overlying the Precambrian measures. The Nelson granite, on the other hand, may be regarded as essentially the uppermost part of the Nelson batholith. Its crustal portions had, consequently, an opportunity to consolidate and fracture while the underlying magma was yet in a plastic or molten condition. Rising metalliferous solutions in working their way to the surface mostly reached this fractured upper zone of Nelson granite before commencing to deposit their valuable load of ore minerals. In even greater measure they escaped into overlying members of Slocan series. The fact that Nelson granite may be found outcropping in the main valley bottoms and the pegmatite-gneiss complex on the higher divides may be explained on the basis of broad folding of Precambrian and later formations, thereby permitting batholithic intrusions to reach the higher elevations at the crests of anticlinal folds and yet be actually at greater depths below the surface than towards the top of synclinal structures where these coincided with contemporaneous structural depressions.

Kuskanax Batholith. Kuskanax batholith constitutes a single well-defined unit extending along the northeastern side of the map-area. Beyond the limits of this area the batholith is believed to be continuous with exposures of a similar batholithic rock outcropping at the heads of Kuskanax and Poplar creeks on the high divide at the headwaters of streams draining northeast into Lardeau valley and southwest into Upper Arrow and Slocan lakes. The name proposed for this batholith has been adopted from that of the large creek entering Upper Arrow lake at Nakusp. This stream cuts entirely across this batholith at about its widest point, a distance, roughly, of 20 miles. The general trend of the batholith is northwesterly and the outcrop area is elliptical.

Within the present map-area the members of the Kuskanax batholith are readily distinguished from those of the neighbouring Nelson batholith. They are, in general, medium to fine-grained types which in places along the border show a well-defined porphyritic texture. Two main types are recognized: syenite, which grades through quartz syenite into granite. The syenite is well-developed along the border of the batholith in the stock-shaped apophysis south of Box lake and along the divide north of Summit lake from Summit peak east. Elsewhere the batholith appeared to be chiefly granite.

The members are mostly light-coloured rocks, though the syenite generally weathers brown and is distinguished thereby from more quartzose types. The latter are also, in general, finer in grain than the syenite and the more quartzose granites have a peculiar gritty feel due apparently to decomposition of the feldspars permitting the abundant quartz grains to be readily torn from the side of a specimen merely by rubbing the hand across a surface. All types, too, carry a minor proportion of the same mafic mineral which occurs as minute, blackish, indeterminate specks through the rock.

Under the microscope the members of the Kuskanax batholith are readily recognized through certain mineralogic peculiarities, as part of one intrusion. All types include an abundance of both orthoclase and microcline, but only minor plagioclase, the latter occurring chiefly in the form of perthitic intergrowths in both of the potash feldspars. The abundance of perthitic intergrowths, in fact, constitutes a very distinctive feature of these rocks. The proportion of quartz varies from almost nil in the syenite to conspicuous proportions in the granites. It evinces but little evidence of strain or fracturing. The characteristic mafic mineral is a dark green or bluish green amphibole which is generally partly altered and difficult to determine. This mineral is present in all types studied and except in one specimen, where a very little biotite was observed, is the only mafic mineral present. Accessory minerals include sphene, apatite, magnetite, yellow garnet, and occasional sulphide grains. Secondary minerals include kaolin, chlorite, and calcite.

A peculiar feature of Kuskanax batholith in those areas studied, relates to the paucity of mineralization connected with it. This is in direct contrast to members of Nelson batholith and, in particular, Nelson granite whose relations to ore mineralization in Slocan have already been indicated. Except, however, for occasional grains of pyrite, no mineralization was noted in members of Kuskanax batholith, a feature that seems to explain why the rock formations intruded by this batholith have provided, to date, such meagre evidence of ore deposition.

SUPERFICIAL DEPOSITS

Deposits of drift cover a large part of the area and obscure the underlying bedrocks. They may for convenience be subdivided into two types, non-sorted and sorted. The former cover much of the upland slopes to, and even for some distance above, timber-line. They represent, in part, remnants of glacial drift which escaped transportation to lower altitudes and, in part, more recent accumulations of soil. Such deposits are of varying, but, in general, not great thickness. The sorted deposits occupy the lower valley slopes and are capable of subdivision into what may be termed bench lands, delta deposits, and stream alluvium. Of these the first are most widespread, thickest, most important agriculturally, and most interesting physiographically. They are composed chiefly of glacial materials accumulated during Pleistocene time and reworked by large streams occupying the valleys towards the close of that period. The wider and more persistent bench lands are, as might be expected, found in the wider, more prominent valleys such as that of Upper Arrow lake, Slocan lake, Wilson creek, Kuskanax creek, Arrowpark creek, etc. These benches occur at different elevations above lake-levels and those bordering the lakes are more continuous than others occurring at irregular intervals up the main tributary streams.

The following table is not exhaustive, but gives the approximate elevations of a number of benches observed within the map-area. The elevations have been computed from aneroid readings and are also subject to correction, for the reason that these benches are not actually horizontal but dip gently towards the centre of the main valleys they border, as well as downstream with that valley, the bench gradients being, in general, less steep, but roughly proportional to the valley gradients.

Locality	Elev. above Slocan lake	Elev. above Summit lake	Elev. above Upper Arrow lake	Elev. above sea-level
	Feet	Feet	Feet	Feet
Bordering Slocan lake on either side mouth of Wilson creek	250			2,007
" " "	330			2,087
" " "	420			2,177
Up Wilson creek, series of benches	800-1,000			2,557-2,757
Valley of Bonanza creek	320			2,077
	400			2,157
	500			2,257
	1,150			2,907
West of Summit lake		580		3,061
		1,680		4,161
		±1,830[1]		±4,311
East of Brouse			1,092	2,487
			1,200	2,595
West of Wilson lake			1,815	3,210
South of Brouse			992	2,387
			2,542	3,937
North of Slewiskin (McDonald)creek			1,250	2,645
West Demars			400	1,795
Mineral City			±850	±2,245
Pingston creek			490	2,885
Kuskanax creek			±900	±2,295
"			±1,155	±2,550
Dog creek			±670	±2,065
Fosthall creek			700	2,095

[1] Those elevations prefixed by "±" are regarded as less accurate than the others.

These bench lands afford a considerable acreage of arable lands as, for example, between Brouse and Nakusp, and in vicinity of West Demars, Arrowpark, and Fosthall creek.

Delta lands are more local in extent, are of recent age, and in process of formation at the present time. Conspicuous among them is the one at the mouth of Kuskanax creek just to the north of the town of Nakusp. Wilson creek has also constructed a delta of considerable size into Slocan lake. Others of less significance are forming at the mouths of Slewiskin (McDonald) and Fosthall creeks. Kuskanax delta is conspicuous for the quantities of white, almost pure quartz, sand composing it and brought downstream through disintegration and erosion of the Kuskanax batholith.

River and stream alluvium occurs in minor proportions in the area. Most of the main streams have, however, cut down to rock bottom and developed canyons in their lower courses.

ECONOMIC GEOLOGY

Mining is of minor importance in the area covered by the present geological investigations. Only at the Big Ledge properties, in the extreme northwest corner of the area, did there appear any reasonable chance of commercializing the discoveries to date. Unfortunately time did not permit of examination of properties in the vicinity of Mineral City [1] where geological conditions seemed on the whole best suited for mineralization and where work in the past has opened up significant discoveries.

For convenience the following brief notes are given with reference to localities in which work has been done or mineralization noted.

VICINITY OF ROSEBERY

A little prospecting has been done in the vicinity of Rosebery, particularly to the south of Wilson creek on the summit and northern slope of the ridge between Wilson and Dennis creeks. In this direction two Crown-granted mineral claims, the Ferry No. 2 and Jeanette (lots 3668 and 1926), had work done on them many years ago. The trail to this property can still be followed for 2,000 feet above Wilson creek, but is completely obliterated for the remainder of the distance. There are no records of any shipment from these claims, but apparently a little silver-lead ore was discovered associated with vein quartz. The locality is not unfavourable for mineral discoveries, as the hill-slopes are underlain by sediments of the Slocan series, including some limestone strata, and the whole is penetrated by porphyritic dykes and a tongue of Nelson granite. Farther down the hill quite a little surface stripping has been done and one or more short adits made to investigate certain irregular veins of quartz in this tongue of granite. These veins carry, here and there, a little galena and pyrite, but nothing of commercial significance was noted.

To the west of Wilson creek and within a mile north of Rosebery a couple of quartz veins, about 2½ feet in width, were observed to carry a little molybdenite, as well as considerable disseminated pyrite.

WEST OF SLOCAN LAKE

A rather likely looking section for prospecting lies west of the head of Slocan lake to the north of the contact of the Slocan series with Nelson granite. Though no work is being done there at present rumours are current that in the past some interesting discoveries were made and subsequently lost track of.

IN VICINITY OF THE RAILWAY

Futile attempts have been made at various points along or near the railway to discover something of value in the Slocan series where the members are conspicuously impregnated with iron sulphides or are intersected by quartz veins and veinlets.

[1] Ann. Rept., Minister of Mines, B.C., 1923, pp. 234–35.

NEAR NAKUSP

The *Bluebird* group of three claims, owned by J. H. Vestrup and O. Salstron of Nakusp, B.C., includes the only discovery of interest in this section. The discovery was made in the canyon of Nakusp creek about a mile from town and within half a mile of and 200 feet above Upper Arrow lake. Here a number of quartz veins have penetrated argillaceous and quartzitic beds of the Slocan series, striking about north 55 degrees west and dipping southwest. The veins vary up to about 3 feet in width, but pinch and swell irregularly and are broken by minor faults. In a general way they follow the trend of the enclosing rocks. The quartz is mostly massive and without visible trace of mineralization. Here and there, however, the texture is more open or vuggy and at such places the quartz is impregnated with sulphides, including galena, sphalerite, pyrite, pyrrhotite, chalcopyrite, and grey copper (tetrahedrite). Quite large lumps of the grey copper were observed. Associated with these minerals is some calcite and a very little of a brownish mineral resembling ankerite or spathic iron. Vugs in the vein quartz also include some large quartz crystals of milky white colour. Adjacent to the pockets of ore minerals the country rock is slightly impregnated with sulphides. Development work includes an adit run for 125 feet partly on, and partly alongside, one or other of the quartz veins. This adit encounters no mineralization of commercial significance.

EAST SHORE OF UPPER ARROW LAKE NORTH OF NAKUSP

Quite a little prospecting, notably by the late D. McBain of Nakusp, has been done on quartz veins intersecting pyritized argillite of the Slocan series on either side of cape Horn. A sparse dissemination of pyrite, and, in some places, chalcopyrite, in these veins and the country rock adjoining has encouraged these efforts, but has resulted in no significant discoveries.

VICINITY OF PINGSTON CREEK

A complete report on the Big Ledge group of properties is given elsewhere in this volume.

About 2½ miles south of the mouth of Pingston creek, some vein quartz carrying pyrite, chalcopyrite, and specks of other sulphides is associated with metamorphosed rocks of Precambrian age. A little prospecting has been done in this vicinity, but the results have not been encouraging.

BIG LEDGE (CONSOLIDATED) PROPERTY, UPPER ARROW LAKE, KOOTENAY DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes and H. C. Gunning

CONTENTS

Illustrations

OWNERSHIP AND LOCATION

The Big Ledge property is a consolidation of the holdings of several individuals,[1] who have amalgamated their interests under one management. Mr. A. St. Clair Brindle, 607-608 Pacific building, Vancouver, B.C., is part owner and consulting engineer.

The property is situated on the west side of Upper Arrow lake opposite St. Leon hot springs and west of Pingston creek a large stream entering the lake about 17 miles south of Arrowhead. A wide, well-graded trail about 8 miles long leads from the lake shore, a short distance below the mouth of Pingston creek, to Sunshine camp situated approximately 3,500 feet above the lake.

FIELD WORK AND ACKNOWLEDGMENTS

The writer spent in all about five days, at different times, in an examination of the Big Ledge and adjoining territory. This, in view of the great length of the ledge and numerous features of interest in its vicinity, left little time for detailed mapping or sampling.

Acknowledgment is made to Messrs. Fowler and Waldren, part owners of Big Ledge, for their kind assistance in facilitating this examination. Thanks are specially due Mr. A. St. Clair Brindle who subsequently supplied maps, drill records, assay returns, and other data of which free use has been made in this report.

[1] *See* Figure 6.

HISTORY

Interest has long been attached to properties located along the Big Ledge, but until 1925, when their amalgamation was effected, very little effort had been made to explore or develop the several holdings. This condition arose partly as a result of friction among the several owners who, in consequence, were unable to co-operate to the extent desired, but is also attributed to the peculiar character of the mineralization which, until recent years, was not considered adaptable to prevailing methods of concentration and metallurgical treatment.

The initial discovery was made in the late nineties by Mr. A. Symons, one of the principal owners. His attention had been directed to the property by a half-breed Indian who had been attracted by the iron-stained appearance and continuity of the Big Ledge. Realizing the possible economic significance of this zone of mineralization, Mr. Symons staked a number of claims along the outcrop. Subsequently other groups were located by other parties on either side of Symons' holdings and along the apparent continuation of the same mineralized zone whose remarkable length and appreciable width had early led to its designation as the "Big Ledge."

Altogether some thirty-five claims are now staked along or adjoining the course of the Big Ledge. Of these, nine are Crown granted and all but the three most westerly claims [1] included in the present amalgamation.[2]

The property was visited by Brock [3] in 1898, and by O'Grady in 1923.[4]

TOPOGRAPHY

The topography in the vicinity of Big Ledge is worthy of special consideration in view of its bearing on any possible future development work. Mineral claims are located continuously along the ledge, in a general east and west direction, over a distance of between 4 and 5 miles (*See* Map 232A). In this distance the elevation rises from less than 4,000 to nearly 7,000 feet. Mount Baldy, on the summit of the divide, to the north of Guy Fawkes claim, has an elevation of approximately 7,240 feet above sea-level. To the north of Big Ledge, and about parallel with it, lies a deep, prominent valley occupied by an important tributary of Pingston creek. To the south of the ledge a smaller and nearly parallel stream, Brownie (Trout) creek[5], drains from Empress lake into Pingston creek. Brownie creek furnishes a source of water supply and power for Central camp and is otherwise of interest in that it empties from the south side of Empress lake into two natural tunnels in crystalline limestone, and follows an underground channel for upwards of a mile before emerging, with a 900-foot head, through a small opening in a similar rock, a short distance above Central camp.

[1] Only the most easterly of these, the Mascot claim, is shown on the map, Figure 6.

[2] Two adjoining claims, Robson and Emma (Lots No. 5408 and 5407), lie to the east of, and are separated by a considerable interval from, the other claims of the Big Ledge consolidation. The Emma (5407) is Crown granted and both claims form part of the holdings of Trites and Brindle. These claims do not appear on the map accompanying this report, but are shown on another map (Cairnes, C.E.: Geol. Surv., Canada, Sum. Rept. 1928, pt. A, Map 232A).

[3] Brock, R. W.: Geol. Surv., Canada, Sum. Rept. 1898, pt. A, p. 70.

[4] O'Grady, B. T.: Ann. Rept., Minister of Mines, B.C., 1923, p. 235.

[5] Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1928, Map 232A.

Up to the elevation of Sunshine and Central camps the hill-slopes are heavily timbered. Above this elevation small timber persists to about 6,000 feet above sea-level. The upper 1,000 feet or so of the hill-slopes are, however, quite open and easily traversed on foot or horseback in almost any direction. Empress and Iron lakes at an elevation of 6,000 feet lie towards the centre of a rock-rimmed amphitheatre-shaped glacial basin (Plate III A) where the structure and character of underlying rocks are well displayed and across the northern slopes of which the Big Ledge is prominently exposed.

GEOLOGY

The rock formations in the vicinity of Big Ledge are chiefly of Precambrian age[1]. The members include a variety of lustrous crystalline schists, crystalline to dense white limestones, and paragneisses. These have been intruded by pegmatitic and gneissic rocks, types correlated with a widespread member of the Nelson batholithic intrusives referred to as the pegmatite-gneiss complex.[2] One lamprophyre dyke, from 3 to 4 feet wide, was observed on Golden Hope claim. Two other dykes of similar character are reported by Mr. Brindle to occur elsewhere on the property.

Members of the Precambrian rocks include one or more bands of *garnetiferous mica schist.* Outcrops of this rock occur close to, or along the foot-wall of, the Big Ledge in its western and central exposures, but are not known to represent a continuous band. This schist carries an abundance of red garnets varying up to one-half inch or more in diameter. Other minerals include a large percentage of quartz, some plagioclase and biotite, a lesser amount of muscovite, a little sericite, and, in one specimen, quite an abundance of kaolinite. Several bands of *limestone,* mostly coarsely crystalline, and up to 50 feet or more in thickness, were also observed. They occur on either side of, as well as within and along, portions of the hanging-wall of the Big Ledge. Some white, dense limestone strata were also noted. All these limestone beds carry impurities including quartz and a variety of lime silicate minerals. Attention, too, is commonly attracted by numerous small metallic flakes of graphite. The *paragneisses* are in general difficult to distinguish from gneissic intrusives with which they are associated. Commonly they carry a larger proportion of biotite (in some cases dark green amphibole) and have, as a result, a "salt and pepper" texture which is not as noticeable in the gneisses. Both rock types, however, carry much the same suite of minerals, chief among which is quartz, plagioclase (about oligoclase), and biotite. Other minerals include orthoclase, amphibole (hornblende and actinolite), muscovite, pyroxene (diopside?), titanite, apatite, magnetite, garnet, sericite, and sulphides. The *pegmatitic intrusives* intersect the gneisses as well as paragneisses and other Precambrian rocks. Quartz, plagioclase, and orthoclase are the abundant minerals. In a specimen taken from a tunnel on Outlook claim the feldspars show corroded edges against the quartz. Small, well-rounded grains of quartz also occur within large crystals of feldspar. Muscovite is the characteristic mica of these rocks. Other minerals include red garnets, sericite, and iron sulphides. The

[1] Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1928, pp. 96, 97 and Map 232A.
[2] Idem., pp. 101–104.

single basic dyke observed on Golden Hope claim is a lamprophyre carrying large crystals of titanaugite, plagioclase near andesine, calcite, ilmenite, pyrite, and an abundance of radiating masses of serpentine and chlorite. No quartz was noted. This dyke appeared to cut all other rocks except, possibly, the pegmatitic intrusives.

The structure of the Precambrian rocks, judging chiefly from exposures at the higher elevations where outcrops are abundant (Plate III B) is mostly quite regular. The general strike is about east and west and the dip invariably to the south at an angle that would average nearly 40 degrees. Below Sunshine camp outcrops are rarely exposed in the vicinity of the Big Ledge, but along the trail leading to Upper Arrow lake[1] the average attitude is apparently not very different from that obtaining above timber-line.

EQUIPMENT AND DEVELOPMENT WORK

Two camps, Central and Sunshine (*See* Figure 6), have been established three-quarters of a mile apart and, roughly, 3,500 feet above Upper Arrow lake. These are capable of accommodating about twenty-five men and are equipped with a blacksmith outfit and other facilities for hand mining. There is also an old camp on Adventurer claim 1,000 feet below the others. The property, as a whole, is well supplied with timber. Water for domestic or power purposes is also readily available.

Work accomplished to date on the Big Ledge is regarded as entirely preliminary. It has been designed to investigate the continuity of the ledge and, at the same time, formulate some idea of the character and extent of its metallization. The work (*See* Figure 6) included numerous open-cuts distributed at irregular intervals along the Big Ledge; some 700 feet of tunnelling; and, altogether, 16 diamond drill holes, aggregating 3,400 feet of drilling, distributed chiefly over central and western claims. The drill holes were sunk in each case from the surface close to and approximately at right angles to the ore zone. They are, consequently, all shallow, the deepest, No. 2 hole, being only 350 feet long.

MINERALIZATION

DESCRIPTION OF THE BIG LEDGE

Mineralization on consolidated Big Ledge properties is confined to a belt or zone remarkable alike for its continuity and for its general uniformity in appearance and character of its mineralization. This ledge has been traced in part by outcrop and in part by a series of irregularly spaced open-cuts, over a minimum distance, between Adventurer camp and the summit of the divide on Skyline claim, of about 3 miles. In this distance it varies from about 75 to over 200 feet in thickness and would probably average 135 feet. Over the same distance the ledge rises from about 2,600 to 5,600 feet above Upper Arrow lake. Above timber-line, towards the west end of the property, the outcrop is readily distinguished by its reddish appearance due to oxidation of the abundant iron sulphides, pyrrhotite and pyrite, by which it is chiefly mineralized. The ledge,

[1] Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1928, Map 232A.

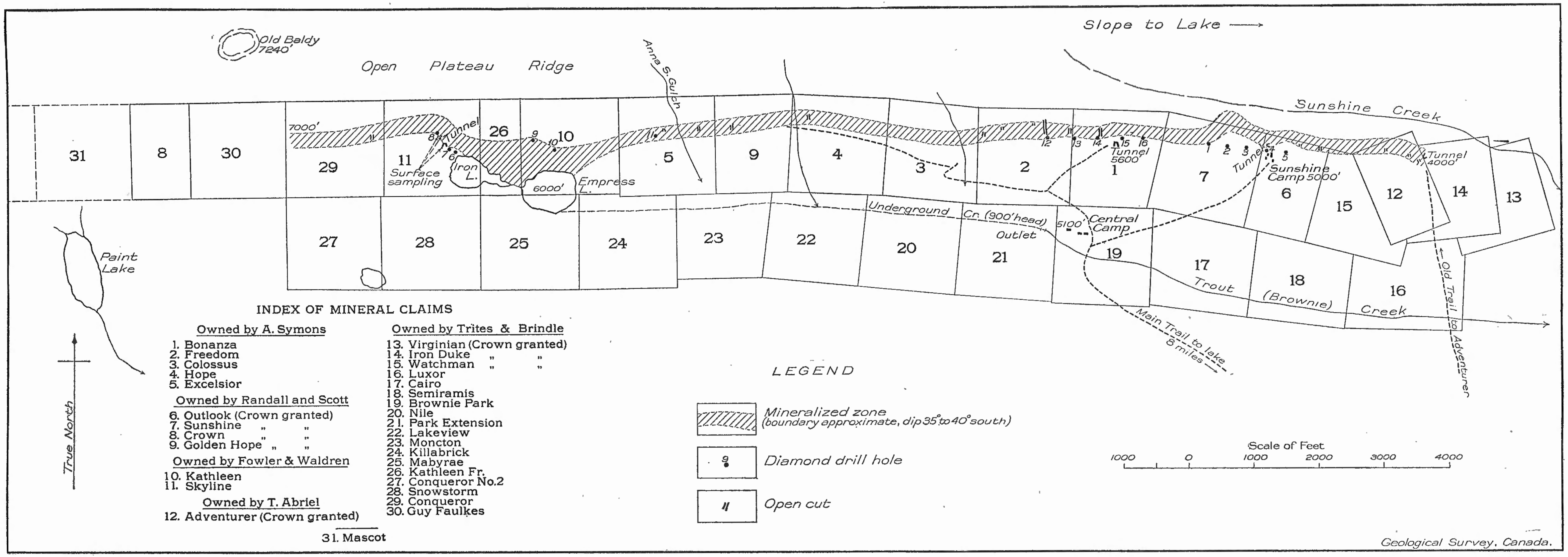

Figure 6. Sketch plan of Big Ledge (consolidated) mineral claims, Arrow Lake mining division, B.C.

in this more open country (Plate III A), appears to conform, or, at least, to be closely alined, with the enclosing strata. The walls were not readily defined at the surface, but it is claimed that in drilling operations difficulty was rarely experienced in detecting the exact boundaries of the ledge. The hanging-wall has been eroded for some distance along the northern flank of the basin overlooking Empress and Iron lakes. Below timber-line the course of the ledge is obscured by drift and soil. Here and there open-cuts expose a zone of mineralization similar to and about in line with that observed at the higher elevations and the assumption is, consequently, that the one zone persists easterly to, and, probably, for some distance beyond, Adventurer camp.

Towards the west the ledge strikes, on an average, nearly east and west and dips at an angle of nearly 40 degrees to the south. Farther east the structure, judging from its exposures in a series of open-cuts and in a tunnel on Adventurer claim, appears more variable. In this direction the strike swings to more nearly south 65 degrees to 75 degrees west, and the dip alternates from a steep angle to the south, near Sunshine camp, to about 20 degrees on Adventurer claim.

The original character of the rock composing Big Ledge is now, by reason of the alteration that has occurred, a matter of doubt. That at least part of the ledge included a limestone bed or beds is suggested by the presence, here and there along the zone and particularly near the hanging-wall, of lenses and irregular bodies of crystalline limestone. The texture, too, of much of the more altered part of the ledge, though composed of a rock essentially igneous in composition, has a granular appearance very like that of the limestones. A thin section of such a rock was examined under the microscope and seen to be composed largely of orthoclase, plagioclase, quartz, and biotite. Other constituents included numerous grains of apatite, considerable pleochroic titanite, a few grains of diopside, and sulphide minerals. The granular recrystallized appearance of this rock suggested its derivation from a pre-existing bed and the presence of the calcium-bearing minerals apatite, titanite, and diopside suggested, in turn, that this rock may have been limestone or, at least, a limy rock.

Here and there the ledge rock has been penetrated by pegmatitic intrusives which, in places, as in the tunnel on Outlook claim near Sunshine camp, carry an appreciable impregnation of sulphides.

DISTRIBUTION OF MINERALIZATION IN THE BIG LEDGE

The Big Ledge is nowhere mineralized across its entire width. Mineralization is, in fact, mostly confined to bands or lenses within the zone of this ledge. These bands vary from a few inches to 60 feet in thickness. They appear at scattered horizons within the zone and are separated by relatively great widths of barren or sparsely mineralized country rock. The position and thickness of these bands or lenses at widely spaced intervals along the course of the ledge have been indicated by a number of shallow diamond drill holes and by a series of open-cuts. The logs of these drill holes vary greatly and consequently afford little opportunity for a satisfactory interpretation of the continuity or shape of the mineralized bodies. In a general way the most persistent mineralization appears, from these logs as well as from open-cuts across and natural exposures of the ledge, to follow along or close to the hanging-wall where it has a variable width of from a few feet to 60 feet and might average 10 feet or more. Elsewhere bands or lenses of mineralization are distributed less regularly across central portions of the zone and, in some cases, on or close to the foot-wall rocks. They appear in each case to conform closely with the strike of the ledge, and the suggestion is that they are roughly tabular or flat, lens-shaped and that they follow more or less along the course of strata which have been partly to completely replaced by mineralizing processes. It is quite uncertain, however, whether these mineralized bodies pitch with, or rake at an angle across, the dip of the ledge or the strata composing it. Consequently it is impossible to say whether such mineralized widths as appear to correspond in position from hole to hole are actually continuous for such considerable distances, or whether these widths form parts or distinct lenses raking across the dip of the ledge. On the other hand, and owing to the limited depth of drilling operations, it cannot be said that lenses of mineralization may not, by reason of some such pronounced rake, actually persist farther than is indicated by these drill records. The most encouraging feature in the light of explorations to date relates to the apparent persistence of mineralization along or close to the hanging-wall. More work in this section would not only outline the extent of this mineralization, but would doubtless throw light on the behaviour of mineralized bodies elsewhere within the boundaries of the Big Ledge.

ORE MINERALS

The mineralized bands or lenses contain a varying and in many cases high percentage of sulphides, of which pyrrhotite is, in most places, easily the most abundant. Pyrite ranks second and sphalerite third in amount. Here and there, and particularly on Skyline claim, galena is a noticeable, but only locally an important, constituent. The sulphide minerals have impregnated or entirely replaced the country rock and all stages from barren rock to masses of sulphide were observed. The sulphides are mostly quite coarsely crystalline. Their oxidation at the surface has stained the outcrop of the ledge various shades of red. Bodies of pyrrhotite are also commonly coated with a film of whitish iron sulphate.

GENESIS AND PARAGENESIS

The mineralization on Big Ledge is thought to be related to Nelson batholithic intrusives which have invaded, metamorphosed, and, in part, assimilated and replaced the older Precambrian rocks. The occurrence is rather unique in that elsewhere in the district the pegmatite-gneiss complex of the Nelson batholith rarely carries appreciable sulphide mineralization either in itself or in its association with Precambrian rocks. It would appear that the Big Ledge is, in effect, but the lower part of an originally more extensive zone of mineralization. The upper part of this zone probably carried a somewhat different suite of minerals in which, for example, galena may well have been an important constituent.

An examination of Big Ledge along the length of its outcrop or where exposed by open-cuts did not reveal evidence of important fissuring, though such, if present, may possibly have been obscured by subsequent mineral deposition. There is, however, the suggestion, based largely on an appearance of conformity with enclosing Precambrian strata, that the rock members of Big Ledge proved more pervious and more susceptible to replacement by rising metalliferous solutions than adjacent strata. Here again, however, evidence of such peculiarity is obscured by the intense alteration to which these rocks have been subjected.

As a matter of fact Big Ledge mineralization may involve a combination of both fissuring and replacement. Along its more westerly exposures the ledge does appear to conform or be closely alined with enclosing strata and there is evidence to show that the original rocks in this zone were, in part at least, limestone or very limy beds which by their very nature are particularly susceptible to replacement. In this section, then, replacement along a single stratigraphic zone seems a not unreasonable explanation for the presence of mineralization in the Big Ledge. Farther east, however, this explanation finds less to support it. The wall-rocks, for example, do not seem to correspond from point to point along the course of the Ledge. These differences in composition might, of course, be attributed to variations in the character of metamorphism of the same bed, but it appears equally probable that where, for example, a very similar garnetiferous schist appears along the footwall of the Big Ledge on the more westerly claims and again in the vicinity of Sunshine camp, but is not noted at intermediate points, that two bands of such schist are represented and, in consequence, that the Big Ledge may not be quite conformable with enclosing strata. The dip of the ledge, too, apparently varies, east of Sunshine camp, from steep to quite low angles, whereas such rock exposures as were observed on these lower slopes continued to preserve much the same attitude as higher up the hill. Features like these suggest that fissuring may have had quite an important rôle, though replacement has everywhere been a significant contributing factor.

Examination of ore specimens under the microscope indicates that replacement of the country rock by the sulphide minerals has been an important factor in the mineralization of Big Ledge. The sulphides may occur either as solid masses, veinlets, or disseminated grains. Pyrrhotite, as the most abundant sulphide, is minutely intergrown with a minor proportion of sphalerite, indicating that these two sulphides were introduced contemporaneously. This relation is of importance in indicating the difficulty that must be expected in any attempt made to separate these sulphides mechanically. Pyrite, the second most abundant sulphide, occurs largely in bodies or masses more or less distinct from the pyrrhotite. Similarly, galena, though occasionally observed in very minor proportions associated with other sulphides, is, in its more noticeable occurrences on Skyline claim, mostly separate from them. It favours limestone or limy schists and in this respect indicates a rock preference which is less evident in the case of the other sulphides. In general, too, the galena appears to have been deposited later than the other principal sulphides.

Under the microscope masses of nearly solid sulphide are seen to contain numerous and generally well-rounded grains of such minerals as quartz, apatite, titanite, pyroxene (diopside ?), tremolite, and muscovite. In one specimen one or two grains of a mineral resembling olivine were also noted. The presence of such minerals as apatite, titanite, pyroxene, and olivine might suggest a magmatic relation with the sulphides and indicate that these sulphide masses were intruded as an ore magma carrying crystals of these other minerals. This view, however, is largely discountenanced by the observation that such minerals as those listed above occur elsewhere within the country rock of Big Ledge where no sulphides are present, or are represented merely as disseminated grains. The rounded edges of the silicate grains seen within masses of sulphide instead of representing corrosion by a sulphide melt may, more probably, be regarded as the result of replacement by metalliferous solutions carrying the sulphide.

ESTIMATION OF VALUES

Except for small amounts of galena noted in Nos. 6 and 8 drill holes and on the surface of Skyline claim, the only mineral of present economic significance in the Big Ledge, so far as developments to date have shown, is sphalerite or zinc blende. A study of assay returns based on samples taken from the drill cores indicates that the proportion of zinc in the mineralized bands or lenses varies from less than 1 to over 12 per cent. Selected samples may be obtained in which the percentage of zinc may reach a much higher figure, but the above represents assays across widths, in most cases, of several feet.

The following calculations as to percentages of zinc contained in Big Ledge cannot at best be regarded as more than approximate, as some sixteen drill holes irregularly spaced along a zone over 4 miles in length can hardly be expected to afford satisfactory data on which to base an estimate of the values contained in this zone. These records, however, represent the best information available and in view of the fact that the assay returns are mostly of the same order of magnitude, such tables as follow may be expected to give at least some idea of the average percentage of zinc contained not only within the ledge as a whole but also across selected portions of it. In this connexion one other feature might properly be considered. The drill holes are for investigation of the Big Ledge close to the surface only. There are no deep holes. Consequently, little is known of the character of the mineralization at any considerable distance below the surface. To some extent this information appears to be supplied by nature, in that a longitudinal section with a vertical range of 3,000 feet is exposed between Skyline and Adventurer claims. This might seem to imply that 3,000 feet vertically below the Skyline exposures we might expect to find mineralization of a type similar to that on Adventurer claim. Such, however, is not necessarily the case. The mineralized bodies within Big Ledge may, for example, rake more or less closely with the surface, a feature characteristic of many ore deposits in Kootenay district. Mineralization, in such a case, might be confined to a depth, at most, of a few hundred feet. Although such a possibility represents a rather extreme case, the chance of a more or less pronounced easterly rake should be kept in mind. On the other hand the rake may be approximately with, or to the west of, the dip of the ledge, in which cases the natural section exposed along the slope of the hill might be expected to represent, more or less closely, the character of mineralization anywhere within the Big Ledge down to the lowest level of the section.

TABLE I

No. of drill hole	Thickness of Big Ledge	Average % of zinc
1	158	0·55
2	170	0·60
3	144	1·49
4	146	0·08
5	88	0·35
6	166	0·48 (also about 0·1% lead)
7	210	0·32
15	78	1·54
16	75	0·95

The above table is compiled from assay logs of those drill holes only which cross both foot- and hanging-walls of the Big Ledge. Computing from this table alone, the average thickness of Big Ledge would be 137 feet and the average percentage of zinc across this width 0·64.

TABLE II

No. of drill hole	Selected width	Average % of zinc
1	11	4·00
2	12	6·38
3	60	3·58
4	33	0·36
5	72	0·43
6	38	1·99
7	27	2·01
11	17	2·63
12	14	2·49
13	36	1·76
14	37	3·04
15	16	5·99
16	5	12·80

In table II the selected width chosen in each case includes from one to several mineralized bands situated so close to each other as to suggest that they might, if values were sufficiently encouraging, be mined together as a unit. The table indicates that the average width of "selected width" over the area drilled is 29 feet and that the average percentage of zinc in this is 2·45 per cent.

TABLE III

No. of drill hole	Selected width	Average % of zinc
	Feet	
1	4	7·00
2	4	8·50
3	5	10·00
4	5	2·20
5	4	6·80
6	3	11·20
7	5	7·20
11	5	8·60
12	3	7·80
13	2	9·00
14	5	12·10
15	5	6·08
16	5	12·80
Average	4·23	8·35

The "selected width" in table III includes the highest grade zinc encountered in each hole. The figures for average width and average percentage of zinc must, however, not be confused as meaning that any single body of zinc ore of the character indicated by these averages persists along Big Ledge over the area drilled.

KOOTENAY LAKE DISTRICT, BRITISH COLUMBIA

By J. F. Walker

CONTENTS

Illustrations

INTRODUCTION

Kootenay Lake area as described in this report lies between longitudes 116° 30′ and 117° and latitudes 49° 30′ and 50° 30′. It includes Duncan lake and the northern and greater part of Kootenay lake, which lie within the Purcell trench, and to the east reaches to the summit of the Purcell range.

The geographic base of the accompanying map of the area is a compilation of parts of various published maps, a traverse of Kootenay lake south of Kaslo by A. C. T. Sheppard, a reconnaissance survey of Fry creek by the writer, and reconnaissance surveys east of Kootenay lake in the southeast part of the area, by M. F. Bancroft.

The geology of the northeast corner north of mount Gleason has been transcribed from the Windermere map. The geology north from Lardeau and east to Duncan river is from the Lardeau map now proceeding to publication. The geology from Schroeder creek south to Woodberry[1] creek is the work of C. E. Cairnes. The geology from Riondel north, with the exception of the southern boundary of the Fry Creek granite area and the granite area lying along the lake, which are from the West Kootenay sheet, is the work of J. F. Walker and H. C. Gunning. The geology south of Riondel is largely the work of M. F. Bancroft supplemented by the writer.

Messrs. Swanston Gibson and T. H. Warden rendered efficient assistance in the field during the season of 1927. Messrs. S. S. Fowler and B. L. Eastman kindly rendered assistance in the examination of the Blue Bell mine. R. V. D. Guthrie, A. S. H. Deverson, and others, facilitated the work of the Survey in many ways.

The first geological work on Kootenay lake was a reconnaissance survey in 1889 by G. M. Dawson. This was followed by the mapping of

[1] Geographic Board spelling is Woodbury.

the West Kootenay sheet by R. W. Brock and R. G. McConnell during the years from 1894 to 1900. James McEvoy in 1899 made a reconnaissance survey of the East Kootenay sheet and touched the southeast corner of the area. R. W. Brock in 1903, 1904, and 1907 made a geological reconnaissance survey of Lardeau map-area, but did not publish a geological map. A geological map of Slocan mining area, representing work by O. E. LeRoy and C. W. Drysdale, was published in 1916 and in 1920 the Ainsworth sheet by Schofield was published. Bancroft spent the season of 1914 and 1915 on the east side of Kootenay lake south of Riondel and the results of his work are incorporated for the first time in the accompanying map (236A).

The reports of the British Columbia Minister of Mines contain a wealth of information concerning the mining operations in the area.

Kootenay lake south from Kaslo has an average width of about 2 miles. North of Kaslo it contracts to about a mile in width and then expands to an average width of about 1½ miles, the valley north beyond the lake maintaining approximately the same width. The lake bottom drops rapidly to depths of 400 to 450 feet, which is about the average depth of the lake.

The bordering mountains rise steeply with relatively small, scattered areas of bench land suitable for agriculture. The largest areas of arable land are south of Duncan lake, at Johnsons landing, Kaslo, Riondel, and Crawford bay.

The northeastern part of the area, in the vicinity of Glacier, Hamill, and Fry creeks, is very rugged and inaccessible. Peaks here reach elevations of 10,000 feet above sea-level and tower 6,000 feet above the valleys which are narrow and deep. Along the east side of Kootenay lake the tributary creeks have carved out a series of narrow ridges, running east and west, ranging in elevation from 7,000 feet on the ends overlooking the lake to 8,000 feet and higher on their eastern ends. On the west side of the lake the area takes in the slopes to near the summits of the ridges overlooking the valley.

GENERAL GEOLOGY

The western slopes of the Purcell range are carved in Precambrian sediments of Purcell and Windermere age separated by a marked unconformity. Carboniferous and Triassic sediments overlie the Precambrian to the west of Kootenay lake and occupy but a small part of the map-area.

Greenstone dykes and sills cut the Precambrian rocks and also the Milford group of Triassic and Carboniferous ages. They do not cut the Slocan series,[1] also of Triassic age, hence are considered to be Triassic in age.

The Nelson batholith outcrops along the western edge of the map-area and with the Fry Creek granite area and smaller intrusions of granite throughout the area is assigned to the Post-Triassic. Mineralization and the intrusion of lamprophyre dykes appear to be a very late stage of the batholithic intrusion.

Pleistocene and Recent deposits are found chiefly along the Purcell trench and its larger tributary valleys.

[1] Cairnes, C. E.: Personal communication.

Table of Formations

Quaternary	Recent	Alluvium, stream gravels
	Pleistocene	Glacial mud, sands, gravel, and till
Mesozoic and (?) Tertiary	Post-Triassic	Nelson batholith Stocks and smaller intrusions
	Triassic	Slocan series
		Disconformity
		Kaslo series
	Unconformity	
Mesozoic and Palæozoic	Triassic and Carboniferous	Milford group
	Unconformity	
Precambrian	Windermere	Lardeau series Badshot formation Hamill series Horsethief series Toby conglomerate
	Unconformity	
	Purcell	Upper Purcell Undivided Purcell

PRECAMBRIAN

The part of the southeastern part of the map-area now mapped as occupied by undivided Purcell strata and which fell within the limits of the West Kootenay sheet, was mapped by McConnell and Brock as being underlain by Lower Selkirk strata thought to be of Cambrian age.[1] Schofield in 1913 [2] stated that, ". . . . . . The Selkirk (strata) . . . . . . are equivalent in part to the Purcell series since the Selkirk series rest(s) conformably upon the Creston formation of the Purcell series." The Selkirk series as mapped on the West Kootenay sheet and as correlated by Schofield is now known to include not only Purcell rocks but also Windermere rocks.

Schofield [3] in 1913 and 1914 stated that the Shuswap series along Kootenay lake was but metamorphosed Selkirk strata and, therefore, Beltian in age. He also stated that the strata along the west side of Kootenay lake, more particularly in the neighbourhood of Ainsworth, which previous workers had subdivided into Shuswap (Early Precambrian), Niskonlith (Lower Cambrian), Selkirk (Cambrian and Ordovician), and Slocan (Carboniferous?), should all . . . . . . "probably be referred to the Beltian." At a later date, Schofield [4] in giving his final account of the

[1] West Kootenay sheet: Explanatory notes.
[2] Schofield, S. J.: Sum. Rept. 1913, pp. 130 and 135–6.
[3] Sum. Rept., 1913, p. 136; Sum. Rept. 1914, pp. 38, 41.
[4] Schofield, S. J.: Geol. Surv., Canada, Mem. 117.

geology of the vicinity of Ainsworth, revised his earlier statements. The finding, first by Drysdale in 1916 and second by Bancroft in 1917, of fossils in the Slocan series north of Ainsworth, was thought to fix the age of that series as Carboniferous.[1] At Ainsworth, Schofield found the Slocan strata to be conformably underlain by strata previously subdivided into Selkirk and Shuswap.[2] To these older strata Schofield applied the name Ainsworth series, but since the Ainsworth seemed to conformably underlie the supposedly Carboniferous Slocan series, he concluded that the . . . . "Ainsworth series is Carboniferous or pre-Carboniferous and probably post-Beltian in age." The general situation as envisaged by Schofield is as follows.[3]

"The sedimentary rocks exposed around Ainsworth are Carboniferous and in part possibly pre-Carboniferous...... These .... rocks are underlain by the Purcell series........ The contact between the Purcell series (Beltian) and the overlying Palæozoic rocks...... is believed to lie in the vicinity of the watershed east of Kootenay lake, since there is an apparently continuous record of sedimentation from the Beltian of East Kootenay to the Carboniferous of Ainsworth".

Though Schofield changed his opinions regarding the age of the strata, his fundamental concept remained unchanged. His earlier work led him to believe that the strata bordering both sides of Kootenay lake and which earlier workers subdivided (in descending order) into Slocan, Selkirk, Niskonlith, and Shuswap, was one conformable series and that the so-called Shuswap was merely highly metamorphosed facies of this single assemblage. East of Kootenay lake, this conformable assemblage had been found to conformably succeed a member within the Purcell series, within what much later has been defined as being the Lower Purcell series. Since the Purcell series was definitely known to be Precambrian, the apparently conformably overlying assemblage bordering Kootenay lake and including the Slocan series as its youngest division, was assigned to the Precambrian also. But when, later on, newly discovered fossiliferous evidence seemed to place the Slocan in the Carboniferous, Schofield believing there was no break between the Slocan and underlying strata was forced to conclude that the underlying strata were also of Palæozoic age. To the underlying strata he gave the name Ainsworth series whose base, as he stated, must lie somewhere east of Kootenay lake amongst the conformable succession of strata that there passes down into the Purcell series. The implied definition of the Ainsworth series was, therefore, the Palæozoic strata conformably underlying the Slocan series and conformably overlying the Purcell series. Or the Ainsworth series might have been defined in more general terms as a conformable succession older than the Slocan series and younger than the Purcell series. If this had been done and if it had not been claimed that the Ainsworth is conformable with both the overlying Slocan series and the underlying Purcell series, the term Windermere series would not have been coined.

Bancroft in 1915 continued the study of the strata developed east from Kootenay lake and reported[4] that they formed an

...."enormous thickness of conformably sedimentary rocks (which) has been subdivided into three series....: the Purcell series, the Selkirk series, and the Shuswap series of Kootenay lake. The Purcell series.... occupies most of the region east of the divide...

[1] Op. cit., p. 18.
[2] Op. cit., pp. 14-15.
[3] Op. cit., p. 27.
[4] Sum. Rept. 1915, p. 96.

The Selkirk.... is to be found on the western slope of the Purcell range and on the basis of field evidence is to be considered as in part the equivalent of the Purcell series. The eastern geological boundary of the Selkirk series is along the Creston formation, a member of the lower part of the Purcell series. The Creston formation appears to be the conformable base of the Selkirk series.... The Shuswap series.... is represented on the northwest side of the area investigated and appears to pass.... conformably over the Selkirk series."

This is the same general conception as put forward by Schofield, but more recent work has proved the existence, within the supposedly conformable succession, of a break separating the Purcell strata from the overlying assemblage.

In 1916, Drysdale worked in Slocan area. In his account of this work[1] and on an accompanying map, the rocks in the vicinity of Kaslo are subdivided, in ascending order, into Ainsworth or Shuswap series, Kaslo volcanics, and Slocan series. The Ainsworth or Shuswap series is stated to be pre-Beltian; as mapped it corresponds roughly with the local development of Shuswap rocks outlined by earlier workers. The Niskonlith and part of the Selkirk series of former observers are classed with the Slocan, and the remainder of the Selkirk strata are grouped under the new term, Kaslo volcanics. The Kaslo and Slocan strata as determined by structure and fossiliferous evidence were assigned to the Palæozoic. The contact between the Ainsworth or Shuswap and the Kaslo-Slocan succession was described as a fault. Elsewhere in the same volume[2], Drysdale indicated his belief that the Ainsworth or Shuswap rocks unconformably underlay the Purcell series. Bancroft after a further study, in 1919, of Slocan area[3], pointed out that the general structure had been misconceived by Drysdale and that the succession along the west side of Kootenay lake was, in ascending order, Ainsworth series (formerly the Shuswap), Slocan series, and Milford series. The Kaslo series of Drysdale was supposed by Bancroft to be composed of intrusives. The important result of Bancroft's work was the reaffirming that the Ainsworth (the old Shuswap) and the Slocan strata were not separated by a fault, but that instead, the Ainsworth underlies, and appears to be conformably succeeded by, the Slocan series of Carboniferous age. Bancroft was of the opinion that both series were of Palæozoic age.

In a succeeding year, Bancroft, reporting on the Lardeau area, stated[4] that in that district a northward extension of the Ainsworth-Slocan assemblage, overlay "probably Palæozoic, possibly Precambrian" strata which he named the Duncan series. This general conclusion was reaffirmed by Bancroft in a succeeding report.[5]

The present writer, as a result of work in Windermere district, has been able to show[6] that, in that district, the Purcell series is unconformably overlain by a thick assemblage of Precambrian strata to which the name, Windermere series, was given. In this district the Windermere series consists of the Toby conglomerate overlain by the Horsethief formation. These strata have been traced westward by the writer and in the vicinity of Hamill and Fry creek it was possible to establish the correlation of the strata of Windermere and Lardeau map-areas. As a result, it is

[1] Sum. Rept. 1916, pp. 56–57.
[2] Op. cit., p. 59.
[3] Sum. Rept. 1919, pp. 40–43.
[4] Sum. Rept. 1920, pp. 99–100.
[5] Sum. Rept. 1921, pt. A, p. 107.
[6] Walker, J. F.: Mem. 148, pp. 6 et seq.

known that the strata in the Lardeau to which Bancroft gave the name Duncan series, are a part of the Windermere series. The name Duncan is now replaced by Lardeau, for the name Duncan had previously been used for a Cretaceous formation on Vancouver island.

The Windermere strata in Lardeau map-area are unconformable below the Carboniferous, in part perhaps Triassic, Milford group. In Slocan area, the Milford group is unconformably below the Slocan series now known to be of Triassic age. The Ainsworth strata along the west shore of Kootenay lake are without doubt a part of the Windermere group and much older than the Slocan series.

Undivided Purcell

The area of undivided Purcell rocks in the southeastern part of the map-area is largely composed of grey to greenish quartzites, grey, black, buff, to reddish schists, and some beds of magnesian limestone.

The succession is not definitely known, but the quartzites appear to form the lower and greater part of the succession with schists, quartzite, and limestone forming the higher members.

The whole succession is highly folded, with northerly strikes and structures. The structures strike across the area of downfaulted Kitchener rocks as shown on the Cranbrook map-area and although no definite correlation can be made with the Purcell divisions of Cranbrook map-area there seems to be little reason to doubt their Purcell age.

Upper Purcell

The Upper Purcell strata in the northeast corner of the map-area, belong chiefly to the Dutch Creek formation, with only small outcrops of the Mount Nelson formation. The Dutch Creek formation as it occurs in Windermere map-area[1] is the northern continuation of the Gateway, Phillips, and Roosville formations of Cranbrook map-area. The Dutch Creek formation is composed essentially of grey to almost black or green slate, platy magnesium limestone grading to platy greenish quartzite, and vari-coloured slate. The maximum observed thickness of the formation in Windermere map-area is about 3,500 feet.

The Mount Nelson formation is a succession of crystalline magnesium limestones and slates and has at its base and also near the upper erosional surface, massive white quartzites. It has an observed thickness of 3,400 feet. The magnesian limestones are grey, blue, white, purple, and brick red on fresh fracture and weather to grey, cream, buff, and purple. The slates are grey to black, green, and purplish, and weather to the same colours. The Mount Nelson formation conformably overlies the Dutch Creek formation and is the youngest known member of the Purcell series.

Toby Conglomerate

The Toby conglomerate is the basal member of the Windermere series. The exposures in the northeastern part of the map-area have been described in the report on Windermere map-area. The formation has been there described as a piedmont deposit, variable in thickness, suggesting

[1] Geol. Surv., Canada, Mem. 148.

fan structure, and composed of a heterogeneous assemblage of fragments and boulders derived from the rocks of the underlying Purcell series. The southern exposures east from Crawford bay resemble in every way those to the north. The composition of the conglomerate varies from point to point: at one place being largely composed of limestone boulders in a limy matrix, and at another of quartzite limestone and slate boulders and fragments in a limy slate or siliceous matrix. The conglomerate rests on different horizons of the immediately underlying Purcell rocks. In Windermere map-area, angular unconformities up to 45 degrees have been observed. In the southern part of Kootenay Lake district, the conglomerate has been subjected to pressure sufficient in places to squeeze the fragments into elongated shapes. Though angular discordance in the southern part is not as noticeable as in the north, the conglomerate appears to strike across the edges of structures in the underlying Purcell rocks.

Although there is a considerable gap between the exposures of the conglomerate in the northern and southern parts, sufficient work has been done to establish the continuity of the overlying rocks.

Horsethief Formation

The Horsethief formation, which may be better called Horsethief series, extends throughout the greater part of the map-area in a westerly dipping belt.

In the northern part, the series is about 5,000 feet thick and is composed essentially of slate with numerous beds of pebble conglomerate and some beds of blue and grey limestone. In the southern part of the area, the series has an apparent thickness of about 14,000 feet, but this is due to folding and the thickness can be taken as not greater than 7,000 feet. The series there consists essentially of argillaceous schist with beds of fine conglomerate and some grey quartzite and grey limestone. Some beds of heavy boulder conglomerate occur in the lower part of the series, indicating that the conditions giving rise to the massive Toby conglomerate were still active to a slight extent.

The Horsethief series conformably overlies the Toby conglomerate. In the eastern part of Windermere map-area it is overlain unconformably by the Upper Cambrian Ottertail limestone. Within the present map-area it is overlain conformably by the Hamill series of Windermere age.

Hamill Series

The Hamill series[1] conformably overlies the Horsethief series and is part of the same great sedimentary succession. It is a succession of strata varying from quartzite to schist phyllite and limestone. The quartzites form the lower part of the series and are white to light green and grey. The quartzites are massive and form many of the highest, most rugged peaks along the west side of the Purcell range. Above the massive quartzites is a succession of phyllites, schists, and quartzites, with minor beds of limestone.

In the vicinity of Crawford creek the lower quartzites are arkosic, in part fine conglomerate, and have an estimated thickness of about 2,500 feet. Overlying these heavy quartzites are schists and quartzites, with a

[1] The new name, Hamill series, is derived from Hamill creek where the series is well composed.

total thickness of not less than 5,000 feet. The whole series has a thickness of at least 7,500 feet and possibly as great as 10,000 feet. The series seems to have about the same thickness in the northern part of the map-area. Just north of the Fry Creek granite area the series is faulted and its thickness thereby greatly reduced.

Badshot Formation

The name Badshot is here given to the well-known Lime Dyke of the Lardeau. It has been traced south through Lardeau map-area to the ridge north of Hamill creek. Limestone float was found where its projected course would cross Hamill creek and the formation could be seen on the east end of Comb mountain. It was found again to the north of Fry creek and traced to near the granite where faulting obscures the sections.

South of the Fry Creek granite area two horizons of limestone were found at various localities: on the ridges between Campbell and Powder creeks, and between Bernard and Loki creeks; on Tam O'Shanter creek; and on the ridge connecting Blue Bell and Crawford mountains. These limestones can also be seen on intervening ridges. They were traced from Blue Bell Mountain ridge to Crawford bay. The lower of these bands of limestone corresponds in stratigraphic position to the Badshot formation and has been mapped as such.

The Badshot is generally a grey to white limestone, but locally is siliceous or weathers to a cream colour. The formation is either massive or finely laminated. It thickens and thins and in many places has been thickened through folding and squeezing of the formation. Its thickness perhaps ranges between 100 and 250 feet. It conformably overlies the Hamill series and forms a splendid horizon marker.

Lardeau Series

The Lardeau[1] series, developed in and named after Lardeau map-area, borders Kootenay lake throughout the greater part of the map-area. It rests conformably on the Badshot formation and is the youngest known member of the Windermere.

The Lardeau series is a succession of slates, phyllites, schists, quartzites, and holds several bands of limestone. It has a maximum thickness in Lardeau map-area of about 15,000 feet. Along Kootenay lake the greatest thickness exposed is not greater than 10,000 feet. The rocks are variously metamorphosed due to proximity to the granitic rocks of the Nelson batholith. On Crawford Bay peninsula where from the numerous granitic tongues it is apparent that the sedimentary cover is comparatively thin, the sediments are highly metamorphosed crystalline schists and gneissic rocks. Somewhat similar conditions hold along the lake. The series where it is free from granitic intrusions is predominantly composed of phyllites instead of the crystalline schists. It was the intense metamorphism generally exhibited by the series that led Dawson and others to consider these rocks as the oldest in the country and to correlate them with the Shuswap. They are now known to be the youngest known Precambrian rocks in Kootenay district.

[1] As already stated, this series was given the name Duncan, but since this name had been applied to another formation, it is here replaced by the name Lardeau.

PALÆOZOIC AND MESOZOIC

Upper Carboniferous and Triassic

Milford Group. The oldest fossiliferous rocks in the map-area belong to the Milford group. Fossils from lower members of this group have been identified as Carboniferous forms—whereas fossils from upper members seem to be undoubtedly Mesozoic. Whether the Milford strata are a continuous succession or consist of two or more disconformable members, is not known.

The Milford group occupies only a small area along the western side of the map-area. It has been definitely traced south of Kaslo creek and with reasonable certainty to Woodberry creek. South from Woodberry creek its extension is not definitely known.

The Milford group disconformably overlies the Lardeau series. In Lardeau map-area it rests on widely separated horizons of rocks of Windermere age and has, locally, a basal conglomerate. It is overlain by the Kaslo series or by the Slocan series which in places overlaps the Kaslo series.

Triassic

Kaslo Series. Basic dykes and sills largely altered to chlorite and associated minerals occur in many places. These are believed to be intrusive phases of the Kaslo eruptives and, hence, to be Triassic in age. Certain of the greenstones are of unknown origin and may be volcanics of older intrusives. The Kaslo series occupies a small area on the northwest side of the map-area. This series has been traced by C. E. Cairnes, south to near Fletcher creek, where it dies out. The series is an assemblage of altered volcanics, intrusives, and sediments. It unconformably overlies the Milford group and is overlain disconformably by the Slocan series.

Slocan Series. The Slocan strata are the youngest sedimentary rocks in the area. The series has been traced, by Cairnes, south to Woodberry creek, Schofield and earlier workers have shown it to extend south to near the West arm of Kootenay lake, but south from Woodberry creek its boundaries are not accurately known. The small part of the Slocan series exposed within the map-area is made up chiefly of grey limestone, dark flaggy limestone, argillite, and slate.

Post-Triassic

All intrusive rocks except those considered to be related to the Kaslo volcanics are here grouped as post-Triassic. They are chiefly granites and granodiorites, with apophyses of related characters.

The eastern edge of the Nelson batholith lies along the western side of the area north of the West arm of Kootenay lake. It is largely a light grey porphyritic granite. Similar granite occurs near the mouth of Grey creek. Numerous tongues of porphyritic granite and pegmatite, from a fraction of an inch to over 100 feet in width, are injected along the bedding and joint-planes of the Lardeau series from Crawford Bay peninsula north along the east side of Kootenay lake and east to near the summits of the ridges overlooking the valley. The sedimentary rocks in the vicinity of these intrusive tongues are highly altered and form the Shuswap of earlier writers, but are now known to be only metamorphosed parts of the Lardeau series.

The large area of granite south of Fry creek is light grey and of medium texture. Its relation to the porphyritic granite of the Nelson batholith is not known, but it resembles rocks that both intrude and grade into the porphyritic rocks of the Nelson batholith.[1]

The granite crossing Glacier creek is also a light-coloured, medium to fine-grained rock resembling that south of Fry creek. The small areas of granite near mount Gleason and at the lake of the Hanging Glaciers approach granodiorite in composition.

STRUCTURAL GEOLOGY

The structure of the Purcell range may be briefly described as a huge, northward pitching arch composed of numerous synclinoria and anticlinoria. Within the map-area the structures belong to the westerly plunging side of the major structure.

In the vicinity of Hamill creek, Windermere sediments, from the Toby conglomerate to the Badshot formation inclusive, lie in a major synclinal structure followed westward by an anticlinal structure which is in part overturned to the west and succeeded westward by a synclinal structure also overturned to the west. The axis of this syncline passes near the mouth of the south fork of Hamill creek. West of this syncline is a low anticlinal arch spanning the north end of Kootenay lake. It is followed to the west by a syncline and this by an appressed anticlinal structure.

In the vicinity of Crawford creek, the formations immediately west of the outcrop of the Toby conglomerate are folded as on Hamill creek, but on a smaller scale.

On the west side of Kootenay lake on the north fork of Woodberry creek, a tightly folded synclinal structure is followed to the west by an anticlinal structure. West of this there appears to be a synclinal structure which may be the southern continuation of a large synclinal structure developed in the Slocan series to the north.[1]

The structure of the strata underlying Kootenay lake is inferred from the structures found to the north and on either side of the lake, to be a major syncline followed westward by a major anticline, and it is supposed that the lower 5,000 feet of the section of Lardeau strata exposed on the west side of the lake are approximately equivalent to the upper 5,000 feet of the section of Lardeau beds exposed on the east side of the lake.

ECONOMIC GEOLOGY

Only those properties along the east side of Kootenay lake which have had work done on them in recent years are here described. Several old prospects up Crawford creek and south from it, were referred to in the Summary Report for 1915 and are described or mentioned in reports of the British Columbia Minister of Mines. The properties of the Ainsworth camp are described in Memoir 117 and a report on the region about Kaslo is in course of preparation by C. E. Cairnes.

[1] Cairnes, C. E.: Personal communication.

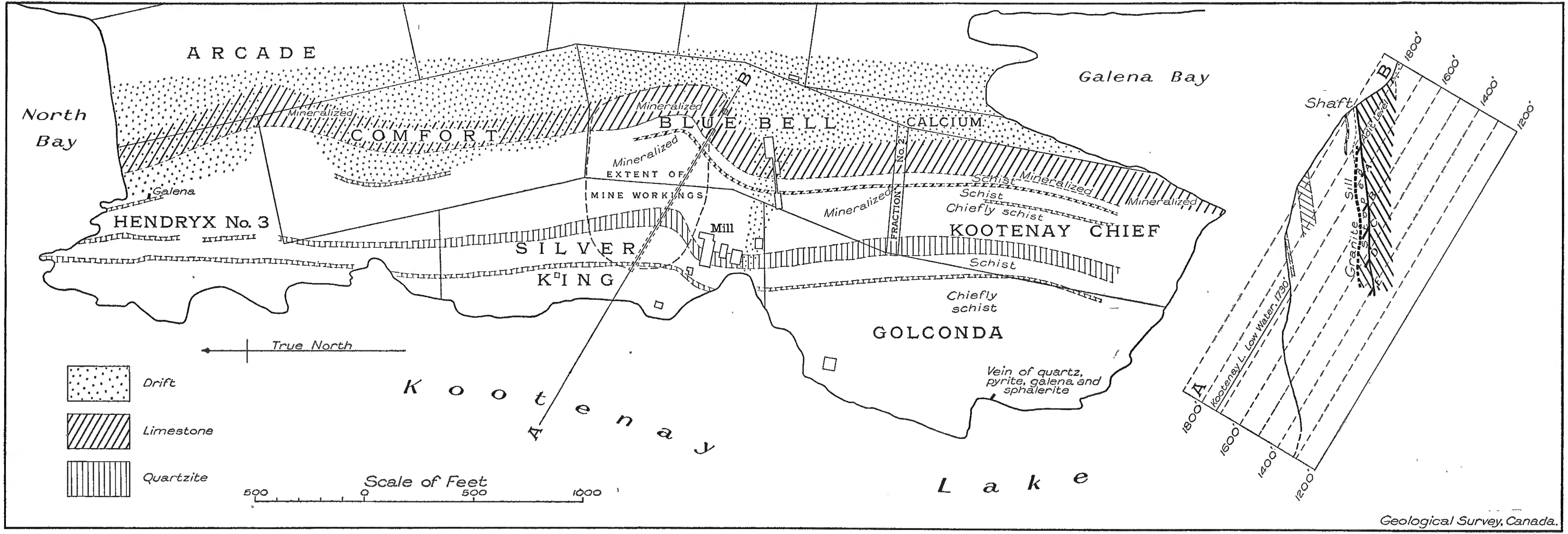

Figure 7. Blue Bell mine, Riondel, Kootenay lake, B.C.

BLUE BELL MINE[1]

The Blue Bell mine, at Riondel on the east side of Kootenay lake, is one of the oldest mines in British Columbia. According to popular belief, the original discovery was made in 1825 by the botanist, David Douglas, and it was rediscovered in 1845 by Father P. de Smet. It is evident, however, from the journals of these travellers that they were not on Kootenay lake during those years and nowhere in the journal of Douglas is there evidence that he ever visited the lake. De Smet may have visited the lake, but his mention of lead ore is not as being on Kootenay lake, but apparently, on Kootenay river south of the International Boundary. In the year 1865, Indians told Edgar Dewdney, builder of the famous Dewdney trail, that they made bullets from lead obtained in Chikamin mountain, but he neither examined nor staked the ground. It seems evident that the Blue Bell was known to the early explorers and that the Indians had learned from those explorers the art of making bullets from its lead ores. An old working on the property is credited to the Hudson's Bay Company. George Hearst, of California, deceived by specimens of high-grade ore from some other locality, visited the Blue Bell showing in 1873. The real history of the Blue Bell begins with the staking of the property in 1882 by Robert Evan Sproule. The only Gold commissioner in the Kootenay at this time resided on Wild Horse creek many days travel from Kootenay lake. The law, however, called for prompt registration of the staking of mineral claims and also bound a man to not more than seventy-two hours absence from his claim at any one time during the season. It is obvious that Sproule could not comply with the law. Thomas Hammil, representing Captain Ainsworth of Portland, knowing the fallacy of the law, took the precaution to take the Gold commissioner from Wild Horse creek with him on his trip into the Kootenay Lake country close on the heels of Sproule. Hammil restaked Sproule's claims and registered them. Sproule disputed Hammil's claims on the ground of the impossibility of complying with the law and the following year won a decision over Hammil in the first court held on Kootenay lake. This decision was upset on appeal and resulted in the murder of Hammil by the incensed Sproule.

The Ainsworths allowed the Hammil interests to lapse and in 1884 Dr. W. A. Hendrix and an American Company acquired the property. This company built a tote road from Sand Point, Idaho, to Bonners ferry on Kootenay river and brought in a small tow boat for freighting supplies to the property. A little work was done on the property during the season of 1885, but development really started in 1887 and during the next three years, after some 1,500 feet of workings had been driven, property was estimated to contain about half a million tons of ore. By 1894 the workings comprised some 3,000 feet of tunnels, shafts, and raises and the mine was ready to produce 150 tons a day. The following year the mill and smelter at Pilot bay were completed and the Blue Bell produced 52,000 tons of ore. The cost of plant amounted to about $650,000. The mine and smelter were closed down in 1896 pending the completion of the Crow's Nest branch of the Canadian Pacific railway, which would make cheaper fuel available and reduce transportation costs which had prohibited operation of mine and smelter at a profit.

[1] By J. F. Walker and H. C. Gunning.

The property was not reopened by the Hendryx interests, but passed into the hands of Mr. Campbell Sweeny of the Bank of Montreal, Vancouver, in 1899. In 1905 the Canadian Metal Company acquired the mine and smelter which they renovated and, in 1906, 11,000 tons of ore was shipped to the smelter and 10,000 tons stored in the mine. Mr. S. S. Fowler was in charge of operations. The property was believed to contain about a million tons of ore. Development continued until June, 1907, by which time a large volume of ore had been stored in the mine. The mine was then closed down pending construction of a new mill at the property. This was completed in March, 1908. Machine shops and bunk houses were built and also a 3-mile pipe-line from Tam O'Shanter creek to supply power to operate the mill. Under a 700-foot head, 475 horsepower was generated. During the latter part of the year 19,000 tons were milled and production continued until March, 1910, when the property was closed down pending reorganization of the company and preparations to mine to greater depths and to increase the mill output.

Up to this time ore had been mined only above the adit level. The Hendryx interests had mined only higher grade ore, but the Canadian Metal Company had won 90,000 tons of milling ore.

Development was resumed in 1912 and hoisting through a new shaft started July 1. The mine produced about 200 tons per day toward the end of the year. The following year, 80,460 tons were mined and milled. In 1914, 50,000 tons were mined before the property was closed down in August. The mine had at this time been opened down to the C level. After a year's idleness the production was resumed and in five months, 23,500 tons were mined and milled. This production came from C level. Production was maintained until 1917, by which time the mine had been opened down to E level 370 feet vertically below the adit level. During 1917, 58,620 tons were mined, including about 1,000 tons of oxidized ore shipped direct to Trail.

During 1916, C. D. Wheeler did some stripping on the north end of the Comfort claim and shipped 500 tons of ore. He also put down two diamond drill holes to depths of 190 and 207 feet.

The Blue Bell in 1917 had reached a stage where greater pumping facilities were needed and a new 1,000 gallon per minute pump was installed. The production from 1918 to 1921 was small and mainly from oxidized ore overlooked by the Hendryx interests, and from the old glory-holes. The property finally closed down. Mr. S. S. Fowler, who had been in charge of operations for the Canadian Metal Company, in association with B. L. Eastman, acquired the property in 1924, unwatered the mine, and renovated the mill, adding eighteen flotation cells to it. Operations started early in the summer of 1925 and during the remainder of the year 17,500 tons were mined and milled and averaged 6 per cent Pb, $8\frac{1}{2}$ per cent Zn, and 2 ounces Ag. To Trail, 4,800 tons were shipped for milling, as well as 117 tons of crude oxidized ore. During 1926, 32,310 tons were won from various parts of the mine. Tam O'Shanter lake was impounded, thus insuring a water supply during the autumn and winter. The property was operated until September, 1927, when it was again closed down. Production, as before, came from the old workings, no new development being done.

Up to the present the development of the Blue Bell has been confined to the main ore showing, in which three irregular ore-bodies have been largely mined out to the depth of E level. They have not been bottomed. There is still some ore left in these workings and about the shaft. These ore-bodies down to D level, however, have been mined out to such a stage that new development must be done before mill feed can be maintained or mill reconstruction warranted. This has been fully realized by the owners who have recently organized a new company capitalized at $2,000,000, to take over and develop the Blue Bell. Any such organization has until recently been almost impossible, for it was essential to the development of the Blue Bell that it should control the Comfort claim held by the Ainsworth interests. This old claim had been staked under the apex law. The eastern side line cut the mineral showing at the north end of the claim, part of the showing thus being on Blue Bell ground and part on the Comfort. Under the apex law neither party could mine this showing without entering into litigation with the other. The Comfort claim has recently come under Blue Bell control.

At the time of writing, the depth to which ore extends is unknown and the value of the ground immediately north and south of the workings is unknown. On the north end of the Comfort claim and crossing to the Arcade, is a good surface showing. Facing Galena bay are promising showings on the Kootenay Chief and a small one on the small limestone band on Fraction No. 2. A small vein on the Golconda and another on the Hendryx No. 3 are in schists and quartzites and in themselves are of no importance, but they suggest the possibility of mineralization in the limestone beneath.

The strata about the Blue Bell belong to the Lardeau series. They consist of schists, quartzites, and limestones, striking north and dipping, on an average, 35 degrees west. Strike and dip vary locally due to small rolls, such as may be seen along the west side of the promontory, in the strata; the dip varies from almost flat to vertical.

Thin sheets of pegmatitic granite are numerous along bedding planes of the strata. Lamprophyre dykes are common and generally follow two pronounced systems of joints which strike respectively north 70 degrees west to north 60 degrees west and south 85 degrees west to south 75 degrees west. Along the east side of Galena bay and on the small point jutting into the bay pegmatite and coarse granite are more pronounced than elsewhere.

The surface rises gently from the north end of the promontory to an elevation of 200 feet above Kootenay lake at the mine workings. A small draw cuts across the promontory just south of the workings, the ridge continuing south of it to the tip of the promontory. It is this change in topography that accounts for the sharp bend in the outcrops of the formations at the workings and also the gentle curve south from there. The bend in the course followed by the strata near the north end of the Comfort claim is, apparently, due to a structural feature. The rocks at this point dip gently west, whereas at North bay, a short distance away, they are vertical. West from North bay, the dip flattens somewhat, indicating a roll in the formation.

The quartzite belts shown on the accompanying figure (No. 7) do not represent all the quartzite outcropping on the property, but merely indicate such horizons as were traced. From the courses followed by these horizons the position of the top of the limestone under covered areas has been deduced. The closeness of the limestone to the quartzite at North bay is due to the vertical attitude of the strata which elsewhere dip westerly. The ore-bodies, so far developed, occur as irregular, pipe-like, or square-sectioned, replacements in the upper part of a band of limestone 150 to 200 feet thick. About 60 feet stratigraphically above the main limestone band is a band about 12 feet thick which is also mineralized.

The primary ore minerals are, in order of decreasing abundance: pyrrhotite and pyrite, sphalerite, galena, arsenopyrite, and chalcopyrite. Quartz and limestone are the principal gangue minerals.

A sill of coarse granite has been intruded along or near the contact between the limestone and overlying schists. Its thickness varies from almost nothing up to 8 feet. Several, small, granitic dykes cut the limestone. These intrusives are pre-mineral and have partly controlled ore deposition. Pronounced joints cut the limestone and they also have exercised some control over the mineralization. Small rolls both along the strike and down the dip appear to have acted as channels and barriers to the movement of mineralizing solutions. Some beds in the limestone have apparently not been as favourable to replacement as others.

Apparently the mineralizing solutions ascending along fractures and bedding planes found the granite sill and schists an almost impervious barrier and were forced to follow the limestone. The pre-mineral dykes also formed local barriers. The mineralizing solution, working along joints and bedding planes, replaced the limestone where conditions were favourable. Some joints appear to have acted as local barriers to the mineralizing solutions; the reason for this is not apparent, possibly the presence of gouge was the controlling factor. There is a suggestion that the small rolls along the strike acted as channels tending to confine the mineralizing solutions to the structures concave toward the ascending solutions. There is a suggestion that the rolls down the dip acted as temporary dams, causing the solution to precipitate their minerals on the steeper parts of the local structures. This appears to have been the case on the adit level where the best ore is west of, and below, an extensive zone of almost horizontal limestone. At other places in the mine there are indications that variations in dip have exerted some control over the localizing of ore deposition.

A microscopic study of the Blue Bell ores and wall-rock alteration shows that quartz and ankeritic carbonates replaced the limestone in the earliest stages of mineralization prior to sulphide deposition. It appears that a little mica was formed prior to sulphide deposition and was later altered to chlorite. A small amount of a greenish pyroxene (?) now altered beyond identification formed about this time. Quartz continued to form throughout the period of mineralization.

Pyrite, pyrrhotite, and sphalerite were the first sulphides to crystallize. Pyrite formed also in the late stages of mineralization. Sphalerite continued to crystallize at later stages with galena, which mineral continued to crystallize at a still later stage without sphalerite. The later sulphides replaced the earlier ones.

On the Kootenay Chief claim a 10-foot bed in the limestone has been converted to ankeritic carbonates and some quartz, and has had developed in it a large amount of a black, lustrous mineral which approaches knebelite, a silicate of iron and manganese. This mineral has been replaced by galena.

Apatite is found in large, rounded grains in the limestone near the ores and is apparently an alteration product.

The pre-mineral dykes are more altered than the limestone. At the north end of A level, a grey dyke, consisting, away from the ore, of about 20 per cent quartz in a mass of sericite, muscovite, and calcite, shows in contact with the ore a narrow zone dark green in colour. This colour is the result of the introduction of 15 per cent or 20 per cent of a green serpentine or chlorite.

The pre-mineral granitic dykes, where little altered, are composed of large crystals of green hornblende and some brown biotite in a fine-grained groundmass of quartz, orthoclase, and plagioclase feldspar. Apatite and calcite are accessory minerals. Where altered near the ore, the hornblende, biotite, and feldspars have changed to chlorite and (or) serpentine. Some fine-grained quartz and perhaps a little carbonate are also present. Some dykes are entirely altered to chlorite and serpentine, so that they resemble the weathered lamprophyres that followed mineralization.

Oxidation extends to the lowest workings of the Blue Bell. It is found chiefly in two zones, one in the north, and the other in the south, end of the workings. The oxidation has resulted in the leaching of the pyrite, pyrrhotite, and some of the sphalerite. Marcasite, anglesite, cerussite, some smithsonite, gypsum, hydrous iron oxides, malachite, green iron sulphate, and much black or grey mud have formed. Native copper, pyromorphite, and several rare minerals have been encountered.

At the time of writing the property is closed down and full of water which flows from the adit level. Hence the present water table is 370 feet higher than the lowest workings and these show intense oxidation. The greatest depth of Kootenay lake is about 100 feet below E level. Assuming that oxidation was produced by descending meteoric waters, it is evident that the water table at the time of oxidation must have been lower than E level.

There is no evidence that the level of Kootenay lake has, in recent time, been lower than at present. The shallow outlet is evidence that the lake-level, in recent time, has been little if any lower than now. The lake, apparently, has been produced by damming of the south end of the valley by morainal material. The presence of lake deposits resting on till is evidence that at one time the water-level was considerably higher than now. It is unlikely that oxidation took place during the Glacial period. It, therefore, appears that the oxidation took place before Glacial time when the valley was occupied by a stream and the water table consequently was lower than at present.

How much filling has occurred along the bottom of Kootenay lake is unknown. The bottom is comparatively flat and 400 to 450 feet below lake-level. Because of modification by glaciation it is difficult to form a clear idea of the shape of the valley beneath the filling. It is thus impossible to estimate the depth to which oxidation may go on the Blue Bell.

If there has been little filling of the lake then oxidation may end a short distance below the deepest mine workings. If there has been perhaps 200 or 300 feet or more of filling, then the depth to which oxidation extends may be a considerable distance below the present workings.

KIRBY [1]

The Kirby group, owned by the Shepherd Mining Company, is about 1 mile northeast of the Blue Bell mine. Several thousand feet of tunnelling has been done on the property.

The rocks exposed underground are quartzites, grey mica schists, mica-hornblende schists, and calcareous schists striking north 5 degrees to 10 degrees west and dipping 45 degrees to the west. Dykes of porphyritic granite, granite, and black lamprophyre cut the above. The principal veins, three in number, occur as distinct, bedded fissure veins, principally in the schist but in places cutting granitic dykes or sills. In a few places the calcareous schists are sparingly impregnated with sulphides, principally pyrite. A series of steep fissures connect the main veins, cutting across the strike of the sediments.

The ore minerals, pyrite, sphalerite, and galena, occur with quartz and some carbonates in bedded shear zones, along with fragments of the country rock. No. 3 vein, the most easterly, has been drifted on for about 700 feet and varies in width from almost nothing to 16 feet. The ore minerals are sparingly developed throughout the greater part of the vein and only one small stope has been made. It contains from 2 to 4 feet of ore for a height above the drift of about 40 feet. The ore averages around 10 per cent combined lead and zinc. The silver values are low. On the surface, and underground, one or two of the crosscutting fissures are mineralized with galena, sphalerite, and ruby silver in quartz. These showings are small. Underground one small, well-defined vein in granite ceases suddenly when it encounters the adjoining quartzite. The lamprophyre dykes appear to be later than the ore.

The property, studied in its relation to the Blue Bell, indicates very forcibly that quartzites and schists are, in this locality, unfavourable to the formation of large ore-bodies. Veins similar to those on the Kirby are found in the quartzites and schists of the Bluebell peninsula, but all the commercial ore-bodies so far developed are in crystalline limestone. It is of interest to note that a wide bed of limestone outcrops on the shore of Kootenay lake some distance north of the Kirby and that, extended to the south along its strike, this bed would pass to the east of the Kirby workings. It is an interesting prospecting possibility.

BERENGARIA

Mr. Dean while sluicing ground for material with which to fill a wharf, discovered mineral within a few feet of Kootenay lake at Deanshaven not far south of Riondel. At the time of the writer's visit this mineral showing had been uncovered sufficiently to show its nature. The greater part of the top and one face had been uncovered, showing it to be a large boulder about 30 by 20 by 10 feet and standing about on end. The lower

[1] By H. C. Gunning.

part of the boulder is embedded in blue boulder clay containing a heterogeneous assemblage of angular rock fragments. Overlying the boulder clay and covering the boulder are stratified sands and fine gravels which dip gently toward Kootenay lake. There is no evidence of erosion on the sides of the boulder to show that it was long exposed after being embedded in the boulder clay and before being covered with the stratified material. The boulder lies just south of a rock ledge which has probably aided in its preservation.

Small fragments of mineral are reported to have been found nearby and such fragments have been found as far south as Crawford Bay peninsula. The mineral fragments as well as the boulder are very like the Blue Bell ores and the fact that they are found in glacial material south of the Blue Bell, strongly suggests that they have been plucked and carried by the ice from the Blue Bell outcrop to their present position.

PEGLEG[1]

The Pegleg is on the south fork of Fry creek, about 3 miles above the junction of the south fork with the main creek. The workings are on the west side of the creek and about 1,000 feet above creek bottom.

The prospect is located in a limestone and quartzite inclusion, several hundred feet long, in the large granite area south of Fry creek and Kootenay lake. The limestone and calcareous quartzite have in places been extremely altered to a mass of garnet, titanite, fluorite, quartz, pyroxene, and scapolite. Molybdenite and some pyrite are sparingly developed, particularly along irregular quartz veins.

LEVIATHAN[1]

The Leviathan is on the south side of Campbell creek, about 2½ miles from Kootenay lake.

What appears to have been a calcareous quartzite is mineralized across 60 feet or more with pyrrhotite, some pyrite, and very little chalcopyrite. Gold values are too low to be of commercial value. The original rock has been altered to quartz, garnet, biotite, and pyroxene. Chalcopyrite with some pyrrhotite occurs in a small fissure in a pegmatite granite dyke in the workings. Granite and granodiorite dykes and sills occur in the vicinity of the workings. It is evident that the mineralization postdated these intrusions. Some 400 feet of development has been done on this property.

A short distance southwest of the Leviathan and farther away from the granite and also at a higher elevation, galena and sphalerite in small amounts replace limestone bands on the Otto and adjoining claims.

[1] By H. C. Gunning.

GEOLOGY AND MINERAL DEPOSITS OF BIG BEND MAP-AREA, BRITISH COLUMBIA

By H. C. Gunning

CONTENTS

Illustrations

INTRODUCTION

Big Bend district lies within the Selkirk Mountain range. It is bounded on the north, east, and west by Columbia river and on the south by the main line of the Canadian Pacific railway. These boundaries embrace about 2,400 square miles of territory, much of which is not excelled in Canada for rugged mountain scenery. During the summer of 1928 the writer made a reconnaissance survey of the general and structural geology of the southwestern portion of the district, covering about 1,000 square miles. Along the main line of the Canadian Pacific railway, work was done from Revelstoke to Caribou creek. The easterly limit of the area investigated extends in a northwesterly direction from the head of Caribou creek to the forks of Bigmouth creek, and the westerly boundary is Columbia river from Bigmouth creek to Revelstoke.

The general geological work was entirely of a reconnaissance nature, detailed investigations being carried out only on some of the mining properties. The extent and the extremely rugged nature of the district necessitated limiting work, even in the area covered, to the more easily accessible parts. Consequently the result embodied in this report must be considered merely as a basis for any future, more detailed work that may be done.

Previous Work

Alfred R. C. Selwyn and George M. Dawson made the first geological investigations in the district, their work being limited to the section along the main blue line of the Canadian Pacific railway. Dawson's[1] contri-

[1] Bull. Geol. Soc. Am., vol. II, p. 165 (1891).

bution is particularly valuable. In 1915 R. A. Daly's report, embodying the results of reconnaissance work from Golden to Kamloops during the summers of 1911 and 1912, was published as Memoir 68 of the Geological Survey, Canada. It contains detailed descriptions of the rocks along the main line of the Canadian Pacific railway. M. F. Bancroft during his work on Lardeau map-area, from 1917 to 1920, studied the area bordering the railway from Albert canyon to Revelstoke, but his results were never published in full. In 1927 the writer spent one day examining the rocks from Lauretta to Revelstoke. Much valuable information is contained in the reports of the British Columbia Minister of Mines, particularly in those from 1917 to the present. Brief geological notes are appended to the publications by Wheeler and Palmer, that are noted in the bibliography. Charles W. Drysdale visited the Lanark mine in 1917 and collected specimens, but published no report.

Acknowledgments

During the field season of 1928 the writer was efficiently assisted by M. S. Hedley, R. M. Logie, and H. I. Williams. The work was greatly facilitated by assistance from Mr. A. G. Langley, Resident Mining Engineer, Mr. W. Maxwell, and other government officials of Revelstoke. Aid and hospitality were generously given by the various mining officials, prospectors, and inhabitants of the district.

Bibliography

Bancroft, H. H........The works of H. H. Bancroft.
"History of British Columbia", vol. 32, p. 530 et seq. (1887).

Daly, R. A............"A Geological Reconnaissance Between Golden and Kamloops, B.C., along the Canadian Pacific Railway"; Geol. Surv., Canada, Mem. 68 (1915).

Dawson, G. M.........Geol. Surv., Canada, Ann. Rept. 1887-88, pt. R, p. 5.
Geol. Surv., Canada, Sum. Rept. 1889, pt. B, p. 36; 1890, pt. A, p. 20.
Bull. Geol. Soc. Am., vol. II, p. 165 (1891).
Bull. Geol. Soc. Am., vol. XII, p. 57 (1901).

Hurst, M. E..........."Arsenic-bearing Deposits in Canada"; Geol. Surv., Canada, Econ. Geol. Series, No. 4, p. 78 (1927).

Godard, J. S..........."Investigations in Ore Dressing and Metallurgy"; Mines Branch, Dept. of Mines, Canada, 1926, No. 688, p. 13 (1928).

Palmer, Howard......."Mountaineering and Exploration in the Selkirks", 1914.

Selwyn, A. R. C.......Geol. Surv., Canada, Sum. Rept. 1887, p. 4.

Wheeler, A. O........."The Selkirk Range"; Government Printing Bureau, 1905.

Annual Reports, Minister of Mines, British Columbia, 1874-1927.

GENERAL CHARACTER OF THE DISTRICT

Topography

The district forms the northern part of Selkirk Mountain range and is exceptionally rugged, many individual peaks attaining elevations of from 10,000 to 11,000 feet (*See* Plate IV A). The valley of Columbia river is the deepest depression, being 1,500 feet above sea-level at Revelstoke. Illecillewaet river occupies a deep, transverse valley attaining an elevation of 3,700 feet above sea-level at Glacier. There are many large, permanent ice fields. The eastern side is, on the whole, the most rugged part of the district, but, within the area studied by the writer many sections, particularly that west of the upper part of the North fork[1] of Illecillewaet river, are practically inaccessible. Many of the peaks are precipitous and the ridges are generally much broken by peaks and valleys. Traversing on the summits is, therefore, exceedingly difficult. Some of the uplands, however, are open and relatively rolling; and among these should be mentioned the northwest corner of Glacier National park, at the headwaters of Caribou creek, and the summit bordering Columbia river from LaForme creek to Downie creek. There is also an exceedingly pleasant area around the headwaters of McCulloch creek. The principal valleys, those of Bigmouth, Coldstream, Downie, and Carnes creeks, and the North fork of the Illecillewaet, are deep, more or less U-shaped depressions with very low gradients for the greater part of their length. At their heads, many of the valleys rise suddenly, or precipitously, to the source of the stream. Consequently they make very poor bases from which to examine the geology of the surrounding peaks and ridges.

Timber

The slopes of the mountains below about 6,000 feet are heavily timbered. Hemlock and red cedar are the most abundant trees. Spruce is rather sparingly present and there are occasional stands of white pine. The valleys of Columbia river and its larger tributaries contain the best forests and many timber limits are being held for future use. On the whole the timber is not high grade, much of the cedar and hemlock being rotten at the core. Alder, devil's club, and ferns grow luxuriantly in the valleys.

Climate

The climate at Revelstoke is portrayed by the following table, for 1915, supplied by the Meteorological Service of Canada.

Months	Temperatures						Monthly mean	Rain		Snow	
	Mean Max.	Mean Min.	Mean daily range	Max.	Min.	Range		Amount	Days	Amount	Days
	°	°	°	°	°	°	°	In.		In.	
January	26·2	14·8	11·4	38	−4	42	20·5	0·00	0	34·0	9
February	37·1	27·0	10·1	43	18	25	32·1	0·03	1	21·5	8
March	49·2	28·9	20·3	60	19	41	39·1	0·84	6	0·0	0
April	60·1	37·2	22·9	74	28	46	48·6	3·19	11	....	......
May	66·4	43·8	22·6	79	32	47	55·1	4·83	17	....	......
June	69·4	46·5	22·9	85	38	47	58·0	2·93	13	....	......
July	75·1	50·8	24·3	87	45	42	63·0	4·91	18	....	......
August	81·8	50·7	31·1	87	45	42	66·2	0·72	3	....	......
September	62·1	41·8	20·3	79	32	47	51·9	2·51	12	....	......
October	51·0	37·4	13·6	59	28	31	44·2	5·87	20	....	......
November	37·5	26·7	10·8	50	15	35	32·1	1·48	10	22·0	8
December	31·7	21·3	10·4	43	−5	48	26·5	2·02	6	31·0	11
Year	54·0	35·6	18·4	87	− 5	92	44·8	29·33	117	108·5	36

[1] This is Tangier river in Geographic Board report.

Revelstoke, however, enjoys a somewhat drier and milder climate than most of the Big Bend. The high mountains and numerous ice fields in the heart of the district cause a heavier rainfall and a much heavier snowfall than obtains at Revelstoke. During the summer months local electric storms and showers are common and the higher land masses seem to form centres around which these concentrate. At the higher altitudes fresh snow may fall until early in July and the first autumn falls of importance generally come during the middle or latter part of September. It is not uncommon, however, to find fresh snow on the peaks and ridges late in August or early in September. Some time in October the snow comes to stay over a large part of the area. The main valleys, of course, remain open for much longer periods.

Transportation

Progression is the greatest problem in the district. The trails that existed during the summer of 1928 are shown on the accompanying map (No. 237A). The road up Columbia valley is in good condition for automobile traffic, from Revelstoke to Carnes creek. From Carnes creek to French creek a good pack trail is kept open, a narrow road existing from Downie creek to Old Goldstream. The side trails up McCulloch creek, Downie creek, to Standard basin, and up LaForme creek are in poor repair. The trail up Carnes creek is in good condition. A good automobile road affords easy access to the uplands in Mount Revelstoke National park. The trail up Silver creek is in good condition and that up the North fork of Illecillewaet river is good except for weeds and occasional landslides. The old trail up Albert creek is badly covered with windfalls. The trail to the Lanark mine is passable for men and the trails up Caribou creek and to the Donald mine are good. The Canadian Pacific railway affords convenient transportation along Illecillewaet valley. Columbia river from Beavermouth to Revelstoke is navigable for small boats, but the numerous rapids make it advisable, if not absolutely necessary, to employ a boatman who knows the river. Many lives have been lost between Goldstream and Revelstoke. Goldstream and Downie creeks are the only tributaries of Columbia river on the western side of the district that are at all navigable, and both of these have bad rapids or falls in their lower reaches. Away from the Columbia or the main trails progression is exceedingly difficult. Particularly rough areas exist around Carnes peak, from mount Holway to Fang rock, in the region around Downie peak, and at the upper reaches of Bigmouth creek and French creek.

Horses can be hired at Albert canyon and at Revelstoke. Fire ranger's cabins stand at Carnes creek, 4 miles south of McIntosh's ranch, at Downie creek, and at Goldstream, also at Flat creek and on mount Revelstoke. The other cabins shown on the map belong to mining companies or prospectors. McIntosh's ranch is about 7 miles south of Downie creek, on the bank of Columbia river. There is a good halfway cabin 15 miles up the North fork of the Illecillewaet. Revelstoke, with numerous stores and hotels and a population of about 3,500, affords an excellent base for supplies. Mail is delivered up the Big Bend road and trail twice a month during the summer and once a month during the rest of the year.

GENERAL GEOLOGY

Underlying the map-area is a great series of metamorphosed Precambrian sediments which strike from north to northwest and dip to the east. Extrusive greenstones are interbedded with the sediments at certain horizons and intrusive rocks of similar appearance are rather sparingingly developed. All these rocks are complexly folded in a series of essentially isoclinal anticlines and synclines. The sediments include crystalline limestones, quartzites, mica schists, slates, phyllites, argillites, and chlorite schists, and are cut by numerous stocks, dykes, and sills of granitic rocks of Mesozoic age. The latter include granite, porphyritic granite, granodiorite, quartz diorite, granite pegmatite, aplite, and a few fine-grained lamprophyre dykes. Ortho- and paragneisses are abundantly developed in the southwestern corner of the map-area.

SEDIMENTARY ROCKS

Sediments underlie a large part of the district. On the accompanying map (No. 237A) they are divided, on a lithologic basis, into two major subdivisions. Member 1 of this division is divided into two subdivisions, member 1 A which outcrops on the easterly side of the mapped area and member 1 B which outcrops on the westerly side. Member 2 occupies the central part of the area.

Member 2 consists of a thick and complexly folded series of crystalline limestones, argillaceous and carbonaceous sediments varying from argillite to slate and schists, mica schists, quartzites, and chlorite schists. Limestones and argillaceous to carbonaceous sediments are most abundantly developed. With the exception of local areas of extreme folding and the region north of and adjoining Goldstream river, the average strike is west of north; the dips are, with few exceptions, to the east. On the whole, the dips on the east are steeper than those on the west in this member. On the east and west sides of the member are two broad zones which contain several important horizons of crystalline limestone. Quartzites and schists or slates are interbedded with these limestones. The central part of the member contains less limestone and is predominantly argillaceous, quartzite, mica schists, and chlorite schists being present in relatively minor amounts.

Member 2 crosses Illecillewæt valley between Caribou creek and Albert creek. R. A. Daly[1] has described the geological section between these limits and member 2 corresponds with this Albert Canyon division of the Selkirk series, excluding the basal quartzite on the westerly side. There is no need to repeat the petrographic descriptions which Daly has given in such excellent detail. However, in the light of more extensive field work than Daly was able to perform in the limited time at his disposal, the distribution of rocks in his section must be slightly changed. Daly mentions but one horizon of marble on Albert creek. The exposures in the area he covered are poor and towards the headwaters of Albert creek and on Silver creek there are at least five important beds of marble, separated by schists and quartzite. The upper four of these beds would consequently fall well within the limits of Daly's Moose metargillites. At the top of his Laurie formation Daly places 4,000 feet of phyllitic metargillite. Recent

[1] Geol. Surv., Canada, Mem. 68 (1915).

field work, outside the limits of Daly's section, has shown the existence of a broad zone of crystalline limestones and calcareous sediments at the top of Daly's Laurie formation. These rocks are well exposed across several thousand feet at the head of Caribou creek and appear again at, and east of, the summit of Flat creek (*See* Plate IV B). They dip to the east under the basal beds of Daly's Cougar quartzites. The limestones vary in colour from pure white to dark grey, are distinctly crystalline, and are interbedded with slates, phyllites, and quartzitic grey sediments.

North of Illecillewaet valley the crystalline limestones on the east and west sides of member 2 become much more abundant. On the west, in the vicinity of Carnes peak, they attain their maximum dimensions and form two distinct zones which are separated by about 3,000 feet of quartzites, slates, and schists, and a few small beds of crystalline limestone. The thicker of these two zones forms much of Carnes peak and extends eastward across the North fork of Downie creek. Interbedded with the limestones are graphitic schists. The dips are low and rolling to the east. The thinner zone, to the west of and below the quartzites, passes on either side of the lake shown draining into the north fork of Carnes creek and forms the peaks immediately east of the Roseberry mine. Black to grey slates and schists and some quartzite are interbedded with the limestones. The individual beds of limestone in both zones are markedly lenticular, it being not uncommon to find a bed some 20 or 30 feet thick decreasing to zero in both directions within a total distance of about 1,000 feet. This fact, in conjunction with complex folding or contortion and the rugged topography of the district, makes it manifestly impossible to follow a single horizon for any considerable distance along its strike. This westerly belt of limestones can be easily followed from the headwaters of French creek to Silver creek and thence across the main line of the Canadian Pacific railway to the upper reaches of Albert creek.

Somewhat similar conditions obtain on the eastern side of member 2. Limestones are abundantly developed from the head of Caribou creek to and beyond the upper reaches of the North fork of Downie creek. Here again, complex folding, the lenticular nature of the limestone beds, and high relief render it impossible to follow any single horizon, but the continuity of the calcareous zone is easily established. Grey to black slates and phyllites, impure quartzites, and mica schists are interbedded with the limestones. The latter are most abundantly developed in the region, along the North fork of Illecillewaet river, lying east, northeast, and southeast of mount Moloch and in this region the most complex and instructive folding of the district was encountered. On the summits north of the sharp bend in the North fork of Downie creek no limestones are exposed, although they are abundantly developed near the headwaters of that stream. Argillaceous slates and schists occupy the horizon where the northerly extension of the limestones would be expected.

The sediments in the central part of member 2, between the two calcareous zones, have not been studied in detail. One complete section was obtained on the heights north of Downie creek and its north fork. From the headwaters of Boulder creek past Downie peak there are at least a dozen conspicuous beds of white to grey marble interbedded with grey slates and phyllites, mica schists, and quartzites. East of that, member 2 consists largely of argillaceous sediments converted to slates and schists, some chlorite schists and quartzites, with minor limestone horizons. Eastward from the forks of Silver creek, above the calcareous zone, is a series of black to grey slates and phyllites, some of them calcareous or quartzitic, extending nearly to the headwaters of the east fork of Silver creek. Above and east of these, quartzitic sediments and chlorite and mica schists are more abundant, continuing so to the slopes of the North fork of the Illecillewaet where are carbonaceous sediments with minor amounts of limestone and quartzite, corresponding to Daly's Laurie formation as exposed in Illecillewaet valley.

It is evident that a detailed lithologic section across any one part of the area has no general application. All that can be said is that member 2 consists essentially of crystalline limestones and argillaceous or carbonaceous sediments in various stages of metamorphism from argillite to mica schists, with lesser quantities of quartzite and chlorite schists. Also that, within the member, there are two broad zones, one on the west and one on the east, in which crystalline limestones are most abundantly developed.

In the vicinity of the Lanark mine, near Laurie, grey to black carbonaceous sediments, varying from flaggy argillites to slates, and pure white to impure carbonaceous crystalline limestones, are well exposed. These rocks appear less metamorphosed than those elsewhere in member 2, although they are, in places, faulted and complexly folded. The limestones are in many cases impure and flaggy and might be expected to contain fossils, as they closely resemble the rocks of several of the infolds of the fossiliferous Milford group, which have been found in Lardeau map-area to the south.[1] It is reported[2] that Drysdale found fossils in the rocks at the Lanark mine in 1917. These fossils which Drysdale collected are too poorly preserved to warrant any statement other than that they may be sections of crinoid stems. Similar material was found by the writer at the Lanark mine in grey, impure limestones. It may be said then, that at the Lanark mine and for considerable distances both east and west of it, sediments that may be of upper Palæozoic age are found. If they are Palæozoic they almost surely constitute an infolded syncline in member 2, similar to several of the areas of the Milford group in Lardeau map-area. It is interesting to note that near the head of Caribou creek, on its west side, outcrops of slightly sheared, grey conglomerate containing pebbles of white quartzite up to 3 inches long were found by the writer. Float of similar material was encountered near the Donald mine. Whether this conglomerate, which is the only rock of its kind encountered in the area, has any relation to the possibly Palæozoic rocks a short distance west at the Lanark is unknown and can only be ascertained by much more detailed work than has yet been done. No evidence of any unconformity has as yet been found.

Member 1, which includes the remainder of the sedimentary rocks of Big Bend area, is subdivided into members 1 A and 1 B. The rocks of member 1 A on the eastern side of the district are predominantly quartzites, being the equivalent of the lower or westerly part of Daly's Cougar quartzites of the main line section. The quartzites near the

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[1] Walker, J. F., and Bancroft, M. F.: "Lardeau Map-area, B.C., General Geology and Geological Map". Gunning, H. C.: "Mineral Deposits"; Geol. Surv., Canada, Mem. 161 (In press).
[2] Geol. Surv., Canada, Mem. 117, p. 18 (1920).

main line are fully described by Daly. They vary in colour from white to green or grey and are fine grained to gritty, grading to pebble quartzites in which many of the pebbles are strongly iridescent and bluish. Farther north, near the headwaters of the North fork of the Illecillewaet, they are predominantly fine grained, grits or pebbly beds being very sparingly developed. Interbedded with the quartzites are slates and mica schists, chloritic schists, and a few small beds of limestone. Greenstones are present in this member and in 1 B, but their nature and distribution will be described in a separate section.

Member 1 B, adjoining Columbia river from LaForme creek to Bigmouth creek, consists of argillaceous mica schists, quartzites, chlorite schists, small and generally discontinuous beds of crystalline limestone, and occasional garnetiferous schists, amphibolites, and andalusite schists. Greenstones are also present. The sediments strike north to northwest, or even due west, and dip at low angles to the east. In the vicinity of Old Goldstream, at the end of the road north of Downie creek, the strikes of the sediments are nearly due west and the dips are steep to the north. The exposures are too poor to elucidate the significance of the change in attitude. Possibly it is connected with the presence of intrusive rocks which outcrop on the road a few miles south of Old Goldstream.

Greenstones

Greenstones occur in members 1 A and 1 B. In 1 A, at the headwaters of the south fork of Mountain creek, they occur in bands up to 500 or 600 feet wide across the lower or western 3,000 feet or so of the member. Daly has mentioned them in the Cougar quartzite near the main line of the Canadian Pacific railway. They also occur in a wide belt in member 1 A west of the upper reaches of the North fork of Downie creek and continue north across that stream. They are interbedded with quartzite, schists, and occasional small beds of limestone. Over large areas they are massive to schistose chloritic or serpentinous rocks, showing no trace of igneous texture or of flow structure. In very few instances they present a mottled, grey-green appearance resembling diorite. In numerous places they are strongly amygdaloidal, the amygdules, generally less than one-half inch in diameter, being filled with quartz, epidote, or calcite, and occasionally with fresh, well-formed crystals of albite. Epidote is, in places, abundantly developed in large, irregular areas. In member 1 A, on the divide between Goldstream river and the North fork of Downie creek, angular fragments of quartzite were noticed in the greenstone. Shearing has bent the component minerals of the latter around the fragments.

The greenstones in member 1 B are best developed along the summits from Standard peak to the head of Keystone creek, where they form bands, generally conformable with the adjoining sediments, up to 400 or 500 feet wide. In Standard basin these rocks were studied in some detail in the hope that some general conclusion as to their origin might be obtained. In this place they differ from the greenstones in member 1 A in the general absence of amygdules. In two places they distinctly cut the interbedded sediments. The greenstones now consist of serpentine, chlorite, and carbonates produced by alteration. Many of them contain considerable magnetite. At one or two places, in the adits of the Standard group, the rock is crystalline, spotted grey-green in colour, and resembles very closely some of the intrusive phases of the Kaslo series, near Kaslo.[1] Under the microscope this rock is seen to consist of zoisite, green hornblende, serpentine, and small amounts of orthoclase, albite (?), and quartz. Probably it originally approached a diorite in composition. Near the heads of Fivemile creek and Keystone creek similar rocks are exposed in the same general stratigraphic zone. Here, however, some of them are again amygdaloidal and strongly resemble flows. In one place, near the Keystone group of claims, one body resembles diorite, as at Standard basin, and is distinctly intrusive into the adjoining sediments.

Many thin sections of the more massive greenstones were studied, but no definite evidence of their original composition was obtained. Chlorite, serpentine, and epidote are the most abundant constituents and the traces of original feldspars and quartz remaining unaltered are too meagre to justify a definite statement.

It appears, then, that the greenstones found in members 1 A and 1 B are largely extrusives, but that some are definitely intrusive. The two types are with difficulty distinguished in the field and are, apparently, always closely associated geographically. The flows, being interbedded with Precambrian sediments, must themselves be Precambrian in age. The intrusives may also be of Precambrian age, but they so closely resemble intrusive material from the Triassic Kaslo series of Lardeau and Slocan map-areas that the possibility of a Triassic age must not be overlooked. The problem of the greenstones in the Precambrian rocks of Kootenay district is one that will need much further study before it is clearly understood.

GRANITIC ROCKS

Granitic rocks are shown on the accompanying map (No. 237A) in different parts of the area. They occur as stocks, irregular bodies, and dykes, cutting the sediments described above. It is noteworthy that four of the bodies mapped occur at about the same stratigraphic horizon, approximately at the contact of members 1 B and 2 of this report. To the south, in Lardeau map-area, the Kuskanax batholith and associated rocks occur in about the same stratigraphic position. This suggests a zone of intrusion along a rather definite stratigraphic horizon and, as the mineral deposits of the district are believed to be connected with the intrusive rocks, the fact is of considerable importance.

The granitic rocks of the various bodies shown on the map vary considerably in composition and texture and, as the different bodies are nowhere visibly connected, it will be convenient to describe them separately.

Porphyritic Granite on Carnes Creek

The intrusive body of porphyritic granite at the small lake on the north fork of Carnes creek is a typical stock. The sediments around it are complexly folded. Thus the sediments at its south end strike east-west and dip steeply south, although the normal strike in the locality is west of north and the dip rather flat to the east. At its northern extremity the granite forms a great wedge, injected essentially along the bedding of the

[1] Cairnes, C. E.: Personal communication.

sediments. Although injection has evidently been the major process of intrusion in this body, yet the contacts, in detail, crosscut the sediments and stoping has been operative. The main body is remarkably uniform in texture and composition. It is dull grey and porphyritic, phenocrysts of microcline attaining lengths of 3 inches and widths of an inch or more. The holocrystalline groundmass, constituting about 70 per cent of the rock, is composed of oligoclase, some orthoclase and microcline, about 15 per cent quartz, and variable quantities of green hornblende, biotite, apatite, titanite, epidote, and pyrrhotite. The plagioclase is frequently well-zoned, apparently varying in composition from oligoclase in the centre to albite on the edges of zoned crystals. The groundmass of the rock certainly approaches the composition of a granodiorite, but, when the phenocrysts of microcline, forming about 30 per cent of the rock, are added, the average composition most closely approaches a granite. The rock is identical in appearance with certain phases of the Nelson batholith exposed in the region about Kootenay lake.

Near the edge of the main intrusive, dykes of medium-grained hornblende granite, quartz monzonite, and porphyritic alkali granite (largely potash feldspar with hornblende and quartz) cut the sediments. Garnet, titanite, apatite, pyrite or pyrrhotite, epidote, and calcite are accessory minerals in these dyke rocks.

The effects of contact metamorphism in the vicinity of the main stock are surprisingly slight. Limestones are generally, but not always, more coarsely crystalline next to the intrusive than away from it. Argillaceous sediments are baked and somewhat silicified. Garnet, epidote, diopside, zoisite, calcite, muscovite, and pyrite are very locally developed. The impure calcareous sediments seem to have been most susceptible to the formation of new minerals. It is not uncommon to find inclusions of pure limestone in the granite, that are practically unaltered. Contact metamorphic minerals have been somewhat more abundantly developed where numerous dykes cut the sediments to the north of the main stock. In several places there coarse crystals of albite have been developed in impure quartzitic sediments.

Granite on Downie Creek

The body of granite on Downie creek, east of Boulder creek, has not been studied in great detail. One fairly complete cross-section was obtained on the steep mountain side about 3 miles due east of Boulder creek. At this place the granite is conformable with overlying limestone and quartzite, its upper contact evidently being sill-like. The upper, or easterly, part of the granite for several hundred feet is fine grained, light grey, and consists of microcline, orthoclase, and albite-oligoclase, with about 15 per cent quartz, in proportions that give the composition of normal granite. There is, also, a small quantity of green biotite and muscovite. The western or lower part of the exposure is coarser grained and darker in colour, consisting of orthoclase, some microcline, oligoclase in large crystals some of which are zoned, about 20 per cent quartz, green biotite, apatite, a little muscovite, and less magnetite. The feldspars are clouded by alteration products. The rock is still a granite, being somewhat more calcic than the upper or easterly portion. Near the headwaters of Canyon creek, on the Montgomery group, dykes of the granite are exposed and some of the main body is crossed by the trail to the property. A fairly representative sample of a large body exposed on the trail is granite of even, medium texture. It consists of orthoclase, microcline, some micrographic intergrowths of quartz and feldspar, 10 or 15 per cent of albite-oligoclase, about the same amount of quartz, and a little biotite and muscovite. Here, as on the eastern section, the granite varies from light grey, rather fine-grained varieties to a more calcic, darker-coloured and coarser-grained rock. Pegmatite dykes cut the main body.

In the adjoining sediments, and in sedimentary inclusions in the granite, garnet, epidote, pyroxene, calcite, and quartz have been developed in moderate amount. In much of the limestone are radiating clusters and coarse crystals of tremolite and a little actinolite was noted. In places the rocks are extensively silicified.

Porphyritic Granite on Bigmouth Creek

The granite west of Argonaut peak and south of Bigmouth creek is porphyritic for the most part. It resembles, but is darker in colour than, the granite on Carnes creek. Crystals of microcline, up to 2 inches in length, are embedded in a greenish grey base of feldspar, quartz, and ferromagnesian minerals. Under the microscope the rock is seen to contain, as well as numerous large phenocrysts of microcline, about 15 per cent of rose-tinted quartz, plagioclase about the composition of pure oligoclase, orthoclase, and microcline in small grains, biotite, epidote, and titanite. The rock may be termed a porphyritic granite, as the phenocrysts of microcline form a large percentage of the whole. However, an analysis of this and the Carnes Creek granite might indicate a composition approaching that of quartz monzonite or granodiorite if the latter term be made to include all those rocks intermediate in composition between granite and quartz diorite. Many dykes, varying from feldspathic pegmatites to feldspar porphyries and aplites, cut the main body and the adjoining sediments. A thin section of an aplite sill consists of albite-oligoclase, orthoclase, microcline, quartz, muscovite, and biotite, the rock being a true granite in composition. Within the main granite are many nodular bodies of ferromagnesian minerals.

The sediments near the granite have been greatly altered. Limestones are coarsely crystalline and argillaceous sediments are baked and silicified. Garnet, epidote, tremolite, actinolite, biotite, muscovite, and chlorite are abundantly developed. Tourmaline was observed in considerable quantities some distance south of the intrusion. Within the granite are many large and small inclusions of the sediments.

Granites on the North Fork of Illecillewaet River

The granitic rocks west of the North fork of Illecillewaet river have not been studied in detail due to the excessive ruggedness of this part of the district. Only the borders of the main intrusion or intrusions were examined. Specimens collected and studied under the microscope are porphyritic, with microcline phenocrysts in a fairly coarse-grained groundmass of microcline, orthoclase, plagioclase, approaching oligoclase in composition, and 15 or 20 per cent quartz. The rock contains large crystals of green hornblende and minor amounts of epidote, biotite, titanite, apatite, and pyrite. The field work was hardly sufficient to warrant giving a definite rock name to the whole mass or masses of igneous rock, but what information is available indicates a composition about on the border between granite and granodiorite. Dykes, apophyses of the main mass, of granitic composition and porphyritic texture, cut the adjoining sediments which are baked and metamorphosed and contain many barren or pyritic quartz veins. The easterly contact of the main intrusive, where examined, dips rather flatly to the east.

The sediments cut by the granite include black slates, quartzitic slates, and carbonaceous limestones. In the slates, some of which are calcareous, near some of the porphyritic dykes, much colourless to light brown amphibole is developed in crystals which are black in the hand specimen. Microcline, orthoclase, albite, muscovite, actinolite, titanite, and quartz are also observed under the microscope, much of the potash feldspar probably being an original constituent of the sediment. The amphibole most closely approaches the variety pargasite, the colour only differing from published descriptions. The maximum extinction angle is 25 degrees, 2v approximates 60 degrees, elongation is positive, and the mineral is biaxial negative. It has undoubtedly been formed by contact metamorphism, as the crystals gradually disappear from a bed with increase of distance from the intrusion.

Porphyritic Granodiorite on Caribou Creek

At the Donald mine, on the west side of Caribou creek, near the Canadian Pacific railway, a small stock of porphyritic granodiorite cuts quartzites and slates. It is described fully on the section devoted to Woolsey Mines, Limited, page 173. Dykes of hornblende granite and granite aplite are described in the same place. In addition, a short distance east of the small lake shown on the map, there are fine-grained, rusty weathering dykes which are with difficulty distinguished from some of the rusty quartzites of the locality. These, under the microscope, are seen to be badly altered and now consist of albite-oligoclase, quartz, hornblende altered to biotite, muscovite, sericite, and pyrite. Originally the rock was probably a granodiorite.

Between the Donald and the granite west of the North fork of the Illecillewaet are many dykes of feldspar porphyry, which vary in appearance between the different types described at these two localities. They cut the sediments, and float from them is found on the sidehills and in the valleys along the North fork and its tributaries.

Granite on Albert Creek

The granite mapped near the headwaters of Albert creek is the northwesterly end of a much larger body (*See* Map 235A; Lardeau area, Kootenay district, B.C., in press). The contact is irregular and many dykes and sills cut the neighbouring sediments. On the whole, the igneous rock is a typical, rather fine-grained granite containing microcline, orthoclase, oligoclase, quartz, biotite, muscovite, titanite, apatite, and magnetite. Some of the plagioclase is zoned. Some of the dykes bordering the main mass are slightly sheared, so that they are partly gneissic, and one large dyke of quartz diorite was observed, its predominant feldspar being andesine. Aplite and pegmatite dykes are quite common within a radius of a mile or so from the main mass. Barren quartz veins are quite abundant and a little chalcopyrite and tourmaline are associated with some of the aplite dykes on the north side of Albert creek. On the whole, contact metamorphism has been slight.

Other Areas of Granite

The areas of granite shown on the map on the north side of Downie creek and west of Boulder creek have been encountered only as float. The outcrops are easily discernible from the heights at the head of Boulder creek and from Keystone basin. Many large boulders of float on the trail up Downie creek indicate that the rock is a fine to medium-grained, grey granite similar to that found east of Boulder creek.

On the Big Bend trail, 10 miles north of Downie creek, several large dykes of fairly coarse-grained biotite granite cut schists and quartzites. The dykes are not shown on the accompanying map, but they may be part of a large body of granite. Heavy timber and underbrush cover the rocks in the vicinity.

Age of the Granitic Rocks

The granitic intrusives of the western part of Big Bend map-area are believed, with some confidence, to belong to the general period of Mesozoic, post-Triassic intrusions which are so abundantly developed in Kootenay district. The rocks in the Big Bend are similar in appearance to many of the granites found farther south and, moreover, intrusive bodies of similar nature occur almost continuously from the International Boundary to Bigmouth creek. The granites to the south of the Big Bend have been studied, at several places, in considerable detail and there can be little doubt of their general age. Whether or not some may be post-Mesozoic can not be proved in Big Bend district. The intrusions on the North fork of the Illecillewaet and at the Donald mine are somewhat different in appearance and in composition from the other bodies, but there is no way of telling whether or not they belong to the same general period of intrusion as those on the west side of the area. Certainly those at the Donald mine have been extensively sheared in places and are considerably altered near later ore-bearing veins. Lacking definite information, the writer prefers to place all the granitic rocks of the area in one general period of intrusion which may have extended from the early Jurassic to the early Tertiary.

LAMPROPHYRE DYKES

Lamprophyre dykes are sparingly developed in Big Bend map-area. Daly[1] has described two small dykes of "dark, greenish grey, somewhat porphyritic, medium-grained minette" and a basaltic sill at Albert Canyon gorge on the main line of the Canadian Pacific railway. The present writer observed one small, fine-grained, black dyke about three-fourths mile above the railway in Albert creek. In the field it resembled a lamprophyre, but under the microscope it was seen to consist of light brown to bluish tourmaline and quartz, a little specularite, and probably some greatly altered orthoclase. The rock is slightly amygdaloidal. A dark grey, fine-

[1] Geol. Surv., Canada, Mem. 68, p. 135 (1915).

grained lamprophyre dyke in Silver creek, about $1\frac{1}{2}$ miles below the forks, consists of biotite, quartz, and alteration products; chief among which is calcite. Fluorite and quartz were observed in amygdules. The rock probably resembles most closely the minette at Albert Canyon gorge. It is greatly altered.

GRANITE, GNEISS, SEDIMENT COMPLEX

Between Albert canyon and Revelstoke and northward to LaForme creek is an area of mica schists, quartzites, a few small bands of fine-grained, crystalline limestones and amphibolites, cut by numerous dykes, sills, and irregular bodies of granitic and gneissic granitic rocks. In addition there are large areas of true gneisses, some of which are paragneisses and others orthogneisses. Pegmatite dykes cut all the above-mentioned rocks.

On the main line of the Canadian Pacific railway the exposures are about 50 per cent fresh, fine-grained granite, as sills, dykes, and irregular bodies. Intimately associated with these fresh granitic rocks are large quantities of gneissic granites, varying in colour but generally of greenish or dark grey tints, frequently weathering rusty. Problematical gneisses, grey to greenish, some of them well foliated, are also well developed. Mica schists and quartzites occur in rather minor amounts. The eastern side of the complex is made up of several thousand feet of well-foliated gneiss, grey to green in colour, cut by numerous dykes of granite and pegmatite. This is Daly's sill or laccolith of orthogneiss.[1] Pegmatite dykes cut the gneiss and the fresh granites and many are garnetiferous. A few small crystals of beryl were found in pegmatites on the Silver Creek trail a short distance from Illecillewaet river. Above the foliated gneiss are gneissic quartzites and then the sediments of member 2 of this report. The strike of the gneiss and the overlying sediments is northwest and the dips rather flat to the east.

In Revelstoke National park, from Revelstoke to the head of Clachnacudainn creek which flows into the Illecillewaet at Twin Butte, the rocks are well exposed. Grey gneisses, quartzites, mica schists, amphibolites, gneissic granites, granites, and pegmatites occur in amazing complexity. The sediments are greatly contorted, but most commonly the strike of them, and of the gneisses, varies from north to northwest and the dip from 0 degree to 60 degrees to the west. With the exception of the one large area shown on the map sediments are confined to small and irregular areas, generally completely surrounded by granitic rocks, and they themselves are extensively metamorphosed. Amphibolites have evidently been formed, by alteration, from sediments. The granites vary from dark green gneissic varieties to fine-grained, fresh, grey ones, the latter cutting the former. Later than all these are pegmatites, rich in muscovite, quartz, or red garnets. Some of them are slightly sheared.

At the northern end of the complex, on LaForme creek, grey, even-grained gneisses, showing little foliation, predominate. They are probably orthogneisses. Schists and gneissic rocks of sedimentary origin are sparsely developed, as are fresh granites. Quartzites and mica schists, intruded by gneissic granite, cover the gneisses on the east, the general trend in the locality being northwest and the dips about 45 degrees to the northeast.

[1] Geol. Surv., Canada, Mem. 68.

A short distance north of LaForme creek, along the strike of the gneisses, mica schists, quartzites, limestones, and amphibolites appear and are cut by dykes of granite and pegmatite. It is evident that the sediments gradually give way, along their strike, to the gneissic rocks on the south.

Special attention was paid to the geology on Silver creek and on Albert creek in the vicinity of Albert Canyon station, in an attempt to solve the relation of the granite-gneiss-sediment complex to the overlying sediments which constitute the lower part of Daly's Beltian. The outcrops in this critical zone are poor, the rocks being covered with a heavy mantle of soil and timber. On Albert creek, a little less than one-half mile from the Canadian Pacific Railway tracks, white crystalline limestone is exposed in two places. The westerly exposure is about 50 feet wide. In it the limestone is very variable in grain and contains lenses of impurities, probably originally sedimentary material, which now consist of hornblende, epidote, zoisite, and augite with some quartz, titanite, apatite, and calcite and a few specks of chalcopyrite. The strike is a little west of north and the dip about 45 degrees to the northeast. Two hundred yards upstream, or to the west, coarsely crystalline limestone is interbedded with gneissic rocks that may have been impure arkosic sandstones. Now they consist of quartz, intermediate plagioclase, titaniferous augite, epidote, uralite (hornblende), apatite, titanite, and calcite. The gneisses and limestone are greatly contorted, the limestone containing many knots and lenses of material similar to that described in the easterly exposure. A somewhat sheared, coarse, feldspathic dyke cuts across the gneisses from the west and ends abruptly at the first prominent band of limestone that it encounters. Farther west the rocks are poorly exposed, but appear to grade through gneissic quartzites or paragneisses to granitic orthogneisses. They are cut by dykes of aplite and pegmatite.

Better outcrops were found in the same stratigraphic horizon, on the south side of Albert creek, about 5 miles above its junction with Illecillewaet river. On the ridge immediately north of the small body of granite shown on the map, and described on page 147, crystalline limestones are interbedded with quartzites and schists and strike northeast, dipping steeply southeast. On top of the ridge, at elevations between 5,500 and 6,000 feet, these sediments are cut by numerous sills and dykes of fine-grained granite and pegmatite. Below 5,500 feet, on the Albert Creek slope, grey gneisses are interbedded with the limestone and quartzite and the dykes persist. At 5,000 feet the exposures are entirely of grey gneiss whose foliation parallels the bedding of the sediments above, and which is cut by similar granitic and pegmatitic dykes. Five hundred feet lower, towards Albert creek, the same gneisses are well exposed, but their strike is now northwest and their dip 45 degrees to the northeast. The section spans the nose of an anticline whose axis trends south of east and plunges steeply in the same direction. On the north side of Albert creek the sediments also trend northwest and dip to the northeast.

The section proves that the fresh granitic dykes, including aplites and pegmatites that cut the gneisses, also cut the overlying sediments. No unconformity was noted. The gneisses are exactly similar to those encountered elsewhere in the granite-gneiss-sediment complex. The intimate manner in which the gneisses are interbedded with the sediments indicates that they have been formed by replacement and injection in the sediments by a granitic magma.

Similar conditions were found to exist on Silver creek below the east fork. Quartzites, schists, and gneisses alternate for a distance, in the creek bed, of half a mile or more, and crystalline limestones occur well within the area of gneisses.

Several thin sections of the fresher granitic rocks from various parts of the complex were studied under the microscope. A rather typical specimen from Revelstoke National park was a typical granite containing large quantities of microcline and some orthoclase, a small amount of albite-oligoclase, and abundant quartz. Micrographic intergrowths of quartz and feldspar were observed. Biotite, muscovite, apatite, and pyrite were accessories. Thin sections of specimens collected in the vicinity of Albert creek were very similar, the potash feldspars always greatly predominating over the plagioclase which varied in composition from oligoclase to nearly pure albite. Titanite is a fairly common accessory. These rocks are thus very similar to the fine-grained granites which are found cutting the sediments at various places in the map-area and also to the rocks of the Kuskanax batholith along Upper Arrow lake. Consequently the granites of the complex are believed to be of Mesozoic age.

The area now covered by the granite-gneiss-sediment complex is considered to have been originally entirely underlain by quartzites, schists, and limestones belonging to member 2. Some time during the Mesozoic era, probably in Jurassic days, these sediments were intruded by a granitic magma. The original sediments were in large part converted to gneisses by impregnation and injection during the early stages of igneous activity. Some of the sediments were converted to amphibolites. Subsequently numerous dykes, sills, and irregular bodies of granite were intruded. Dark coloured, femic rocks were the earliest phases of the granite to be intruded and they were effected by the forces coincident with intrusion, being rendered more or less gneissic. The later phases of the granite are the leucocratic rocks which have been described in the previous paragraph. They cut the sediments, gneisses, and gneissic granites and are fresh to partly gneissic, fine-grained, massive rocks. The latest intrusives are numerous pegmatite dykes which cut all the rocks of the complex.

STRUCTURAL GEOLOGY

The major geologic structure is a broad synclinal trough whose axis trends northwest-southeast through the centre of the mapped area. Within this major syncline the rocks are complexly folded into a series of synclines and anticlines whose axes, on the whole, parallel the regional strike of the sedimentary formations and plunge towards the southeast. From the head of Caribou creek to the upper reaches of the North fork of Downie creek, the rocks are folded in a series of anticlines and synclines which, in conjunction with drag folding and the distribution of the sedimentary formations, indicate a syncline on the west. West of the North fork of the Illecillewaet and northeast of mount Moloch the member 1 A plunges steeply to the south under the limestones and associated sediments of member 2 and the latter are on the western limb of a syncline. The limestones form well-defined horizons from which the complex folding can be easily perceived. From the North fork of the Illecillewaet westward towards mount Moloch there are at least three tightly folded synclines and anticlines whose axial planes dip to the east. It appears that, a short distance east of mount Moloch, the sediments form the eastern limb of another major syncline, the western limb of which is exposed in the vicinity of and west of Carnes peak, where the sediments dip very flatly to the east. It is concluded that the sediments of member 2 occupy a synclinal trough and overlie the rocks mapped as 1 A and 1 B. Also, member 1 A on the east is correlated with the upper or easterly part of member 1 B on the west. Within this great syncline there are numerous anticlines and synclines. The axis of one of the latter lies approximately parallel to, and a little east of, the valleys of the upper reaches of the North forks of Downie creek and Illecillewaet river, probably crossing the main line of the Canadian Pacific railway somewhere in the vicinity of the Lanark mine. A second syncline axis lies about parallel to, and a little east of, the valley of the South fork of Downie creek. Between these two, numerous synclines and anticlines constitute a major anticlinal structure which plunges towards the south. This latter structure accounts for the fact that the great thickness of quartzites, schists, and greenstones exposed in member 1 A west of the upper reaches of the North fork of Downie creek do not outcrop along the main line of the Canadian Pacific railway. Similarly the rocks in member 2 exposed along the North fork of the Illecillewaet rise towards the north and are finally limited to the narrow syncline lying along the valley of the upper reaches of the North fork of Downie creek.

Along the western edge of member 2 the rocks are folded in a series of overturned, flat-lying folds which dip towards the east. These folds account for the irregularity of the western contact of the member.

No faulting of major dimensions has been observed. A short distance east of Downie peak a fault, striking northeast and standing nearly vertical, has offset the beds not more than 200 or 300 feet. It is possible that faulting has taken place on the ridge between the south fork of Carnes creek and the east fork of LaForme creek, accounting in part for the irregular western contact of member 2 at this place, but no well-defined fault plane was found. The rocks, however, are contorted and sheared along a line, trending approximately east and west, that, extended west, would parallel and lie a little north of the lower reaches of the east fork of LaForme creek. The schistosity of the rocks, with minor exceptions where complex local folding exists, is parallel to the bedding. On several of the mining properties large, bedded shear zones have been observed. It is consequently quite possible that bedded faults of major dimensions exist but have not been detected.

CORRELATIONS

In view of the exploratory nature of the work in Big Bend map-area and the consequent lack of complete information on the area as a whole it has been deemed advisable to omit formational and series or group names from the map and report. In the present section only those correlations that are reasonably sure will be made.

The section along the main line of the Canadian Pacific railway was studied in some detail by R. A. Daly.[1] Daly's Albert Canyon division of the Selkirk series, which is the equivalent of Dawson's Niskonlith

[1] Geol. Surv., Canada, Mem. 68 (1915).

series,[1] corresponds with member 2 of this report if Daly's basal quartzite is omitted. That is, member 2 includes Daly's lowest limestone, Moose metargillite, Illecillewaet quartzite, and Laurie formation. Member 3, the granite-gneiss-sediment complex, is the equivalent of Daly's Shuswap sill-sediment complex as exposed between Albert canyon and Revelstoke. The same rocks were also considered as Shuswap in age by G. M. Dawson.[2] Member 1 A as correlated with Daly's Cougar quartzites, which Dawson placed in the lower part of the Selkirk series, and member 1 B, is the northward continuation of the sediments of Daly's Shuswap.

Lardeau map-area [3] is immediately south of the western part of Big Bend map-area. The two areas overlap between Albert canyon and Revelstoke. Member 2 of the Big Bend includes the Lardeau series, the Badshot formation, and about 1,000 feet of the underlying Hamill series of Lardeau map-area. A complete tie between the rocks of the two areas has been made by the writer in the region south of Albert creek. For practical reasons connected with mapping it was found to be impossible to use the subdivisions as made in the Lardeau, in Big Bend district. With the publication of this report and the memoir on Lardeau map-area information will be available that will permit of direct correlations from Kootenay lake to the northern end of the mapped area in Big Bend district.

ECONOMIC GEOLOGY

INTRODUCTION AND HISTORY

The metallic mineral deposits of Big Bend map-area contain values in lead, zinc, silver, gold, copper, and arsenic. In the non-metallic deposits asbestos, talc, and mica have been found. Placer gold occurs in several streams draining into Columbia river north of Revelstoke, particularly in the vicinity of Goldstream river. The metallic deposits are the most important. The only mine that has ever produced important quantities of ore is the Lanark, near Laurie on the main line of the Canadian Pacific railway. Today there are no producing mines in the district, but several properties are being actively developed. Several million dollars of placer gold have been extracted in the past sixty-three years, largely from French and McCulloch creeks and today an attempt is being made, on a large scale, to hydraulic ground along French creek.

In February, 1865, reports of placer gold in Big Bend district first reached Victoria. Later in the year four boats left Fort Colville and ascended Columbia river. The leaders were William Downie, Hank Carnes, Nelson de Mars, Louis Lee, and Steve Liberty. These pioneers and their associates prospected the creeks flowing into Columbia river and first struck gold on Carnes creek. Richer finds were made on French creek and by August there were about 150 men in the district. In 1866 the steamboat "49," under Captain White, made thirty-seven trips from Marcus to Laporte, just north of Downie creek, and it is estimated that there were between 8,000 and 10,000 people in the region by the end of the season. The passengers paid $25 each for the boat trip and freight cost $200 per ton. The known yield of placer gold for 1865 was: French creek,

[1] Dawson, G. M.: Bull. Geol. Soc. Am., vol. II, p. 165 (1891).
[2] Op. cit., p. 170.
[3] *See* Geol. Surv., Canada, Mem. 161 (In press).

$32,000; McCulloch creek, $2,700; and Carnes creek, $3,000. Much of the gold recovered was not reported and it is estimated that gold to the value of $3,000,000 was extracted in 1865 and 1866. During the latter year the town of Kirbyville was founded near the mouth of Goldstream river and several thousand people resided there. Lumber for the workings was cut in a small sawmill. During 1867 interest waned, due largely to the difficult nature of the ground and also to the fact that the gold-bearing areas were too small to support the large number of people who had flocked to the camp. In 1869 there were only thirty-seven men on French creek and the district continued partly deserted to 1878. In 1879, five men journeyed to French creek from Kamloops and examined the old workings there, but took no further action. Four years later Messrs. Myoff and Ratchford made the same trip via the Government trail from Seymour Arm which was constructed in 1865. The same year some twenty mineral claims were staked in the vicinity of Illecillewaet. During 1885 interest revived in the placer workings and also in gold-quartz veins that had been discovered around the headwaters of McCulloch creek. In 1886, five companies were working placer ground on McCulloch creek and similar activity was reported on Carnes creek. High values had been obtained from the deposits near Illecillewaet and lode mining was beginning. Several properties near Laurie, including the Lanark mine, were worked in 1887 and extensive placer operations were under way on French, McCulloch, Smith, and Carnes creeks. Placer operations in the Big Bend and lode mining at Illecillewaet continued during 1888 and 1889. During 1890 the placer deposits were partly deserted, but lode deposits at Illecillewaet, principally the Lanark mine, were active and smelters had been erected at Golden and Revelstoke. Lode mining continued during 1891 and 1892, but in 1893 mining was practically at a standstill. In 1894 a little placer work was done on French, McCulloch, and Smith creeks, the Consolation mine on French creek producing about $6,000 in placer gold. Also some attention was paid to lode deposits on McCulloch and Carnes creeks. In 1895 work continued on placer deposits, the principal operations being at the Consolation mine. Interest in lode mining was increasing and during the following year the Ole Bull and Orphan Boy groups on McCulloch creek received extensive development. Numerous claims were staked in Keystone and Standard basins and placer mining continued active. Interest revived in Illecillewaet district and the Waverley-Tangier group on the North fork of the Illecillewaet was examined. During 1897 and 1898 lode mining was active throughout the district, but developments at the Lanark mine proved disappointing. In the latter year Goldfields of British Columbia, Limited, did much work on the Waverley-Tangier group. By this time most of the claims now known had been staked. Placer mining was largely limited to French creek. The year 1899 saw little change in conditions. From 1900 to 1906 placer and lode mining continued, the most important operations taking place at the Standard mine. During the next two years some hydraulicking was done on French, McCulloch, and Smith creeks. In 1908 the mica deposits around Mica creek, in the northern part of the district, were discovered and they were actively developed during 1909 and 1910. From 1911 to 1914 placer and lode deposits received a little development. In 1915 the Lanark mine was re-opened and shipments commenced the following year; the Mastodon group on LaForme creek was also actively developed. Lode mining increased during the succeeding years, but, with the exception of the Lanark mine, which was finally abandoned in 1925, no shipments of ore were made. For the last three years a certain amount of prospecting and development have been done on the lode deposits and small-scale placer operations have been carried out. At present four of the lode deposits are being actively developed and large-scale placer operations are under way at French creek. An automobile road is being constructed along Columbia river, north from Revelstoke, by the provincial government and it should stimulate interest in mining by rendering the northern part of the district more accessible.

TYPES OF DEPOSITS

The lode deposits of the district occur as fissure veins and as replacements in limestone or other sediments. Fissure filling has been the most important process in the formation of the deposits. One or two deposits have been formed largely by replacement, however, and this process has been operative in portions of many of the veins. On a basis of mineral content the deposits may be divided into several distinct types as follows:

Gold-quartz veins
Copper deposits
Lead-zinc deposits
Quartz-tetrahedrite veins

The gold quartz veins are represented by the Ole Bull, Orphan Boy, and other properties near the headwaters of Graham and McCulloch creeks. The quartz veins, mineralized with pyrite, free gold, and occasionally with pyrrhotite, occupy well-defined fissures which generally cut the bedding of sediments at sharp angles. Gold values are erratic and occur in the pyrite, or as free gold in the quartz, or in crushed zones along the sides of the veins. The veins vary from a few inches to about 6 feet in width, averaging between 2 and 3 feet. At present no work is being done on any of the properties and none has proved to be of much commercial importance. On the Carbonate Chief property similar veins are exposed.

Deposits valuable for their content of chalcopyrite are sparingly developed. The Montgomery group, a high-temperature replacement deposit in sediments near the contact of a stock of granite, contains chalcopyrite in a gangue of pyrrhotite, some pyrite, and silicified and altered country rock. At the Standard group veins and replacements of chalcopyrite, with pyrite and pyrrhotite, occur in greenstone. The former property is practically undeveloped and presents the possibility of a large tonnage of low-grade copper ore. The Standard contains some small high-grade bodies of chalcopyrite, but has little chance of ever becoming an important producer.

Deposits containing lead and zinc with variable values in gold and silver occur at numerous places. These deposits fall naturally into two distinct groups, both of which are of the fissure type. In one deposit only has replacement been of major importance. The first group includes relatively high temperature deposits in which pyrrhotite is abundantly developed. In these deposits the silver values are low, seldom attaining 1 ounce of silver per unit of lead. Similarly low values in gold are also present. The Donald mine, the deposits on the Keystone and adjoining claims, and the J and L and the A and E groups belong to this class. With the exception of the deposits on Keystone claim, where the sulphides have replaced limestone, all the above occupy well-defined fissures which, when they occur in sediments, are nearly or quite parallel to the bedding. The A and E and the J and L groups contain deposits that are quite unique in that, in addition to the sulphides of lead, zinc, and iron, there is considerable arsenopyrite with which fairly low but important values in gold are associated.

The second and largest group includes lower-temperature deposits in which galena, sphalerite, and pyrite are the principal sulphides, pyrrhotite being absent. The values in gold are generally low, but those in silver are higher than in the pyrrhotite-bearing deposits. This is due to the appearance of argentiferous tetrahedrite and other silver-bearing minerals such as ruby silver and jamesonite or boulangerite in the ores. This group includes the deposits on the Lanark and adjoining claims, on the Snowflake and Morton Woolsey groups on Silver creek, on the Waverley-Tangier group, and others. All occur in veins or shear zones that are practically bedded. The Waverley deposit is exceptional in that the ores, so far as they are at present developed, are almost entirely oxidized and that they have been formed, in large part, by replacement of limestone.

Recent discoveries (*See* page 185) in the lower level of the Snowflake have revealed the presence of stannite (sulpho-stannate of copper, iron, and zinc) in the ore. Although no authentic information regarding the magnitude of the deposit is available, the occurrence is of considerable economic and scientific interest as stannite has not previously been found in British Columbia. As is noted on page 186, the mineral is not an easy one to identify and, if present in small amounts, might easily be confused with zinc blende or grey copper. Consequently it would seem advisable to have samples from the lead-zinc deposits of the district tested for tin when any assaying is being done.

It is interesting to note that cassiterite is generally associated with stannite, and that cassiterite is most frequently found in quartz veins associated with acidic intrusives such as granite and pegmatite. Cassiterite is also found in pegmatite dykes. Fresh granite and granitic pegmatites occur in abundance in the granite-gneiss-sediment complex which is found short distances west and south of the Snowflake. The writer has found beryl in some of the pegmatites exposed on the Snowflake trail a short distance from the railway. The granite and granitic pegmatites of the complex are assigned to the same period of intrusion as the other granitic rocks of the region which are believed to have supplied the emanations that formed the ore deposits of the district. No tin has as yet been found in the pegmatite, but future investigators might well bear in mind the possibility of cassiterite being associated with them.

The quartz-tetrahedrite veins include several small deposits that contain exceptionally high silver values, such as those on the Juno, Tiger, and George claims. They are evidently closely associated with the previous group, as galena and sphalerite occasionally occur abundantly in the veins. Typically the deposits are small and the ore minerals are irregularly distributed as bunches and stringers throughout the quartz. Argentiferous grey copper is the most abundant ore mineral.

ORIGIN AND DISTRIBUTION

The lode deposits are believed to have been formed by ascending solutions which originated in the magmas that formed the numerous granitic intrusions of the district. The similar appearance and composition of the different intrusive bodies leads to the belief that they are closely related in age and origin. The distribution of the mineral deposits points to a derivation from the granitic magmas. The Montgomery group is a high-temperature deposit in sediments immediately adjoining a small stock of granite. To the south of the same body of granite the deposits in the vicinity of Keystone basin indicate a zoning away from the granite. Watery quartz with much pyrrhotite and a little chalcopyrite occur near the granite. To the west, or farther away from the granite, pyrrhotite, pyrite, galena, and sphalerite are associated with veins of quartz and ankerite. Still farther west, on the Keystone claim, galena and sphalerite are more abundantly developed, although pyrrhotite is still present. These deposits represent a gradation from high to lower temperature deposits as distance from the outcropping granite is attained. Somewhat the same thing is evident to the south of the body of granite that lies northeast of Carnes creek. On the A and E, and on the J and L groups pyrrhotite and arsenopyrite are plentifully developed in the lead-zinc ores, indicating a high-temperature type of deposit. Farther south, on the Mastodon and adjoining properties, these two minerals are absent and argentiferous grey copper begins to appear in important amounts with the galena and sphalerite. Still farther south, on the Snowflake and Morton Woolsey properties, galena, containing some grey copper and a little ruby silver, is the predominant mineral. If all these deposits be assumed to have originated from the same general source, they certainly represent a distinct gradation from high to lower temperature types going away from the exposed granite. It is probable that the different stocks of granite exposed along the western side of the map-area are connected at some distance beneath the present surface and that ore-bearing emanations have been set free from this deep-seated magma. Consequently the actual source or sources of the solutions may be in no way directly connected with the exposed bodies of granite which are merely the eroded higher portions of the parent magma. It may be logically assumed that the farther one goes from exposed granite, the more deeply buried is the parent magma. Consequently the high-temperature types of deposits would be found closer to exposed granite, or, where they occur well removed from exposed granite, at lower elevations than the lower temperature types. It would be well to remember that the high silver values accompany the low-temperature deposits. From the above reasoning it follows that, with increased depth on any deposit, a change in mineral content might be expected. Thus, if a silver-lead deposit were followed to considerable depth, that is, towards the source of the mineralizing solutions, an increase in sphalerite, chalcopyrite, pyrrhotite, or arsenopyrite might be expected. That this change would necessarily occur does not follow, for the amount and composition of material available for mineralization and complex structural relations might materially alter the theoretical conception. More than one period of ore deposition would also alter the distribution of ore minerals.

The intrusive bodies on Caribou creek and west of the North fork of Illecillewaet river are similar in general appearance and composition. They are slightly more basic than the granitic bodies on the west side of the area. Whether or not they are of the same age as the latter is open to question, but, as direct evidence is, and probably always will be, lacking, it seems logical to assume that they are. The mineral deposits that occur on the east side of the area may be assumed to have originated from magmas that gave rise to these intrusives. The ore-bearing solutions postdated the consolidation of the intrusive rocks, however, for the deposits at the Donald mine occur along joints and fissures in massive porphyritic granodiorite.

The mineral deposits of the district occur along two principal zones. One zone extends along the western side of the district, following more or less closely the western boundary of member 2 of this report. The second zone extends from the headwaters of the North fork of Downie creek to the main line of the Canadian Pacific railway between Illecillewaet and Caribou creek.

It has been stated above that the mineral deposits are believed to have been formed by emanations from deep-seated magmas. Consequently the deposits may be expected to be reasonably persistent at depth. The copper deposits on the Standard group are possible exceptions. Their occurrence in the greenstones, and their erratic but widespread distribution suggests a local origin connected with the greenstones.

FUTURE OF THE DISTRICT

The future of mining in the Big Bend depends principally on developments in the lode deposits. Of these the lead-zinc deposits are the most important and it is possible that some of the properties that are now being developed will become producing mines in the future. In addition, one copper property may contain large, low-grade ore-bodies. Though it seems scarcely probable that the Big Bend will ever become one of the most important mining districts of the province, yet it is certainly deserving of more careful prospecting than it has yet received. Attention should be directed to the two principal zones of mineralization already mentioned. The area between the upper reaches of Carnes creek and LaForme creek and the forks of Silver creek is relatively easily accessible and contains numerous signs of mineralization. Also, any ores found in this area might be expected to yield good silver values. Prospecting there should not be wasted effort. The improved transportation facilities which will result from the construction of the automobile road along Columbia river, will, it is hoped, attract those interested in prospecting and mining to the district.

Description of Properties

GOLD-QUARTZ VEINS

Ole Bull, Orphan Boy, and Adjoining Claims

In the district around the heads of McCulloch and Graham creeks, many gold-quartz veins were staked in the days following the rush in 1865 to French creek. Apparently little or no work was done at this time. In 1895, after a long period of quiescence, the Ole Bull was worked and in 1896 good gold values were obtained from it and from the Orphan Boy.

Operations continued until 1900 and it is reported that some exceptionally rich pockets were encountered on the Orphan Boy. Since 1900 no work is recorded and the claims are at present deserted. A fair trail leads from the mouth of McCulloch creek to the Ole Bull cabin, at timber-line.

In the district impure quartzites, mica schists, and chlorite schists vary in strike from north 60 degrees west to north 30 degrees west and dip from 15 degrees to 40 degrees to the northeast. They are cut by numerous quartz veins, a large proportion of which follow a pronounced system of joints, striking north 10 degrees east to north 20 degrees east and dipping steeply west. A few veins are bedded. With the quartz are pyrite and some pyrrhotite and occasionally a little green chromium mica. The sediments, in some places, are extensively carbonated near the veins. Gold occurs free or in the pyrite and the values are erratically distributed throughout the veins. It is probable that all the gold is associated with the sulphides and is set free by oxidation of the latter. If this be so, free gold would be found only in the oxidized portions of the veins.

On the Ole Bull group there are several, parallel, well-defined quartz veins which vary in width from 6 inches to 3 feet. Numerous outcrops and open-cuts show the veins to be persistent along their strike. On one vein, near the cabin, an old shaft is now full of water. The vein, which is 2 feet wide, is much crushed and sparsely mineralized with pyrite. Just beneath the foot-wall of the vein, which dips 80 degrees northwest, are two 6-inch rusty stringers of crushed quartz. From the rusty quartz and from the crushed and rusty schists adjoining the stringers, small angular or porous colours of gold were obtained by panning. Much less gold was obtained by panning the gouge along the hanging-wall of the main vein and only a few tiny colours were won by crushing and panning the quartz of the main vein.

The Orphan Boy claim, now deserted, is about 1½ miles west of the Ole Bull. It was not examined, but quartz veins similar to those on the Ole Bull were noticed in the vicinity.

At the head of Graham creek a quartz vein, up to 6 feet wide, striking north 10 degrees east and dipping steeply west, is exposed by several old open-cuts. It is sparingly and erratically mineralized with pyrite and contains green chrome mica.

Carbonate Chief

On the west side of the basin at the head of Fivemile creek are numerous quartz veins, occasionally heavily mineralized with white pyrite, which cut a series of black to grey schists and impure quartzite. On some of these the Carbonate Chief claim is staked. The old cabin, beside the trail from Columbia river to Standard basin, is still standing, but the workings are completely caved. No information regarding the claim is available.

Roseberry

The Roseberry group, including the Salisbury claim, is on the ridge between Carnes creek and its north fork. It is 3,300 feet above the forks, from which it is reached by a steep zigzag trail. The property was extensively developed by Carnes Creek Consolidated Company, Limited, from 1897 to 1900. It is now lying idle and is in poor repair. It is reported that, in the Roseberry workings, on the north side of the ridge, mineralization carrying gold values occurred across a width of 50 feet with about 5 feet of high-grade sulphides along one part of the lead. Time did not permit of an examination of the property, but the Salisbury surface showings, on the south side of the ridge, were examined in passing. Arsenopyrite occurs there in several irregular veins, from ½ inch to 3 inches wide, and is accompanied by a little pyrite. The veins occur in a much altered intrusion of diorite, or in dykes of a dark green, altered rock resembling diabase, which cut the diorite. Near the veins the rocks are silicified and carbonated. An old adit whose portal the trail passes is completely caved.

COPPER DEPOSITS

Montgomery Group

The Montgomery group is between Canyon creek and Boulder creek, principally on the slopes draining into the former. A fair trail, about 7 miles long, leads from the Columbia River trail just north of Downie creek to Boulder creek. From the mouth of Boulder creek, at elevation 2,000 feet, a steep trail, now in poor repair, climbs for about 4 miles to the property at elevation 5,200 feet. The owner of the property is J. C. Montgomery of Revelstoke, B.C. On the western end of the group additional claims are held by E. E. McBean, A. McIntosh, and others. Mr. Montgomery staked the claims, which are in exceedingly rugged country, in 1896. Since then considerable surface stripping has been done. In 1917 Granby Consolidated Mining, Smelting, and Power Company took an option on the property and made several large open-cuts. There is a small cabin near the workings. There is some good timber on the claims, and on Downie creek, between Canyon and Boulder creeks, on ground held by Mr. Montgomery, abundant timber and waterpower are available.

On the claims a series of pure white to grey crystalline limestones interbedded with quartzites, argillaceous quartzites, black and grey slates, mica schists, chlorite schists, and impure calcareous members strike north 25 degrees to 40 degrees west and dip 25 degrees to 40 degrees northeast. Limestones occur principally near and above (northeast of) the mineralized zone. Below the latter the rocks are mica schists, light green chlorite schists, andalusite schists, and impure argillaceous and quartzitic sediments. All the sediments are strongly metamorphosed. The limestones are fine to coarsely crystalline and mica is widespread in the non-calcareous members. Garnet and epidote are quite abundantly developed. Tremolite is present in much of the limestone and some actinolite was observed.

Intruding the sediments, to the south of the ore zone, is a large stock of granite. The main body, near the showings, is of fine to intermediate grain. Orthoclase and microcline are the abundant feldspars, albite-oligoclase forming from 10 to 15 per cent of the rock. Micrographic intergrowths of quartz and orthoclase occur. Biotite and muscovite are the principal accessory minerals. The granite extends southward from the showings to and across Downie creek and several miles southeast from Boulder creek. Where observed on the trails the main mass varies from coarse irregular to fine grained. Pegmatitic dykes cut the granite. Near the workings many fine-grained, granitic dykes cut the overlying sediments. The garnets, epidotes, tremolite, and actinolite noted in the sediments have been formed during contact metamorphism by the granite. At its easterly side the granite is in conformable or nearly conformable contact with overlying limestones, the contact dipping east beneath the sediments. Elsewhere the contacts are steep and very irregular. Many of the associated dykes are also conformable with the bedding of the sediments.

The ores occur as bedded replacements. The mineralization consists of pyrrhotite, some pyrite, chalcopyrite, and a little sphalerite. Galena is very rarely present in minute amounts. The essential sulphides are pyrrhotite and chalcopyrite, the values being in copper with a small amount of gold and silver. The gangue is quartz and silicified wall-rock, with occasional garnet, epidote, and actinolite and, in some places, considerable dark green chlorite. The sulphides occur in grey to greenish, siliceous, vitreous rocks which probably varied originally from quartzitic to calcareous sediments. No ore was observed in the pure limestones, but metamorphism has greatly altered the original composition of the rocks within the mineralized zone.

The main ore zone has been developed by five major open-cuts. The lowest cut, a short distance east of the cabin, at elevation 5,200 feet, on a steep hillside sloping south, is 80 feet long and cuts across the ore zone from foot-wall to hanging-wall at an oblique angle. Consequently the exposed width of mineralization is at least double the actual width. Much of the cut exposes massive pyrrhotite containing only very small quantities of chalcopyrite and a little watery quartz. On the hanging-wall side of the cut there are about 6 feet of light grey silicified rock and quartz that contains much chalcopyrite, a little pyrrhotite, and small quantities of sphalerite. A short distance southeast of and below the cut are many fine-grained granitic dykes, offshoots of the nearby granite. The relation of these dykes to the ore was not determined. The same general zone of mineralization follows the strike of the sediments across and up the hillside to the northwest and has been exposed by four additional open-cuts. In these cuts the mineralization extends across widths up to 40 feet. Massive pyrrhotite, low grade in copper as before, occupies widths of from 5 to 15 feet. In three of the cuts from 1 to 3 feet of higher grade copper ore occurs in the grey, silicified rock on the hanging-wall side of the ore zone. In one cut, the first above the lowest one described, the same material is found within the more massive pyrrhotite. On the divide between the waters of Boulder and Canyon creeks, at elevation about 6,000 feet, northwest of the above-described cuts, the ore zone has not been clearly exposed, but is probably represented by considerable iron oxide on the surface. It is stated that, on the Boulder Creek slope, some good ore occurs on this and other, more northeasterly, leads.

Seven hundred feet vertically above and north of the first cut described, is a second zone of mineralization. In it, on the face of a steep bluff, is about 40 feet of disseminated pyrrhotite in siliceous, altered sediments. Garnet and chlorite are developed and it is probable that the original rocks were, in part at least, calcareous. The copper content, in the parts observed by the writer, is very low. Overlying the ore zone are grey, siliceous slates. Between this and the lower zone of mineralization

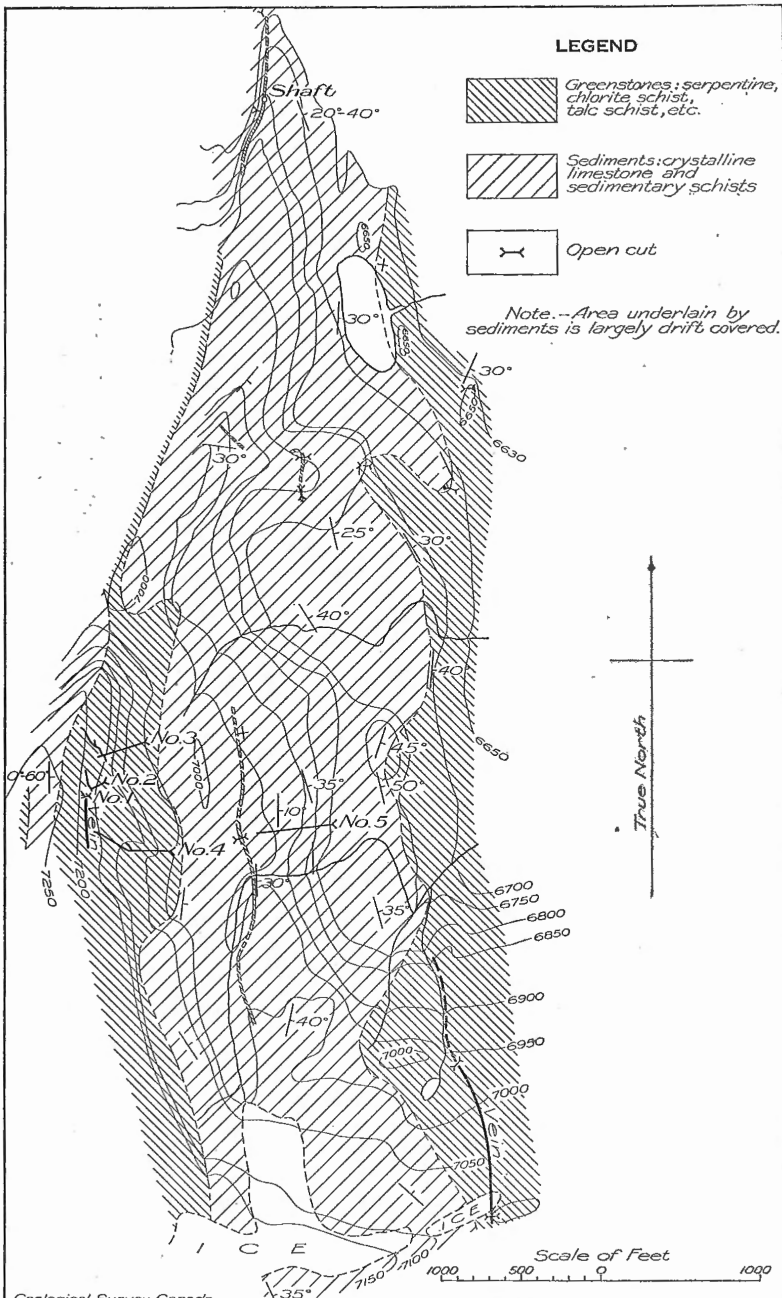


Figure 8. Standard basin, Columbia river, Kootenay district, B.C.

is a series of grey siliceous garnetiferous sediments, mica schists, and impure grey limestones, all cut by granitic dykes. The ore zone was traced for several thousand feet northwest to the Boulder Creek divide. Practically no work has been done on it, but signs of mineralization could be found at intervals.

The owner states that there are other less important leads on the property, some of which contain considerable zinc blende. A specimen given by him, and said to come from the Boulder Creek slope, consists of fine-grained pyrite, cut by minute veinlets of sphalerite, very little chalcopyrite, and a trace of galena.

The mineralization occurs as replacement deposits following the bedding of the sediments and is very persistent along the strike and through a vertical range of about 1,000 feet. The more massive sulphides evidently occur as lens-like or irregularly outlined bodies within the wider zones of mineralization. Chalcopyrite occurs most abundantly in light grey, siliceous country rock on the hanging-wall side of the main ore zone, occasionally in similar manner within the ore zone. Much of the pyrrhotite, however, also contains low values in copper. Values in gold and silver are said to be low.

The property has not been developed to a stage where its possibilities can be fully realized. A brief examination indicates, however, that the mineralization is sufficiently extensive to encourage further investigation. The question to be decided is whether, over widths suitable to large, low-cost mining operations, the values would be sufficiently high to yield a profit. To determine this considerable open-cutting and careful large-scale sampling would be necessary.

Standard Group

This group of claims is in Standard basin at the head of Standard creek. The workings are from 6,600 to 7,200 feet (by barometer) above sea-level, that is, at and above timber-line. An old trail leads to the property from the main Columbia River trail just south of McIntosh's ranch. R. Abernethy of Marpole, B.C., is the present owner. The claims, originally staked in 1896, were first developed by the Boston and B.C. Copper Mining and Smelting Company in 1898 and 1899. From 1900 to 1906, inclusive, the Prince Mining and Development Company of Revelstoke, B.C., continued operations. Some additional work was done in 1912. Today the property is lying idle. Development consists of about 2,000 feet of tunnels and raises on five principal levels, and numerous open-cuts, as shown on the accompanying figure (Figure 8). Two old cabins, still in fairly good repair, are situated several hundred feet below the workings.

The accompanying figure shows the general geology in the neighbourhood of the workings. Two large, sill-like intrusions of greenstone are separated by a broad zone of sediments. The average strike of the sediments is a little west of north and the average dip from 20 degrees to 40 degrees to the east. Locally, contortion has produced wide variations from these averages. The sediments consist of white to grey crystalline limestone, pyritic graphitic schists, and grey sericite schists. The limestones occur most abundantly in the central and eastern parts of the sedimentary zone. Small sills of greenstone, now converted to chlorite schist, occur in the sediments, as shown on the figure. The greenstones are greatly altered igneous rocks, now converted to serpentine, chlorite schist, or talc schist. The least altered varieties, found in No. 3 adit, are mottled grey-green in colour, resembling diorite. Thin sections of this rock reveal remnants of potash and albite feldspar and a little quartz in a mass of green to brown hornblende and zoisite. Magnetite is a common constituent. Originally the rock may have approached a diorite. The fact that much of the greenstone is now serpentine suggests an original composition more basic than diorite. Here, as elsewhere in the district, it is difficult to tell whether some of the greenstones are not extrusives rather than sill-like intrusives. Crosscutting relations with the sediments were noted in but two places in connexion with the smaller bodies of greenstone.

The ore minerals are pyrite, pyrrhotite, chalcopyrite, and a little sphalerite. Generally they occur as fine-grained mixtures, but some small bodies of fairly pure chalcopyrite are exposed. The ores occur only in the greenstone, along shear zones or as replacement bodies that parallel the general strike and dip of the formations. Some watery quartz and a little calcite accompany the ores. Along parts of the mineralized zones, and in other places, the greenstone is converted to a mixture of talc and carbonates of iron, magnesium, and calcium, with or without veins and irregular bodies of green chromium mica. Numerous barren quartz veins cut the sediments and the greenstone.

The best showings are in Nos. 1, 2, and 3 adits (*See* Figure 8). A raise connects the southerly end of No. 3 adit with the northerly end of No. 2 adit and a second raise connects No. 2 adit with the portal of No. 1 adit. Near the portal of No. 1 adit a shear zone, about 10 feet wide, is rather sparingly mineralized and the greenstone, across about 40 feet, is extensively pyritized. A few small stringers of chalcopyrite are exposed in the shear zone. In the raise from No. 2 adit there are several lens-shaped bodies, from 6 inches to 1 foot wide, of pyritic copper ore, across the width of the raise which follows the dip of the mineralized zone. From the bottom of the raise the vein has been followed by a drift in No. 2 adit to the north. The mineralization is persistent, consisting of lenses of pyrite, chalcopyrite, and pyrrhotite from 6 inches to 3 feet wide. In a short drift to the south from the bottom of the raise the mineralization ceases abruptly. The raise from No. 3 adit connects with the north end of the drift to the north in No. 2 adit. Fairly rich copper ore, 3 feet wide, continues down the raise a short distance, but soon breaks up into narrow, lenticular veinlets and disappears into the bottom of the raise about 30 feet above No. 3 adit. At the end it is offset a short distance to the west by a flat fault. Much drifting and crosscutting have been done in No. 3 adit, but only one important showing has been encountered. About 40 feet west and 50 feet north of the bottom of the raise a 5-foot vein, containing 2 feet of solid pyrite and chalcopyrite, was encountered on the north side of a crosscut running almost due west. The showing, which may be a continuation of the mineralization exposed in the raise above, does not continue across the crosscut, nor has it been encountered in a drift and crosscut to the north. It is apparently lens-shaped and of small dimensions.

In neither No. 4 nor No. 5 adit was any mineralization encountered. No. 5 is entirely in sediments and No. 4 passes through the greenstone and into the sediments on the west thereof. The other showings, in the numerous surface cuts, are all small and quite discontinuous, most of them being lenticular replacements in schisted greenstone. Some small bodies containing much chalcopyrite are exposed. The continuous lead shown on the southeastern corner of the figure is extensively pyritized across widths of 10 feet or more and contains narrow stringers of chalcopyrite in several places. Over a mineable width it would probably be below commercial grade. The two short adits on the northern end of the area represented by the figure were intended to explore a small showing of chalcopyrite along the greenstone dyke shown near them. Nothing of importance was found.

On the whole, although some small bodies of rich copper ore have been developed, the exposures do not indicate the persistence and quantity that would be necessary to make a mine.

In No. 2 and No. 3 adits, along shear zones in the greenstones, small quantities of slip-fibre asbestos and larger amounts of pure, light green talc are exposed. The occurrences are mentioned in a separate section on non-metallic minerals.

Iron Cap

This group was not visited by the writer. It is on the divide between LaForme creek and Fifteenmile creek. The Annual Report of the Minister of Mines, British Columbia, 1919, states that chalcopyrite and pyrite occur in a dyke of augite-diorite (?), but that the deposit is low in copper values. There is no good trail to the workings which were operated by A. Kitson of Revelstoke, B.C.

LEAD-ZINC DEPOSITS

J and L Group

This group is on the shoulder between the east and south forks of Carnes creek, about 8 miles by trail from the Columbia River auto road just north of Carnes creek. There is a good cabin on the bank of the east fork of Carnes creek, about one-quarter mile from the lower workings. The J and L, Annie M, '98 York, and Dunbar claims are staked from northwest to southeast along the showings. In 1924 the Porcupine Goldfields Development and Finance Company, Limited, held the property under option and employed about fourteen men driving the lower adit ahead 70 feet on the vein and starting another adit halfway between it and the east fork. The latter passed through 70 feet of drift and entered solid rock, but did not reach the vein. M. E. Hurst examined the property in 1924 and published a complete report on it. The owner, E. E. McBean, of Revelstoke, B.C., has recently optioned the property to Regina interests. The following paragraphs are extracted from Mr. Hurst's report.[1]

"The rocks in the vicinity of the J and L deposits are chiefly schist and limestone with occasional bands of quartzite. The vein or mineralized zone occurs at or near a schist-limestone contact which strikes north 65 to 75 degrees west (magnetic) and dips 30 to 55 degrees to the northeast (into the hill). This contact has been traced at intervals by open-cuts and trenches for several thousand feet up and across the hill-side (*See* Figure 9).

[1] "Arsenic-bearing Deposits in Canada"; Geol. Surv., Canada, Econ. Geol. Ser. No. 4, 1927, p. 77.

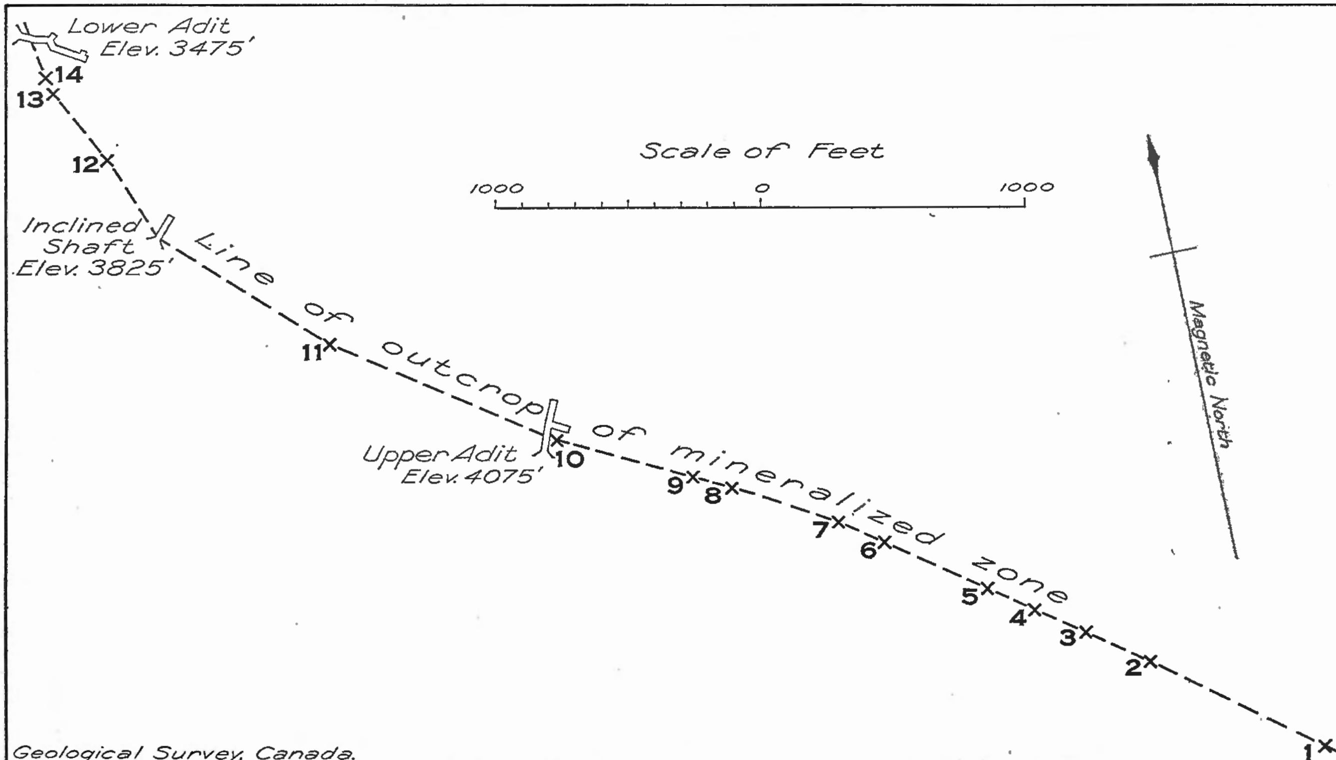


Figure 9. Plan of J and L property, Carnes creek, Kootenay district, B.C.

The mineralized zone is not continuous throughout this distance. In places it reaches a width of 6 to 8 feet. The hanging-wall consists of schist and the foot-wall of limestone. Gouge is present in many places. The ore is a fine-grained mixture of zinc blende, galena, arsenopyrite, pyrite, and chalcopyrite, with minor amounts of quartz and calcite. The sulphides occur as veinlets, lenses, or bunches occasionally as much as 3 feet wide, but usually not more than 12 to 16 inches. The vein matter has been extensively altered and decomposed by oxidation.

The positions of various outcrops and workings along the mineralized zone are indicated on Figure 9. At locality No. 1 the zone, partly mineralized, has a width of 24 inches. At locality No. 2 it is 12 inches wide, and at locality No. 3 it is 24 inches wide. At locality No. 4 pyrite and arsenopyrite, with a width of 30 inches are exposed for a length of 6 feet. At locality No. 5 the mineralized zone is 12 to 18 inches wide and is visible for a length of 4 feet. At locality No. 6 the width is 16 inches and the exposed length is 4 feet. At locality No. 7 an open-cut reveals two bands of sulphides each 12 inches wide, separated by 8 feet of partly mineralized schist. At locality No. 8 an open-cut has been made on the schist-limestone contact. At locality No. 9 the schist-limestone contact is exposed. At locality No. 10, 36 inches of oxidized vein matter appears in an open-cut. At locality No. 11 the schist-limestone contact is visible and there is present 24 to 36 inches of sulphides, mostly pyrite, with quartz and schist. At locality No. 12 the schist-limestone contact is exposed, but no sulphides are present, and the same condition holds at locality No. 13. At locality No. 14 a short adit exposed 30 inches of sulphides.

At an elevation of 4,075 feet an adit (upper) was driven 90 feet to crosscut the vein at a depth of 60 feet below the outcrop. At this point a winze was sunk at an angle of 37 degrees for 120 feet on the vein. This passed through soft, white to brown, decomposed schist and vein matter for about 40 feet. Stringers and streaks of sulphides varying from 1 to 30 inches in width were then followed downward for 80 feet farther. From the top of the winze, a drift was run southeasterly for 80 feet in highly altered schist in which the vein matter appeared to be 6 or 12 inches wide.

At an elevation of 3,825 feet a shaft was sunk at an angle of 43 degrees for 125 feet on the vein. Stringers and bunches of the sulphide minerals, varying from almost nothing up to 30 inches in width, extend more or less continuously from the top to the bottom of the shaft. In places the schistose hanging-wall is impregnated with sulphides for a foot or more from the vein.

An adit was driven at an elevation of 3,475 feet for 225 feet in a southeasterly direction along the schist-limestone contact. For most of this distance it passes through the limestone on the foot-wall side of the vein. The contact is marked by 12 inches of rusty, decomposed material for about 65 feet from the adit. From this point lenses and patches of sulphides, 4 to 18 inches wide, occur at intervals on the northeast side of the adit up to the face. Two crosscuts driven into the quartz schist of the hanging-wall showed very little mineralization.

Other showings of arsenopyrite occur between the lower adit and the east fork of Carnes creek. It is likely that some of these do not mark the continuation of the main vein, but of veins lying to the northeast which have not been explored.

The principal values in the J and L deposit are in gold, silver, and possibly, arsenic. The following assays were made from samples taken from the various showings by B. T. O'Grady in 1922 and are quoted in the Report of the Minister of Mines, for that year.

Sample No.	Description	Ounces per ton		Per cent		Copper
		Gold	Silver	Zinc	Lead	
1	Open-cut. Elevation 4,350 feet. Sample across 8 inches	0·8	0·8	4·0	nil	nil
2	Open-cut. Elevation 4,250 feet. Sample across 2 feet	0·36	2·0	3·0	nil	nil
3	Open-cut. Elevation 4,200 feet. Sample across 8 feet	0·24	4·5	2·0	2·0	nil
4	Open-cut. Elevation 4,150 feet. Sample across 2½ feet on hanging-wall side	0·3	2·0	5·0	nil	nil
5	Same as 4. Sample across 1 foot on foot-wall side	0·26	1·2	3·0	tr.	nil

Sample No.	Description	Ounces per ton		Per cent		Copper
		Gold	Silver	Zinc	Lead	
6	Bottom of winze from adit. Elevation 3,870 feet. Across 6 feet......................	0·32	3·0	2·5	3·0	nil
7	Drift on vein in adit. Elevation 3,870 feet. Across 4½ feet decomposed vein matter..	0·60	6·0	2·0	8·0	nil
8	Open-cut. Elevation 3,750 feet. Sample across 2 feet............................	0·30	0·8	2·0	nil	nil
9	Incline shaft. Elevation 3,620 feet. Across 1½ feet at bottom........................	0·42	9·0	6·0	8·0	nil
10	Same as 9. Across 2 feet. Fifty feet from bottom.................................	0·62	8·0	7·0	4·0	0·5
11	Short adit. Elevation 3,260 feet. Sample across 2½ feet...........................	1·14	1·5	9·0	1·0	nil
12	Main adit. Elevation 3,160 feet. Across 2 feet at 160 feet..........................	0·30	7·0	20·0	9·0	nil
13	Grab sample from ore dump at portal of main adit....................................	0·62	8·0	14·0	8·0	0·7

The average value in the ore, as indicated by the assays quoted above, is in the neighbourhood of $10 a ton. W. E. Narkaus, a mining engineer who examined the property, took twenty samples from the various showings. The lowest assay for gold and silver combined was $4.15 and the highest $27.10 a ton. The average for the twenty samples was $12.04 a ton in gold and silver and 12·7 per cent of As_2O_3. The J and L is obviously not a high-grade deposit. It is, therefore, doubtful if the ore could be mined, hand-sorted, and shipped to a smelter at a profit, even if transportation facilities were vastly improved. The future of the property lies in the development of a sufficient tonnage of ore to warrant the erection of a mill capable of recovering all the values present."

In 1926 Porcupine Goldfields Development and Finance Company, Limited, submitted a sample of ore from the J and L, weighing 70 pounds, to the Mines Branch, Department of Mines, Ottawa, and the following investigations were made.[1]

"*Characteristics of the Ore.* The ore is complex and consists principally of the sulphides of arsenic, zinc, lead, and iron, with smaller quantities of the sulphides of copper and antimony. The gold is chiefly associated with the arsenopyrite and pyrite and the silver with the galena. The gangue is siliceous.

Sampling and Analysis. The entire lot was crushed to ½ inch, cut once, reduced to −10 mesh and cut twice, reduced to −48 mesh and cut twice, then reduced to 150 mesh at which size the head sample was taken. Analysis was as follows:

Gold...........	0·52 oz. per ton	Copper..........	0·15 per cent
Silver...........	3·50 "	Lead............	6·0 "
Zinc............	4·57 per cent	Iron.............	21·8 "
Arsenic.........	11·90 "	Antimony........	0·22 "
Insoluble........	16·38 "		

Purpose of Tests. The purpose of these tests was: (1) to ascertain if the gold could be extracted by cyanidation; (2) to separate the sulphides of lead, zinc, and arsenic.

Tests Nos. 1, 2, 3, and 4

Cyanidation. The purpose was: (1) to ascertain if the gold and silver values could be extracted by cyanidation; (2) if finer grinding aided the extraction; (3) if water washing aided the extraction or reduced the cyanide consumption; and (4) if the addition of an oxidizing agent, sodium peroxide, made any appreciable difference in the extraction. In test No. 1, 500 grammes of the ore were dry crushed to −65 mesh. In test No. 2, 500

[1] Godard, J. S.: Mines Branch, Dept. of Mines, Canada, "Investigations in Ore Dressing and Metallurgy", 1926, p. 13.

grammes were dry crushed to −150 mesh. In test No. 3, 500 grammes were wet crushed in a ball mill and screened through 150 mesh, the oversize returned for regrinding, until all passed 150 mesh. The pulp was dewatered before cyanidation. In test No. 4, 500 grammes of ore were crushed as in test No. 3, pulp dewatered. All four tests were cyanided in a 1:3 pulp, using 0·10 per cent KCN. Time of agitation was 48 hours. In test No. 4, 0·25 gramme sodium peroxide was added after 7 hours, and again after 31 hours' agitation.

Summary

Test No.	Heads assay, oz. per ton		Tailing assay, oz. per ton		Extraction per cent		Reagent consumption, lb. per ton		
	Au	Ag	Au	Ag	Au	Ag	KCN	CaO	Na_2O_2
1	0·52	3·50	0·49	2·41	5·8	31·2	5·04	11·40	None
2	0·52	3·50	0·49	3·04	5·8	13·2	5·84	10·48	None
3	0·52	3·50	0·50	3·04	3·8	13·2	5·08	6·60	None
4	0·52	3·50	0·50	3·10	3·8	11·4	5·40	5·40	2·00

Conclusions

1. The extractions obtained were almost negligible.

2. Grinding—Finer grinding made no practical difference in the gold extraction. The best silver extraction was obtained in test No. 1 when coarse crushing was used.

3. Water washing did not aid in the extraction. It reduced the cyanide consumption slightly in the 150-mesh material.

4. Oxidizer—The addition of sodium peroxide did not aid in the extraction.

In the raw state, this ore cannot be successfully treated by the cyanide process.

Test No. 5

Selective Flotation at 150 mesh and Tabling the Tailings. The purpose of this test was to ascertain: (1) if a practical separation of the lead, zinc, and arsenic could be made by selective flotation; (2) with which sulphide the gold and silver were associated; and (3) if tabling the flotation tailing would assist in the recovery.

A sample of 1,000 grammes of −48 mesh ore was ground to 150 mesh in a ball mill and selectively floated in a Ruth machine. The flotation tailing was tabled on a small Wilfley table.

Results:

Product	Weight per cent	Assays					Per cent of values				
		Au	Ag	Pb	Zn	As	Au	Ag	Pb	Zn	As
		oz. per ton	oz. per ton	%	%	%					
Lead concentrate	16·6	0·46	15·72	20·67	18·36	7·07	14·2	61·1	54·8	25·6	9·9
Zinc concentrate	22·0	0·37	3·20	4·77	27·97	7·63	15·2	16·5	16·7	51·7	14·2
Arsenic concentrate	26·7	0·80	1·62	2·56	6·44	19·47	40·2	10·1	10·9	14·4	43·8
Table concentrate	6·0	0·91	4·19	5·15	2·31	20·21	10·3	5·9	4·9	1·2	10·2
Table tailing	13·8	0·34	0·65	2·05	2·52	10·11	8·8	2·1	4·5	2·9	11·8
Slimes	14·9	0·40	1·24	3·46	3·32	8·00	11·3	4·3	8·2	4·2	10·1

Conclusions

(1) *Separation.* A rough separation can be obtained by selective flotation.

(2) *Association.* The gold is principally associated with the arsenopyrite, the silver with the galena.

(3) *Tabling of Flotation Tailing.* Tabling of the flotation tailing was effective in this test, largely on account of the poor results in the flotation of the arsenic. With improvement in the flotation of the arsenic, this step might be omitted.

Selective Flotation Tests

The purpose of these tests was to separate the lead and zinc, and the arsenic.

Test No.	Product	Weight per cent	Assays					Per cent of values				
			Au	Ag	Pb	Zn	As	Au	Ag	Pb	Zn	As
			oz. per ton	oz. per ton	per cent	per cent	per cent					
6	Lead concentrate.........	13·5	0·52	16·72	19·92	18·21	7·00	14·6	61·4	39·2	21·6	7·2
	Zinc concentrate..........	25·6	0·30	3·84	6·97	31·08	6·88	15·9	26·7	26·0	69·8	13·4
	Arsenic concentrate.......	47·6	0·68	0·84	3·49	1·66	21·39	67·3	10·8	24·2	6·9	77·7
	Tailing..................	13·3	0·08	0·30	5·48	1·44	1·67	2·2	1·1	10·6	1·7	1·7
7	Lead concentrate.........	11·1	0·48	20·80	23·80	20·12	5·58	9·5	62·0	36·8	19·7	4·8
	Zinc concentrate..........	20·4	0·22	3·18	6·23	35·01	5·08	8·0	17·4	17·7	62·9	8·1
	Arsenic concentrate.......	53·2	0·84	1·32	4·48	3·32	20·65	80·0	18·8	33·3	15·5	85·8
	Tailing..................	15·3	0·09	0·43	5·73	1·41	1·12	2·5	1·8	12·2	1·9	1·3
8	Lead concentrate.........	10·7	0·54	15·86	20·32	20·79	6·30	11·4	47·4	36·0	19·5	5·3
	Zinc concentrate..........	35·9	0·39	4·17	6·95	24·04	8·39	27·6	41·8	41·3	75·5	23·8
	Arsenic concentrate.......	37·8	0·77	0·87	1·47	1·28	22·77	57·3	9·1	9·2	4·2	68·2
	Tailing..................	15·6	0·12	0·39	5·23	0·57	2·16	3·7	1·7	13·5	0·8	2·7
10	Lead concentrate.........	6·4	0·62	7·38	11·00	14·53	9·67	8·2	13·7	11·7	8·1	4·7
	Zinc concentrate..........	26·5	0·23	7·19	12·43	33·95	4·64	12·5	55·2	54·9	78·7	9·4
	Arsenic concentrate.......	52·8	0·71	1·95	2·56	2·54	20·61	76·6	29·8	22·5	11·7	83·5
	Tailing..................	14·5	0·09	0·31	4·56	1·19	2·16	2·7	1·3	10·9	1·5	2·4
11	Lead concentrate.........	32·7	0·48	8·17	11·35	18·34	10·62	30·4	76·0	65·5	53·6	28·4
	Zinc concentrate..........	16·8	0·48	2·10	3·09	19·06	11·00	15·7	10·0	9·2	28·7	15·1
	Arsenic concentrate.......	36·6	0·72	1·16	1·78	4·93	18·13	51·2	12·0	11·5	16·2	54·3
	Tailing..................	13·9	0·10	0·50	5·63	1·17	1·92	2·7	2·0	13·8	1·5	2·2
12	Lead concentrate.........	15·7	0·52	10·40	13·75	18·55	9·98	15·2	46·8	36·7	25·9	11·7
	Zinc concentrate..........	23·1	0·37	5·55	7·62	27·66	8·20	15·7	30·2	29·9	56·8	14·1
	Arsenic concentrate.......	46·9	0·76	1·50	2·54	3·74	20·67	66·0	20·2	20·2	15·6	72·3
	Tailing..................	14·3	0·12	0·68	5·45	1·25	1·78	3·1	2·8	13·2	1·7	1·9
13	Bulk concentrate.........	30·9	0·70	1·30	1·99	7·04	19·02	40·6	11·3	10·4	18·9	47·0
	Arsenic concentrate.......	52·1	0·56	5·84	8·39	17·44	11·70	54·9	85·8	74·3	79·2	48·6
	Tailing..................	17·0	0·14	0·60	5·28	1·27	3·24	4·5	2·9	15·3	1·9	4·4
14	Lead concentrate.........	23·7	0·54	10·32	14·29	17·30	10·68	23·3	66·3	56·2	35·6	18·5
	Zinc concentrate..........	35·5	0·52	2·50	4·21	18·13	13·42	33·8	24·1	24·7	55·9	34·7
	Arsenic concentrate.......	29·3	0·76	1·04	1·99	2·80	21·24	40·7	8·3	9·7	7·1	45·4
	Tailing..................	11·5	0·10	0·43	4·96	1·40	1·59	2·2	1·3	9·4	1·4	1·4

Conclusions

The flotation of the sulphides was not satisfactory, poor recoveries and poor separations being made in each test. The ore is slightly oxidized and this interfered with the flotation."

The writer spent a few hours on the property in 1928. The schist on the hanging-wall of the vein is an altered quartzite, sheared to sericite schist. Under the microscope it is seen to consist of quartz, pyrite in cubes, sericite, and a little talc. The ore lies along a well-defined shear zone on the contact of marble and schist and has been formed in part by filling of the shear zone and in part by replacement, particularly of the foot-wall marble. Polished surfaces of the ores, which are exceedingly fine grained, were studied. Pyrite and arsenopyrite generally occur as relatively large, rounded, or crushed grains, most of which are easily visible to the naked eye. Sphalerite, galena, and some pyrite form an extremely fine-grained intergrowth. In the galena, and occasionally in the sphalerite, are minute areas of grey copper which is, presumably, argentiferous. Chalcopyrite is visible in small amount in the sphalerite. In connexion with the above report by Mr. Godard it should be noted that it is concluded that the oxidized condition of the ores interfered with the flotation. It is possible that better results might be obtained from unoxidized material.

A and E Group

The A and E, No. 2, No. 3, and No. 4 claims are owned by E. E. McBean and A. Kitson of Revelstoke, B.C. They are on the southwest side of the upper part of the north fork of Carnes creek, and are reached by a trail that continues east from the Roseberry and Salisbury workings for a mile or more to the summit dividing the north fork from the main stream (*See* Plate IV A). From the summit, where there are several old open-cuts, a steep descent of about 1,000 feet takes one to the lower workings. The showings range in elevation from 6,000 to 7,200 feet. A small amount of open-cutting has been done on the claims.

The rocks in the vicinity are grey to white crystalline limestones, black carbonaceous schists, and a few intercalations of grey, sericite schist. A few small sills of minette (?), consisting of feldspar, quartz in small amount, biotite, serpentine, and calcite cut the sediments, but are not known to have any direct connexion with the mineralization. They are brownish grey in colour and weather rusty. The sediments strike north 15 degrees to north 25 degrees west and dip from 40 degrees to 50 degrees northeast (*See* Plate IV A). There are two principal zones of mineralization on the property. The southwesterly one occurs at the contact of grey marble and underlying black schist. It is exposed on the side of a steep bluff for several hundred feet vertically, and, on the summit to the southeast, by several open-cuts, now badly caved. The rugged nature of the locality prevented a close examination of this lead, but 2 to 3 feet of pyrite, sphalerite, and galena were observed in several places. Apparently the sulphides have replaced the limestone along the contact shear zone and are arranged along the zone as lenticular bodies. A second lead, some 200 feet stratigraphically above and northeast of the other, and approximately parallel to it, was being developed by open-cuts at the time of examination. It is in the limestone which contains narrow beds of grey sericite schist. For 150 feet on a steep hillside the vein is well exposed and varies in width from 6 inches to 2½ feet. Pyrrhotite, pyrite, sphalerite, and galena are very finely intergrown. Grey copper occurs in small amount in the galena. The main lead occupies a bedded fissure, but smaller veins, some of which contain almost pure galena, intersect it at small angles. Farther down the hillside are other small exposures, in the lowest of which, about 600 feet below the uppermost, there is much arsenopyrite in the lead zinc ore. Thirty feet stratigraphically below the upper showings is a similar smaller lead.

Very little work has as yet been done on the property. The ores resemble closely those of the J and L group, but contain less arsenic and would probably average a little higher in lead. The continuity of the

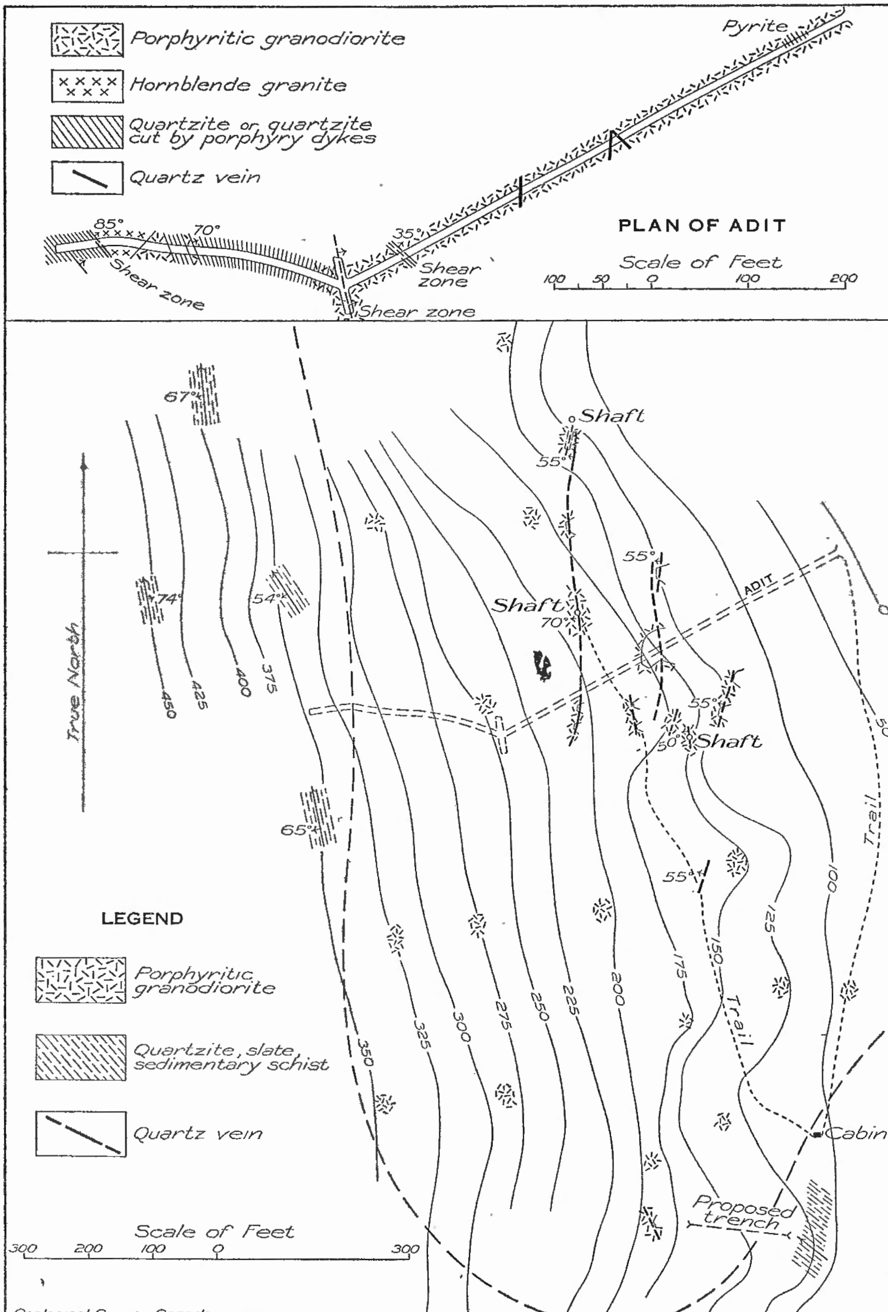


Figure 10. Woolsey Mines, Limited, Cariboo creek, Kootenay district, B.C.

surface showings is certainly sufficient to encourage further development. Mr. McBean kindly supplied the writer with the following assays of samples taken at random from the surface showings:

Gold	Silver	Lead	Zinc	Arsenic
Ozs.	Ozs.	Per cent	Per cent	Per cent
trace	0·8	3·4	10·6	
0·01	0·7	2·6	13·1	
0·01	2·2	7·1	9·5	
trace	0·3	....	4·1	
0·32	5·1	2·7	10·5	
0·17	1·1	1·0	9·6	
0·45	14·4	20·5	3·1	
0·54	35·1	....	....	4·94
0·01	2·6	....	30·6	
0·01	0·8	....	....	
0·02	1·2	....	....	

A picked sample of fairly clean lead ore from the upper end of the easterly vein assayed

0·32	33·4	33·3	14·0

and a sample containing much arsenopyrite returned

0·20	7·2	1·0	26·0

Mr. McBean states that a good trail could be cut to the property following the south side of the north fork of Carnes creek from the J and L trail, thus avoiding the present difficult approach over the divide east of the Roseberry.

Woolsey Mines, Limited (Donald Mine)

This property is on the south side of Caribou creek, in Glacier National park, about 3½ miles by trail from Flat Creek siding on the Canadian Pacific railway and 2,500 feet above the railroad. As the crow flies it is about 1½ miles from workings to railroad. The Donald, Round Hill (Crown granted), King Solomon No. 2 and No. 3, the Hilda Jack, and Clifford mineral claims, which form the group, are owned by the Woolsey Mines, Limited, of Victoria, B.C. The capitalization of the company is $1,000,000 divided into 4,000,000 shares of par value 25 cents. The original owners took 1,800,000 shares as payment for the claims. David Woolsey staked the Donald claim in the late eighties and subsequently worked it for the Caribou Creek Mining Company. Developments consist of a shaft—now flooded—a short adit, and several open-cuts on the Round Hill claim and two other shallow shafts, numerous open-cuts, and about 900 feet of tunnel, principally as a long crosscut. The accompanying figure (Figure 10) shows the topography, geology, and workings on the property.

The claims are staked largely on a small stock of porphyritic granodiorite. In the field it is green with white feldspar phenocrysts up to one-half inch in diameter. Under the microscope phenocrysts of orthoclase, microcline, and oligoclase-andesine are visible. Quartz forms about 10 per cent of the rock and green hornblende and biotite are present in large quantities. Accessory minerals are titanite, epidote, augite, calcite, and ilmenite (?). The feldspars are extensively sericitized. Underground and on the surface a few fine-grained, dark green dykes that resemble diorite were observed. Under the microscope a specimen of this rock from near the face of the adit is seen to be extensively altered to sericite and epidote. The original components are microcline, a little orthoclase, and oligoclase, about 15 per cent quartz, green hornblende, and biotite, and a small quantity of apatite. Microscopically the rock is identified as hornblende granite. Cutting the above are small dykes of rather fine-grained, light grey granite. They contain no hornblende and the hornblende of the adjoining igneous rock is altered, near them, to biotite and chlorite.

All the above rocks cut a series of quartzites, mica schists, phyllites, and slates which strike from northwest to due north and dip steeply east or west. The schists and quartzites contain noticeable amounts of potash feldspar and plagioclase and sericite is abundantly developed.

The ore minerals, pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite, occur, with quartz, siderite, and ankerite, in well-defined fissure veins cutting the porphyritic granodiorite. The quartz is white to watery and frequently coarsely crystalline. In large part it preceded the sulphides which cut it along cracks and fissures and fill in around the crystals in the more coarsely crystalline parts. Siderite and ankerite are abundantly developed in one part of the property and chalcopyrite is there more abundant than elsewhere. The carbonates also clearly antedate the sulphides. Near some of the veins the porphyry is extensively bleached and seriticized. The sulphides occur as irregular bodies or stringers in or alongside the quartz fissures, in some places completely filling a vein across widths as great as 10 or 11 feet. Some of the larger bodies of quartz are practically barren of sulphides.

Three major, and several minor, quartz veins have been exposed on the property. The most important, the westerly one, shown on the accompanying figure, has been developed by two shafts, three or four open-cuts, and a short drift. The vein trends a little east of north and dips irregularly, but generally steeply to the west. The old shaft on the northern end of the vein is now flooded, but there is a considerable quantity of quartz and iron carbonates, well mineralized with sulphides, among which chalcopyrite is abundant, on the dump. In the drift immediately south of this shaft the vein is 3 or 4 feet wide and well but irregularly mineralized, chiefly with pyrite. It dips at about 55 degrees to the west. There are many angular inclusions of granodiorite in the coarsely crystalline quartz. The vein can be followed on the surface to the next shaft on the south. The latter is down about 12 feet on the vein, which is well defined in a greatly crushed zone of porphyry and dips about 70 degrees to the west. The vein is 10 feet wide and is heavily mineralized with pyrrhotite, pyrite, galena, and sphalerite. This is the best showing on the property. The same vein is exposed for a width of $3\frac{1}{2}$ feet in two open-cuts 150 feet south of the shaft.

The veins lying east of the above are, on the whole, not so promising, although in several places there is strong mineralization. The sulphides generally occur as irregular bodies or relatively small veins in or near the main quartz veins. Occasionally clean galena is found, but most frequently it is admixed with large proportions of pyrite, sphalerite, and pyrrhotite. In the third shaft shown on the figure the vein is 5 feet wide and fairly well mineralized. Below and southeast of the long crosscut adit a large exposure of quartz, in porphyry, is very sparingly mineralized with pyrite.

The long adit was apparently driven in the hope of encountering the downward continuation of some or all of the above-mentioned veins. For 620 feet it cuts strongly jointed porphyritic granodiorite and exposes numerous quartz veins varying from mere stringers to irregular bodies of quartz 8 feet wide. Seventy-six feet from the portal is a body of quartz and pyrite of no apparent continuity. At 620 feet a pronounced shear zone cutting porphyry and sediments was encountered, but it contained no ore. The zone dips steeply east. Farther west quartzites and some slates, cut by dykes of porphyritic granodiorite, hornblende granite, and fine-grained, light grey granite were exposed, but no ore was encountered. Most of the quartz veins in the porphyry follow joints or small shear zones.

It will be observed that the westerly contact of the granodiorite exposed underground is some distance east of the presumed contact on the surface; and that the veins dip to the west. If it may be assumed that the westerly contact of the porphyry is dipping east, then the veins, dipping west, would tend to approach the west contact of the porphyry on depth. In the case of the westerly vein, at least, this is an important situation, for it is not known whether the quartzites will be favourable hosts for the veins. The veins that have been observed in them are small and practically barren.

The long crosscut is so far below the surface showings that it is not surprising that no correlation can be made between it and the surface exposures. This is particularly true in view of the fact that nothing is known as to the rake or pitch of the ore-bodies in the veins. The logical step in further development would seem to be a careful surface prospecting, particularly of the westerly vein. A depth of 50 feet or so on the vein could be obtained by a short adit from the east towards the northerly end of the exposures. Also, the important increase in copper content in the vein at its northerly end would seem to justify special attention being paid to this part of the property.

Waverley-Tangier Group

The Waverley-Tangier group of sixteen mineral claims, three of which are Crown-granted, is owned by Waverley-Tangier Mines, Limited (N.P.L.), of Vancouver, B.C. The capitalization is 16,000,000 shares with a par value of 25 cents. J. B. Williams of Vancouver is president and E. J. Cameron is vice-president and managing director. From 1896 to 1899 the property was worked by Goldfields of B.C., Limited. In 1920 the property was purchased by G. H. Walters of Spokane and Waverley Mines Company was formed. In the following years a little work was done during the summer months.

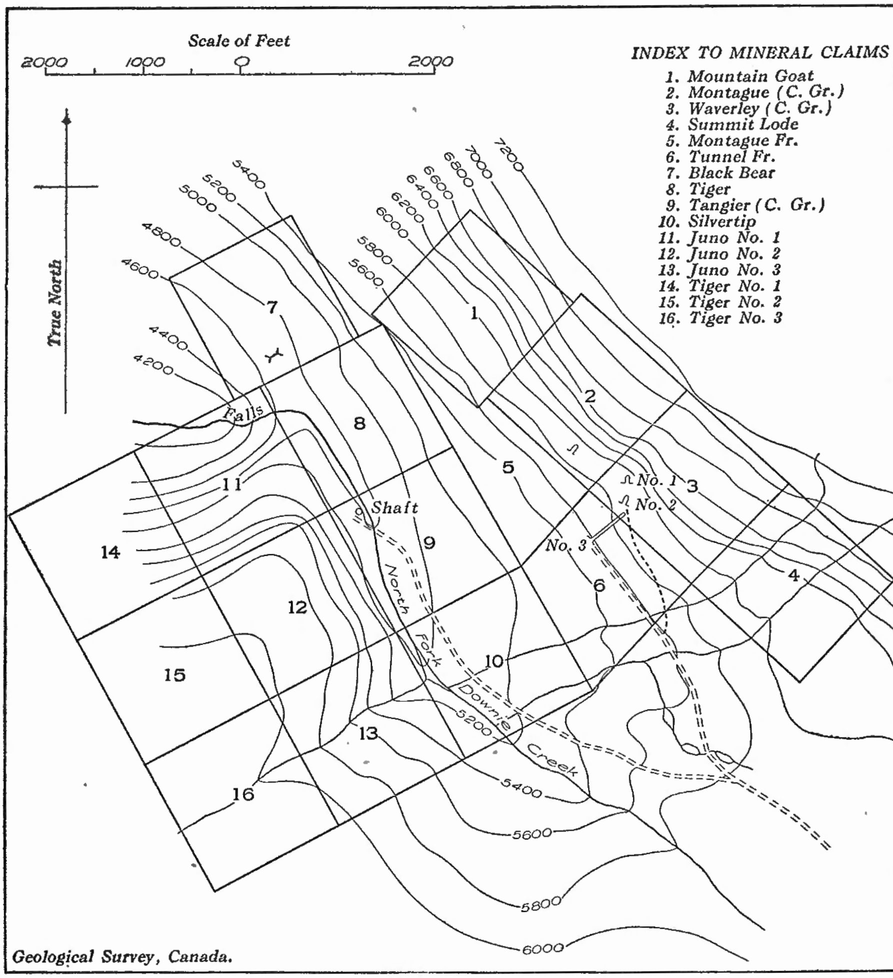


Figure 11. Waverley-Tangier groups, Downie creek, Kootenay district, B.C.

The claims are at the head of the North fork of Downie creek, immediately north of the divide separating that stream from the North fork of Illecillewaet river (Figure 11). By trail the workings are about 27 miles from Albert Canyon, a station on the main line of the Canadian Pacific railway. An old road from Albert Canyon to the property, constructed in the nineties by Goldfields of British Columbia, an English company, has fallen into disrepair, and is now only a trail, passable for packhorses and men. This trail follows the North fork of Illecillewaet river. The country through which it passes is mountainous and very rugged and snowslides sweep the trail at several points during the winter and spring. From an elevation of 2,227 feet at Albert Canyon station, the trail climbs gradually for about 24 miles and then quite rapidly for one mile or so to the summit, at an elevation of about 5,600 feet. From the summit an even grade continues to the Waverley cabins, but a descent of nearly 1,000 feet is necessary to reach the Tangier. The Waverley is on the north side of Downie creek, the claims being staked on a steep mountain side at elevations between 5,300 and 7,200 feet. The Tangier shaft is on the bank of Downie creek, about one-quarter mile west of the Waverley, at an elevation of 4,800 feet. They are two distinctly separate properties. The round trip from Albert Canyon to the workings takes, normally, four days, but can be done in less.

The climate at the properties is rather severe—a heavy snowfall being of most direct importance. Snow does not leave the summit of the trail until June or early July and the autumn falls begin about the end of September.

A short distance below the Tangier shaft the North fork of Downie creek enters a canyon and then drops several hundred feet in falls. In the summer months, an abundance of waterpower is available. The situation in the winter months during the freeze-up is unknown to the writer. Fairly good spruce and hemlock are abundant near the Tangier and some persist at the Waverley workings.

The rocks underlying the claims include light grey, coarsely crystalline limestones with interbedded argillaceous, carbonaceous, or siliceous varieties that are generally fine-grained quartzites, argillaceous and carbonaceous to graphitic schists and phyllites, and some grey talcose and sericitic schists. The average strike is northwest and the dip steep (60 degrees to 90 degrees) to the northeast. Minor folding of a complex nature is abundant and shear zones and fissures are common. In the crystalline limestone at the Waverley two major joint systems, striking north 15 degrees east and north 45 degrees west and dipping 70 degrees northwest and 30 degrees southwest, respectively, are developed.

All the workings on the Waverley group are in a band of light grey, crystalline limestone with fine-grained, argillaceous, and carbonaceous limestones intercalated, the whole calcareous member being about 2,500 feet thick. Below, or west of the marble, are argillaceous to carbonaceous grey or black schists and phyllites, and above, or east of it, green or grey phyllites appear as intercalations in the limestone before the latter gives way to grey or brown quartzites with interbedded green and light grey phyllites. All the rocks dip steeply to the northeast and strike northwest. They are rather complexly contorted by minor folds. It appears from the exposures examined that the Waverley veins are confined to a zone of dark grey or black, fine-grained limestone within the main light grey, coarsely crystalline band, and this zone is more complexly folded and twisted than the surrounding rocks. Within the zone are intercalations of the normal light grey marble.

The ores exposed in the Waverley are highly oxidized and consist of decomposed limestone, vein calcite, quartz, limonite, anglesite (lead sulphate), some cerussite (lead carbonate), malachite, and azurite, smithsonite (zinc carbonate), and occasional residual nodules of galena and argentiferous tetrahedrite. Silver and gold values are present. The total values are variable, ranging from practically zero to $60 or $70 per ton and more in the parts rich in residual sulphides. The present ores have been formed by oxidation, by descending meteoric waters, of original gold and silver-bearing pyritic galena-sphalerite deposits in limestone. The sulphides were deposited along fissures in the limestone and by replacement of the limestone. Consequently the ores are found as irregular bodies more or less elongated along the predominating shear and fault zones. These zones trend about north 60 degrees west (astronomic) and are generally bedded. Other fissures, trending northwest to northeast, have influenced the location of the larger ore-bodies. Veins of quartz and calcite, trending more northerly than the main ore zones, are also developed underground, but they are barren in most places.

The developments on the Waverley are as follows.

No. 1 tunnel, at elevation 6,155 feet, is short and includes a winze down 28 feet on a lead of oxidized material containing some nuggets of galena and tetrahedrite. The lead is from 2 to 6 feet wide, strikes north 20 degrees west, dips about 50 degrees east, and occupies a shear zone in dark grey limestone. The walls are smooth fault walls. From the bottom of the winze a short drift has been made to the northwest. A sample taken across 3 feet on the foot-wall side of the lead at the face of the drift contained a few small specks of galena in oxidized products and assayed per ton:

Gold, 0·01 ounce; silver, 5·50 ounces; lead, 2·43 per cent; zinc, 3·60 per cent; copper, nil.

Some material that would probably be higher grade occurs in the winze and is 2 to 3 feet wide. In the face of the adit a large quartz vein, quite barren, was encountered. It is also exposed on the surface near the portal of the adit.

No. 2 tunnel. No. 2 tunnel is driven 300 feet as a crosscut below No. 1 tunnel, at an elevation of 6,070 feet. In it are several hundred feet of drifting and a shaft to connect with a raise from No. 3 tunnel below.

Fifty-five feet from the portal a bedded shear zone, dipping steeply north 30 degrees east, was encountered and drifted on to the northwest and southeast. Oxidized material, varying in width from a few inches to 6 feet, is exposed for a length of 120 feet, with the largest accumulation immediately west of a fault trending north 30 degrees west and dipping 60 degrees northeast. Southeast of this fault no important mineralization is found. At the junction of drift and main crosscut a small stope has been put up and in it up to 2 feet of oxidized ore may still be seen, lying along the bedded fissure. East of this lead, for nearly 60 feet, the walls of the main crosscut are extensively oxidized. The whole width is probably low-grade ore, although there are several horses of practically barren limestone. A sample taken across 5 feet of the best looking material on the north side of the crosscut just east of the above-mentioned drift assayed per ton:

Gold, 0·12 ounce; silver, 46·33 ounces; lead, 2·10 per cent; zinc, 26·70 per cent; and copper, 1·35 per cent.

The sample contained several nuggets of sulphides and is undoubtedly richer than the average material exposed in the crosscut.

At the eastern end of this oxidized zone is a vein, 10 feet wide, of quartz and calcite. Exposed in a drift for 70 feet to the southeast, it pinches and swells between two smooth walls and is barren. A drift driven northeast from a point 25 feet east of the vein encountered it 100 feet from the main crosscut. A short crosscut exposes the vein, partly oxidized, for a width of 5 feet. Assays shown on the original mine plan state that it contains good gold values at this point. It was not sampled by the writer. Eighty feet northeast of this vein a second vein of calcite and quartz has been drifted on for 80 feet in a north 15 degrees west direction. It varies in width from 18 inches to 5 feet and is quite barren.

No. 3 Tunnel. No. 3 tunnel, elevation 5,700 feet, was driven as a crosscut below No. 2 tunnel for 760 feet. It is connected by a raise with the shaft from No. 2 tunnel and three intermediate levels—the 150-foot, the 250-foot, and 350-foot levels, at elevations 6,005, 5,895, and 5,790 feet respectively—have been made.

The 150-foot level, 65 feet below No. 2 tunnel, is connected to the shaft from the latter. It is merely a short drift in crushed and oxidized material lying along an irregular shear zone. A channel sample across 5 feet on the northeast side of the drift assayed per ton:

Gold, 0·08 ounce; silver, 15·75 ounces; lead, 14·24 per cent; zinc, 0·00 per cent; and copper, nil.

Green copper stain is visible at several points in the drift.

The 250-foot level, at elevation 5,895 feet, is directly below the 150-foot level. Considerable work of a rather desultory nature has been done. Three major, approximately parallel fissures with well-defined walls, striking about north 60 degrees west and dipping 70 degrees northeast, were encountered. The middle of these, corresponding to the mineralized one in No. 2 tunnel, is mineralized with a few inches to over 5 feet of oxidized material, for a length, in drifts, of about 80 feet and the same material is exposed in the walls of the main crosscut for a width, across the strike of the lead to the east of the fissure, of about 28 feet. There are several barren horses of limestone in this width. A sample across 6 feet in the main crosscut assayed per ton:

Gold, 0·05 ounce; silver, 21·84 ounces; zinc, 6·77 per cent; lead, 16·73 per cent; copper, 0·29 per cent.

and one taken across 12 feet on the east side of a drift to the northwest from the main crosscut assayed:

Gold, 0·08 ounce; silver, 11·47 ounces; zinc, 5·50 per cent; lead, 2·11 per cent; and copper, 0·08 per cent.

The oxidized ore in this level peters out, lens-like, to northwest and southeast along the shear zone and is quite irregular in nature and distribution. The mineralization occurred at the junction of fissures, trending northeast, and west of north, with the main fissure.

Seventy feet northeast of the above mineralized fissure, on the west wall of a drift on a parallel fissure, about 25 feet of oxidized material was encountered. A sample across 13 feet of this contained a few nuggets of galena and assayed per ton:

Gold, 0·10 ounce; silver, 18·26 ounces; zinc, 11·48 per cent; lead, 11·88 per cent; and copper, 0·09 per cent.

This showing has no visible connexion with the other ore on the level.

The 350-foot level, at elevation 5,790 feet, directly below the 250-foot level, is rather discouraging. The only showing of ore in about 300 feet of drifting and crosscutting is 12 feet of oxidized material on the side of one drift. It probably lies on the downward continuation of the fissure mineralized above. In case of future work being done on the property, this would be a good place to start. If this showing represents the total downward continuation of the ore showings exposed above, its outline and trend should be defined. Barren, tight fissures, corresponding to those encountered on the 250-foot level, were encountered, and one large, barren calcite vein.

In the lower or No. 3 tunnel, elevation 5,700 feet, much work has been done, crosscutting and drifting below the upper workings, but no ore has been encountered. The fissures are present, but they are barren of sulphides and contain no important quantities of oxidation products.

On the surface the vein encountered in No. 1 tunnel has been exposed by shallow open-cuts for several hundred feet southeast from the portal of the tunnel. At the time of the writer's visit these cuts were in poor shape, but they indicated the general but irregular persistence of vein material. About 250 yards to the northwest of No. 1 tunnel it is reported that a short crosscut on the Montague claim has exposed about 4 feet of oxidized ore on the northwesterly continuation of the main vein. The writer did not visit the occurrence.

Two principal veins of oxidized lead-silver ore, with additional values in gold and zinc, have been explored. The vein exposed in No. 1 tunnel and probably encountered in the eastern end of No. 2 tunnel has not been sufficiently developed to warrant an estimate of its value as an ore carrier. Some good ore occurs in the winze in No. 1 tunnel on this vein. The second vein, lying southwest of the above, is developed in No. 2 tunnel and again on the 150- and 250-foot levels. The largest bodies of ore are irregular replacements in limestone, more or less elongated along the bedded fissure, where crosscutting fissures of northwesterly to northeasterly trend intersect the main vein. On the 350-foot level, 280 feet below No. 2 tunnel, the downward continuation of the ore exposed above is small and undeveloped. In the lower adit, 90 feet lower, no commercial ore has been found. The irregular nature and distribution of the ore typical of replacement bodies in limestone, render it manifestly impossible to estimate with any accuracy the amount and value of the ore exposed, as no work has been done between the levels mentioned. The raise from No. 3 tunnel is driven on a barren fault lying west of the ore zone.

If the ore does not continue to greater depth than the 350-foot level the future of the mine is not very encouraging. Consequently, any further work contemplated should be done on the 250-foot level and above it, in an endeavour to define the outline and trend of the ore zone. The location of the property is such that any work will be expensive and larger ore reserves than are at present partly developed will be necessary before the property can be profitably put in the producing class. A good mine map is a first necessity to further development. It is possible that the ore follows the intersections of two or more of the intersecting fissures encountered underground and that the trend of this intersection has removed the ore zone beyond the limits explored in the lower workings. It is to be expected that, if the mineralization continues to greater depths, sulphide ores, similar to those from which the present oxidized ores have been formed, will be found.

Tangier

On the Tangier claim a band of white to grey marble at least 120 feet wide strikes north 30 degrees to 35 degrees west and dips very steeply east or is vertical. In it are at least two small bands of grey to black carbonaceous schist. On the west the marble is adjoined by a considerable thickness of pyritic, black, carbonaceous schist. The workings are on the edge of Downie creek.

A shaft goes down 80 feet to the "100-foot" level and from the bottom of it crosscuts and drifts have been made. From the southeasterly drift, 180 feet southeast of the shaft, a winze has been sunk on the vein for about 50 feet. It is now partly filled with water.

The shaft is now timbered, but it was presumably sunk on a vein at the contact of limestone and pyritic schist. From the bottom of the shaft the vein has been drifted on for 220 feet to the southeast. It consists of calcite and some quartz and a fine-grained mixture of pyrite, jamesonite, galena, sphalerite, and, at several places, small amounts of grey copper. The mineral identified as jamesonite (lead-sulph-antimonide) is quite abundantly but finely intergrown with the sphalerite and must contribute a large percentage of the lead in the ores. The vein is in the marble at or near the schist contact and occurs generally between two well-defined fault walls. Occasionally replacement of limestone by vein matter has enlarged the vein beyond the walls. Some mineralization was noted in the schists to the west of the vein proper. The width of the vein varies from 5 feet to a little more, to practically zero as the walls approach and withdraw, and averages about 2 feet.

The sulphides, occurring very clean in several places, are arranged in lenticular bodies along the vein. Grey copper seems most abundant where quartz is the predominant gangue mineral. At the southeastern face of the drift about 4 feet of quartz and calcite contain disseminations of sulphides and grey copper. The winze could not be carefully examined, but vein matter persists to the level of the water.

In the drift to the northeast from the bottom of the shaft the vein is persistent, varying in width from zero to 6 feet. In consists of quartz and calcite in brecciated marble between two fault walls, but, for the 140 feet exposed, the only ore minerals visible are small quantities of pyrite and occasional small bunches and specks of galena and sphalerite. There is much muscovite in parts of the vein.

Elsewhere in the underground workings nothing of commercial importance is exposed, although there are two or three large calcite veins and many small stringers, some of which contain a little pyrite. In the carbonaceous schist to the west of the vein pyrite is abundantly developed and quartz lenses are numerous.

It is reported that the vein has been traced for some distance on the surface and that an old tunnel a short way north of the shaft encountered some good ore. These workings are too badly caved to afford any information at present.

The writer took no samples for assay from the Tangier. Much of the ore is a solid intergrowth of very fine-grained sulphides that will require fine grinding for concentration. Assays given by B. T. O'Grady, assistant resident mining engineer, of sulphide ore from the shaft dump, show values of: gold, 0·06 ounce; silver, 16·0 ounces; lead, 8·5 per cent; and zinc, 5 per cent; and some of the cleaner pyrite assayed 5·6 ounces of gold per ton. These assays cannot be taken as representative of the ore exposed underground. It is reported by the present management that 15 tons of sulphide ore, shipped to Wales in the early days, contained 1·5 ounces gold, 130 ounces silver, and 25 per cent lead per ton. The shipment must have been carefully hand picked.

On the *Juno*, *Tiger*, and *Black Bear* claims of the Tangier group some surface stripping has been done on quartz veins and stringers that are mineralized, irregularly, with bunches and streaks of grey copper and an as yet unidentified silver-bearing mineral which resembles bournonite under the microscope. Pyrite, sphalerite, and galena are sparingly present. The deposits are typically small and the ore minerals erratic in distribution, but high silver values may be expected. Some of the veins might produce small quantities of high-grade ore which could best be extracted by two or three men by "gophering" methods. The showings on the Juno—a series of small quartz stringers across about 50 feet of limestone lying several hundred yards northwest of the Tangier shaft—appeared most promising at the time of examination. Those on the Tiger and Black Bear claims do not merit much more than the necessary yearly assessment work which should be expended in tracing the veins on the surface in the hope of finding worth-while pockets of ore minerals.

Snowflake Group

The Snowflake group of nine mineral claims is owned by the Snowflake Mining Company of Vancouver, B.C. The property is on Silver creek, 9 miles by trail north of the main line of the Canadian Pacific railway, at elevations between 5,400 and 6,500 feet. It is developed by five upper adits, from 5,800 to 6,000 feet above sea-level, a long, lower crosscut at 5,400 feet, and numerous open-cuts. The writer examined the property in June, 1928.

The rocks on the Snowflake group vary from hard, black, siliceous slates through argillaceous and cabonaceous members to impure, dark grey limestones. The average strike is northwest and the dip 35 degrees to 65 degrees northeast. Minor contortions and shear zones are common. A rather pronounced system of jointing trends about northeast and dips steeply southeast. All the sediments are cut by numerous, small, barren, quartz stringers.

Several approximately bedded quartz veins have been uncovered on the Snowflake group. On the adjoining Woolsey group at least seven have received development. On the Snowflake the veins are quite continuous along their strike and vary in width of quartz and included rock fragments from a few inches to nearly 20 feet. The veins consist of white, milky quartz, coarsely crystalline as a general rule, and frequently containing many vugs lined with quartz crystals, with a large percentage of fragments and bands of country rock in the wider parts. The quartz was introduced along fissures that followed more or less closely the bedding of the sediments which are extensively crushed and sheared. Cross-fissures containing narrow stringers of quartz cut across the sediments and sometimes penetrate the main veins. Occasionally fissures or joints striking about northwest and dipping flatly southwest are present. The main vein is the so-called No. 1 or "17-foot" vein. It has been traced for several hundred feet across the property and has also been developed on the adjoining Woolsey group. It varies considerably in width. Other parallel veins will be mentioned later.

The ore minerals, in order of abundance, are: galena, sphalerite, pyrite, and a little chalcopyrite. Under the microscope small amounts of grey copper and ruby silver were observed in some of the galena. Quartz, a little calcite, and inclusions of wall-rock form the gangue. Silver values, as indicated by a few small shipments, average about one ounce per unit of lead.

Within the quartz veins the sulphides, principally galena, occur as irregular bunches and stringers along fractures or as vug fillings. The most pronounced ore-shoots are found on the foot-wall sides of the bedded quartz veins where the adjoining sediments have been crushed and sheared. The ore makes then in the crushed wall-rock and in the lower part of the vein. Occasionally small bodies of sulphides are found on the hanging-wall sides or in fissures intersecting the main veins at various angles. In one or two places, particularly in No. 4 tunnel (lowest level), calcareous members are replaced by a low-grade zinc ore with abundant fine-grained quartz. The ore-shoots are extremely irregular. They pinch and swell in the vein and their continuity cannot be assumed any great distance beyond an exposure. Occasionally their boundaries are bedding planes and joints which, running approximately at right angles to one another, outline square or chimney-shaped bodies. It is evident that the coarse-grained, white quartz of the veins on the whole preceded the deposition of the sulphides and was somewhat crushed before they were introduced. Consequently, the veins in themselves cannot be considered as ore-bodies, but merely as favourable horizons in which the slightly later sulphide-bearing solutions may have formed ore deposits. A later generation of fine-grained, watery quartz accompanied the sulphides in one or two places and is finely intergrown with them.

No. 1 adit, elevation 5,900 feet, was driven as a drift for about 85 feet on the foot-wall side of No. 1 vein. It encountered a joint striking parallel to the main vein, but dipping at right angles to it, or 45 degrees southwest. For the length of the drift this joint was mineralized with from 2 inches to perhaps 30 inches of galena and a little sphalerite. The sulphides also penetrate the sediments for a short distance along narrow, irregular fractures leaving the main joint. Near the face a little ore occurs in the main or No.

1 vein. Most of the ore in this adit has been extracted and the possibilities of ore at depth on the mineralized joint have not been explored.

No. 2 adit has been driven as a crosscut and then as a drift for 140 feet on the No. 1 vein. The portal is 60 feet below that of No. 1 adit. The vein is up to 12 feet wide and consists of quartz and rock inclusions with a little pyrite in one place and a small quantity of disseminated galena in another. No commercial ore appears in the adit.

No. 3 adit, 55 feet below and 280 feet east of No. 2, was driven a short distance below a promising surface showing of galena in the main or No. 1 vein. Thirty inches and less of banded ore is exposed for 15 feet in a drift. The ore peters out, lens-like, at the west end. At the east end, in a winze, the ore continues irregularly to about 25 feet below the level of the adit. The bottom of the winze is filled with water.

No. 4 crosscut, on the same vein, a short distance west of No. 3 adit, exposed 5 feet of quartz and inclusions with from 4 to 10 inches of galena and a little pyrite on the foot-wall side against crushed slates. More quartz is encountered towards the face of the crosscut and is slightly mineralized with small stringers of galena. No drifting has been done.

No. 2 crosscut, just east of No. 1 adit, is 35 feet long and exposes an 8-inch lens of galena about 6 feet long, on the foot-wall side of the No. 1 vein. Between No. 2 crosscut and No. 4 crosscut a 15-inch square blow-out of galena is bounded by the joints and bedding in the sediments near the vein.

Several hundred yards northwest of the above workings No. 2 vein, lying northeast of No. 1 vein, is exposed in an open-cut. It is about 2½ feet wide and is irregularly mineralized with bunches of galena and pyrite in the coarsely crystalline and vuggy quartz. Thirty feet northeast of No. 2 vein is the No. 3 vein, on Snowflake No. 2 mineral claim. It is irregular in width up to 3 feet, being otherwise similar to No. 2. Ten inches of clean galena is exposed for a length of 2½ feet on the foot-wall side of the vein. A little pyrite is present.

There are other less important surface showings on the property.

No. 4 adit, about 500 feet vertically below No. 1 adit, is a long cross-cut. At the time of the writer's visit, the main vein had not been reached. About 315 feet from the portal several inches of pyrite and sphalerite occurred as a replacement in a narrow, calcareous bed. Two hundred and sixty feet from the portal a vein, lens-shaped, striking north 10 degrees east, dipping 75 degrees east, was encountered. It is about 20 inches wide and is very sparingly mineralized with sphalerite, galena, and pyrite in a gangue of fine-grained quartz and a little calcite. It has not been explored along its strike.

None of the upper adits or crosscuts has attained more than a few feet of depth on the vein, with the single exception of No. 2 adit which shows no commercial ore.

The only ore in the mine that is partly blocked out is that in No. 3 adit. The quoted dimensions indicate a maximum of between 200 and 300 tons of probable ore of a good milling grade. The other showings are merely small shoots whose continuity for any distance beyond the exposed portions cannot be reasonably assumed. Most of them are too small to warrant extraction in any other way than by "gophering" methods. On the whole, developments indicate that the ore-shoots are of good grade in lead and carry low silver values and that they are of small size and irregular outline. The most favourable horizons to prospect are zones of crushing and folding in the slates and schists near the quartz veins. Replacement of calcareous members by sulphides is an important possibility. However, as the principal veins are bedded the likelihood of finding this type of ore-body is considerably less than if the veins crosscut the various sedimentary horizons.

The type of deposit to which the Snowflake belongs—large quartz veins containing irregular sulphide bodies—is quite common from the International Boundary to the main line of the Canadian Pacific railway, in Kootenay district. Experience indicates that the irregular distribution and dimensions of the ore-shoots may be expected to persist. Surface showings and the upper workings on the Snowflake are sufficiently promising to warrant careful, conservative, exploration in the hope of finding large ore-bodies. Future development must depend largely on what is encountered when the long, lower crosscut reaches the main vein.

Since the property was examined by the writer the large quartz vein has been encountered in the lower crosscut which is presumably the No. 1 or "17-foot" vein exposed on the surface. The showing was examined by J. D. Galloway, the provincial mineralogist, and reported on by him in a special bulletin of the British Columbia Department of Mines published late in 1928. He states that, between two walls 45 feet 9 inches apart, there are two bands of quartz 6 feet 10 inches and 4 feet wide, respectively, and much barren or slightly mineralized slate. Pyrite and sphalerite occur with the quartz; galena is not appreciably developed. Since Mr. Galloway's examination drifting and raising have been done on the vein in the lower level. Recently a sample from this level has been received in Ottawa through the Vancouver office of the Geological Survey. It consists of quartz, sphalerite, pyrite, and a dark grey, metallic mineral which was reported to contain tin and had been identified as stannite. A small amount of this mineral was analysed by Mr. R. J. C. Fabry of the Division of Mineralogy, Geological Survey, and gave the following composition:

	Per cent		Per cent
Sn	26·65	Zn	7·72
Cu	31·56	Mn	nil
Fe	3·65	Ni	nil
		S	29·76
		Total	99·34

This analysis agrees fairly closely with the composition of stannite as given by Dana in "A System of Mineralogy". The mineral was not assayed for silver, but the original analysis by Mr. Eldridge of Vancouver is reported to have contained over 100 ounces per ton.

Part of the specimen was polished and examined under the microscope. In reflected light the stannite is greyish white with a brownish tinge, and closely resembles tetrahedrite. It tarnishes to a light brown with cold dilute nitric acid. As it was difficult to differentiate between it and tetrahedrite (grey copper) it was examined under polarized light. Whereas grey copper is isometric and consequently is dark with crossed nicols, the stannite, being tetrazonal, is polarizing and gives distinct interference colours. Also it shows well-defined twinning lamellæ in several places.

Associated with the stannite are well crystallized pyrite, sphalerite, and chalcopyrite. The sphalerite occurs as veinlets in the stannite or as irregular areas in or away from it and contains many specks of chalcopyrite. There are very few specks of chalcopyrite in the stannite. The sulphides occur in rather coarsely crystalline, fractured, white quartz. The writer has been unable to find any stannite in specimens collected from the upper workings during the original examination. It seems improbable, however, that it should be entirely absent in that part of the property.

In the field or in hand specimens the stannite might be mistaken for zinc blende or for grey copper. It resembles sphalerite when tarnished, but gives a black streak rather than the ordinary white or brown, resinous one of zinc blende. On fresh surfaces it has a dark steel-grey colour which would not readily be confused with zinc blende. It is somewhat coarser in grain than the ordinary grey copper of the district, and exhibits an indistinct cleavage. In addition it is darker in colour and less silvery in appearance than grey copper.

Stannite occurs in important amount in various deposits in Bolivia and is associated with tetrahedrite, cassiterite, pyrite, arsenopyrite, sphalerite, ruby silver, jamesonite, and other complex minerals.[1] The last reference contains a partial list of literature on the Bolivian tin deposits.

Woolsey Group, Silver Creek

This group of claims is on the east fork of Silver creek and lies immediately southeast of the Snowflake group. The camp buildings, on the edge of Silver creek, are 4,200 feet above sea-level. The original staker was P. E. Kennedy. David Woolsey optioned the property in 1917 and in 1925 Bernier Metals Corporation of Vancouver was formed. At present the claims are being developed by Morton Woolsey Consolidated Mines, Limited. A good bunk house and cook house combined and a small power house have been erected. The power house is equipped with a Petter S type, 2-cylinder oil engine and a Holman's 2-cylinder compressor, belt driven, which supplies 300 to 350 cubic feet of air per minute at a pressure of 100 pounds per square inch. Most of the property is on a steep hillside sloping eastward to Silver creek and is developed by numerous open-cuts and Nos. 1, 2, and 3 adits at elevations of 4,200, 4,770, and 5,060 feet (barometric), respectively.

The same black to grey slates and impure limestones that occur on the Snowflake cross the claim. The strikes vary from north 60 degrees west to north 20 degrees west and dip at 50 degrees or less to the northeast. Numerous quartz veins occupy well-defined fissures that follow the bedding of the sediments. The most important one is probably the southeasterly continuation of No. 1 vein on the Snowflake group. On it the two upper adits are driven and it is the main objective of a long crosscut in No. 3 adit. The veins are similar to those described on the Snowflake group. The sulphides, principally pyrite and galena with small amounts of sphalerite and chalcopyrite, are later than the quartz of the veins. They occur in crushed or fractured quartz, in the crushed sediments adjoining the veins and occasionally as irregular bodies of small dimensions filling vugs

[1] Davy, W. M.: "Economic Geology", vol. 15, pp. 463-496 (1920).
Buerger, M. J., and Maury, J. L.: "Economic Geology", vol. 22, pp. 1-13 (1927).
Lindgren, W., and Creveling, J. G.: "Economic Geology", vol. 23, pp. 233-262 (1928).

or porous crystalline spaces in the veins. The galena carries up to 3 or 4 ounces of silver per unit of lead, but would probably average about 1 ounce to a unit.

No. 1 adit is driven for 100 feet as a drift on the main vein which varies in width from 6 inches to 3 feet and is sparingly mineralized in one or two places with pyrite and galena.

No. 2 adit, 290 feet vertically lower on the same vein, follows the foot-wall for 135 feet. At 78 feet and 120 feet from the portal crosscuts were made through the vein. At the face the vein is barren, but in the two cross-cuts and in one at the portal sulphides occur as narrow bands, particularly at or near the hanging-wall, across widths of 20 feet or less of quartz and included rock fragments. It is doubtful if, at any place, the width of 20 feet or so would contain more than 5 per cent combined pyrite and galena. In a cut above the portal the vein dips 5 degrees more flatly than the sediments. From 6 inches to 18 inches of galena, with little pyrite and sphalerite, is exposed for a length of 15 feet along the dip on the foot-wall side of the vein where the sediments are greatly crushed. Forty-five feet south of the portal a parallel quartz vein about 3 feet wide is poorly mineralized.

No. 3 adit is driven 200 feet north, 60 degrees west, and then, on June 1928, 204 feet south, 46 degrees west, as a crosscut. Its objective is the main vein developed in the upper levels, but it would also cut other veins that are known to occur on the hanging-wall side of the main one. When examined it had cut two veins, one about 30 feet wide, of barren quartz, and was being continued.

On the east side of Silver creek, opposite the mine buildings, a bedded quartz vein from 5 to 10 feet wide is exposed over a vertical range of 200 feet. It strikes north 60 degrees west and dips at 40 degrees to the north-east. The quartz is coarsely crystalline and encloses many fragments of wall-rock. The vein is sparingly mineralized throughout with narrow stringers and small, irregular bodies of pyrite, galena, and a little sphalerite. At the upper end of the showing, elevation 4,500 feet, there is 10 inches of finely banded, watery quartz intergrown with pyrite, galena, and sphalerite in the centre of the vein. This quartz and all the sulphides are distinctly later than the white, crystalline quartz of the vein.

It will be seen from the above description that the Morton Woolsey and the Snowflake are essentially parts of the same occurrence. Consequently developments in one are of vital importance to the other. They might best be worked by one management.

Lanark Mine

In 1883 the first claims were staked in Illecillewaet district. Interest centred in the area immediately north of Laurie and the Lanark was the principal property. By 1888 the Selkirk Mining and Smelting Company, Limited, is stated to have had about 100,000 tons of ore in sight. During 1887 and 1888, 420 tons of ore was shipped to San Francisco and the profit is said to have been $65 per ton, the values being in lead and silver. Developments continued until 1893 when work ceased until 1896. During 1896 operations were continued and in 1897 the Lillooet Fraser River and Cariboo Goldfields, Limited, had apparently stoped out all the available ore in the Lanark, so that work was suspended before 1900. No further development is recorded until 1913. In 1915 the property was reopened by W. B. Dornberg and more ore was encountered, so that in 1916 ten cars were shipped and 15,000 tons were reported to be in sight. In 1917 two hundred tons of concentrates were shipped from the mill and works, and small shipments continued until 1923. Mr. Dornberg installed diamond drills in 1924, but the results were disappointing and in 1925 the property was dismantled. Today it is deserted. The old mill, also dismantled, which was connected to the mine by a two-span aerial tram 7,000 feet long stands beside the Canadian Pacific railway track at Laurie. The cabins at the mine, 2,600 feet above the railway, are still in fairly good condition, but the trail is badly washed out in places. The mine was developed by adits and raises to a depth of 400 feet and below that by a shaft for about 150 feet. This shaft is now filled with water and all the workings are in such poor condition that a detailed examination could not be made.

The rocks in the vicinity of the mine are grey to black slates, light grey limestones, and gradational varieties. They strike northwest and dip from 50 degrees to 65 degrees northeast on the average, but are locally much contorted. The main lead, where observed on the surface, is at the contact of a broad band of grey limestone and overlying slates. In a large glory hole at elevation 5,600 feet, the vein is about 18 feet wide and consists of white quartz and calcite in crushed wall-rock. Pyrite, sphalerite, galena, and a small amount of grey copper occur rather sparingly throughout and are concentrated for a width of 5 feet on the foot-wall side. One hundred feet farther up the hill, to the northwest, the vein, 5 feet wide, is again exposed on the same contact. It is stated in old reports that the vein decreased in width from 20 to 25 feet in the upper workings to 4 or 5 feet in the lower workings.

Crystal and Wonderful Claims

On the adjoining Crystal claim there are numerous small showings of fairly clean galena. The main Lanark lead is said to continue across the claim. Some of the veins occur entirely within the slates. Two short adits and a shaft were observed on the Wonderful claim, about one-half mile west of the Lanark workings. Veins similar to that seen on the Lanark, but much smaller, are exposed, the maximum observed width of sulphides being 20 inches. An upper adit, 65 feet long, exposes lenses of quartz and calcite in slates, but no appreciable quantity of ore minerals.

Claims in or near Keystone Basin

In 1895 and succeeding years numerous claims were staked in the area surrounding the headwaters of Keystone creek which drains into Columbia river a few miles south of Downie creek. Considerable development work was done in these early days, but interest soon waned and of recent years the showings have received little attention. Mr. Alec McIntosh is the present owner of several claims and is most familiar with the district. Access is by the trail to Standard basin; a branch trail, now largely obliterated, goes north to Keystone basin from a point a little less than one mile east of the old Carbonate Chief cabin.

The Keystone claim has received most development. On it are two short adits and a winze from the lower one. An old cabin stands a short way northwest of the workings which are 7,000 feet above sea-level in open, grass-covered country with a steep, rocky ridge immediately to the south. In the vicinity are crystalline limestones, carbonaceous slates, mica schists, and greenstones. The average strike of the sediments is northeast and the dip is 15 degrees to the southeast. At the adits they strike north 30 degrees west and dip 10 degrees or less southwest. The upper adit is driven 50 feet in a southerly direction on a 5-foot band of grey limestone intercalated with carbonaceous and micaceous schists. For 45 feet the limestone is replaced, along the bedding, by quartz, pyrite, pyrrhotite, sphalerite, galena, and a little chalcopyrite. Twenty-eight feet from the portal a fissure striking north 30 degrees east and dipping 75 degrees southeast, was encountered. It is poorly mineralized with quartz, calcite, and a little pyrite and no ore was found on the drift southeast of it. Twenty-five feet vertically below this adit a second adit has been driven 100 feet in a parallel direction, but no ore is visible. The steep fissure was encountered and a winze sunk on it for a depth of about 35 feet. A short raise connects the two adits. In the winze the fissure is poorly mineralized with quartz, calcite, and a little pyrite and sphalerite. Evidently the mineralizing solutions ascended along the steep fissure, mineralizing it slightly, and spread out and partly replaced, by sulphides, the limestone in the upper adit. The prospect does not show much promise of containing valuable ore-bodies.

Immediately east of the Keystone is the *Black Dog claim* on which no workings were found.

Adjoining the Black Dog on the east is the *Kodak claim* owned by Mr. McIntosh. On it a quartz vein, 3 feet and less in width, cuts schists and is mineralized with stringers and irregular patches of pyrite, pyrrhotite, sphalerite, galena, and chalcopyrite. About one-half mile farther east graphitic schists are replaced, across a width of 5 feet or more, by small amounts of smoky quartz, pyrrhotite, and very little chalcopyrite.

Silver Shield and Silver Bell

These claims, owned by Mr. A. McIntosh, are about 2 miles southeast of the Keystone group, on the northwest side of Standard creek. They were not examined, but the owner states that he has exposed some promising showings of lead-zinc ore and that small quantities of clean silver-lead ore are available.

Mastodon Group and Adjoining Claims

The Mastodon group is on the divide between the south fork of Carnes creek, and LaForme creek. An old trail, now in rather poor repair, leads from 19-mile, on the Big Bend road, to the crossing over LaForme creek, about 5 miles. Thence for 3 miles it climbs quickly to the cabins near the mine, elevation 4,600 feet. The cabins are in good condition. The first claims in the vicinity were staked about 1897 and in the following few years considerable development work was done. In 1916 the Mastodon Mining Company of Lethbridge, Alberta, was formed and during 1917 and 1918 the property was actively developed. At present no work is being done. Developments consist of two inclined shafts, one down over 130 feet and the other 35 feet, some drifting and crosscutting in the former, a little open-cutting, and one crosscut adit about 135 feet long.

In the vicinity of the workings crystalline limestone, varying from white through grey to black, and intercalations of grey, sericite schist strike on the average north 25 degrees west and dip from 35 degrees to 50 degrees east. Two principal veins have been explored. They occur along fissures that conform with the bedding of the sediments or cut it at a small angle across the dip. In some places the ore minerals have replaced the limestone away from the main fissures. The ore minerals are pyrite, sphalerite, galena, and grey copper (tetrahedrite?). Values are principally in lead, zinc, and silver. The gangue minerals are quartz and calcite.

The deep shaft and crosscut adit are on the westerly vein. In the shaft, for a depth of about 100 feet on the dip of 40 degrees, the vein varies from 3 feet of fairly pure, partly oxidized, sulphide, principally galena and sphalerite, to essentially nothing, averaging perhaps 6 inches in width. The vein lies along a clean fault dipping 5 degrees more steeply than the bedding of grey limestone, black limestone, and grey sericite schist. The walls of the fault approach and withdraw from one another, causing the variation in thickness of the vein. A drift and crosscut from a depth, on the dip, of 100 feet, were flooded with water at the time of examination, but it is reported that several feet of sphalerite, replacing limestone below the foot-wall, were found. Some of this ore, containing small quantities of grey copper, may be seen on the dump. Elsewhere very little grey copper was observed. The adit is driven as a crosscut on the same lead about 250 feet south of the shaft. It exposed two 6-inch veins of oxidized material showing lead and copper stains. Above the adit oxidized lead zinc ore is piled along an old, caved open-cut.

About 160 feet vertically above, and several hundred feet southeast of, the adit the second vein is developed by a shallow shaft. In it galena and grey copper with calcite and watery quartz occur along a bedded fissure in banded grey to white marble dipping 45 degrees east. From a width of 6 to 12 inches at the top the vein pinches to an inch or less at the bottom of the shaft. The ore should contain good silver values.

It is reported that the vein has also been exposed on some bluffs in the Carnes Creek slope, but these showings were not found by the writer.

Adjoining Claims

To the southeast of the Mastodon numerous claims were staked in the early days. None of them was known to the writer and no guide was available. However, along the summits above and southeast of the Mastodon numerous signs of mineralization, principally galena, sphalerite, and grey copper, were observed. The formation consists of limestone and interbedded schists and quartzites and the ore minerals, where observed, occurred in the limestone as fissures or replacements. The rocks are complexly folded and crushed in many places. It seems that the whole area from the Mastodon to the head of Silver creek would be worthy of rather careful prospecting. Good silver values might be expected in the ores and the limestones offer favourable prospecting horizons.

QUARTZ-TETRAHEDRITE VEINS

George Group

The old George group, staked in 1896, is 21 miles up the North fork of Illecillewaet river and includes the George, Reggie, and Alto claims. Messrs. Woolsey, McCarter, and Kilpatrick were the original owners. In 1903, 5½ tons shipped to Trail are reported to have returned $110 per ton and 2½ tons sent to Tacoma assayed $116 per ton. The values are principally in silver. Since the death of David Woolsey, well known old-time prospector of Revelstoke district, the claims have reverted to his estate and last year his sons re-examined the property and did a little surface stripping.

On the claims, 400 feet above the North fork trail, an old adit and winze from which the early shipment came are badly caved. Dull grey, flaggy, crystalline limestone with slaty intercalations strikes north 15 degrees west and dips from 30 degrees to 50 degrees east. The same limestone continues north to the Waverley mine. Irregular lenticular veins, up to 18 inches wide, of white quartz and calcite, cut the limestone and are mineralized with pyrite, sphalerite, and galena. A mineral, thought to be grey copper in the field, when examined under the microscope was found to resemble boulangerite (lead sulphantimonide) most closely. It is present in large amount in the ores and a sample of it, mixed with other sulphides, was assayed for Mr. Woolsey who states that it contained several hundred ounces in silver per ton. The occurrence is similar to certain rich silver ores of Lardeau district where the same mineral was identified.

The deposit, as far as could be judged from a hasty examination, offers little possibility of producing large quantities of ore, but is well worth investigation by individuals in the hope of uncovering high-grade pockets or shoots that would stand the cost of being packed to the railroad and shipped to a smelter. Although no grey copper was noted by the writer it probably occurs in the veins.

The *Silver Gland* is above timber-line at the headwaters of Ninemile creek which empties into the North fork of the Illecillewaet about 9 miles from Albert Canyon station. A steep trail leads to the property from the main North fork trail. The owners are J. H. S. Munro and associates of Revelstoke. The writer did not make an examination. It is reported that the showings contain high-grade silver lead ore. The claims are located on the northwesterly continuation of the zone of sediments that pass the Lanark mine.

Other Occurrences

Deposits similar to that described for the George group occur on the Tiger, Black Bear, and Juno claims and are mentioned in the description of the Waverley-Tangier group to which the claims belong.

On the summits east of the Roseberry and south of the A and E group a series of quartz veins have been staked by McBean and Kitson on the Eagle, Ptarmigan, and other claims. Some of the veins are slightly mineralized. Mr. Kitson states that he has recently uncovered some interesting mineralization. A specimen which he gave to the writer consists of white quartz heavily mineralized with grey copper and two additional minerals which agree most closely microchemically with bournonite (lead-copper sulphantimonide) and boulangerite (lead sulphantimonide). Pyrite and chalcopyrite are present in small amount. The mineralization is identical with that of some of the small, high-grade silver deposits of Lardeau district and resembles that on the George group described above.

PLACER DEPOSITS

Placer gold is found in French creek, McCulloch creek, Camp creek, the lower reaches of Goldstream river, and in Carnes creek. All these streams, particularly the first two and the last, have been worked extensively in the last sixty-three years and an unknown quantity of gold, valued at least at several million dollars, has been extracted. At present operations are confined almost entirely to French and McCulloch creeks, although some work is done every season along the lower reaches of Goldstream river. Gold occurs in the quartz veins around the heads of McCulloch and Graham creeks and these veins are believed to have supplied the gold for the placers. As far as is known, no gold is found in Goldstream river above French creek. French and McCulloch creeks have been so extensively worked in the past that it is now exceedingly difficult to locate virgin ground.

The gold occurs as rather coarse grains and nuggets, many of which are angular or slightly porous. Apparently they have not been transported for great distances. It is found principally on or very close to bedrock, although finely divided colours are scattered throughout most of the gravels and much of the surface soil. Fine colours can be obtained from most of the small streams draining into McCulloch creek, from its source to its mouth. On French creek gold is known to occur from the mouth to the meadows about 6 miles upstream. Galena is frequently found with the gold on the riffles. Boulders are a great hindrance to placer operations. The beds of French and McCulloch creeks are covered thickly with them in weights varying from a few pounds to 40 or 50 tons. To work the accompanying gravels requires much time, labour, and dynamite. However, past operations have proved that if an area of unworked bedrock can be found in either of the channels, good values may confidently be expected.

During the past season Messrs. D. Philmore and C. Williams were working in the middle of McCulloch creek about one mile from its mouth. They were confident that they had found a portion of the stream bed that had not been worked before. Boulders were causing trouble, but from the gravels near bedrock some gold was being obtained, including nuggets worth from $1 to $10, or more. No clean-up had been made at the time of the examination and it is not known whether the operations were a commercial success. Mr. L. Maley and an associate had staked several bench and creek leases farther upstream and were doing some work.

On French creek the French Creek Development Company, Limited, under the direction of president N. Remillard, was proceeding with extensive developments on the Cougar, Gopher, and Goat leases. Mr. Remillard has worked in the vicinity for some twenty years and, with associates, has prospected, by tunnels and shafts, a large area of bench land on the west side of the stream one mile from its mouth. These old workings could not be examined, but Mr. Remillard is confident that he has located an old buried stream channel in which the values near bedrock will be commercially profitable. At present the bench is covered with soil, boulders, and heavy timber. The company, working under a serious handicap due to lack of good transportation facilities, has erected a small sawmill and constructed 6,000 feet of 4 feet by 3 feet flume and a little more than 2,300 feet of pipe-line grading from 4 feet to 15 inches in diameter. It is intended to operate two monitors during the summer of 1929.

With the exception of the ground being developed on French creek, there seems to be little chance of finding buried channels in the district around Goldstream river. Where French creek joins Goldstream river the main valley is broad and flat and heavily timbered. In 1924 Goldfields American Development Company of New York put down two holes, 50 and 89 feet deep, near the centre of Goldstream valley opposite the mouth of French creek. Mr. Eugene H. Dawson who was in charge of the work reports that at 89 feet the drill was still in fine gravel and sand and that no values were obtained from either hole. His conclusion is that the source of gold supply (French creek in this case) is inadequate sufficiently to enrich Goldstream valley to make a profitable mining operation, and, further, that the depth to bedrock is too great for dredging operations.

NON-METALLIC MINERALS

Asbestos, talc, and mica, of commercial grade, are known to occur in the Big Bend. Asbestos is not known as yet in commercial quantities. It occurs, as good slip fibres, along shear zones in the serpentine on the Standard group of claims and is associated with talc. It is also reported from the Monarch group on the west side of Columbia river a short distance above Goldstream river.

There is much talc on the Standard group. Some of it, along shear zones in the serpentine, is very pure, but no large quantities of it are exposed. It also occurs, intimately mixed with carbonates and serpentine, along broad zones of alteration in the greenstone. Langley[1] mentions 7 feet of impure talc on the Monarch group, and states that the neighbouring schists are talcose. It is unlikely that any of the talc, or the asbestos, could be extracted profitably under existing conditions.

It is reported that mica of good commercial grade occurs in numerous pegmatite dykes in the region around the headwaters of Mica creek, in the northern part of the district. The occurrences were first mentioned in the annual report of the British Columbia Minister of Mines for 1908 and in the succeeding three years Big Bend Mica Mines, Limited, did extensive development work on some of the showings. In recent years the properties have lain idle and the old trails have fallen into disrepair. Consequently the writer did not examine the occurrences and nothing can be added to previous reports. Recently an effort has been made by Revelstoke interests to secure transportation facilities.

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

DEEP BORINGS IN BRITISH COLUMBIA AND YUKON

By D. C. Maddox

The Borings Division, Geological Survey, Canada, was established for the purpose of collecting records and samples from borings put down for oil, gas, or water, also for non-metallic minerals and for coal. In the richly metalliferous province of British Columbia and of Yukon territory most of the drilling is done with a diamond drill for the purpose of testing at depth the value of metallic ore deposits; with this work the Borings Division is not concerned. In the collection of data as to wells put down for water, special report forms are provided for the recording of such data. An appeal for co-operation is made to all persons having wells drilled or who possess information as to other wells that are being drilled. The value of the information which the division is able to supply in reply to inquiries as to water conditions is directly proportional to the amount of information on hand and to the accuracy and detail of such information. A few widely scattered records do not form a satisfactory basis for a report on water conditions in any area. It should be strongly emphasised, also, that information of this nature must be collected at the time the well is being sunk, otherwise its accuracy is often questionable. Information as to water wells serves the dual purpose of supplying data as to subsurface water conditions and of providing knowledge of the nature of the subsurface rocks.

The Borings Division has a laboratory specially equipped for the purpose of sample examination and a report of the results of the examination is sent to the driller as soon as it becomes available. Special attention is given to samples of rocks or minerals which the driller encounters in the course of his work and which he wishes to have identified.

Drilling for oil and gas in British Columbia during 1928 seems to have been confined to Sage Creek area, Flathead district, in the southeastern part of the province. In this area work was done on two wells—the B. C. Oil and Gas Company No. 1, and the Glacier No. 1. Fifty-eight samples covering depths from 18 to 600 feet were received from the B.C. Oil and Gas Company's well and were examined by the usual methods. These involved the use of the binocular microscope on the washed samples and the use of cold dilute hydrochloric acid. In addition to these tests the amount of material insoluble in acid was determined on twelve samples spaced at 50-foot intervals. All samples were bottled for future reference.

Three samples taken during the sinking of test pits in a lake deposit near Goldhill, Lardeau district, were submitted for examination. In addition to the usual tests, the amount of material soluble in acid was determined, disintegration tests were run on all samples, and the coarser mud-free material was examined under the microscope in order to identify the organic forms. A search for diatoms was made and permanent mounts of some of the material were made.

A sample of material fron an artesian well, put down by Mr. M. Blacklock at Langley Prairie, was referred to the Borings Division for examination. It would appear that the well was discharging large quantities of this material and the owner wished to ascertain if it had any commercial value. Mechanical analysis proved that the material was a silt. Some work was done in identifying some of the minerals in this silt with a view to determining its possible use.

Mr. K. Cole of Salmon Arm sent some information as to his well, as well as an analysis of the water.

OTHER FIELD WORK

Geological

J. R. MARSHALL. Mr. Marshall, assisted by N. F. G. Davis, completed the geological and topographical reconnaissance of Clearwater Lake map-area, British Columbia.

H. S. BOSTOCK. Mr. Bostock continued the geological mapping of Dog Lake map-area (longitude 119°30′ to 120°00′, latitude 49°15′ to 49°30′), Similkameen district, British Columbia.

C. E. CAIRNES. Mr. Cairnes completed the mapping of the geology and the study of the mineral deposits, Slocan area (longitude 117°00′ to 117°30′, latitude 49°45′ to 50°00′), Kootenay district, British Columbia.

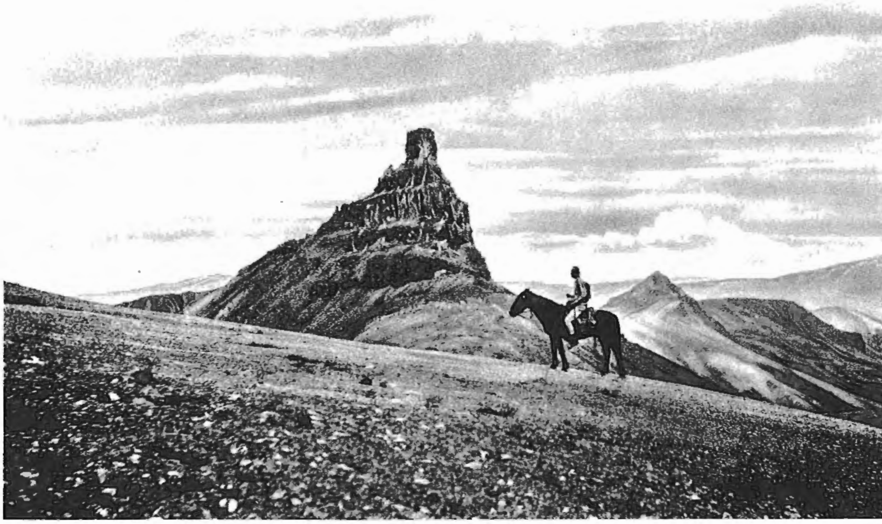
J. F. WALKER. Mr. Walker commenced the study of the mineral deposits of Salmo map-area (longitude 117°00′ to 117°30′, latitude 49°00′ to 49°15′), Kootenay district, British Columbia.

Topographical

A. C. T. SHEPPARD and A. C. TUTTLE. Mr. Sheppard, assisted by Mr. Tuttle, carried out the detailed topographical mapping of the coal area at Corbin, British Columbia. This area of approximately 5 square miles was mapped on a scale of 1 inch to 800 feet with contour interval of 25 feet. Mr. Sheppard also visited in the field the parties of R. Bartlett and S. M. Steeves in order to advise on matters relating to field work.

R. BARTLETT. Mr. Bartlett topographically mapped approximately 80 square miles in the vicinity of Alice Arm, British Columbia. This map is to be published on a scale of 1 inch to 1 mile with a contour interval of 100 feet.

S. M. STEEVES. Mr. Steeves started the topographical mapping of the Salmo quadrangle (latitude 49°00′ to 49°15′ north, longitude 117°00′ to 117°30′ west), British Columbia. This map is to be published on a scale of 1 inch to 1 mile with a contour interval of 100 feet. Approximately 165 square miles were completed during the season.



A. Castle mountain from the northwest.

B. Divide between headwaters of Gun creek and Bridge river.

A. Sliced porphyry, brecciated by later fault.

B. Looking east from Castle mountain.

A. Open country above Empress and Iron lakes in vicinity of Big Ledge, showing abundant exposures and prevailing structure of the Pre-cambrian rocks.

B. An outcrop of Big Ledge on Excelsior mineral claim.

A. Looking north from summit above A and E group on Carnes creek. A and E veins occur in and at base of limestone on right of picture.

B. Contorted limestone at head of Caribou creek; looking east.

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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 three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.