CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report 1931, Part A

CONTENTS

OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1932

No. 2305

CANADA

DEPARTMENT OF MINES

HON. W. A. GORDON, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR

Summary Report 1931, Part A

CONTENTS

OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1932

No. 2305

THE MINING INDUSTRY OF YUKON, 1931

By H. S. Bostock

CONTENTS

Illustration

INTRODUCTION

During the 1931 field season the writer was mainly engaged on work connected with the geological and topographical mapping of the Laberge map-area and, therefore, could devote little time to the collecting of information regarding the progress of the mineral industry in Yukon. It was possible, however, to make a brief examination of Livingstone placer camp and of the lode gold strike made in 1930 northwest of Carmacks.

LIVINGSTONE PLACER CAMP

Livingstone is the site of a placer camp that has been of some importance in the past. Gold was first discovered in the vicinity in 1898 and since then a very considerable amount is said to have been taken from the creeks in the neighbourhood. At the present time Livingstone, once a booming placer camp, consists of a dozen or more cabins in various stages of delapidation and is inhabited by a half dozen prospectors and trappers. During 1931 a little hydraulicking was done on Lake creek and the results are reported to be encouraging. Some development of a similar nature was also begun on Little Violet and Summit creeks. During the last two summers several families of Indians were occupied intermittently in "sniping" among the old diggings of the creeks. The camp is on the east side of the valley of the South Fork, Big Salmon river, and is about 52 miles directly northeast of Whitehorse. It was examined in 1901 by R. G. McConnell and his report was published in part A, Annual Report, volume XIV, of the Geological Survey. The present writer paid a brief visit to the camp in 1931. The information gathered by the writer is supplemented in this report by that contained in the report of R. G. McConnell and by a few details from unpublished notes made by D. D. Cairnes in 1907.

Five routes have been used to reach Livingstone. The most important route follows Teslin river from Hootalinqua at the confluence of Teslin and Lewes rivers, for 19 miles upstream to Mason landing, and from there crosses by a rough wagon road the ridge that separates the valleys of South Fork and Teslin rivers. This road is 14 miles long and the summit of it is at about 3,900 feet elevation, or nearly 2,000 feet above Teslin river and 1,300 feet above South Fork river. Another route frequently used at the present time is that of the winter road from Whitehorse which strikes Teslin river at Winter crossing, 16 miles above Mason landing, and reaches Livingstone 11 miles farther along, by a pass 2,800 feet in elevation. A third route is an old trail from the south, which connects with Teslin river near Boswell. The other two routes have now fallen into disuse. One ascended Teslin river to Seventeenmile cabin and crossed the ridge by a pass some miles north of the road from Mason landing. The other followed Big Salmon and South Fork rivers, but these two streams are difficult to ascend and now only the section of the route on the Big Salmon is sometimes used going downstream. A trail leads easterly up Livingstone creek to Quiet lake and other trails connect with the workings on various creeks.

The head of the South Fork is in the mountains southeast of Livingstone. In the upper part of its course it runs westward to join Fish creek. At the junction it turns northward and follows a wide main valley to Big Salmon river. At Livingstone the valley of the South Fork marks the border between the mountains to the east and the Yukon Plateau region to the west, though the plateau surface is represented along the eastern side of the valley by rounded ridges extending westward from the mountains. Where the wagon road crosses it the valley extends approximately north and south and has a comparatively flat floor about 2 miles wide. West of the valley flat, the land rises moderately steeply to form the ridge between it and Teslin river.

Along the east side of the flat valley floor a ridge rises 200 to 300 feet high and extends from Martin creek to Cottoneva creek, though broken by several gaps. East of this ridge, between it and the foot of the mountain slopes to the east, runs a narrow valley. From the east side of this narrow valley the main valley wall rises abruptly for 1,500 feet, above which it rises more gently in ridges that slope upwards to elevations of between 5,000 and 5,500 feet. The summits of these ridges are remnants of the Yukon plateau. Farther to the east the mountains rise an additional 1,000 feet in the form of a range of originally more rounded eminences whose northerly slopes, once occupied by alpine glaciers, are cut into by cirques divided by sharp ridges and surmounted in places by rugged peaks.

The creeks entering the main valley from the east occupy hanging valleys and this is also true of the head of the South Fork itself to the south above the junction of Fish creek. These valleys have gentler gradients, are broader, and their bounding slopes are less steep in their upper parts than in their lower, western sections where they drop abruptly into the main valley of the South Fork.

Evidence of continental glaciation is present throughout the district in the form of a mantle of till on the gentler slopes and the tops of the ridges, and the presence of erratics which occur at all elevations. An erratic found on the highest point reached in the neighbourhood, over 7,000 feet, shows that the ice at its maximum reached above this elevation. A few striæ observed in the surrounding country indicate the direction of movement of the ice to have been towards the north and northwest and down the valley of South Fork river. The valleys in the mountains are typically U-shaped in cross-section. Their floors are covered by moraines and fluvial deposits. The cirques at their heads are evidence of alpine glaciers subsequent to the continental glaciation. The valley of the South Fork is filled with stream gravels which are pitted here and there by kettle-holes.

GENERAL GEOLOGY

The valley of the South Fork at Livingstone also marks the geological boundary between the rocks that form the plateau region on the west and those that compose the mountains on the east. On the west side of the valley the rocks are of the relatively unmetamorphosed volcanic and sedimentary formations that form most of the plateau region between lake Laberge and Teslin river. On the east side of the valley, a series of intensely metamorphosed sedimentary and igneous rocks occur, which dip towards the valley and, apparently, pass beneath the strata that outcrop on the other side of the valley 2 miles to the west.

The general features of these rocks as given here are based on rather limited field observation. The lowest members of the section dealt with occur at the head of Livingstone creek and northward along the ridge that separates it and the heads of the other tributaries of the South Fork between it and Mendocina creek from the upper part of Mendocina creek. These rocks are a group of basic and ultra-basic igneous rocks and schists, diorite, pyroxenite, and peridotite being among the varieties noted. They are all intensely fractured and sheared, and chloritic schists occur among them. Numerous segregations of magnetite were noted in the ultra-basic types. To the west of these rocks, the hills are formed of grey, quartz-mica schists, white and grey schists, and sheared quartzites. A number of lenses of limestone are interspersed through their eastern members. To the west is a belt of green, sheared rocks chiefly of igneous origin, foliated diorite and diabase types with green, chloritic schists occurring among them. Farther west these rocks are followed by grey, quartz-biotite schists, white and light grey sericite schists, and lead-coloured argillites, succeeded by a second series of green rocks, mostly tuffs, and these by a band of interbedded cherty quartzites and limestones with some sericitic, chloritic, talc and graphitic schists among them. The schists and associated quartzites and limestones strike approximately north 30 degrees west and dip from 20 to 60 degrees to the west. R. G. McConnell remarks that the schists are partly of igneous and partly of clastic origin and resemble in a general way the gold-bearing schists of Klondike district. Many lenses of vein quartz carrying small quantities of sulphides and in some cases visible free gold, occur in the schists and seem to be more abundant in the western members.

The schists of the north part of the ridge referred to above are cut by some small bodies of granitic rocks and in the mountains to the southeast of Livingstone at the head of the South Fork these rocks occur in bodies of batholithic dimensions.

The original source of the placer gold, found in the creeks flowing from the east, is most probably the quartz veins in the schists. The majority of these are small lenses a few inches wide and only a few feet long. In places, however, they were noted to be over 2 feet wide and more than 100 feet long. It is said that some of these small veins were discovered to be very rich in free gold, but that when such small lenses with high values were taken out no visible continuations remained.

PLACER DEPOSITS

The creeks that are reported to carry gold are St. Germain creek on the left bank of the South Fork and all those from Mendocina to May creek, a distance of 12 miles, on the right bank. The creeks from Little Violet to Livingstone appear to have been the most productive.

Livingstone Creek. Livingstone has been by far the most productive of the creeks. No records of production are available, but "old timers" say that this creek produced over $1,000,000 in gold. The creek flows westerly to where at the edge of the main valley it enters the narrow valley at the foot of the main slope, which it follows north for 2 miles before again turning west and breaking through the flanking ridge on the west. The stream where it turns north after leaving the hills is about 15 feet wide and above this point is 6 miles long. It heads in a cirque and from there for about 3 miles it follows a shallow, U-shaped valley with a gradient of about 100 feet a mile. Lower down, the valley takes on a V-shaped section and narrows to a canyon for the last three-quarters of a mile before it turns north. In the narrower part of the valley and in the canyon the floor is 50 to 100 feet wide and in the canyon the gradient increases to a maximum of about 500 feet a mile. In the lower part of the canyon, rock outcrops on both sides, but towards the head the south wall is composed of a great thickness of sand, clay, gravel, and till with large boulders.

The old workings are in the lower mile or so of the canyon. Their history is said to have been one of alternate periods of rise and decline in production from 1898 to 1920 when production virtually ceased. The better ground was in the lower part of the canyon where the creek flows between the rock walls. As this became worked out production began to decline and higher up the channel of the creek was yielding even poorer results. Shortly afterwards, however, an old channel with good pay was discovered under the overburden on the south side a little below the head of the canyon. This channel was on bedrock a few feet higher than the present creek channel where they joined. It was found to extend upstream, but its gradient was more gentle than that of the present creek channel and half a mile or so above its lower end the old channel was 40 feet below and over 1,000 feet to the south of the present channel with a rim of bedrock rising between them. The old channel lay under a great depth of frozen ground, though the pay gravels at the bottom were unfrozen. The paystreak in the old channel is said to have been on the average about 30 feet wide and 2 feet deep. Since the pay gravels lay in a stream channel cut in rock it is probable they were of pre-Glacial age like those found on Lake creek, which are described later. The old channel of Livingstone creek was at first worked in separate claims, some of which had long adits and inclines extending southerly from the present channel. The upper claims were difficult to work on account of water, the pay gravels being unfrozen and below the level of the entries on the creek. These circumstances finally lead to amalgamation of these claims and the connecting of the workings for drainage and operating purposes, and once more operations revived. As the old channel was followed up the gold was found to become finer and scarcer, rich patches such as were present in the lower part did not occur, and the channel no longer paid to work. Finally an attempt was made to work these claims on the old channel by hydraulicking the whole channel, but the great depth of frozen overburden and the doubtfulness of the returns led to the abandoning of the project soon after it was begun.

Some distance up the creek, abreast of the workings on the old channel of the south side, another buried channel is reported to have been discovered. An adit was run into it, but the results are not known and in spite of the ground being reported to be unfrozen it appears to have been abandoned without much work being done.

At the mouth of the canyon where the creek turns abruptly north rich ground is supposed to exist and in the past an attempt was made to test it. A steam plant and pumps were installed and a shaft was put down with great difficulty—owing to water and great boulders—to a depth of 70 feet and abandoned before reaching bedrock.

The gold from the creek was very coarse as a whole and a number of nuggets were found worth over $200 each and some over $400. The gold had a dull, copperish tinge and the average assay value is stated to have been $18.20 to the ounce.[1] A few nuggets showed a rough surface and included fragments of quartz, but as a rule they were worn quite smooth. A great deal of magnetite in coarse lumps and as sand was present with the gold. This magnetite came from the ultra-basic rocks at the head of the creek. Small quantities of galena, native copper, garnets, and cinnabar are also said to have occurred with the gold.

Lake Creek. During the season of 1930 Mr. T. Kerruish took up a placer lease on Lake creek and the work on this lease has been the chief development in the camp during the last two seasons.[2] The valley of Lake creek has a relatively gentle gradient in its upper part, but as it approaches the main valley of the South Fork it enters a narrow canyon and drops steeply to the level of the side valley already referred to. The present development, as well as the old workings, is all above the canyon. In the past this creek is reported to have produced many thousands of dollars in gold taken from an old channel in which the paystreak was said to be about 15 feet wide and to lie close to the present course of the creek on its south side. The old workings, the results of several successive independent owners, burrowed irregularly through the old channel and a number of very rich pockets were removed, leaving intervening patches of ground untouched. Though the total depth of gravels was only 15 to 30 feet and though they were unfrozen and contained only a few large boulders, hydraulicking was not used as the creek is small. Mr. Kerruish, however, has made a reservoir on it and has put in a small hydraulic plant which has proved very successful. The effectiveness of the hydraulic plant was enhanced in 1931 by the wet season which provided an unusually prolonged flow of water in the creek. During the past two seasons a long cut 20 to 30 feet wide was made, extending up the channel followed by the old workings. The returns are reported to be very satisfactory and this work has shown that the old channel is wider than formerly supposed, as the north edge has not been reached yet.

At the time of the writer's visit the top 10 feet or more of drift over an area adjacent to the present cut on the north side was being cleared off in

[1] McConnell, R. G.: Geol. Surv., Canada, Ann. Rept., vol. XIV, pt. A, p. 28.
[2] Cockfield, W. E.: Geol. Surv., Canada, Sum. Rept. 1930, pt. A, p. 2.

preparation for a similar cut next spring, as the limits of the pay channel in that direction appear not to have been reached yet and the ground is virgin. The section on the north side of the cut is about 30 feet thick to bedrock. At the top is 16 feet of glacial till. This overlies 6 feet of poorly sorted gravels containing rounded fragments some of which are of foreign material. This in turn lies on 6 to 8 feet of gravels and sand of a distinctly rusty colour and composed only of local bedrock material, the fragments of which are angular in form and seldom over 12 inches long. Fortunately the whole section contains only a very few large boulders. The rusty gravel lies on bedrock which is decomposed and soft for a depth of a few inches to a foot and can easily be shovelled off the harder rock beneath. The extent of the layer of rusty gravel is uncertain. It is considered to be of pre-Glacial age and to have escaped disturbance by the ice owing to its sheltered position in the bottom of this small valley whose course is transverse to the direction of movement of the ice. As is the case in most of the creeks the schist bedrock strikes across the course of the stream and forms a very favourable surface for the retention of the gold. The rusty gravel is regarded as the paystreak. The gold in it has a copperish tinge and the occasional fragments of quartz enclosed in it are rusty brown. Most of the gold is fairly coarse, and occurs as flat flakes or nuggets with smooth surfaces. The gravels above the paystreak are also said to carry gold, but it is finer, brighter, and yellower, and forms pieces of irregular shape in many cases containing white quartz.

Summit Creek. Summit Creek valley is somewhat similar to Lake Creek valley. The old workings are just at the head of the canyon and do not appear to have been so extensive as on Lake creek. From time to time work has been carried on and during the season some development was in progress.

Little Violet Creek. Little Violet creek, the northernmost of those visited, is small and runs down a narrow valley with a steep gradient which becomes still more steep at its lower end where it drops to the level of the main valley. Some old workings lie above the steeper part of the course and some development work is being started on the creek at the present time. Rusty gravels similar to those on Lake creek outcrop along the creek. The flow of water is small and many boulders make it difficult to work. Because this creek is to the north of the others and the strike of the formations is west of north, the bedrock along it belongs to more easterly horizons than those under the workings of Lake, Summit, and Livingstone creeks. The schists here are less foliated and contain massive members and dykes that form inferior surfaces for the retention of the gold.

Cottoneva Creek. Cottoneva creek is one of the larger creeks of the camp, but its more gentle gradient and the large quantities of coarse gravels have made it difficult to work. However, a considerable amount of work has been done along the creek, for which a relatively large amount of hydraulic and derrick equipment was required. As the result of this the work proved too costly and has been at a standstill for some years. Some exposures of rusty gravels were noted on a soft, decomposed bedrock. The present creek gravels hold a conspicuous quantity of vein quartz and between this creek and Little Violet a number of quartz veins outcrop along the foot of the valley.

Several important factors appear to have contributed to the presence of the placers of the Livingstone camp. The factors that led to the formation of the placers in the first place were: the presence of the quartz veins in the schists, providing a source for the gold; the very long period of erosion prior to the Pleistocene, during which a great thickness of rock was eroded concentrating the gold in the gravels and on the bedrock surface; the cleavage and stratified structure of the schists and their strike across the direction of the courses of the creeks, giving them an unusually favourable bedrock surface for the retention of the gold. The factors that led to the preservation of some of the placers from disturbance by glaciation were: the sheltered positions of the placers in the bottoms of the valleys; the courses of the streams being east and west and transverse to the direction of the movement of the ice; the spurs separating the valleys being high and steep and particularly so on the south side of Livingstone creek, from which direction the ice moved. As a result of these factors the valley bottoms containing the placers were filled with gravel and till and were overridden instead of being scoured by the continental ice-sheet. Another factor contributing to the preservation of the placers was that the mountains at the heads of the streams were not sufficiently high to cause valley glaciers that would have removed the placers after the recession of the continental ice-sheet. An exception to this was Livingstone creek, where fortunately, the valley glacier did not extend far down the creek.

GOLD STRIKE NORTHWEST OF CARMACKS

INTRODUCTION

In 1930 a lode gold strike was reported near Carmacks and attracted considerable attention. The locality is in the east end of the Dawson range and lies about 38 miles northwest of Carmacks by the trail up Crossing creek. The trail follows the road from Carmacks for 10 or 11 miles towards Yukon Crossing and then turns off to the northwest and cuts over a low ridge into Crossing Creek valley. After fording the creek it turns west along the north side of the valley, follows the creek to its head, crosses over the divide and continues for several miles down the valley of Seymour creek, a tributary of Big creek. The latter half of the trail is wet and very little cutting has been done on it. Another route from Carmacks follows the Nansen Creek trail as far as Rowlinson creek, branches off there, and follows up Rowlinson creek and through a pass to the head of Seymour creek. This route is longer and reported to be no better than the other.

In 1917 a small placer stampede took place into the valley of Seymour creek. Though this produced no directly profitable returns it aroused the interest of some of the prospectors in the locality and since then two or three have returned from time to time to look over the surrounding country. Mr. F. Guder, who was one of these, discovered some magnetite float carrying visible gold on the top of the ridge north of Seymour creek. In June, 1930, after he had discovered it in place, he staked the first claim, the Augusta. After the staking of this claim the interest in the locality steadily grew until by the beginning of 1931 well over one hundred claims had been recorded. The locality was visited by the writer in the begin-

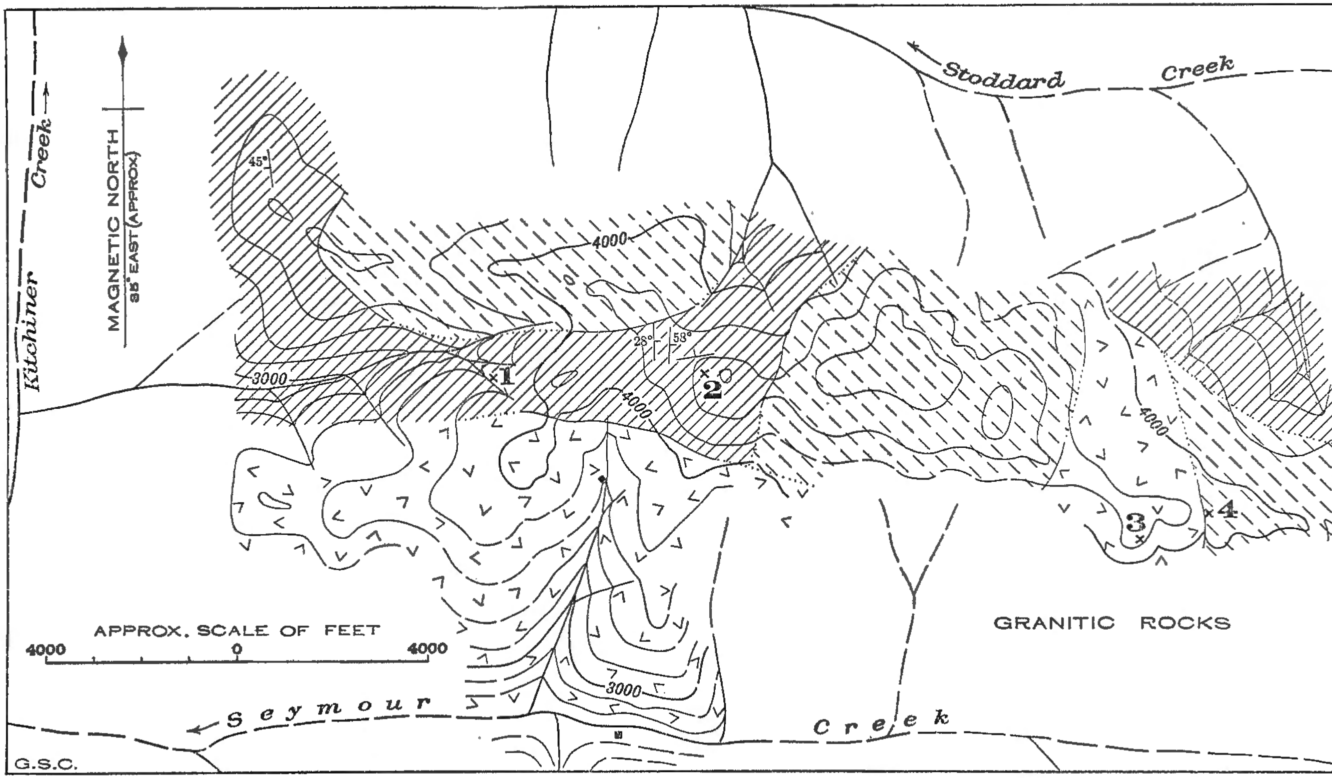


Figure 1. Seymour Creek area, northwest of Carmacks, Yukon. Areas of gneiss, quartzite, and schist shown by pattern of unbroken ruling; syenite porphyry by broken ruling; and granodiorite and granite by angle pattern. Mineral occurrences on claims: 1, galena-bearing vein on Red Fox; 2, magnetite body on Augusta; 3, quartz vein on Rambler; 4, quartz vein on Nabob.

ning of September, 1931. During the summer the assessment work had been done on many of the claims and a few mineral showings discovered.

Most of the claims are located along the top of the ridge which forms the north side of Seymour Creek valley and separates it from Stoddard creek, another tributary to Big creek. The slopes of the ridge rise steeply out of the creek valleys, flatten towards the upper part, and steepen again along the backbone of the ridge. The ridge is steepest on the south side. On the north side the slopes are more gentle and conform with the general northward slope of the whole country. Most of the outcrops occur on the steep lower slopes and here and there along the backbone of the ridges and spurs where in many places the outcrops have a castellated appearance from a distance. The gentler slopes are covered by a mantle of soil and disintegrating rock in which trenches have been dug several feet in depth before reaching rock in a solid condition.

GENERAL GEOLOGY

The ridge on which the claims are staked is composed of a series of metamorphic rocks, and a number of bodies of younger, coarse-grained, intrusive granitic and syenitic rocks. The metamorphic series was observed to extend a few miles north and is reported to cover large areas to the north and west. The younger intrusive rocks occur over a considerable area to the south and east.

The metamorphic series in the area examined consists, in the main, of gneiss and quartzite. The most of the gneiss is composed of light and dark bands which give it a stratified appearance. The dark bands are the thicker and are usually several inches broad, whereas the lighter material forms bands $\frac{1}{4}$ to $\frac{3}{4}$ inch thick. The dark bands are composed of feldspar, some quartz, considerable quantities of hornblende and less of biotite. The light bands are largely of fine-grained, granitic, and aplitic material consisting of feldspar, quartz, and a very little hornblende. The gneiss is foliated parallel to the banding. A considerable amount of unbanded, foliated gneiss of a generally lighter colour and containing more feldspar and quartz is also present. It contains both orthoclase and plagioclase, and equal amounts of biotite and hornblende. The gneiss is cut by unfoliated, scattered aplite and pegmatite dykelets which tend to follow the foliation, usually crossing here and there at a slight angle. In places the rock is traversed by a network of epidote veinlets. The quartzite is thinly bedded in the form of white to light grey layers separated by dark grey to nearly black seams of schist from $\frac{1}{16}$ to 1 inch thick. This schist is composed of quartz and mica with graphite in some seams. Some float of similar schist from thicker beds was also noted. A single boulder of limestone was found on the surface of the area in which the quartzite outcrops and indicates that limestone probably occurs with the quartzites. The gneiss and quartzite are closely folded and vary in dip and strike within almost every outcrop. The quartzite occurs chiefly on the south of the gneiss, but no regular boundary could be traced between them. In all probability they belong to the Yukon group (Precambrian). They are cut by a number of small, diorite dykes. In the immediate vicinity of the magnetite showings on the Augusta claim the surrounding gneiss and quartzite have been much metamorphosed, the metamorphic silicates, garnet, actinolite, and epidote, have been produced and magnetite and specularite have been introduced.

The younger, intrusive series consists of stocks of syenite porphyry, large bodies of granodiorite and granite, and numerous small dykes. Typically the syenite porphyry is very coarse-grained and composed of large, pink, orthoclase phenocrysts in a grey, coarse-grained groundmass of orthoclase, plagioclase, and hornblende. The orthoclase phenocrysts are chunky in form, usually 1½ inches, but in some places 2½ inches, long. They are scattered abundantly through the rock and in some places show the parallel alinement of flow structures. The hornblende is dark green to black. The plagioclase is an oligoclase; it is thickly clouded with alteration products and this is also true of the orthoclase though to a less degree. Orthoclase is more abundant in the groundmass than the plagioclase. A little quartz fills the interstices between the other minerals. Titanite and apatite are present in small quantities. Magnetite occurs as scattered grains of irregular outline, equally abundant in all the essential minerals. Minute fractures traverse the rock and strain shadows occur in the quartz. In several places the rock was noted to be so crushed that its original characters were largely obliterated and the rock consists of large, cracked grains of feldspar, remnants of the phenocrysts, embedded in a meshwork of fine, chloritic material, the whole being traversed by numerous, small veinlets of epidote.

In the case of the syenite porphyry stock outcropping on the summit of the ridge northwest of the Augusta claim, the porphyry slowly changes as the contact with the metamorphic series to the west is approached. The size of grain and the quantity of orthoclase decrease, whereas the amount of hornblende increases, making the rock close to the contact a hornblende syenite of a dark grey colour and uniform grain with a slightly developed ophitic texture. Fragments of gneiss were noted in it close to the contact.

The second body of syenite porphyry lying southeast of the above-mentioned stock outcrops in only a few places, but the area is covered with its float except for stretches where a very large proportion of the float is of dyke rocks such as varieties of diorite, rhyolite, quartz porphyry, and granite. The fragments of the diorite may come from inclusions of older rocks in the syenite porphyry, for in the metamorphic series a small dyke of syenite porphyry was found intruding a small dyke of diorite. The other types represented in the float are almost certainly dykes, judging from the distribution of their float and the occurrence of similar rocks as dykes in the other bodies of syenite porphyry and other rocks. In the southwest corner of this body of syenite porphyry the rhyolite and quartz porphyry float is so abundant that these rocks must make up the major portion of the bedrock.

The most easterly of the three bodies of syenite porphyry contains slightly less hornblende and more quartz than the others. It extends a considerable distance eastward. Dykes of granite and granodiorite cut the eastern body. No mineralization was observed in the syenite porphyry bodies.

The granodiorite and granite form the spurs and lower slopes of the ridge on the Seymour Creek side and are part of an extensive area of these rocks that continues in the hills on the north side of the trail as far east as the ford on Crossing creek and probably forms much of the range to the south. The rocks vary from a grey granodiorite of orthoclase, plagioclase, quartz, hornblende, and biotite to a light pink granite of quartz, orthoclase, plagioclase, and a little mica, but for the most part the types are distinct. It was noted that the outcrops on the lower slopes of Seymour Creek valley from about 3,500 feet downward, and the eastern body, are of granodiorite, whereas along the top of the slope adjacent to the contact with the older rocks they are of granite. The granite and granodiorite are younger than the syenite porphyry bodies, for they cut them in the form of dykes. The granodiorite and granite in turn are cut by dykes of rhyolite, quartz porphyry, lamprophyre, and andesite and by small bodies of aplite and pegmatite.

No sign of glaciation was found upon the ridge on which the claims occur, the general limit of glaciation lying a few miles to the south on the other side of the Dawson range. A tongue of the ice-sheet, however, extended through the range by way of the gap at the head of Rowlinson creek, into the heads of the valleys of Crossing and Seymour creeks. It carved the upper part of Seymour Creek valley, truncating the lower ends of the spurs and giving rise to a U-shaped cross-section, and left an area of glacial debris whose uneven surface gave rise to the lakes at the summit between the two creeks. Since the ridge on which the mineralization has been found was not glaciated, the mantle of soil and rock debris has remained undisturbed since pre-Glacial time. For this reason the sources of float where the slopes are gentle lie directly beneath or a short distance up the slope.

ECONOMIC GEOLOGY

As many of the claims were staked on the snow in the winter and much of the ground is devoid of outcrops, most of the prospecting so far done on the claims has consisted of trenching to find the type of underlying bedrock and the source of mineral float. In this way the magnetite showing on the Augusta, Badger, and Morning claims, a galena vein on the Red Fox claim, and veins on the Rambler and Nabob claims have been found.

Augusta Claim. The best developed mineral deposit is that of the original discovering of the Augusta. The chief showings of this are on the top of the west end of the main ridge between 4,100 and 4,500 feet elevation. The ground slopes steadily downward from the showings to the west and northwest and rises to the east 50 feet or more to a rounded summit. The rocks immediately around the deposit are those of the metamorphic series. The magnetite, which is the chief mineral of the ore, has been exposed in place in six short trenches and a number of shallow pits which are distributed down the slope to the northwest for several hundred feet from where the original find was made near the top of the ridge. Magnetite float has been traced for over 1,000 feet farther to the northwest beyond the excavations along the same line, but it does not continue more than 50 feet to the southeast from the highest trench. The highest trench is the largest working and it is approximately 5 feet wide and 8 feet deep and 30 feet long across the line of the float. The magnetite is exposed throughout its length and breadth, the trench ending as soon as the wall-rock is reached. The next two trenches are about 60 and 125 feet away respectively down the slope. The magnetite shows a width of 12 feet in the upper trench and 6 feet in the lower. In the remaining excavations down the slope the full width of the magnetite is not displayed.

The deposit is of the contact metamorphic type and of the magnetite variety.[1] The minerals present in the ore are magnetite, quartz, specularite, limonite, free gold, actinolite, garnet, and epidote. The magnetite occurs as perfect crystals embedded in limonite or as solid areas of interlocking crystals traversed by veinlets of limonite. The magnetite crystals frequently show a series of alternating pure and less pure zones of growth about a pure central core. The limonite occurs irregularly distributed among the magnetite. It is in solid patches, vein-like masses, or networks surrounding magnetite or cavities in which it forms a cellular structure in some instances. No sign of pseudomorphs of former minerals could be detected in the limonite. The quartz is glassy and crystalline. It occurs as small veins and patches in the magnetite and limonite, usually showing a comb structure and in many cases surrounding vugs into which its crystals project. A little specularite occurs with the quartz and silicates in the ore, but it is much more abundant in the wall-rock where it is in large flakes forming veins and patches among the silicates. The gold occurs here and there as small patches visible to the unaided eye. These patches are scattered through the limonite and under the microscope numerous minute particles can be seen around larger ones. Gold was noted adjacent to magnetite, but never in it. Tiny wires and films of gold also occur between quartz crystals in the vugs. Small patches of silicates, including yellow brown garnet, occur in the ore, but they form a large proportion of the wall-rock. The wall-rock in which the metamorphic silicates occur consists of altered quartzite and schist of the metamorphic series, but gneiss outcrops approximately 60 yards to the north. One boulder of limestone was found about 30 yards down the slope to the southwest. It consisted of finely crystalline, blue-grey limestone with a portion of an adjacent bed composed of metamorphic silicates and specularite adhering to it. The walls of the deposit appear to be sharp but irregular and the dip is uncertain. The present excavations do not reach below the zone of weathering which is unusually deep for this northern latitude on account of the lack of glaciation. It seems probable that the limonite has formed from the weathering of iron sulphides which carried the gold and that when greater depth is reached, where the alterations due to weathering are less complete, the iron sulphides will be found in place of limonite.

Two other showings of similar magnetite occurrences have been discovered by trenching—one on the Badger and one on the Morning which lie respectively north and northeast of the Augusta. The extent and form of these are unknown.

No evidence as to which of the large intrusive bodies in the immediate neighbourhood contributed to the mineralization was found. The magnetite deposits lie between two bodies of syenite porphyry and magnetite is abundant in the porphyry. Possibly the mineralization owes its origin to the syenite porphyry.

[1] Lindgren, W.: "Mineral Deposits," 3rd Edition, p. 801.

Red Fox Claim. A small vein containing galena has been found on the Red Fox claim on the south side of the head of Guder creek. The vein is exposed in two cuts approximately 30 feet apart on the steep side of the draw. It strikes approximately east and dips nearly vertically. It is 6 to 8 inches wide and composed of lumps of sheared galena between which limonite and gouge occur, the exposures being well up in the zone of weathering. The wall-rock is quartzite. Small amounts of chalcopyrite and sphalerite occur in the galena.

Rambler and Nabob Claims. On the Rambler and Nabob claims quartz veins a few inches to a foot wide containing fine crystals of pyrite have been exposed in place in pits 6 to 9 feet deep. The float of vein quartz and limonite which was first discovered on the surface on the Rambler is reported to have contained free gold.

BOWSER RIVER AREA AND NORTH PART OF PORTLAND CANAL AREA, BRITISH COLUMBIA

By George Hanson

CONTENTS

INTRODUCTION

Previous geological work in the country tributary to Stewart at the head of Portland canal has extended northward along Salmon River and Bear River valleys to about latitude 56° 10′, a few miles north of the junction of American creek with Bear river (*See* Figure 2). In 1931, the writer made a geological reconnaissance of the country for about 15 miles farther northward, which embraces the drainage basin of American creek and the upper Bowser River country to the west. The present report will give briefly the main results of the work of 1931.

For hospitality and useful information the writer wishes to acknowledge his indebtedness to the officials of the Premier Gold Mining Company, the B.C. Silver Mining Company, the Buena Vista Mining Company, and the Consolidated Mining and Smelting Company; to the watchmen at several of the mining properties; and to Messrs. Morris, Bryant, Kimball, Rochford, Lake, MacDonald, and other individuals. J. A. Mitchell and Stan Duffell rendered efficient service in the field.

The mineral deposits of the region are described in the Annual Reports of the Minister of Mines of British Columbia. The following bibliography lists the reports published by the Geological Survey, Canada, on Portland Canal area.

McConnell, R. G.: "Portland Canal District, B.C."; Geol. Surv., Canada, Sum. Rept. 1910, pp. 59-90.

"Salmon River and Portland Canal Districts, B.C."; Geol. Surv., Canada, Sum. Rept. 1911, pp. 50-71.

"Portions of Portland Canal and Skeena Mining Divisions, Skeena District, B.C."; Geol. Surv., Canada, Mem. 32 (1913).

O'Neill, J. J.: "Salmon River District, Portland Canal Mining Division, B.C."; Geol. Surv., Canada, Sum. Rept. 1919, pt. B, pp. 7-12.

Schofield, S. J., and Hanson, George: "Salmon River District, B.C."; Geol. Surv., Canada, Sum. Rept. 1920, pt. A, pp. 6-12. Geol. Surv., Canada, Mem. 132 (1922).

Hanson, George: "Bear River and Stewart Map-areas"; Geol. Surv., Canada, Mem. 159 (1929).

PHYSICAL FEATURES

American creek flows south along a valley that is the northern continuation of the great valley occupied by the lower stretches of Bear river and the northern part of Portland canal. To the west of the upper part of American creek is a range of high mountains with peaks such as mounts Mitre and Morkill rising to heights of between 9,000 and 10,000 feet. This mountainous tract separates the southward-flowing waters of American creek on the east from the headwaters of the northward-flowing Bowser river on the west. Farther south Bear River ridge separates the lower part of American Creek valley and its southward continuation, Bear River valley, from Salmon River valley to the west.

Salmon river enters Portland canal 2 miles southwest of the mouth of Bear river. This valley extending northward, in its lower part lies west of the International Boundary, and farther north, about the point where it enters Canada, divides into three approximately parallel valleys. The western of these three valleys is occupied in Canada by Salmon River glacier. Big Missouri ridge culminating northwards in mount Dilsworth separates the western from the middle or Cascade River valley; this forks to form Long Lake valley, the third of the three parallel valleys. East of Long Lake valley, separating it from American Creek valley, lies Bear River ridge, varying in elevation from 5,000 to 6,600 feet.

Two passes traverse the mountains forming the divide between the basin of Salmon river to the south and the headwaters of the northward-flowing Bowser river to the north. The eastern pass leads from the head of the easternmost of the three parallel valleys of the Salmon River system. Its elevation at the divide north of Divide lake is 3,500 feet. The western pass is occupied by Salmon River glacier and its summit elevation is 3,200 feet. The route to the Bowser River country follows this western pass.

Salmon River glacier enters Salmon River valley from the west at a point about 6 miles north of where the valley enters Alaska. The ice flows both north and south along the valley, but the main movement is to the south, and this lobe just reaches the International Boundary. The glacier thus forms an ice dam 800 to 1,000 feet high in Salmon River valley. At the north end of the north lobe is Summit (or Morris) lake, $2\frac{1}{2}$ miles long. If the glacier disappears from Salmon River valley, Summit lake will drain southward by way of Salmon river. Now it drains northerly through a rock gap and is the head of the westerly of the two main branches of Bowser river. The other main branch of this river rises in the eastern pass already alluded to. It flows north to join the western branch on the clay-floored flat formerly covered by Tide lake. The mud-covered floor of the former lake extends some 4 or 5 miles northward along Bowser River valley to where Frankmackie glacier enters it from the west. Formerly this glacier was larger and dammed the valley, thereby forming Tide lake. The glacier began to shrink and the level of the lake dropped until a moraine built along the southern side of the ice formed the actual dam. The moraine was gradually cut through by the discharge from Tide lake until in 1931 the cut had been so deepened that the lake disappeared. Seven miles north of the former foot of Tide lake, Bowser river swings east and about 50 miles farther joins Nass river.

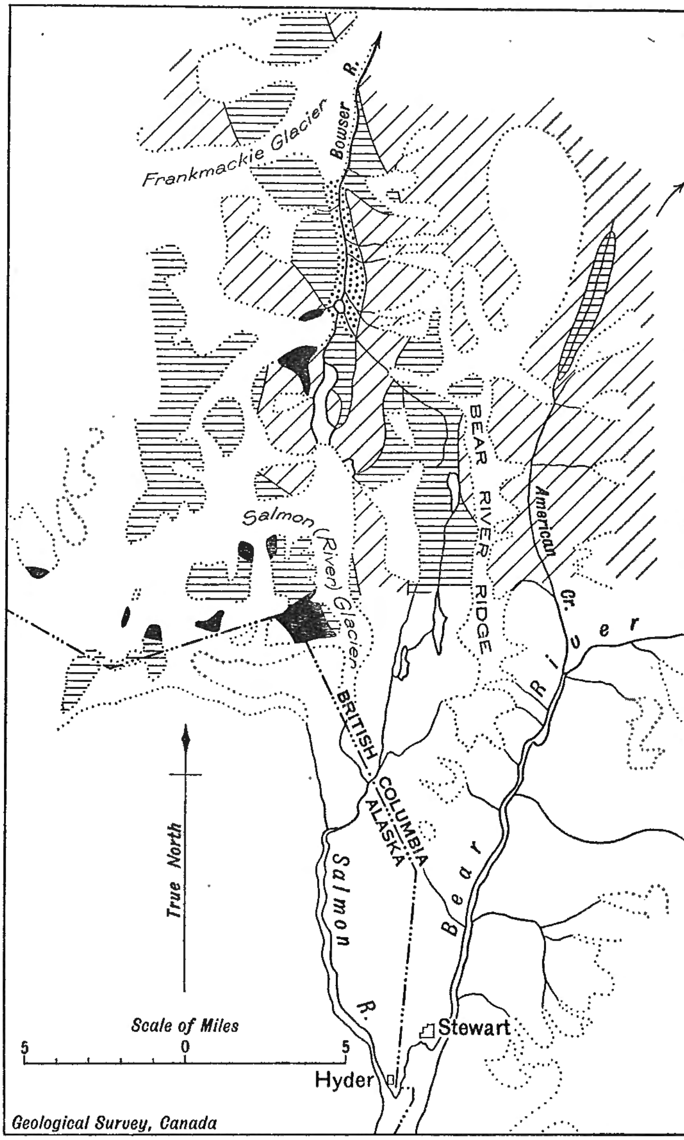


Figure 2. Bowser River and American Creek areas, Cassiar district, British Columbia. Site of Tide lake shown by pattern of stipple; granodiorite by solid black; areas chiefly of sediments (argillite and greywacke) by horizontal ruling; and Bear River volcanics by diagonal ruling.

GENERAL GEOLOGY

The strata of the district embracing American creek and the headwaters of Bowser and Salmon rivers are, for the most part, the same as those found to the south in Bear River and Salmon River districts. The oldest are the Bitter Creek sediments. These are overlain by the Bear River volcanics, consisting of extrusive and intrusive rocks of felsitic and andesitic composition, and cut by bodies of augite porphyrite and quartz porphyry. Overlying the volcanic rocks is another series of sediments known as the Nass formation. The whole assemblage is cut by the Coast Range intrusives and by numerous dykes. The sedimentary-volcanic assemblage is believed to be of Jurassic age. The strata are folded, but not severely, and although vertical dips are common overturning is exceptional. Shearing is local rather than regional.

For some miles along the upper stretches of American creek, black, calcareous argillites and argillaceous limestones outcrop on the lower slopes up to 500 feet above the valley floor. To the north they diminish in quantity and end a short distance south of the divide at the head of American creek. The higher slopes on either side of the valley are occupied by volcanic rocks of the Bear River formation beneath which the sediments seem to dip. The same situation seems to hold at the north end of the valley, at the divide, but there the sediments may be in part cut off by intrusive rocks which are rather plentiful in this locality. To the south the sediments also seem to plunge beneath the volcanic rocks. Farther south, near the mouth of American creek, in Bear River map-area, the sediments of the Bitter Creek formation are broadly developed and appear to plunge northward beneath Bear River volcanics. The sediments along the upper part of American creek occupy the stratigraphical position of, and presumably belong to, the Bitter Creek formation. Apparently the deep valley of American creek has cut through the Bear River volcanics to the Bitter Creek sediments disposed along a northerly-striking anticline plunging at both ends.

No mineral deposits were seen lying within the Bitter Creek sediments displayed along American creek, but deposits do occur at the contact with the overlying volcanics.

The mountains on both sides of American creek are formed of the Bear River volcanics. These consist in part of tuffs and breccias and to a lesser extent of lava flows and minor amounts of sedimentary rocks, but are mainly intrusives predominantly purple or grey. Dykes are numerous. The rocks in general are severely shattered, so much so that broken rock continually tumbles down the mountain sides. Mineral deposits occur in the grey rock varieties. Quartz-feldspar porphyry closely resembling that at the Premier mine occurs near the mouth of American creek, but although it contains much disseminated pyrite it is not known to be ore bearing. The Bear River volcanics extend eastward from American creek for about 15 miles to where they are overlain by sediments of the Nass formation. To the north the volcanics are succeeded by the Nass sediments about 5 miles north of the head of American creek. To the west the Bear River volcanics extend to the site of Tide lake, but farther south they reach only to Bear River ridge, where they are overlain by nearly horizontal argillites of the Nass formation.

In the northern part of Salmon River basin the Bear River volcanics occupy the high ground between Salmon River glacier on the west and Long Lake valley on the east. This area of volcanics extends north-northwestward into Bowser River country as a band 2 to 4 miles wide passing across Summit lake on the west branch of Bowser river. From the eastern side of the head of Summit lake another band-like area of the volcanics extends northward to join the broad area of the Bear River volcanics extending westward from the upper parts of American creek. Between these two bands of volcanic rock in Bowser River valley is an irregular area of sediments, widening to the north. Sediments presumably belonging to the Nass formation bound the northwesterly-extending band of volcanics on the west. Another area of Nass sediments lies east of the band of volcanics running northerly from Summit lake. This eastern area of sediments extends from the upper part of Long Lake valley, across the eastern branch of Bowser river, and ends some miles east of the junction of the two branches of the river.

In Bowser River country the Bear River volcanics appear to be mainly intrusive rocks, with a porphyritic texture and purple colour, but many of the rocks are grey or green and not distinctly porphyritic. These rocks in most places hold fragments of rocks like themselves, and some areas several acres in extent are wholly underlain by fragmental rocks. Many dykes cut the volcanics. Mineral deposits occur in the volcanics, but so far as known only in the grey and green varieties.

Since the Bear River rocks are mainly intrusives, the structure is complex and confused. Their relations to the adjoining sediments are determinable in only a few places. In the south they dip under the sediments of the area extending north from Long Lake valley, but their relations to the sediments lying west of the northwesterly-extending band of volcanics and to the sediments of Bowser River Valley area have not been established. Where observed, the contacts with the sediments of these two areas are vertical or nearly so.

The sediments of the area extending from Long Lake valley into the southeastern part of Bowser River area, since they overlie the volcanic assemblage, belong, presumably, to the Nass formation. They are mainly black argillites, and on mount Dilsworth and to the east are nearly horizontal. In several places along the contact with the Bear River formation, as near the south end of Summit lake, the sediments are severely plicated.

The sediments lying west of the northwesterly-extending band of volcanics stretch westward to the main body of the Coast Range intrusives. Where seen they have, except at the contact with the Bear River volcanics, gentle dips to the west and northwest. As already stated, the contact with the volcanics is steep. In places the dip is towards the volcanics as if the sediments were the older. At nearly all the contacts examined the Bear River rocks are intrusives and cut the sediments. There is no doubt, therefore, that some of the sediments are older than at least some of the rocks of the Bear River formation, but within a space of 2 miles away from the contact the sediments are gently inclined westward and it seems not improbable that they are younger than the volcanics (as a whole) and that towards the contact they have been bent steeply into a synclinal form. That this is the situation seems indicated to the south in Salmon River area where the sediments in the southern continuation of this area seemingly overlie the volcanics to the east, for near the contact the volcanic rocks dip west at angles of about 50 degrees.

The western band of sediments in places is rusty weathering over large patches as the result of oxidation of pyrite. Mineral-bearing quartz veins also traverse the sediments.

The relations of the sediments extending northward from Summit lake are, also, unknown. In the vicinity of Tide Lake flat these sediments form a band 1 mile wide. To the north the band widens rapidly, but to the south it narrows and finally ends at the shore of Summit lake. The strata are mainly calcareous quartzites and argillites, but there is very little of the black argillite typical of the Nass formation. The rocks are greatly contorted and sheared, are much altered, and hold much pryite. The contacts with the Bear River volcanics along both edges of the area are vertical or nearly so. The relations to the volcanic series are not clear. Judged from the disturbed and altered condition of the sediments, they are older than the Nass strata. They are cut by dykes of various kinds. Mineral deposits are present and the area appears to be worthy of prospecting.

The youngest rocks of the district are the Coast Range intrusives. Where seen they are granitic. The eastern boundary of the main body roughly follows the International Boundary, but outlying bodies occur to the north and east. In the vicinity of Summit lake and Tide Lake flat are two or three small stocks, each about 2 miles in diameter. Mineral deposits occur in their vicinity and it seems reasonable to suppose that the granitic rocks may be their source and that, consequently, the country in the vicinity of the stocks should be well worth prospecting.

ECONOMIC GEOLOGY

Only some half dozen mineral deposits were seen in American Creek and Bowser River districts. Those in American Creek area are in the main of the silver-lead type, but carry values in gold up to $5 a ton. The deposits in Bowser River country appear to contain more gold than those in American Creek area. One deposit at Summit lake contains locally as much as 2 ounces of gold a ton. The deposits in this vicinity and near Tide Lake flat contain more pyrrhotite than those about American creek. Too few deposits have been seen to warrant positive statements as to general characters, etc., but a few generalizations do seem to be warranted. Though in Bowser River district mineralization does occur in the sediments to the west, yet in this and American Creek district the mineral deposits are mainly in the Bear River volcanics and mostly restricted to the rocks of this formation that are not purple or red. Just why mineral deposits do not occur in the purple and red rocks is not known; these rocks seem, in general, to be more massive and less sheared than the other rocks of the formation.

SALMON GOLD GROUP

The Salmon gold group of mineral claims is west of Summit lake and 1,000 feet above it. The deposits are at the edge of a glacier and above timber-line, but there is enough timber for camps and mining purposes around the lake. The property was discovered in 1929. The Premier Gold Mining Company took it under option in September, 1931, and by November, when driven out by snow, had been able to explore the showing by twelve diamond-drill holes. At the time of the writer's visit in August, 1931, only a few open-cuts had been made, but as the deposits were naturally rather well exposed a fairly intelligent idea of their size and shape could be obtained. A principal mineralized zone trends northwest up the mountain side. It is joined from the east by at least three parallel veins that strike about south 80 degrees west but swing west and northwest to join the main zone in symmetrical curves. The veins dip steeply north. The main zone appears to dip steeply northeast. It has been traced for about 300 feet and is in general less than 12 feet wide. The veins have been traced for somewhat greater distances and are in general less than 5 feet wide. The mineralization in the main zone consists chiefly of pyrrhotite and carries good values in gold. That in the veins is somewhat similar, but there is more pyrite and quartz and less pyrrhotite. The veins also contain good values in gold. The main zone appeared to have been formed mostly by replacement and the veins mostly by vein filling. Selected samples from the deposits contain values up to $50 in gold a ton. The property was described rather fully by J. T. Mandy in the annual report of the British Columbia Minister of Mines for 1930.

TROY GROUP

The Troy group of mineral claims is at the east edge of the north end of the Salmon River glacier. The property is north of Salmon River district proper but has been described in the British Columbia Minister of Mines reports under Salmon River district. The deposit consists of veins in volcanic rocks of the Bear River formation and in part in the lower beds of the overlying Nass formation. The veins are less than 3 feet wide, but locally contain high values in silver.

OTHER DEPOSITS

Silver-lead deposits were discovered many years ago in the vicinity of Tide Lake and were diamond drilled a few years ago by the Consolidated Mining and Smelting Company. Other deposits in the vicinity are known but have not been developed. Some are in sediments. The Outland Silver Bar group of mineral claims west of the southern part of the Salmon River glacier has been developed by several tunnels and open-cuts. The mineralization is of the silver-lead type. A new find made east of Summit lake by J. Haahti in August, 1931, consists of a vertical, mineralized shear zone 20 feet wide striking east. The rocks are breccias of the Bear River formation. The zone where exposed in an open-cut consists of several well-mineralized bands, each 2 feet wide, consisting of pyrite, galena, and sphalerite in sheared, sparsely mineralized rock. The zone had not been traced beyond the confines of the open-cut at the time of the writer's visit.

On American creek there are several properties that have received attention from mining companies in the last few years. The Terminus, Mountain Boy, and other groups near the mouth of American creek were not visited. Farther north some of the showings of two groups were seen. On the property of the Northern Aerial Prospectors, Limited, there are several deposits of the silver-lead-zinc type that may have merit and certainly are worth prospecting, but which have not been opened up sufficiently to permit intelligent sampling. The deposits are in the Bear River formation on the west side of American creek and about 15 miles from the mouth of the creek. The property of the Excelsior Prospecting Syndicate lies mainly on the east side of American creek 14 miles from the mouth. On this property two open-cuts, 1,500 feet apart, each expose a 20-foot mineral zone having hanging-walls of quartz-feldspar porphyry and foot-walls of calcareous argillite. The area between the open-cuts is entirely covered with talus, but the open-cuts expose conditions so nearly identical that it is likely they are on the same mineral body. The zone is a replacement of black, calcareous sediments and consists of black, cherty streaks of argillaceous limestone and numerous oxidized bands of sulphides. The deposit is so oxidized that it is difficult to obtain samples of unaltered primary vein matter, but pyrite, galena, and sphalerite can be distinguished. According to the owners the deposit carries high values in silver.

PRELIMINARY REPORT ON THE NIMPKISH LAKE QUADRANGLE, VANCOUVER ISLAND, BRITISH COLUMBIA

By H. C. Gunning

CONTENTS

Illustration

INTRODUCTION

In 1931 work was commenced on the Nimpkish Lake quadrangle and about 300 square miles extending south of latitude 50° 30′ as far as Atluck lake and Groves creek and east of 127° 00′ to the summits east of Bonanza lake and its drainage basin were examined. As it will take several years to complete the examination of the whole quadrangle between latitudes 50° 00′ and 50° 30′ and longitudes 126° 00′ and 127° 00′, a final report will not be forthcoming for some time. In the meantime, this brief, preliminary report will discuss the more important geological and economic results of the work done in 1931. For additional information on the area a previous report may be consulted.[1]

As no base map suitable for use in detailed geological investigation was available in 1931, vertical airplane photographs taken in 1930 by the Canadian Air Force were used in the field. These pictures were taken from an altitude of 15,000 feet and their scale is about 3 inches to 1 mile, varying with the altitude and configuration of the ground photographed. They proved most satisfactory for field use in that they afforded a complete, detailed representation of every part of the area, much more detailed than could be expected in a good topographic map. For instance, such landmarks as burned or logged areas, logging railroad grades, slides, creek bottoms, gravel bars, practically every detail of lake shores, houses, and even fallen logs in some open places can be easily discerned on the pictures. On the photographs, geological information such as contacts, faults, or outcrops may be recorded, along with stations occupied. Disadvantages are that the scale varies considerably in different places in any one picture, heights cannot be determined, and bearings cannot be laid down upon, or computed from, the pictures. Prints of these pictures may be obtained from the Director, Civil Government Air Operations, Department of National Defence, Ottawa, at a cost of 40 cents a print. Correspondence should also be marked "Attention Staff Officer, Photography." Each picture is 7 inches by 9 inches so that, if the scale be 3 inches to 1 mile, it covers 7 square miles of territory.

[1] Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 94-143.

During the summer the writer was ably assisted by Messrs. C. F. Hillary, and J. C. Hall, and the work was facilitated by the hospitality and co-operation of residents of the area, particularly Mr. J. Frank Hoy of Wood and English Company and Mr. E. L. Kinman. The writer is also indebted to Messrs. A. J. Campbell and G. J. Jackson for geological specimens and information which they collected during the course of their topographic work.

GENERAL GEOLOGY

The oldest rocks are an assemblage of basic to intermediate, green to almost black, lava flows and associated breccias, tuffs, and dykes. Conformably above these is a thickness of 500 to 1,000 feet of white to grey, crystalline limestone. The limestone becomes darker and argillaceous towards the top and is overlain conformably by a thick series of andesitic flows, tuffs, and breccias, the lower 400 or 500 feet of which consists largely of black argillite, dark grey or black, impure limestone, quartzite, and light green or grey tuffs with a small proportion of interbedded flows. Flows and tuffs dominate the upper part of the series, sediments being scarce or absent.

The thick limestone member is the most prominent horizon marker in the district. Also, it seems probable, on the basis of as yet incomplete field work, that it may be the same formation as the limestone that outcrops so prominently along the east side of the southeast arm of Quatsino sound and continues southeastward past Coast Copper, and for which Dolmage[1] has suggested the name Quatsino limestone. The writer, therefore, proposes to term the main limestone in Nimpkish area the Quatsino formation with the proviso that, if the correlation above suggested be disproved by further field work, the term Nimpkish formation be used instead. The volcanic rocks beneath the Quatsino formation may be termed the Karmutsen volcanics, as they are well exposed all along the Karmutsen range just west of Nimpkish lake. The assemblage of sedimentary and volcanic rocks above the Quatsino formation may well be termed the Bonanza group, as these rocks are well exposed on the upper slopes west of Bonanza lake. If this group be later subdivided, the term Bonanza should be retained for that division lying directly above the Quatsino formation.

Fossils determined by F. H. McLearn as of Upper Triassic age, and including *Pseudomonotis subcircularis*, were found at many places in the lower, sedimentary part of the Bonanza group and a few small ammonites, probably also Triassic, were collected from the upper part of the Quatsino formation.

All the rocks mentioned above are cut by dykes, stocks, or small batholiths of granitic rocks known as the Coast Range intrusives. The larger bodies vary from quartz monzonite to quartz diorite, grandiorite being a convenient appellation where thin sections have not been studied. Dykes include quartz (rhyolite) porphyry, feldspar porphyry, and felsite or aplite. Later than the Coast Range intrusives are numerous, generally small, dykes, varying from diabase to andesite or diorite, which may be associated with the granitic intrusives or may represent a period of Tertiary igneous activity. The Coast Range intrusives are considered to be late Jurassic or early Cretaceous, although the only evidence obtained in the area is that they are post-Upper Triassic.

[1] Geol. Surv., Canada, Sum. Rept. 1918, pt. B, p. 32.

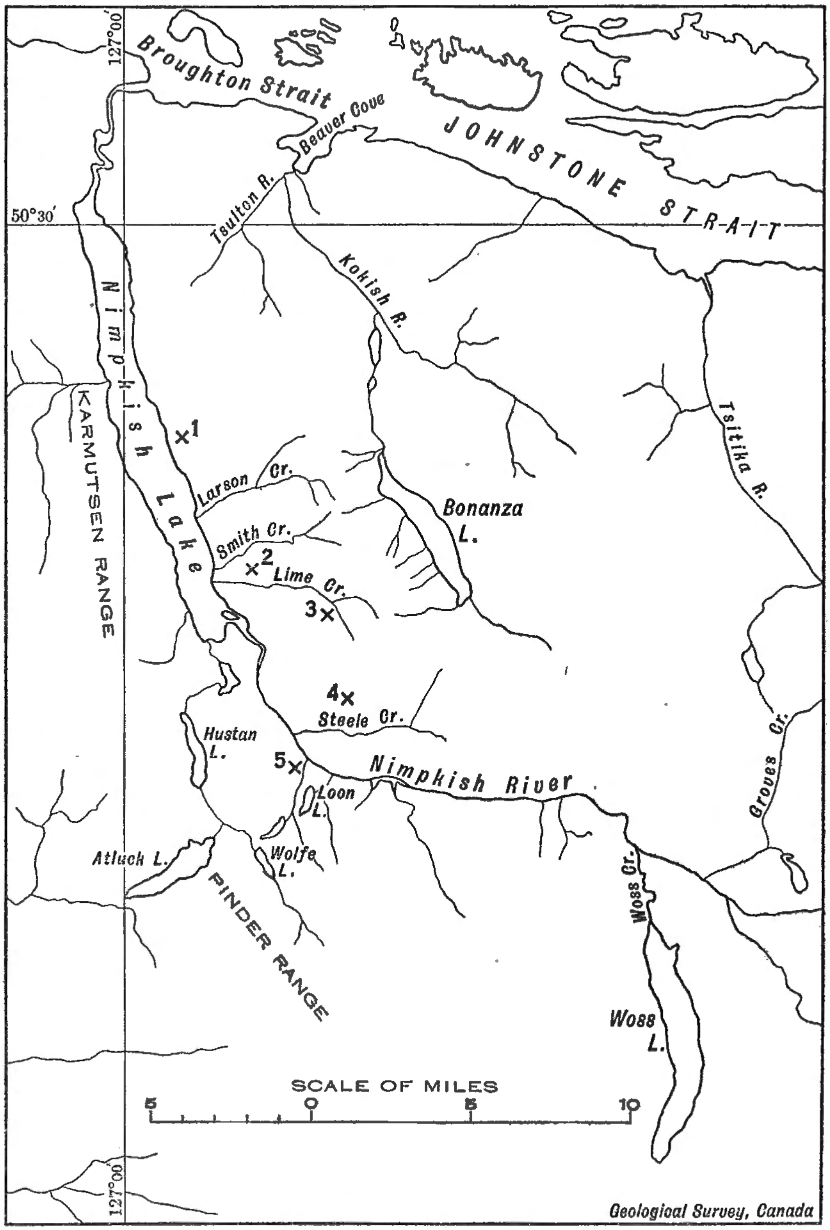


Figure 3. Nimpkish Lake area, northern Vancouver island, British Columbia. Mineral-bearing properties are marked by crosses. 1, Magnet group; 2, Smith Copper group; 3, Kinman property; 4, Nimpkish claims; 5, Klaanch group.

The only geological record later than the dykes is of erosion and glaciation and Pleistocene or Recent deposition.

The volcanic and sedimentary rocks are folded into a series of synclines and anticlines along axes trending north to northwest. The major structure of the area, from east of Bonanza lake to west of Nimpkish lake, is synclinal. This major structure is complicated by close folding and some major faulting in the vicinity of some of the larger, granitic, intrusive bodies. In the region south of Nimpkish lake the major synclinal structure is overturned towards the east.

Because of the structure outlined above, the Karmutsen volcanics are most extensively exposed in the Karmutsen and Pinder ranges west and southwest of Nimpkish lake, and east, north, and south of Bonanza lake. Between the two lakes, from latitude 50° 30′ as far south as Steele creek, are the younger Quatsino formation and overlying sediments and volcanics, cut by the Coast Range intrusives. Within this central area the underlying Karmutsen volcanics have been exposed by erosion in several relatively small areas. Thus, the Quatsino limestone, the most important member in the area both stratigraphically and economically, is exposed, dipping westward, from where it crosses the valley of Tsulton river, 2 miles southwest of Beaver cove, southeastward for 14 miles along the slopes west of Kokish river and Bonanza lake. It also extends across the valley at the outlet of Bonanza lake and is exposed for 3½ miles on the summits and slopes east of the valley. On the western limb of the synclinal structure the limestone occurs east of Nimpkish lake from latitude 50° 30′ (near the foot of the lake) to the head of Lime creek. In this distance it touches the lake shore at the north end, opposite Halfway islands, and again 4 miles north of the south end of the lake, where owing to a plunging synclinal structure it also outcrops along the west shore. The western outcrop is the north end of a band that continues south past Hustan lake and as far as the summits east of Wolfe lake, underlying the broad, flat valley immediately south of Nimpkish lake. In the case of the area east of the southern part of Nimpkish lake, it outcrops over considerable areas north of the mouth of Smith creek, and around the upper reaches of Lime, Smith, and Larson creeks, its continuity in these areas being interrupted by two large intrusions of granodiorite. Near the head of Lime creek, the limestone is cut off on the south by granodiorite which continues southeasterly for at least 12 miles, crossing Nimpkish valley between Loon creek and Woss creek, being from 3 to 6 miles wide from northeast to southwest. Similar granodiorite, probably a continuation of the same body, is exposed farther southeast around the north end of Woss lake.

MINERAL DEPOSITS

All the known mineral deposits of the area are in the immediate vicinity of bodies of quartz monzonite, granodiorite, or quartz diorite (Coast Range intrusives). They are contact metamorphic deposits containing as the valuable minerals, chalcopyrite, zinc blende, or magnetite, occasionally also bornite or galena. Gold values are generally low, only on rare occasions amounting to much over $1 a ton. Although there is some mineralization in the lavas of the Karmutsen volcanics near intrusions, all the most important deposits are in the Quatsino limestone.

Where this rock is intruded by granodiorite bodies it is frequently much altered, near the contact, to garnet, epidote, pyroxene, or other silicates, and in or adjoining the altered zone, one or more of the sulphide minerals named above may be found, frequently as very irregular bodies. Such structures as bedding, fractures, or joints in the limestone seem to have exerted little or no control over the mineralization. There is, however, a distinct tendency for mineralization along the contact between the limestone and the underlying Karmutsen volcanics, and such deposits are generally more regular and continuous than those elsewhere in the limestone. The sediments and volcanics overlying the Quatsino formation do not seem to be favourable hosts for mineralization. Only occasionally were small amounts of chalcopyrite noted in them, in spite of the fact that they are in many places extensively fractured, crushed, silicified, and mineralized with a multitude of tiny veins and seams of quartz, calcite, pyrite, or pyrrhotite. The larger Coast Range intrusive bodies cannot be recommended as very promising prospecting ground, yet they are in places mineralized and, consequently, should not be considered as necessarily barren. One mineralized shear zone, containing pyrite, molybdenite, and a little chalcopyrite has been uncovered in the granodiorite on the Kinman property; and in other parts of the island the writer has noted small veins and in some instances a considerable amount of disseminated chalcopyrite in these rocks. The more basic varieties in particular, including quartz diorite, diorite, and gabbro, might well be examined with some care when they are encountered by prospectors. During the summer of 1931 none of the properties in the area was being actively developed.

KINMAN PROPERTY

This property was described in some detail in 1929[1]. During the winter of 1929-30 it was developed, under option, by Consolidated Mining and Smelting Company, but in the spring of 1930 the option was dropped and the property reverted to the original owners, E. L. Kinman and associates. Since then no work has been done on the claims up to the time of the writer's visit in August, 1931. The 1929 report gives a description of the type of mineralization, which need not be repeated here. It is sufficient, therefore, to note that the ore deposits are contact metamorphic replacements in the Quatsino limestone near the contact of a large body of granodiorite and contain chalcopyrite and zinc blende accompanied by pyrrhotite, magnetite, pyrite, garnet, epidote, and other minerals in varying amount at different places.

In October, 1929, the company began development energetically and in six months had built 4 miles of good trail suitable for pack horses, erected four buildings, and the frames for about eleven tents, so that nearly sixty men could be accommodated, made upwards of 175 open-cuts, did 6,700 feet of diamond drilling in twenty holes, and drove 175 feet of tunnel, in addition to the necessary surveying. By all this work the contact of granodiorite and limestone was quite thoroughly prospected on the surface for over 12,000 feet and the more important showings were further investigated. The fact that such extensive surface work revealed only one additional important surface showing is a distinct

[1] Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 127-30.

compliment to the ability and industry of the original prospectors. The writer is indebted to E. L. Kinman for complete information, including assays, regarding the work performed by Consolidated Mining and Smelting Company.

Copper creek, a tributary of Lime creek, flows northwesterly through the claims and crosses a contact between granodiorite and limestone, trending northeast, 2,100 feet above sea-level. To the northeast of Copper creek the contact has been traced, by outcrops and many open-cuts, for a little over one-half mile to an elevation of 3,300 feet. It is extremely tortuous. Between heights of 200 to 400 feet above Copper creek, three rather small, irregular bodies of pyrrhotite and chalcopyrite, accompanied by silicates, were exposed on the contact, the largest being from 2 to 3 feet wide and 15 feet long. Two hundred feet higher, in a deep bay in the granodiorite, a maximum width of 25 feet of magnetite and silicates was exposed at the contact in two trenches 40 feet apart. For over 2,000 feet along the contact beyond this no important mineralization was discovered. The last showing northeast of Copper creek is at an elevation of 3,300 feet. At this point two deep trenches were made along an easterly direction and 15 feet apart. Each trench ends on the east, against a rusty weathering, greenish grey, lamprophyre dyke which strikes about north 35 degrees west. Immediately west of the dyke, 12 feet of massive pyrrhotite and zinc blende, with minor chalcopyrite, are exposed in the northerly trench, and 8 feet of the same material in the southerly trench. Granodiorite is exposed in two trenches immediately north of the showings. Four samples taken by the company assayed from 4·3 per cent to 9·6 per cent zinc and from a trace to 0·38 per cent copper with only a trace of gold and silver.

The original discovery on the property, consisting of a width of about 25 feet of rich copper ore in limestone near the granodiorite contact on the west wall of a canyon on Copper creek at 2,100 feet elevation, has been developed by an adit driven southwest. The adit passed through about 12 feet of good ore, varying, according to samples taken by the company along the south wall, between the following limits: gold 0·14 ounce, silver 2·38 ounces, copper 11·46 per cent, and zinc 0·30 per cent, to gold 0·38 ounce, silver 3·05 ounces, copper 13·75 per cent, and zinc 0·60 per cent. It then passed through 25 feet of slightly mineralized limestone and garnetite before encountering granodiorite into which it was driven for 20 feet. Subsequently, a branch from this adit was commenced east of the granodiorite contact and driven almost due west along the contact and finally through the granodiorite and into limestone at 63 feet from the portal. From there it was driven southwesterly for 75 feet; passing through, first, nearly 20 feet of barren to slightly mineralized (with pyrrhotite) limestone, then 40 feet of almost solid pyrrhotite or pyrrhotite and calcite, and finally 15 feet of at first poorly mineralized and then barren crystalline limestone. Copper values obtained from assays of the pyrrhotite ranged from 0·18 per cent to 0·67 per cent; gold occurred only as a trace; silver a trace to 0·12 ounce; and zinc nil to $\frac{1}{10}$ of 1 per cent. Two inclined diamond-drill holes were put in from the surface north of the adit to pass beneath the adit, directly below the pyrrhotite showing. One hole, No. 6, inclined at 25° 49′, passed through limestone for 139 feet and then at 45 feet almost directly below the adit encountered 15 feet of mineralization similar to that in the adit, beyond which the hole was entirely in granodiorite. The second hole, from the same setup, inclined at 57° 59′, was entirely in limestone, except for one basic dyke, for its length of 613 feet. It passed 200 feet vertically below the adit. As this hole did not reach the granodiorite, against which the ore occurs in the upper hole and in the adit, it cannot be taken as indicating that the pyrrhotite mineralization does not continue at depth.

For 1,000 feet southwest of the adit, surface work has shown the granodiorite contact to be exceedingly tortuous with one large, irregular tongue protruding northwest into the limestone for 800 feet. The numerous showings of mineralization, most of which are described in the 1929 report, all lie at or very close to the contact of the granodiorite and the most extensive mineralization is found in the narrow bays in the granodiorite on either side of the large tongue. Seven diamond-drill holes have been put down in this vicinity and they indicate that the tongue of granodiorite is in the form of a sheet dipping at 50 degrees or less towards the southwest. The most extensive mineralization on the surface is along the southwest side of the tongue, that is, in the limestone above it. Three drill holes cut this contact below the surface. Hole No. 18, started in limestone 85 feet southwest of the contact and 80 feet due south of one of the best copper zinc showings in this vicinity, encountered the granodiorite at a depth of 100 feet, the hole being vertical. Above the granodiorite was 11 feet of limestone and altered material containing pyrrhotite and chalcopyrite, assays of some of which, taken by the company, contained much more gold than is usually found in the ores on this property. The upper 1·1 feet assayed gold 0·06 ounce, silver 0·34 ounce, copper 0·37 per cent, zinc 1·10 per cent; the next 2·3 feet, gold 2·48 ounces, silver 0·10 ounce, copper 0·29 per cent, and no zinc. Below this, 5 feet of limestone carried nothing but 0·20 per cent copper. Then came 2·4 feet of mineralized material which assayed: gold trace, silver 0·30 ounce, copper 0·31 per cent, and zinc 0·52 per cent, followed by 6 feet of crushed, green, altered material, on top of altered granite, which assayed gold 0·28 ounce, silver a trace, copper a trace, and zinc 1·50 per cent. The second hole, No. 19, also vertical, started 50 feet southwest of a large showing of garnetite and magnetite, a thickness of 17 feet of the latter being exposed and lying practically horizontally upon the garnetite. The hole, commencing 10 feet below the surface, passed through 78 feet of garnetite and magnetite before entering the granodiorite. The magnetite was concentrated in the upper 35 feet. Between depths of 65 feet and 79 feet assays of 0·64 to 1·03 per cent copper were obtained. The third hole was started practically on the limestone-granodiorite contact and inclined at 28 degrees to the southwest. It, also, showed considerable fairly low-grade copper mineralization immediately above the granodiorite.

For 2,000 feet west of this along the contact there is no mineralization of much promise. At the end of this stretch (i.e. 3,000 feet west of the adit in Copper creek), and at an elevation of 2,700 feet, a tongue of granodiorite about 100 feet wide extends northward into the limestone for at least 350 feet from the main body of granodiorite. Immediately west of the tongue and 200 feet north of the main body of granodiorite is the "big showing" of the property. Its surface showing is roughly lenticular, elongated from northwest to southeast, and covers about 3,000 square feet. Several deep trenches have been made in and around it and it has also been explored by five diamond-drill holes. A north-south trench near the west side of the body exposes from 2 to 5 feet of rich chalcopyrite-zinc blende ore lying flat or dipping gently towards the east. The upper and lower contacts against limestone and some green altered limestone are sharply defined but somewhat irregular. The mineralization cuts sharply across the bedding and jointing of the limestone. The bedding at the north end of the trench strikes north 80 degrees east and dips 50 degrees northwards. The ore consists of chalcopyrite, chocolate-coloured zinc blende, and a little pyrite and contains a relatively minor amount of calcite as gangue. A second deep trench at the east side of the showing exposes a maximum vertical thickness of 18 feet of rich copper-zinc ore with, in places, considerable amounts of garnet, epidote, and calcite. In a 5-foot winze at the face, the ore bottoms along an irregular wavy contact with limestone. Along the east side of the trench altered granodiorite and a brown, altered feldspar porphyry are exposed and appear to dip at about 45 degrees north of east or under the ore, the contact between porphyry and overlying limestone being faulted and slickensided. The relation of the porphyry to the granodiorite could not be definitely ascertained, as there is some faulting along their contact also. A third trench at the southeast corner of the showing indicates that the ore terminates abruptly against altered granodiorite.

No. 1 drill hole, inclined at 24° 08′ along a course south 23° 24′ west from a point 100 feet north of the surface showing, passed under the centre of the outcrop at a depth of 120 feet but encountered no ore, continuing in limestone for a total length of 721 feet. Another hole, inclined at 43° 54′ to the southeast, started in ore near the west side of the outcrop but passed into limestone 7·8 feet from the collar and continued in that rock for 354 feet, with the exception of 3·7 feet of altered limestone, containing about 1·5 per cent copper, beginning 63 feet below the collar. A vertical hole 50 feet south of the outcrop encountered no ore. Two vertical holes were started in the granodiorite tongue just southeast of the ore showing. Both passed through the granodiorite and into limestone within 40 feet. One encountered 15 inches of 1·77 per cent copper ore immediately below the granodiorite and, 4 feet lower, 4 feet of mineralization which assayed 0·83 per cent copper. The other hole encountered no mineralization.

There are many other, less important showings on the claims, which need not be described here. The work done indicates clearly that the mineralization has been formed by replacement of limestone at or very close to the contact of the granodiorite. Neither the bedding planes nor jointing and fracturing of the limestone have exerted any apparent control on the mineralization and, consequently, the ore-bodies are of extremely irregular shape. Several thousand tons of high-grade copper or copper-zinc ore could readily be extracted from the present workings, but as yet no very large ore-bodies of commercial grade are indicated. Diamond drilling has provided some very interesting information in regard to the form of the granodiorite intrusion. It appears that the granodiorite is in the form of a fairly flat-lying sheet, underlain at no great depth, at least for several hundred feet back from its contact, by limestone.

SMITH COPPER GROUP

This group of claims was staked in 1929 by G. K. Storey and the late Mr. Smith of Nimpkish lake who did some surface prospecting before Consolidated Mining and Smelting Company optioned the property in the spring of 1930. The company developed the property by numerous open-cuts but dropped their option after about six weeks. The principal showings are on the south side of Smith creek, which flows into the east side of Nimpkish lake about 3 miles north of the south end. A good cabin, near the workings and 1,200 feet above sea-level, is reached by following a trail for about 3 miles from the wharf at the southeast corner of Nimpkish lake.

There are numerous showings of mineralization on the claims, but those that have received development are all within ½ mile of the cabin. In this vicinity the Quatsino limestone, crystalline to dense, and white to light or dark grey in colour, strikes northwest and dips southwest. Individual strikes vary from north 80 degrees west to north 30 degrees west and the dips from 25 degrees to 62 degrees southwest. The limestone is overlain by a series of black, grey, and green argillites, tuffs, and quartzites, with some interbedded, dark grey limestone and a few small flows, and rests upon andesitic and basaltic flows of the Karmutsen volcanics. Within a few hundred feet east of the cabin these rocks are cut off by a large intrusion of grey, medium-grained rock varying in composition from quartz diorite to granodiorite. The intrusive contact is exceedingly tortuous, so much so that though the width of the limestone band is only about 900 feet, the course followed by the contact between the quartz diorite and limestone measures about 3,000 feet. The thickness of the limestone is at least 500 feet. The volcanic and sedimentary rocks are cut by numerous dykes varying in composition from diabase and andesite to grey quartz or feldspar porphyries and felsite. The quartz diorite is cut by aplite dykes and near the contact contains many dark-coloured inclusions.

There are two principal types of mineralization on the property: (1) that which occurs in the limestone or underlying volcanic rocks at or very close to the contact of the quartz diorite, and (2) certain lead-zinc-copper replacement bodies in the limestone.

The first mentioned are typical contact metamorphic deposits. The country rock has been largely or entirely converted to a mixture of silicates including garnet, epidote, pyroxene, actinolite, and chlorite with or without crystalline calcite. The metallic minerals, including pyrrhotite, chalcopyrite, magnetite, pyrite, and zinc blende, are irregularly distributed in this altered zone. By far the most important showings of this type lie in the limestone and have been developed by numerous open-cuts. These indicate that the limestone where cut by the quartz diorite is altered as noted above, with a predominance of garnet, epidote, and pyroxene, across surface widths that vary from almost zero or a few inches to an exceptional maximum of about 75 feet, but that copper is developed sporadically and to only a very minor extent. The most impressive showings are in a large U-shaped bay in the quartz diorite 700 feet south of east from the cabin. There, in a deep cut, labelled 7B by the company, and driven towards but not quite to the intrusive contact, there is 15 feet of heavy pyrrhotite mineralization containing some silicates and foliated magnetite and very little chalcopyrite, and, at the face, abundant barren or very lean silicates. An adjoining cut, just south and east of 7B and slightly higher, exposes the actual contact. The quartz diorite is fine grained and somewhat altered to epidote. At the contact is 1 foot of magnetite with some pyrrhotite and garnet; on the side away from the contact this is bordered by 7 feet of pyrrhotite with some silicates and occasional rich, irregular, small bodies or shoots of chalcopyrite with some zinc blende. Beyond this the silicates continue but contain no appreciable quantity of sulphides. A third cut, 50 feet south of 7B, exposes much silicates, but with, along the north side, only a sparse development of sulphide. No other cut along the contact of the limestone reveals any important quantity of copper. There are, in addition, several small, very irregular developments of zinc blende, accompanied by green and pink manganiferous pyroxene and some quartz, in the limestone within about 100 feet of the intrusive contact.

Immediately north of the limestone, the contact of the quartz diorite and volcanic rocks has been exposed at intervals by open-cuts and by nature for a distance of over 2,000 feet. The volcanics are altered to a mixture of chloritic rock, actinolite, epidote, garnet, quartz, and calcite, the first two minerals being most abundant. Small, irregular bodies of magnetite are present in at least three cuts, and pyrrhotite, accompanied by pyrite or chalcopyrite, is exposed in four. The largest cut, number 12, is 75 feet long and throughout most of its length exposes occasional small amounts of pyrite, pyrrhotite, or chalcopyrite, disseminated in the altered volcanic. At the face there is a small exposure of banded limestone and at its base about 2 feet of magnetite, pyrite, and chalcopyrite. In all probability several of the showings in the volcanic rock are merely altered and mineralized, small fragments or inclusions of flows in the quartz diorite, and as such their extent would be definitely limited.

The second type of mineralization has been opened by five large open-cuts made since the company relinquished its option. These expose an interesting lead-zinc showing north of and below the cabin. The mineralization consists of galena, sphalerite, pyrrhotite, chalcopyrite, and pyrite, with a gangue of epidote, pyroxene (probably a manganiferous hedenbergite, green in colour), garnet, calcite, quartz, and chlorite. It follows the contact of the Quatsino limestone with underlying volcanic rocks which, where exposed, approach basalt in composition but are considerably altered to hornblende, epidote, and other minerals. The mineralization, including silicates, attains a measured width of as much as 34 feet, but the sulphides are almost entirely contained within a definite zone, varying in thickness from 4 to 8 feet, and lying near the top of the silicate zone close to the overlying crystalline limestone. The mineralized section strikes northwest and dips at about 35 degrees to the southwest or into the steep hillside. The 4 to 8-foot thick sulphide zone consists largely of almost solid sulphides. Galena and sphalerite predominate towards the southeast end and chalcopyrite is more abundant towards the northwest where, on the whole, the mineralization is lower grade. The cuts are spaced so that they partly expose a stretch of 170 feet along the ore zone, but in this distance at least four and probably more faults break the ore into a number of blocks. The largest measured displacement on any fault was 14 feet and it is unlikely that any offset is much greater than this. The faults vary in strike from north 8 degrees west to north 40 degrees east and are about vertical. Whether all this faulting is later than the mineralization could not be definitely ascertained, but observations on the best exposed fault, through the two centre cuts, indicated that there had been some pronounced movement since the ore was formed.

There are no outcrops for 75 feet southeast from the most southeasterly open-cut, but at that point 6 feet of altered green rock holding garnet, epidote, chlorite, and a little pyrite, is underlain on the northeast by a 12-inch exposure of medium-grained granodiorite. The southwesterly limit of the alteration is not exposed. A little stripping to the southwest at this point would soon tell whether the mineralization continues this far.

For 200 or 300 feet northwest of the open-cuts there is a heavy drift cover, but beyond, for nearly 500 feet to Smith creek, the contact between limestone and underlying volcanics is exposed at intervals on steep ground. The exposures reveal an irregular development of silicates and pyrite or magnetite, but no mineralization similar to that in the open-cuts. It seems that, within 200 or 300 feet northwest of the open-cuts, then, the mineralization, at the surface, has ceased to be of commercial importance. The following assays, obtained by G. A. Clothier, of samples taken by E. L. Kinman, give some idea of the tenor of the richer ore in the cuts. They are not intended to represent average values. Sample No. 1, from one of the centre cuts, assayed: gold, trace; silver, 1·6 ounces; copper, 0·8 per cent; lead, 20 per cent; zinc, 14·0 per cent. No. 3 taken from a trench towards the southeast end of the workings: gold, trace; silver, 1·6; copper, 2·5 per cent; lead, nil; zinc, 22·0 per cent. No. 2 taken a short distance northwest of No. 1, gave the surprising result of: gold, 7·2 ounces; silver, 11·0 ounces; copper, 3·4 per cent; lead, 15·0 per cent; zinc, 20·0 per cent. Evidently the high gold assay should be regarded with suspicion.

There are numerous other showings of mineral on the original Smith group, but none has received any extensive development. The more important are: magnetite with and without chalcopyrite or bornite on the upper reaches of Smith creek; mineralized float, largely silicate, from the limestone on the steep slopes on the west side of Smith creek opposite the main workings; and some small showings of copper mineralization along or near the contact of the limestone and the overlying sediments and tuffs. Indeed, due to unavoidable circumstances, the claims as a whole have not received as much detailed prospecting as they seem to deserve.

MAGNET GROUP

S. C. Gordon of Alert Bay owns the Magnet group of six claims located a few hundred yards east of Nimpkish lake, a little less than 1 mile southeast of Halfway islands. In the vicinity of the claims the Karmutsen volcanics, dipping gently southwest, are overlain by a fairly thin, flat-lying remnant of the Quatsino limestone. On the southeast these rocks are intruded by a large body of granodiorite which continues southward to the Smith Copper group. Along or near the contact of the granodiorite Mr. Gordon has discovered several showings of magnetite accompanied by garnet and epidote, a little pyrite, and, occasionally, small quantities of chalcopyrite either in the volcanics or in the limestone The only development is one trench, 40 feet long, towards the northern end of the claims. It exposes a low-grade mineralization of magnetite, garnet, epidote, pyrite, and a little pyrrhotite and chalcopyrite in limestone, possibly at the contact with the underlying volcanics. There are a few small exposures of granodiorite about 100 yards east of the cut.

OTHER PROPERTIES

There are several other groups of claims in the vicinity of Nimpkish lake, but none has received any extensive development within the last eighteen months. The *Larson group*, 2 miles northeast of Smith Copper, was staked in 1929 along the contact of granodiorite on the west and Quatsino limestone on the east and is reported to contain showings of bornite and galena. The writer spent some time in the vicinity of the claims but without a guide, and could find neither workings nor any signs of mineralization. On the *Lennie group*, east of Kinmans, neither workings nor mineralization were encountered by the writer. The *Nimpkish claim*, staked by E. L. Kinman in 1928, is on the steep sidehill east of old Camp 7, 6 miles southeast of Nimpkish lake. Development consists of two open-cuts about 1,700 feet above sea-level. The country rock is andesite and andesite tuff with some interbedded limestone. The volcanics are sheared and along this shearing there is an erratic development of magnetite and pyrite accompanied by garnet, epidote, actinolite, and small quantities of chalcopyrite across widths of 4 to 8 feet and less for a length of 30 feet in a northerly direction and in a small showing about 50 feet to the north. No work has been done on the claim within the last two years. There are no recent developments on the old *Klaanch group*, 4 miles south of Nimpkish lake. This property, which contains large magnetite showings, was reported on in 1929.

ECONOMIC POSSIBILITIES

The area between Nimpkish lake and Bonanza lake was prospected by a number of men in 1929, but received little attention in the following year. In 1931 four or five men spent short periods prospecting the area, but, so far as the writer knows, no finds of importance were made. The writer and members of the field party, during the summer, encountered certain signs of mineralization which may be noted now. In the bed of Smith creek, east of the Smith Copper group, at an elevation of 3,000 feet, 3½ miles due east of Nimpkish lake, limestone is exposed for a width of about ¼ mile east and west, dipping from 30 to 45 degrees north 55 degrees east and cut off on the west by granodiorite. In the limestone 200 or 300 yards east of the granodiorite is a zone of garnet and epidote 8 feet wide and striking northwest across the creek. There is little or no sulphide within the zone as exposed in the creek bottom, except that on each side, against the limestone, are small, discontinuous stringers and lenses of chalcopyrite or bornite. Under the microscope small amounts of sphalerite and galena were observed in the richer material. Though the exposure in itself shows nothing of commercial grade and dimensions, the zone might merit a little surface prospecting, as it is pronounced and well defined where exposed in the creek. One mile north of this showing a small stock of granodiorite is exposed on and around the highest peak in the section, at the headwaters of Smith and Larson creeks and creeks flowing to Bonanza lake. Around this body of granodiorite there is the usual abundance of pyritic mineralization in the sediments and volcanics of the Bonanza group. At one place, on the ridge leading down to the northeast from the highest peak, on a steep slope dropping into Larson creek, banded green tuffs, striking north 35 degrees west and dipping 22 degrees to the southwest, are heavily mineralized over an area of about 500 square feet with pyrrhotite, pyrite, and a little chalcopyrite. Nothing like ore of commercial grade was seen unless, as seems improbable, high gold values are associated with the sulphides. The showing indicates, however, that the area surrounding the granodiorite may justify some prospecting by any who could do it without undue expense.

On the slopes east of the north end of Bonanza lake, limestone is intruded by granodiorite and the contact can be followed for nearly 3 miles in a north and south direction. The limestone is also intruded by a few dykes of quartz porphyry. At the south end of the exposed contact the limestone adjoining the granodiorite is extensively altered to garnet, epidote, and a little pyrite, and at the north end, on the slopes about 1 mile north of the lake, in addition to garnetite, considerable pyrrhotite and pyrite were found. No copper minerals were observed. The body of granodiorite is about 2 miles wide and extends south along the east side of Bonanza lake and 4 miles up the east side of the valley draining into the lake from the southeast. No important mineralization was noted around it in the Karmutsen volcanics which it intrudes throughout this distance, but, of course, no attempt was made to prospect the contact.

The only other mineralization noted during the summer was a meagre dissemination of chalcopyrite in some of the basic lavas of the Karmutsen volcanics south of the first west branch of Tsitika river about 6 miles from the main Tsitika and some 11 miles or more from salt water. In this vicinity the volcanic rocks, dipping gently to the northwest, are intruded by a small (?) body of granodiorite, which may have caused the slight mineralization noted. At the end of the season Mr. Dave Ashwood of Alert Bay reported having staked some claims somewhere in the vicinity. Specimens he had taken across widths said to be up to 50 feet consisted of green porphyritic and amygdaloidal rocks, resembling those of the Karmutsen volcanics, much altered to epidote, actinolite, and a carbonate and containing much disseminated chalcopyrite, bornite, and pyrite. If the specimens were representative, the material might average about 2 per cent copper or a little better. The specimens and Mr. Ashwood's description indicated that the showings might be of considerable interest.

Mr. Ashwood's find, and one or two other occurrences encountered during the past three years, prompt mention here of the fact that the volcanic rocks of the Vancouver group may at times be fairly well mineralized with iron and copper sulphides disseminated throughout and yet show little or no evidence of this fact on a weathered surface. In a very moist climate like that of the northern part of Vancouver island, and particularly where the rocks are washed by running water, the sulphides may be entirely leached within a few inches of the surface and all the familiar brown and green or blue stains of iron and copper oxides and carbonates be entirely removed in solution, leaving a seemingly barren, cavity-filled surface resembling amygdaloid. Fortunately this zone of leaching is generally very shallow and an ordinary hand specimen broken from the surface reveals the sulphides below it. It is evident that anyone prospecting these rocks should break off specimens at frequent intervals for examination.

During the summer a trip was made around Woss lake by canoe. The southern part of the lake is surrounded by volcanic rock, including pillow lavas and amygdaloids, and there is some magnificent mountain scenery at the south end. The northern end of the lake is surrounded by comparatively low-lying ground underlain by granodiorite. The streams entering the lake from the east within 2 or 3 miles of the north end carry limestone and granodiorite as well as volcanic float. Outcrops of granodiorite, probably a southerly continuation of the body exposed at and south of Kinman's property, were noted east of the north end of the lake. The writer learns from reliable sources that both limestone and granodiorite are exposed in Nimpkish valley in the vicinity of Vernon lake, 12 miles southeast of Woss lake. It seems probable, therefore, that there may be some ground of interest to the prospector between Vernon lake and the north end of Woss lake. So far as the writer knows this region has never been prospected to any extent.

The limestone of the Quatsino formation that crosses Tsulton river 2 miles southwest of Beaver cove, as well as being apparently very pure at several horizons, contains material suitable for building stone. W. A. Parks,[1] in describing the old quarry near Beaver cove, says " . . . . . large blocks can be procured in places and the marble is of a very desirable variety. On the other hand, the formation is severely jointed for the most part and systematic quarrying could be carried on only at the expense of considerable waste." He describes specimens of white, faintly clouded, and white, blue-lined marble as being of good grade and very desirable. The writer noted some exceptionally attractive mottled grey marbles of fine grain near the base of the formation within 5 or 6 miles south of the old quarry; possibly such varieties extend northward toward Tsulton valley. As Parks mentions, the rock is quite badly jointed in most places and this feature might lead to serious losses in quarrying. South from Tsulton valley for 8 miles there are no major intrusives cutting the limestone, whereas a short distance north of it the limestone is cut off and contorted by a large body of granodiorite. Consequently, the jointing and fracturing may be less extreme to the south of the valley, and indeed this appeared to be so in the outcrops examined by the writer. It is possible that combinations of some of the purer and more argillaceous beds towards the top of the formation might be suitable for Portland cement or other purposes.

[1] "Building Stone of Canada"; vol. 5, Mines Branch, Dept. of Mines, Canada, Pub. No. 452, p. 171.

H.P.H. GROUP, NAHWITTI LAKE, VANCOUVER ISLAND, BRITISH COLUMBIA

By H. C. Gunning

CONTENTS

INTRODUCTION

In June, 1930, Messrs. Meade Hepler, Frank K. Hicklenton, and S. S. Pugh of Hardy Bay discovered lead-zinc mineralization about 2 miles east of Nahwitti lake and staked several claims. Later in the summer the showings were examined by Henry Lee, representing the American Smelting and Refining Company, with the result that an option was taken on the group and development undertaken during the winter. Twenty-eight claims were staked and recorded during the latter part of 1930. Early in the spring of 1931 the company ceased work and relinquished its option. The property then reverted to the original owners and lay idle during the summer of 1931. In September, the writer spent one week examining the claims. The trail to the property commences on the Hardy Bay to Coal Harbour automobile road 1 mile south of Hardy Bay settlement. From there the trail runs 9 miles to the east end of Kains lake where a row-boat is taken for 2½ miles to the west end of the lake. From there it is about 5 miles by trail to the mine buildings. There is a cabin at each end of Kains lake and adequate accommodation at the property for twelve men. The trails are not suitable for packhorses.

Development consists of numerous surface strippings and trenches, two shafts, and an adit 111 feet long. Practically all the work has been done on the H.P.H. Nos. 1 and 2 claims (*See* Figure 4). The showings are on the north slope of a steep ridge that rises 300 feet above the flat valley, to the north, of a large stream that flows west into Nahwitti lake. The valley bottom is a little less than 600 feet by barometer above sea-level. The surrounding district is heavily wooded with cedar, hemlock, and balsam and large areas are low lying and swampy so that outcrops are not, on the whole, abundant. Because of this and the fact that the short time spent in the vicinity was necessarily largely devoted to a study of the mineralized areas, and because no other geological work has ever been done in the vicinity, the following brief remarks on the general geology are of a tentative nature and must be considered as open to revision in the future. The property has been described by Clothier[1] and the writer is indebted to Henry Lee for claim maps and sketches of the workings which were most useful during the examination.

[1] Ann. Rept., Minister of Mines, B.C., 1930, p. 297, and Summary and Review for the six months ending June 30, 1931, p. 15; also Prelim. Rept. for the year 1931, p. 57.

GENERAL GEOLOGY

On the claims massive to banded, grey crystalline limestone outcrops all along the north face of the ridge. The limestone is about 500 feet thick, strikes a little north of west (astronomic), and dips from 35 degrees to 65 degrees to the south. Individual strikes near the principal workings vary from north 84 degrees west to north 64 degrees west. The limestone is considerably jointed, most of the joints being about at right angles to the strike, and in the vicinity of most of the showings it is extensively fractured in a most irregular manner and in places is slightly sheared. There are no outcrops in the flat, swampy valley north of the limestone ridge, but on the north side of the valley several hundred feet north of the limestone, volcanic rocks, including andesite and amygdaloidal flows and andesitic breccias, are exposed. There is also some impure, grey limestone in this section, abundant float being observed, but the rock was not found in place. In all probability the lower contact of the main limestone is near the south side of the drift-covered valley. Near the base of the ridge, along the valley edge, there are a few outcrops of andesite which may be dykes or the upper part of the underlying volcanics. Along and near the top of the ridge, south of the main workings, hard, grey, banded, siliceous, tuffaceous sediments are interbedded with and overlie the limestone, and south of the top of the ridge there is a broad extent of flat, drift-covered ground in which occasional outcrops of andesite, tuffs, and felsite were observed.

Towards the west end of the property, a mile and more from the principal workings, volcanic rocks underlie the limestone and are intruded by much brown and grey, fine-grained feldspar porphyry. The limestone is intruded by a large body of granodiorite and the northerly contact of this intrusive body continues eastward, possibly passing less than 2,500 feet south of the adit. Four thousand five hundred feet east of the adit the granodiorite was again encountered on the south side of the broad drift-covered valley that passes north of the main workings. A thin section of a specimen from this place, in the bed of Granite creek, consists of about 60 per cent andesine, a very small amount of orthoclase, 10 per cent quartz, and about 15 per cent hornblende. Thus, the rock at this place is a normal quartz diorite, but as the exposures of the intrusive are very limited and as the rock varies considerably in appearance where it was observed, some varieties being probably true granodiorite, the mass as a whole will be termed granodiorite.

In the vicinity of the main workings the limestone is cut by several dykes and sills, nowhere observed to be more than 8 feet wide. These consist of fine-grained, light to dark grey diabase, resembling felsite or aplite in appearance and usually containing considerable pyrite or pyrrhotite. The limestone adjoining these intrusives is in places considerably altered and holds small amounts of pyrrhotite and garnet. In a few places, for example, immediately southeast of the powder house, the limestone has been silicified and otherwise altered to a very dense, grey, or mottled brown and grey, hard rock consisting of quartz and variable small amounts of garnet, sericite, chlorite, and apatite, in addition to a little residual calcite. This rock resembles the grey diabase, but seldom contains the abundant disseminated iron sulphide found in that rock.

MINERALIZATION

Mineralization has been found at about twenty-five different places in the limestone within a distance, along its strike, of about 15,000 feet. The most abundant and important type consists of galena and sphalerite in a gangue of black, fine-grained, silicified limestone, or of dark grey limestone. In some places silicification has produced a light grey, crustified or cellular quartz gangue and in others the limestone is distinctly bleached near the ore. In some instances there are present small quantities of pyrite, pyrrhotite, and chalcopyrite. This type of ore varies from siliceous material, the best of which is only of milling grade, to almost pure galena, or galena and sphalerite. Judged by assays given by Clothier, silver values vary from about ½ ounce to about 2 ounces a unit of lead. The bodies have evidently been formed by replacement of the limestone in which they lie and are extremely irregular in outline, varying from small pockets and stringers of no commercial importance to a body exposed for a length of 125 feet and across widths from 1 foot and less to about 12 feet (*See* Figure 4).

Several other types of mineralization are also present. There are several undeveloped exposures of magnetite. On the St. Claire claims at the southwest corner of the group, about 1 mile from the cabins, an extensive development of garnet and epidote with some magnetite, minor pyrrhotite, pyrite, and occasional arsenopyrite, lies against granodiorite. No work has been done at this place. On the Ucan group, 7,000 feet east of the cabins, there is a small showing of zinc blende with a little galena and pyrite in black, silicified limestone, a sample of which Clothier states assayed $8 a ton in gold and 33 per cent zinc. A specimen collected from the same place by the writer assayed: gold, none; silver, 0·47 ounce; lead, none; and silver, 17·77 per cent. This is the only material on the property from which appreciable gold values have been reported.

SHOWINGS ON H.P.H. NOS. 1 AND 2 CLAIMS

The principal showings and all the development of the property are on the H.P.H. Nos. 1 and 2 claims just south of the cabins. Figure 4 shows all the workings except three surface strippings of mineralization lying from 650 to 950 feet east of the adit. Four undeveloped exposures of similar material on the H.P.H. No. 3 claim lie from 1,600 to 2,200 feet west of the adit, and present the extremely irregular outlines typical of all the lead-zinc mineralization encountered on the property. The workings were centred about the large mineralized body under which the adit has been driven. This body consists essentially of galena and sphalerite in a gangue of dark grey limestone and black, silicified limestone with a minor development of pyrrhotite, pyrite, and chalcopyrite in a few places. In places the ore and some of the adjoining limestone are distinctly sheared. Small amounts of a dark green or black silicate, probably approaching knebelite (an iron manganese silicate) in composition, were detected in some of the siliceous ore. In thin sections of siliceous ore from just east of the inclined shaft, actinolite, garnet, and diopside were identified. Cutting across the north part of the collar of the inclined shaft there is a width of 7 feet, north to south, of light green, siliceous material, containing very little sulphide and consisting of garnet, epidote, and minor quartz, feldspar, and calcite.

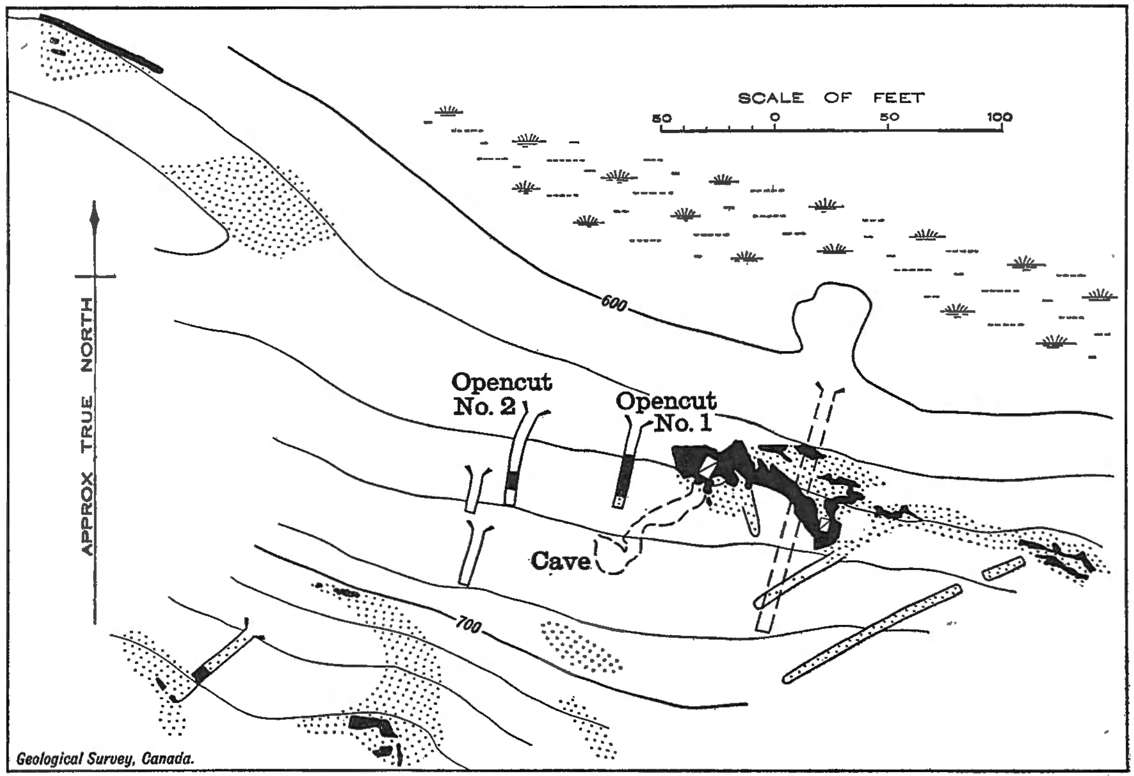


Figure 4. Plan of workings H.P.H. group, Nahwitti lake, Vancouver island, British Columbia. Mineralized areas where exposed shown by solid black; outcrops of limestone by stipple pattern; a few small outcrops of diabase and silicified limestone are not indicated.

It may represent an altered dyke in the limestone. There is good lead-zinc ore both north and south of it on the east side of the shaft, but, towards the west, it apparently increases, taking the place of more desirable lead-zinc ore, for in open-cut 1 immediately south of 8 feet of dark grey diabase the mineralized section consists, from north to south, of the following: 3 feet principally epidote; 6 feet of oxidized material containing magnetite and pyrite; 3 feet of siliceous zinc ore with some epidote; and 8 feet of garnetite with very little sulphide. To the south is grey limestone. In open-cut 2, farther west, the only exposure is 7 feet of oxidized garnetite containing magnetite and pyrite.

The easterly shaft is now partly filled with water and yielded only the information that rich lead ore extends down at least 4 feet on the east side and that galena with zinc blende continues downwards for 8 feet on the west side. Mr. Lee has kindly supplied information on the shaft and his statement is summarized on a later page under "Origin and Form of the Deposits". The westerly shaft is inclined steeply to the south for 12 feet and continued southwesterly for 30 feet as an incline, attaining a depth below the collar of 24 feet. At this point it penetrates a cave in the limestone, about as wide as a small adit and inclined southwest. The cave can be examined for a length of 30 feet. Good mineralization was found in the shaft as far down as the beginning of the incline, beyond which narrow stringers and pockets were encountered along discontinuous joints and fractures. Some fairly small pockets of ore were found lining the walls of the cave.

The adit is 111 feet long and is timbered and sheeted for the first 25 feet. From the end of the timbering it passes through 20 feet of hard, siliceous, grey to green rock containing garnet, epidote, and minor pyrrhotite and pyrite, with an occasional trace of chalcopyrite. The southerly edge of this altered material ends irregularly against grey limestone, dipping from 30 degrees to 45 degrees to the south. From there to the face of the adit is entirely—with one exception—in light to dark grey, fractured and jointed limestone. At 97 feet from the portal 2 to 4 feet of black limestone and silicified limestone containing a fair amount of galena and sphalerite and some quartz were encountered across the back and for about 4 feet down the west wall. They are similar to much of the siliceous lead-zinc ore on the surface and appear to represent the bottom of a body which is probably pitching down to the west at an angle of 30 degrees or less. It seems hardly likely that this body is directly connected with any of the mineralization exposed on the surface. A few shots into the west wall should soon tell whether it is pitching as suggested above or is just a small pocket of ore.

Microscopic examination of polished surfaces of ore from the large surface showing revealed in the galena and sphalerite of some specimens, the presence of small specks of, probably, tetrahedrite, and an unidentified mineral, soft and silver white in colour, which may be dyscrasite (silver antimonide). The largest particles of the latter noted were one-third millimetre in diameter.

ORIGIN AND FORM OF THE DEPOSITS

In all probability the siliceous lead-zinc ores were formed by emanations during or after the intrusion of the granodiorite which outcrops south of the limestone. It also seems probable that there may have been a distinct early phase of mineralization which deposited magnetite, the high temperature silicates including garnet and epidote, and more or less pyrrhotite, pyrite, and chalcopyrite. At all events, the siliceous lead-zinc ores may be safely regarded as of primary igneous origin; their mineral composition points clearly to this conclusion. Granting such an origin, there is reason to hope that at least some of the mineralization exposed on the surface might be fairly persistent beneath, for at least as long as it continues in limestone.

A knowledge of the form and the structural control, if any, of the deposits, is of prime importance to the development of the property. The work done by Mr. Lee, and his personal observations, which have been most generously made available to the writer, shed considerable light on this subject. Probably the first question that should be investigated is—does the fracturing and jointing in the limestone control the mineralization? It is well known that cracks and joints in limestone frequently serve as channels for solutions that replace the limestone and deposit sulphides along or away from the openings. A certain amount of mineralization is found on the H.P.H. group along cracks or joints. But this mineralization is of very minor importance; it has never been found in sufficient quantity to encourage much development along the fractures. Thus, in the inclined shaft and in the cave below it, small streaks or lenses of ore were encountered along irregular and discontinuous fractures, one striking east and dipping 40 degrees south, another dipping 10 degrees to the north of west, a third dipping about 45 degrees to the west, and a fourth striking south 10 degrees east across the northerly part of the cave. In addition there were some small pockets of ore on the west wall of the cave. All these showings were southwest of the main ore near the top of the shaft. Again, the two small pockets of ore in the most southwesterly stripping shown on Figure 4 lie on or against a tight fracture trending north 40 degrees west and dipping 45 degrees southwest, but the greater part of the length of the fracture is barren. Similar occurrences were noted in one or two other places. These showings along fractures or joints are, however, the exception rather than the rule, in spite of the fact that the limestone is extensively jointed and fractured. By far the larger proportion of the showings do not follow along fissures, but are very irregular replacement bodies in the limestone, unreplaced blocks of which are quite common in the ore. Also, as is evident from Figure 4 and equally clear in other exposures on the property, there is a distinct tendency for the mineralized bodies to be elongated approximately east and west, although the principal and most pronounced jointing, while quite complex, trends about north 10 degrees east (astronomic) and dips to the west, almost at right angles to the elongation of the ore-bodies. In other words, the mineralization is elongated *approximately* parallel to the strike of the limestone rather than along joints and at times is poorly banded parallel to this elongation.

Concerning the east shaft, Mr. Lee states[1] that, after about 5 feet of the surface had been blasted off, the shaft was sunk about 18 feet in ore to where a fracture coming in on the east side and dipping west cut off the ore on that side only. About 10 feet deeper, the ore still continuing down the west side, a fracture, dipping east, was encountered on the west side and cut off the ore. These fractures were almost hairline in character and no ore was found below them, but, apparently, they dipped so steeply that they did not intersect above the bottom of the shaft so that about 6 inches of ore remained. Mr. Lee suggested that the 6 inches of ore might be a feeder of the larger ore-body above. A short crosscut to the southwest ran out of ore, thus indicating that the body does not dip south.

The writer noted on the surface examples of where mineralization tended to end against or close to joint planes, but only for very short distances, and in several cases the ore did not end against the plane but merely close to and separated from it by a small but variable thickness of unreplaced limestone. Examples may be seen in the first two strippings east of the easterly shaft. These facts seem to indicate that joint or fracture planes have to some extent tended to *hinder* the movement of mineralizing solutions and to this extent may have exerted some control over mineralization, but the evidence hardly indicates that the "solution" travelled to any important extent along joints or cracks and replaced the adjoining limestone. Figure 4 illustrates quite clearly that the large ore-body does not end abruptly on the east, nor, as far as is known, on the west, against any straight joint or fracture. Rather does the ore constitute a wandering, very irregular body, containing unreplaced remnants of limestone and sending out irregular tongues or fingers into the adjoining limestone, in many cases regardless of pre-existing cracks, joints, or fractures, but in some cases following such channels for short distances or terminating against them. In several cases, for example at the collar of the east shaft, a distinct fracture has ore on both sides for several feet, but continues into unaltered limestone away from the main mineralization, the edge of the ore cutting directly across it. These facts do not indicate any very definite structural control over the mineralization as a whole; rather does it seem that the body may, like its surface expression, wander through the limestone, following a course that to a very minor extent and in a very variable manner was guided by pre-existing features of the limestone such as bedding, composition, cracks, joints, and fractures.

As regards the form of the large body represented in Figure 4, the surface work and the two shafts indicate quite clearly that it is not a flat-lying, tabular body and that it does not dip at a low angle towards the south or southwest. The shafts and the adit also show that it does not dip steeply either north or south. That part directly above the adit must bottom before it reaches the depth of the adit unless it connects with the small ore showing near the face of the adit, which seems rather improbable. The east shaft indicates that, commercially at least, the ore ends within 25 or 30 feet of the surface. From the known facts it is reasonable to conclude that the body is probably an isolated, roughly lenticular mass in the limestone and that it has no great continuity in any direction beyond its surface outcrop. The writer is ready to admit that

[1] Personal communication.

such may be the case. It is difficult, however, to understand how such an isolated mass could form and one wonders whether there is not some feeder or continuation of the deposit that might be of commercial importance. It is interesting at this point to consider a certain type of lead-zinc deposit in limestone which may have some bearing on the problem.

The type is illustrated in Figure 5 adapted from an illustration of certain silver-lead-zinc deposits in the Mesozoic limestone of Mexico so excellently described by Prescott.[1] Deposits of somewhat similar form have been described at Tintic, Utah[2], and elsewhere.

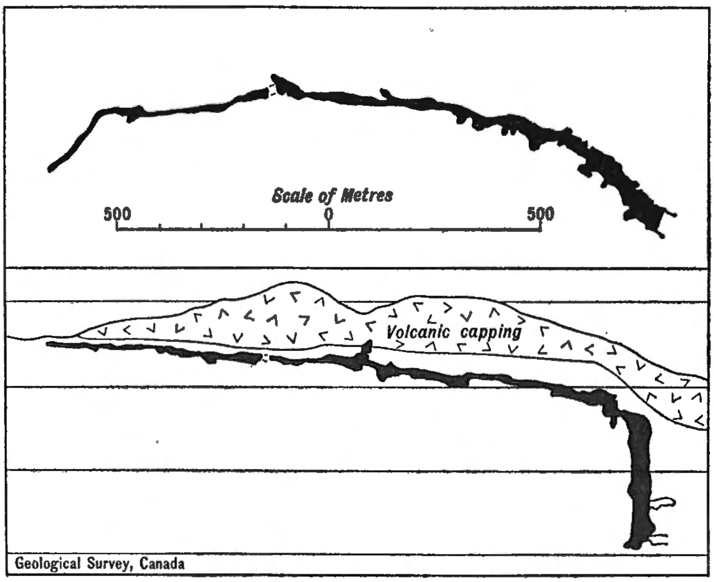


Figure 5. Plan and longitudinal section showing manto and chimney of ore (solid black) in limestone, Santa Eulalia, Mexico. (Adapted after Basil Prescott.)

Prescott's articles are particularly instructive and are well worth the attention of those interested in the development of lead-zinc deposits in limestone. Much of the ore described by Prescott is in the form of flat-lying or gently inclined, conduit-shaped, or worm-like bodies of considerable longitudinal extent, although of relatively small cross-section. Mantos they are called in Mexico. Many of these gently inclined bodies have been proved to have their source in vertical or steeply inclined chimneys, as the figure indicates. It is interesting to note that Prescott, in an early paper,[3] described the Santa Eulalia deposits as being largely controlled by pre-mineral fissures and presented a detailed classification of the fissuring and the mineralization found along each class of fissure. In his second article, published eleven years later, more extensive study and the results

[1] Prescott, Basil: Eng. and Min. Jour., vol. 122, pp. 246 and 289 (1926).
[2] Lindgren, W., Loughlin, G. F., and Heikes, V. C.: U.S. Geol. Surv., Prof. Paper 107, 1919.
[3] Trans. Am. Inst. Min. Eng., vol. 51, p. 57 (1915).

of development work have compelled him to change his views and he concludes, among other things, that "between the point at which the deposits start in depth and the finishing point at the surface, or where the mineralizer enters unfavourable overlying formations, the course of a single ore-body will be controlled by any one, any combination, or all of the following factors: *(a)* selective action of certain limestone, *(b)* variation in composition of the sedimentaries, *(c)* structure of the limestone, *(d)* posture of beds, *(e)* pre-mineral fissures." Later he states, "The rôle the fissures play in these deposits has been greatly over-emphasized. In most cases, though not in all, they have a very minor part in the primary deposition." One of the most important conclusions that Prescott arrives at for the deposits of the Mexican province is that "The ore-bodies are continuous from the point of entrance into the favourable limestones at depth, to the surface, to the point of egress from the favourable beds, or until they *gradually* become extremely attenuated." The present writer has italicized the word gradually as it seems that a realization of this gradual decrease in area of cross-section of an ore-body away from its source is of extreme importance during development of the deposits to which Prescott refers. Prescott emphasizes this point as follows: "An ore-body has not been followed to its commercial limits away from the source if, where last known, it is still in favourable limestone and has a strong cross-section; its end will be approached through a gradual diminution in size and strength." It should be clearly understood that neither Prescott nor the present writer are in any way attempting to discredit the well-known importance of structural control by joints, fissures, bedding, etc., in replacement deposits in limestone. But where the control is not readily apparent or where it becomes so apparently complex as to be practically unsolvable, some or all of the factors described by Prescott may well apply. These suggestions are now advanced in the hope that they may apply to and assist in the development of some lead-zinc replacement deposits in limestone, either on Vancouver island or elsewhere in British Columbia. As a matter of fact one deposit, on the Alice Lake group near Jeune landing on Quatsino sound, is being developed along lines suggested by Prescott's articles by Mr. Clancy, one of the owners, and the results so far are quite encouraging. Primary development there by stripping, deep open-cutting, and crosscutting at depth was as disappointing as that at the H.P.H. group. Later drifting along the ore has proved an interesting but as yet fairly small ore-body.

Returning to the H.P.H., group, it is admitted that the surface showings, including the large body above the adit, may be only parts of more or less isolated bodies, of no great continuity. There is no proof, however, that some of them may not be pipe-like or "manto" deposits somewhat similar to those described by Prescott. The two shafts and the adit produced disappointing results, as they indicate that there is no great tonnage of ore *below* the surface outcrop. They do, not however, tell us anything about the longitudinal extent of the body, which might, as far as the development is concerned, continue a considerable distance towards the west, for example, if it be considered as pipe-shaped or "manto"-like and inclined down into the limestone towards the west end of the surface showing. As mentioned above, the exposure near the face of the adit suggests the possibility that this body pitches or inclines down to the west at a fairly low angle, although some further work there is necessary before much reliance can be placed on this evidence. It should also be remembered that in the case of "manto"-like deposits like those described, the possibility of any great tonnage depends, because of their generally rather limited area of cross-section, on their having rather great longitudinal extents and on their connecting with a more steeply inclined ore "chimney" of commercial dimensions. The deposit on the H.P.H. group due to present depressed metal prices and its inaccessibility, including the almost total absence of any transportation facilities, must present distinct possibilities of a considerable tonnage of ore before it becomes very attractive commercially. As the property now stands this possibility is not very evident.

PART OF CADWALLADER CREEK GOLD MINING AREA, BRIDGE RIVER DISTRICT, BRITISH COLUMBIA

By W. E. Cockfield

CONTENTS

Illustration

INTRODUCTION

Towards the close of the 1931 field season a short time was devoted to a study of the augite-diorite stock in the vicinity of the Lorne mine on Cadwallader creek, Bridge River area. This area has recently become the leading gold producer of the province, owing to the production of one mine, the Pioneer, and considerable attention is being given to other properties in the district. The area has been described by Camsell,[1] Drysdale,[2] and McCann,[3] and is also described in the annual reports of the British Columbia Minister of Mines. The most recent geological map of the area, made by McCann in 1919 and 1920, outlines the position of the Cadwallader Creek augite diorite and the accompanying report stresses its importance in relation to the occurrence of gold-quartz veins. As much of the area underlain by the augite diorite is covered with drift and as underground work at that time was very limited, certain conclusions which were reached with respect to the augite diorite and the veins have been shown by more recent mining development to be open to question. The writer was, consequently, instructed to visit the area and revise the mapping of the augite diorite in the vicinity of the Lorne mine. Messrs. N. McKechnie, H. Sargent, and H. K. Long assisted in the necessary mapping, and thanks are due also to the management of the Bralorne Mines, Limited, who placed every facility necessary for the progress of the work at the disposal of the writer. Acknowledgments are also due to the management of the Pioneer mine for opportunity to visit the property and compare the deposit with that of the Lorne, although time did not permit of making a detailed study of the deposit.

The Cadwallader Creek gold belt is situated along Cadwallader creek, a tributary to the south fork of Bridge river. It is reached by road from Bridge River or Shalalth stations on the Pacific Great Eastern railway, the distance being 55 to 57 miles. The entire trip can be made by automobile, and stages regularly connect with the trains.

[1] Camsell, C.: Geol. Surv., Canada, Sum. Rept. 1911, pp. 111-115.
[2] Drysdale, C. W.: Geol. Surv., Canada, Sum. Rept. 1915, pp. 75-85; Geol. Surv., Canada, Sum. Rept. 1916, pp. 45-53.
[3] McCann, W. S.: "Geology and Mineral Deposits of the Bridge River Map-area, British Columbia"; Geol. Surv., Canada, Mem. 130 (1922).

GENERAL GEOLOGY

Bridge River area lies on the eastern flank of the Coast range, in the transition belt between the Coast mountains and the plateaux of the central interior system. Taken as a whole the region is rugged with a relief of from 6,000 to 7,000 feet.

The rocks of the district have been described by McCann,[1] from whose report the following information relating to the formations occurring in Cadwallader Creek area has been taken. For further details the reader is referred to the original report.

The oldest rocks in Cadwallader Creek area belong to the Bridge River series and occur in the southeast corner of the area mapped during the course of this investigation (*See* Figure 6). The Bridge River series, according to McCann, is composed of metamorphosed sedimentary rocks with interbedded volcanic rocks. The chief sedimentary member of the series is a bluish grey chert that grades into a banded, cherty quartzite in which the bands, one-half inch or more thick, are separated by thin layers of argillite. The cherty quartzite is very fine grained, almost like hornstone, and ranges in colour from black to nearly white. The series also includes thin-bedded, dark, argillaceous strata, highly siliceous in places, with a tendency to pass into chert. A red-weathering, arenaceous member occurs in places and a number of lenses of crystalline limestone occur throughout the area of the Bridge River series. The volcanic rocks included in the series are almost entirely dense, altered, dark basalts grading into andesites.

No fossils have been found in the Bridge River series, but, on the basis of lithological and structural similarities, McCann correlated the strata with the Cache Creek series considered by him to be Pennsylvanian to Permian in age.

According to McCann the rocks next in age to the Bridge River series are a group of serpentine rocks which have apparently two different phases, a porphyritic phase and a dense phase. The former appears to have been derived from such rocks as olivine gabbro porphyry or the porphyritic equivalent of a peridotite. These rocks when weathered are greyish brown with the more resistant pyroxene phenocrysts standing out in relief. The freshly broken surface, however, is dull bluish black. The dense serpentine rocks are more altered than the porphyritic, and were probably originally olivine basalts. The weathered surfaces are reddish brown to brownish yellow, except where the rocks have been crushed, in which cases the rock has been minutely sheared, the slip planes being covered with fine films of serpentine, which gives to the rock a greasy feel.

With regard to age, McCann concludes that the serpentine rocks were extruded over the eroded surface of the Bridge River series before the rocks of the Cadwallader series were deposited. He points to the possibility, however, of the intrusion of the serpentine rocks as sills along the contact of the Bridge River series and the later formations, which would make the serpentines later than the Cadwallader series. In Cadwallader Creek area, the disposition of the serpentine mass in the vicinity of Coronation mine (*See* Figure 6) is such as to make it appear as if the serpentine

[1] McCann, W. S.: Op. cit., pp. 19-44.

body projected into the Cadwallader series, but as outcrops in this vicinity are very few it cannot be definitely asserted that such is the case. Similarly in the case of the serpentine rocks represented as lying in the Cadwallader series near the edge of the diorite stock, the lack of outcrops prohibits the making of definite assertions, and it might be held that this body of serpentine occurred along the augite diorite contact and not as an intrusive into the Cadwallader series.

The rocks of the Cadwallader series consist of conglomerate, sandstone, and shales, with subordinate, thinly bedded limestone and dolomite, and, in the lower part of the series, great thicknesses of greenstones. The pebbles of the conglomerate vary in size from $\frac{1}{4}$ inch to 4 inches, and are principally quartzite, but some are limestone and others are serpentine. The conglomerates are succeeded upwards by shale. Fossils collected by McCann from the upper part of the series indicate that the Cadwallader series is referable to the Upper Triassic.

The augite diorite is the chief country rock of the gold-quartz veins of the area. It ranges from dark greenish grey to black and from fine to coarse in grain. The lighter-coloured varieties are finer grained than the darker, and the latter owe their colour to large crystals of hornblende and chlorite. Microscopic examination showed that the rocks in general are made up of hornblende, augite, plagioclase, orthoclase, and quartz, with chlorite, secondary hornblende, kaolin, zoisite, sericite, and calcite as the alteration products. Accessory constituents include apatite, titanite, and iron oxide. Some fine-grained varieties were observed lacking augite.

McCann deduces that the augite diorite is older than the Bendor quartz diorite and younger than the Cadwallader series, and from this reasoning places it in the Upper Jurassic, corresponding with the period of intrusion of the Coast Range batholith.

The accompanying figure shows the surface outline of the diorite body in the vicinity of the Lorne mine, deduced from the data available. Every effort was made to map all significant outcrops and each claim was, therefore, gone over thoroughly by means of instrumental surveys tied to the corner posts of the claims. This material was supplemented by the geological data obtained from the underground workings. Short visits were also paid to properties lying outside the mapped area to obtain additional data on the diorite body.

The data now available make it appear that the diorite does not form a long, dyke-like body as supposed by McCann, but, instead, a series of disconnected, elongated stocks, arranged probably *en échelon*. The shapes of two of these stocks and the way they are offset to the right with respect to one another are shown by the accompanying figure and it seems probable that a similar arrangement holds true southeast of the Pioneer mine. This offsetting to the right is also a characteristic of the post-mineral faulting developed near the veins and the question as to whether this offsetting of the bodies of diorite is the result of faulting becomes of some importance.

The augite diorite near its contacts with the enclosing rocks is in many cases fine grained and contains numerous inclusions of the rocks into which it has been injected. These inclusions may be noted in the underground workings of the Pioneer mine, the Lorne mine, and in a

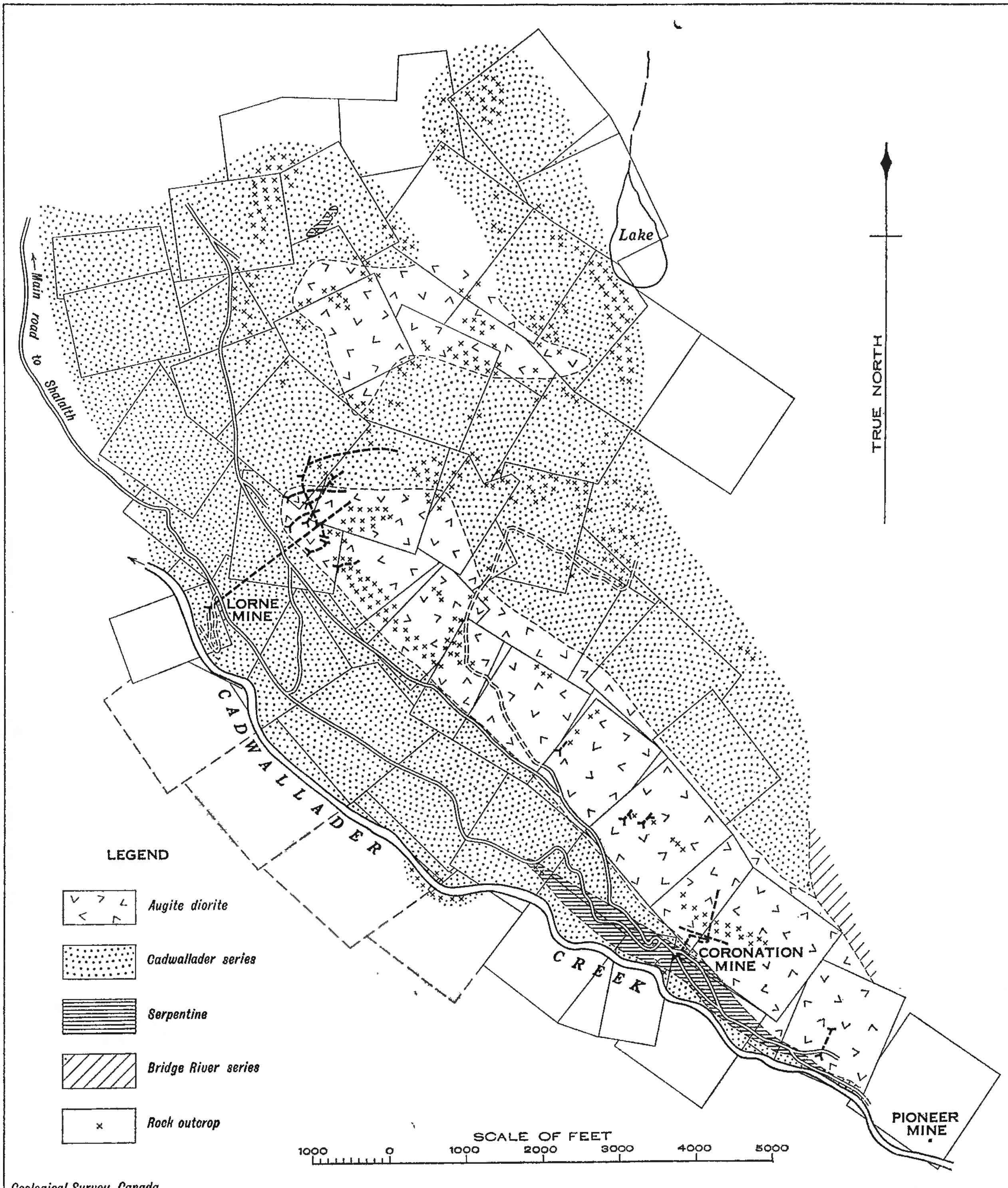


Figure 6. Part of Cadwallader Creek gold mining area, Lillooet district, British Columbia.

number of the surface outcrops. At the northern end of the large stock on which are situated the Lorne and Pioneer mines, the contact was examined with extreme care to see if the arrangement of the two bodies of diorite was the result of faulting. The workings of the Lorne mine cross the contact at a number of places. The gradational character of the contact and the inclusions of argillite in the diorite indicate an intrusive and not a faulted contact. The conclusion reached is that the *échelon* arrangement of the bodies of augite diorite is not the result of faulting, but rather that the bodies are the apexes of a single stock of diorite that has been partly unroofed.

The slopes of the contact between the augite diorite and its enclosing rocks apparently vary from place to place. At the Pioneer mine the slope at the intersection of the vein with the contact between the serpentine and diorite has an inclination of roughly 30 degrees from the horizontal. At the Lorne mine the relative position of the contact on, respectively, the upper and the lower levels, indicates a slope of approximately 60 degrees. At other points, though the data are not so exact, the indicated slope is somewhat steeper. It may, however, be assumed that, in so far as its western contact is concerned, the diorite shows a large increase in area with depth. There are no data with regard to the eastern contact.

North of the Lorne mine the main stock is cut off entirely by the Cadwallader series, as is shown in the accompanying figure (Figure 6). A second area offset to the right occurs, and some uncertainty exists as to whether this connects with the diorite occurring farther north in the vicinity of the Jewess (California) or whether the areas are separated. No outcrops that would prove this point could be found in the critical area.

Associated with the augite diorite are a number of fine-grained porphyritic dykes (albitite porphyry). These in many places are closely associated with the gold-quartz veins; in some cases occupying the same fissure. These rocks are light grey, brown, or red. They are usually fine grained, with phenocrysts of feldspar and occasionally of quartz. Microscopic examination has shown them to be made up largely of albite, in small interlocking grains penetrated by small crystals of sericite.

Dykes of diabase also occur in the rocks surrounding the augite diorite. These are reported to be common in the vicinity of the Wayside mine and a few were seen around the margins of the smaller augite diorite stock shown in the accompanying figure.

Pleistocene and Recent unconsolidated deposits, including glacial and stream deposits, cover a large part of the area, so that bedrock outcrops are relatively scarce.

ECONOMIC GEOLOGY

THE VEIN SYSTEMS

McCann described two vein systems, one having a general northeast-southwest direction and the other northwest-southeast; the latter, consequently, strikes in the general direction of the augite diorite stock, and McCann referred to this as the "Parallel" system; the other he called the "Transverse" system. This latter was based entirely on occurrences in the vicinity of the Lorne mine and when it was supposed the diorite body continued far northward. But now that it is known that the diorite body ends in this vicinity and that its contact swings to an easterly course, a new significance is given to the local group of veins, the so-called "Transverse" system, for these now are known to parallel a nearby contact. The veins of this particular stock are, in a general way, parallel to its margin, and thus all the veins may be considered as belonging to a single system which is marginal. On examing the veins in detail, however, it will be found that they make an acute angle with the line of contact of the augite diorite with its enclosing rocks; in other words, the fissuring that developed after the intrusion and solidification of the augite diorite is not precisely parallel to the margin of the diorite body but is, in some instances at least, inclined across it at small angles.

The main veins discovered and developed to date are confined to the augite diorite. In exceptional cases veins have been found outside the diorite and in the case of one of these, the "Shaft" vein of the Lorne mine, some exceedingly rich ore has been found in it. It is believed that the main veins are located in the diorite because it is a brittle, homogeneous rock favourable to the development of fissures and that in the weaker, less competent rocks that surround the diorite the forces tending to cause fissuring were more or less absorbed by rock flowage.

Veins that show ribbon structure, due to alternations of bands of quartz with seams of gouge and sulphides, are in general of higher grade than those of a more massive character. In many places stringers pass into the walls, forming acute angles with the main veins. The intersection of these stringers with the main vein is in places the location of extremely high-grade shoots.

The Veins

The veins are of quartz containing minor amounts of sulphides, telluride, and free gold. Most of the veins are quite narrow. They range from seams to veins 12 feet thick, but thicknesses of over 3 to 3½ feet are quite exceptional and by far the greater number of the veins developed to date average under rather than over 3 feet thick. This, to some extent, is compensated by the persistence in length which is a marked feature of those veins that have been proved by development to date. Lengths of from 800 to 2,000 feet have been proved on some of the veins.

The main metallic minerals are gold, arsenopyrite, pyrite, chalcopyrite, galena, sphalerite, stibnite, tetrahedrite, and a telluride, sylvanite or possible calaverite. The gold apparently occurs distributed in the quartz, but locally it is concentrated into shoots of ore in which the particles of gold are readily visible to the naked eye. Spectacular values have been reported from points in both the Lorne and Pioneer mines.

Arsenopyrite is common both in the quartz veins and in the altered wall-rock of the veins. It is usually quite abundant in the thin, black seams that give the quartz its ribbon structure, and which are partly gouge and partly sulphides.

Pyrite is the most abundant metallic mineral in the veins and in the altered wall-rock.

Chalcopyrite is rare; galena and sphalerite occur only sparingly.

Stibnite and tetrahedrite are reported by McCann, the former from the Ida May and Coronation mines, and the latter from the Wedge vein of the Lorne mine and on the Forty Thieves claim.

Tellurides were noted in small quantities in polished sections made from specimens of high-grade ore from the Lorne mine, but exact identification of the mineral could not be made. McCann reports tellurides from the Ida May and Shaft veins of the Lorne mine. An analysis of the mineral showed that it was apparently sylvanite, but it seemed to carry more silver than would be expected in that mineral.

The gangue minerals include quartz, calcite, sericite, siderite, dolomite, and mariposite. Quartz is by far the predominant gangue mineral and is in nearly all cases white. In some veins it is massive, whereas in others a pronounced ribbon structure is present.

Calcite is not very common in the veins, but is found in some and also in stringers in the altered wall-rocks.

Sericite occurs in the partings of the ribboned quartz and also in the altered wall-rock. Siderite and dolomite are reported by McCann from some localities.

Mariposite (chrome mica) is found sparingly in a number of the veins, but only locally is it abundant. It was noted in the underground workings of both the Lorne and Pioneer mines and, according to information received, usually accompanies high-grade ore. The identification of this mineral was verified by Mr. E. Poitevin of the Mineralogical Division, Geological Survey, Canada.

As will be seen from the descriptions of the properties given on later pages, there is a definite concentration of ore into shoots, with low-grade material lying between the shoots. The factors governing the occurrences of the shoots have not been ascertained. In the Pioneer mine, on the lower levels, there are, apparently, two main shoots separated by a low-grade part of the vein, and it might appear, where the vein fissure crosses from the augite diorite into the serpentine, that in the softer rock the fissure did not remain open but was filled with a more or less impervious gouge which acted as a dam to the mineral solutions and thus caused the formation of the ore-shoot back of the dam. Though this explanation might conceivably apply to the Pioneer ore-body as a whole, it would not explain the splitting of the ore-body into two main shoots, as the low-grade portion occurs in the middle part of the vein, with an ore-shoot near the diorite-serpentine contact and a second shoot at the end of the vein away from the contact. A further complication is that a wedge of ore occurs in the central part of the lean vein on the lowest level and might be considered as the apex of a third shoot. Locally at least, there can be little doubt that there are small enrichments at the intersection of stringers or branch veins with the main veins, but the main shoots of ore in the Pioneer and on the King vein of the Lorne do not appear to be accounted for by these causes. On the other hand, a small shoot of extremely high-grade ore in the shaft vein of the Lorne occurs at such an intersection. It is, therefore, probable that no single reason accounts for all the ore-shoots of the area.

Post-Mineral Faulting

The veins are repeatedly faulted, but in most cases the horizontal displacement of such faults is not large. In most cases the displacement measures from 2 to 4 feet, the maximum measured displacement being 10 feet. No faults with large displacement were noted. In the Lorne mine there are several strong post-mineral faults, but work had not progressed to the stage where the displacement could actually be measured. The southwesterly extension of the King vein is cut off by a fault which apparently also shows in the adit tunnel, and the vein has not been found beyond the fault.

DESCRIPTIONS OF PROPERTIES

As the time available for this investigation was limited and was largely taken up in an attempt to delimit the boundaries of the augite diorite mass in this vicinity, only the salient points with regard to the properties visited will be given. For more detailed information the reader is referred to the annual reports of the British Columbia Minister of Mines and to McCann's report on the area.

Pioneer Mine

This property is situated towards what McCann shows as the southeastern end of the main augite diorite stock. Farther to the southeast, however, this, or another body of the same rock, appears, but time did not permit the working out of the surface geology in the detail necessary to limit the probable surface outlines of the diorite in this vicinity, and only a brief examination of the property itself could be made.

This property has been the chief producer of Bridge River area, and from a small beginning the operation has grown in magnitude until the Pioneer mine has assumed first place amongst the gold producers of the province, and gives promise of being an important producer for some time to come.

The vein is located near the southwestern contact of the augite diorite with serpentine, and from the number of inclusions contained in the diorite, the vein appears to be located in the contact zone of this rock. Both the vein and the contact have a northwesterly trend, but the vein is inclined across the contact at a low angle. The trend of the contact is here about north 55 degrees west, whereas the strike of the vein is north 75 degrees west and towards its western end it assumes a strike of nearly due west. The dip of the vein is steep, being generally about 75 degrees to the north or northeast, but locally it flattens or rolls and in a few cases it assumes an overturned attitude, having a southerly dip.

The vein is of quartz with strong ribbon structure. Sulphides occur along the dark bands and to a lesser extent in the massive quartz. Arsenopyrite, pyrite, and galena are present. Mariposite (chrome mica) occurs locally, in some cases accompanies the best ore, and appears to be of increasing importance west of the shaft, toward the serpentine contact. A small quantity of nickel is reported from the cyanide precipitates, but no nickel-bearing mineral has as yet been identified in the ore. Free gold occurs in the quartz. The vein varies from a seam to 8 feet in thickness and from a few cents to several hundred dollars a ton in value. The average tenor of the ore appears to be increasing with depth; the value of the mill-heads at the time of examination was about $22 a ton.

The length of the vein and also of the ore is increasing with depth. The vein at the western end of the workings terminates in a seam in the serpentine and, owing to the dip of the vein and of the diorite-serpentine contact, the intersection of the vein with this contact has a pitch to the west of about 30 degrees. At the eastern end the vein narrows down and terminates on several levels against a fault, although on other levels it has been picked up beyond. The eastern end of the vein as so far developed has a steep pitch to the east, consequently the vein has a considerably greater length on each successive level downward. This increase in length is nearly 250 feet a level that is, for each 125 feet vertical depth on the vein. Thus the vein on the sixth level has been developed for slightly over 1,300 feet and on the eighth level for slightly over 1,800 feet. Above the fifth level the pitch of the contact is steeper and the increase in length not so noticeable. On the ninth level the vein has been developed for nearly 1,300 feet with approximately 700 feet to go before reaching the calculated position of the diorite-serpentine contact. The western part of the ore-body below the fifth level shows also greater widths than the average of the body as a whole. With the increase of the length of the vein on successive levels there has been no dropping off in values; in fact the ore on the eighth level shows a higher assay value than the calculated averages of higher levels. The average width of the ore is probably close to 3 feet.

The ore below the fifth level is split into two definite shoots by a narrow, lean portion, but on the eighth and ninth levels part of this zone is pay ore. One shoot follows down the pitch of the serpentine-diorite contact, and the other is towards the eastern end of the vein, leaving part of the central portion lean.

Many stringers or branches intersect the vein at low angles, and in the vicinity of these intersections the ore is in many cases not only rich, but wide. These branches in general have not been explored in the lower levels of the mine; the common experience with them in the district is that they peter out within a short distance, but in some instances they have been followed for several hundred feet.

Cross faults are common, but in many cases the horizontal displacement is scarcely more than the width of the vein. In a few instances displacements up to 8 or 10 feet were noted, but no faults with large horizontal displacement were seen.

The western end of the vein terminates against the serpentine contact where the vein narrows to a thin seam. The serpentine forms a rock that is unfavourable for ore deposition for the reason that it does not fracture readily and the gouge formed along a fracture would tend to form a barrier or dam to the ore solutions. It is not known whether the forces that caused the fissure were taken up in the serpentine or whether the fissure continues in the Cadwallader rocks beyond. Though the augite diorite contains nearly all the important deposits of the camp, it should be remembered that the shaft vein of the Lorne mine occurs in the Cadwallader rocks and extremely rich, though small, shoots of ore occur in it. At this point, however, so far as is known, no serpentine occurs between the diorite and the rocks of the Cadwallader series. The question as to whether the Pioneer vein might be expected to cross the serpentine belt and to strengthen again in the rocks of the Cadwallader series must remain unanswered, but in view of the occurrence of the serpentine at this point, and the probability of it forming an impervious barrier to the ore-bearing solutions, it is considered unlikely that ore-shoots would occur beyond the serpentine.

The present development of the Pioneer includes the sinking of a new vertical shaft to a depth of 1,000 feet below the ninth level and the raising of this shaft to the surface. The mill capacity is being increased from 100 to 300 tons daily and, consequently, a substantial increase in the gold production of the property may be anticipated. From the facts that have been ascertained by development to date there is every reason to expect that the ore-body will continue to considerable depths, and this view is strengthened by the striking similarity of this and other ore-bodies of the area and those of Grass Valley, California, where mining has been carried to great depths. All told the future of the Pioneer mine seems a bright one.

Bralorne Mines, Limited

This company is a reorganization of the Lorne Gold Mines, Limited, by which additional capital has been furnished by the Bralco Investment Company in order to develop and equip the property. The holdings of the company comprise some forty-seven claims and fractions and include the old Lorne, Coronation, Blackbird, Ida May, Hiram, and Copeland claims. The claims owned by the Bralorne Mines, Limited, stretch northwestward from the Pioneer ground for about 14,000 feet and cover a large part of the surface area of the augite diorite stock over that distance. The work at present being done is confined to the former Lorne mine, but there are also interesting possibilities at other points on the holdings of the company, notably the Coronation and Ida May properties. Present development is being devoted to putting the Lorne property in shape to produce ore to feed the mill that is under construction, and it is, consequently, expected that early in 1932, the property will be producing, at least sufficient to carry future development work forward.

The principal veins on the former Lorne property are the King, Shaft, Wedge, Woodchuck, and Alhambra. Of these the King vein has to date proved to be by far the most important. The upper workings on these veins have been described by McCann,[1] and there is no necessity of repeating that description here. In 1928 and 1929 Lorne Gold Mines, Limited, carried on an extensive campaign of development, not only on the Lorne property but also on the Ida May and Coronation groups. This work has been described by Nichols.[2]

A long adit roughly parallel to the strike of the veins was driven into the hill from a point near Cadwallader creek, at an elevation of 3,400 feet. As the upper workings lie above an elevation of 4,000 feet, this adit was planned to tap the veins at a considerable depth below the points to which they had been previously developed. From a point 1,784 feet in from the portal of the adit, a crosscut was driven northerly for some 1,200 feet,

[1] McCann, W. S.: Op. cit., pp. 86-89.
[2] Nichols, H. G.: Ann. Rept., B.C. Minister of Mines, 1928, pp. 216-218; 1929, pp. 231-233.

intersecting, in turn, veins which have been correlated with the King, Wedge, and Shaft veins. Each of these veins has been drifted on from the crosscut. A southerly crosscut from the adit tapped a vein correlated with the Alhambra vein at a distance of 230 feet from the adit, and this vein was drifted on for 150 feet. Several other veins and stringers were encountered in the underground workings, but these have not been drifted on. The workings to date have encountered no vein that can be correlated definitely with the Woodchuck vein, which outcrops above. A raise is being put up from this level on the King vein to connect with the King No. 4 tunnel 600 feet above, and from this raise two exploratory sub-levels have been driven on the vein.

The King vein was drifted on for 150 feet to the west of the crosscut and for approximately 900 feet east of the crosscut. In the west drift it is cut off by a fault, which can also be seen in the adit tunnel, and a small amount of crosscutting in the fault zone has not yet resulted in the discovery of the vein beyond the fault. The drifting on the King vein has resulted in the discovery of an ore-shoot 285 feet long and 28 inches thick, with an average value of over $20 a ton, as well as several subsidiary shoots. The King vein as a whole varies from 6 inches to 30 inches in thickness and dips at 62 degrees northwesterly. It has a well-marked ribbon structure and carries arsenopyrite, pyrite, galena, and free gold. Mariposite is abundant in places and was noted to be more common on sub-level B than in the other workings. Development work now in progress on the King vein, in addition to the raise noted, consists of sinking a shaft from the 3,400-foot level.

The vein correlated with the Wedge was encountered in the northern crosscut about 740 feet from the adit and was drifted on both sides of the crosscut for a total of 160 feet. Where encountered by the crosscut it had a width of 14 to 15 inches, and, it is reported, carried good values, but in the drifting done it varies from an inch or two to a foot in thickness and the values are reported to be disappointing.

The vein correlated with the Shaft vein was encountered in the crosscut at 886 feet from the adit and has been drifted on to the east of the crosscut for a distance of 1,200 feet, with minor crosscuts and a raise. It varies in thickness from a stringer to 14 or 15 inches at the raise, and shows pronounced ribbon structure; no large ore-shoot was found in the distance drifted, but several small shoots of ore were discovered, some of them carrying very high values. At one point, some 340 feet from the crosscut, spectacular values in gold were obtained. Tellurides were detected in polished specimens of the ore, in addition to arsenopyrite and pyrite. A large part of the Shaft vein drift lies in the sediments of the Cadwallader series. The vein is inclined at 70 degrees to the northwest, and it is estimated that in this vicinity the diorite-Cadwallader series contact has a somewhat flatter pitch to the west, probably not exceeding 60 degrees, and if these relative attitudes are maintained on lower workings the Shaft vein may be expected to lie within the diorite.

The workings on the Alhambra vein were being used for the storage of ore extracted during development elsewhere, and, consequently, the vein could not be examined. Nichols, however, reports the vein as not particularly well defined, though having widths of from 6 inches to 2 feet and values of from $10 to $20 a ton.

It cannot be said that the extensive development campaign that was formerly carried out at the Lorne mine proved the veins to come up to the indications that were given by the upper levels. But the veins were proved to continue to a considerable depth and workable shoots of ore have been found in them; this, as well as the length over which some of the veins have been traced on the 3,400-foot level, is ample justification for assuming that the veins extend to much greater depths and, consequently, they are worth exploring. It has already been pointed out that the Shaft vein will likely enter the augite diorite on lower levels and it is probable that should this occur the vein will occupy a much stronger or more definite fissure. Because of the numerous branches which join the veins at different points, the correlation of some of the veins on the 3,400-foot level with those of upper levels must be regarded as uncertain until more work has been done.

A considerable amount of work has been done at the Coronation mine, but as only the upper workings, from which the ore has been removed, were accessible no details can be given.

On the Ida May surface trenching has proved the vein for a considerable distance and it is reported that good values were found, but that more work is required to prove definite ore-shoots.

There are, therefore, several possibilities of interest in the ground held by Bralorne Mines, Limited, in addition to the work now in progress at the old Lorne mine itself.

Why Not

A brief visit was paid to the Why Not claim where an adit is being driven on the Why Not vein. Two veins are visible on a cliff face overlooking the south fork of Bridge river; one of these is the Why Not vein and the other is assumed to be the Jewess (California vein). Both dip at angles of from 30 to 40 degrees into the hill and are inclined at an acute angle to one another, the strike of the Why Not being north 55 degrees west magnetic and of the Jewess north 80 degrees west. The adit had been driven in over 300 feet, partly on the Why Not vein, in the hope of encountering the intersection of the two veins.

Jewess

On the Jewess (California) claim a short adit has been driven on a shear zone 74 inches wide striking north 60 degrees west and dipping 60 degrees northeast. The workings are in diorite. There is a heavy lens of quartz near the adit entrance, but most of the working is in crushed country rock with veinlets of quartz in the shear zone. Pyrite, arsenopyrite, and mariposite were noted in the tunnel.

Gloria Kitty

On the Gloria Kitty fraction a second tunnel is being driven on a vein about 2 feet wide in an albitite dyke. The vein consists of quartz with included country rock and carries good showings of sulphides. In places there is a marked ribbon structure to the vein. The dyke is well mineralized with iron pyrite and it appeared as if the vein were widening towards the face.

President Group

A brief visit was also paid to one of the workings on the President group, owned by F. R. MacDonald and Wm. McAdams, which is situated about 1½ miles to 2 miles southwest of the Pioneer and adjoins the Pioneer Extension group, which lies to the northeast and is owned by the same people.

Here two seams of quartz, which trend about north 55 degrees east and are inclined at 46 degrees, apparently mark the foot- and hanging-walls of a fissure with altered rock between. The narrower quartz seam is about 1 inch, and the wider 2 inches, thick. The seams are 18 inches apart near the mouth of the adit and are 4 feet apart at the face, which is in only a short distance. The quartz of the stringers contains occasional specks of gold that are visible to the naked eye. The country rock is altered diorite.

OIL POSSIBILITIES BETWEEN SODA CREEK AND QUESNEL, CARIBOO DISTRICT, BRITISH COLUMBIA

By W. E. Cockfield

CONTENTS

INTRODUCTION

A short time at the beginning of the field season of 1931 was devoted to a study of the Fraser River formation between Soda Creek and Quesnel with a view to determining the possibilities of commercial oil production. The greater part of the time was devoted to the study of the rocks in the vicinity of the structure being drilled at Australian ranch.

Though no geological map of the area has been made, the salient points of the geology are well known as a result of a number of investigations. The existence of sedimentary rocks of Tertiary age in this vicinity has been known since 1871 when Dawson[1] described the "Lignite Beds" in the vicinity of Quesnel. Several years later he described similar rocks on Blackwater river[2], about 30 to 40 miles northwest of Quesnel. During the summers of 1918 and 1919, Reinecke[3] made a geological reconnaissance which covered the area in question. His account has been largely used for the general geology in connexion with the work on the oil possibilities. In 1929 and 1930 geological work carried on by the Resources Survey of the Pacific Great Eastern railway included the geological mapping of the west Cariboo block, which embraced the west side of Fraser valley between Soda Creek and Quesnel. The report of this work is as yet unpublished, but, through the courtesy of the provincial authorities, certain data were made available to the writer and assisted materially in his work.

The area lies in the valley of Fraser river, between the village of Soda Creek and the town of Quesnel. It is readily accessible, as the line of the Pacific Great Eastern railway follows Fraser river between these two points, and the Cariboo highway, one of the main roads of the province, also follows Fraser river in this section of its course. There is also a road for part of the distance on the west side of Fraser river, connecting with the Cariboo highway at Quesnel and Alexandria.

A drilling for oil on Australian ranch has aroused considerable interest and has resulted in the staking of a large number of leases in Fraser valley both above and below Quesnel. The drill hole being sunk is on the holdings of the Cariboo Clay and Coal Company, who gave a drilling contract

[1] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1871-1872, pp. 58-9.
[2] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1875-6, pp. 255-60.
[3] Reinecke, L.: "Mineral Deposits Between Lillooet and Prince George, British Columbia"; Geol. Surv., Canada, Mem. 118 (1920).

to Mr. Frank A. Patrick for the petroleum and natural gas rights on a royalty basis. The leases are described by Lay[1], who also gives information with regard to coal showings and the structure. Drilling operations were commenced in October, 1930, and continued with interruptions until the autumn of 1931, when the work was temporarily closed down.

GENERAL GEOLOGY

The following account of the general geology is based mostly on the work of Reinecke, as the work of the writer was confined largely to observations on the Fraser River formation.

The oldest rocks outcropping in the area belong to the Lower Cache Creek series of Carboniferous age and consist of quartzites, argillites, metamorphosed lava flows, schists, and bands of serpentine and limestone. These outcrop in the vicinity of Soda Creek, but, so far as known, not elsewhere in the area. All the Cache Creek rocks have been much metamorphosed, both by mechanical shearing and by recrystallization.

Later than the Cache Creek rocks, and separated from them by a great time interval, is a group of rocks which Reinecke referred to the Lower Lavas. These consist of andesites, basalts, and tuffs, and belong to the Tertiary. Reinecke shows that the flows in places dip at high angles in contrast with the upper flat-lying lavas, and also produces evidence to show that they are older than the Fraser River formation. The Lower Lavas outcrop in the canyon of Fraser river just above Soda Creek, and at points 5 and 9 miles north of that village. Farther north still, they form a rock bluff near the road and show very well-developed columnar jointing. An outcrop occurs on the east side of the river about a mile above the mouth of Australian creek and Reinecke reports another on the west side of the river, just below the mouth of Australian creek. The age of these rocks is given by Dawson as Miocene, to which period he also assigned the "Lignite Group". There appear, however, to be good reasons for assigning the "Lignite Group" to the late Eocene, and if this be done the Lower Lavas must be assigned to the Eocene or to an older period.

The Lower Lavas are followed by the "Lignite Group". For this formation Reinecke has suggested the name Fraser River as being more definite. The rocks of this formation consist of sandstones, shales, clays, gravels, sands, beds of lignite, and diatomaceous earths. They constitute the formation being drilled for oil and, consequently, will be described later in greater detail. Fossil plants collected by the writer show the formation to be the probable equivalent of the Kenai of Alaska, which is usually considered to be late Eocene.

Overlying the rocks of the Fraser River formation are flat-lying flows of basalt, in places amygdaloidal. Near Quesnel they outcrop on the west edge of Fraser valley and farther south are found on both the east and west sides, forming the upper rim of the valley. Reinecke reports a flow resting unconformably on diatomaceous earth beds of the Fraser River formation southwest of Quesnel.

[1] Lay, D.: British Columbia Minister of Mines Report, 1930.

The chief interest from the point of view of petroleum and natural gas production lies in the rocks of the Fraser River formation. Exposures of these are rather infrequent in the area, owing to the heavy covering of alluvium and glacial drift, and because of high water in Fraser river certain sections were concealed in 1931. The mapping done by the Resources Survey of the Pacific Great Eastern railway, however, showed three main areas lying on the western bank of the river; one extending from Quesnel downstream about 6 miles; a second from a point above Australian down to Alexandria; and a third near Soda Creek. On the east side of Fraser river exposures were noted near Quesnel, Dragon, Australian, and Alexandria. At no point have both the top and bottom of the formation been observed, and as there is no general correspondence between sections taken at different points, no estimate of the thickness can be given. Reinecke published a number of sections, which it is unnecessary to repeat here. The maximum thickness obtained in any of these was 535 feet.

The gravels of this formation are yellow to brown and in most cases fairly well cemented. The pebbles are composed of quartz, lava, and altered sedimentary rocks and are in general quite well rounded. The clays vary considerably in colour, but are predominantly grey to nearly white. In places they are buff or brown and in some places quite dark with considerable quantities of vegetable remains. Locally they are well cemented to a shale or argillite. The diatomaceous earth is cream coloured to white, very porous, and of low specific gravity.

At the town of Quesnel the beds are exposed in the eastern bank of Fraser river and again on the south bank of Quesnel river at a point where the highway bridge crosses this stream. Of the first-mentioned exposure, owing to high water in the river, only a foot or two of the beds could be seen. Here they consisted of clays with numerous discontinuous seams of lignite and were dipping gently northward. At the exposure on the south bank of Quesnel river about 10 feet of beds were exposed, consisting of cemented gravel, sand, and clay, with discontinuous seams of lignite. Shaly beds with laminæ little thicker than a piece of paper make up part of the section. The beds at this point are dipping eastward at 5 degrees.

The beds are also exposed along the railway cutting for a considerable distance below the mouth of Quesnel river, and terminate in a high bluff of reddish and yellowish baked clays, which attract attention on account of their bright colouring. They apparently owe their colour and induration to the burning of beds of lignite which they once held.[1] The general dip of these beds is northwesterly, and their continuity is broken by one or two small faults. No determinable fossils were secured from these outcrops. Fragments of wood partly altered to lignite, but in which the woody structure is quite apparent, are exceedingly numerous. Dawson[2] reports the recovery of a number of plants, and from a single layer secured a number of species of insects in a very good state of preservation.

The general structure suggested in this vicinity is that of a shallow syncline, lying under the town of Quesnel. The beds on the southern limb of the syncline have apparently been truncated by erosion near the southern end of the bluff where the baked clays occur. More recent

[1] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1871-2, pp. 58-9.
[2] Dawson, G. M.: Ibid., p. 59; Geol. Surv., Canada, Rept. of Prog. 1875-6, pp. 258-60, 266-280.

sands and gravels, containing pebbles of lignite, presumably derived from the erosion of the Fraser River formation, have been deposited against the upturned edges of the Fraser River beds, so that the continuity of the ridge overlooking the river is not broken, although it is formed in one place of Tertiary rocks and in another of more recent gravels. The beds of recent sands and gravels themselves afford evidences of slight folding.

At Australian, beds of the Fraser River formation are exposed at intervals on both sides of the river down to Alexandria ferry. An important exposure occurs on Australian creek, a short distance above the railway trestle that crosses the creek. The section has been given in detail by Reinecke[1] and need not be repeated. It consists of sand, clay, shale, and lignite. An entry has been driven into the main lignite seam, which has a thickness of about 4 feet, a strike of north 65 degrees east, magnetic, and a dip of approximately 20 degrees to the northwest. The lignite contains numerous small lumps of resin. From horizons varying from 15 to 30 feet above the coal seam the writer collected numerous specimens of fossil leaves. These were examined by W. A. Bell of the Geological Survey, who reports as follows:

"The following species were identified:

Taxodium occidentale Newberry
Juglans cf. *nigella* Heer
Alnus alaskana Newberry
Quercus? sp.
Trochodendroides sp.

Although the number of identifiable species is very few, it is most probable that the florule is of the same age as the Kenai of Alaska, which is generally considered as late Eocene."

Another outcrop of Fraser River formation occurs on the bank of Fraser river a short distance south of the mouth of Australian creek. This consists of indurated clays with thin seams of lignite that strike north 55 degrees east, magnetic, and dip southeast at about 21 degrees. From this exposure a second collection of plants was made, on which W. A. Bell reports:

"The following species occur in this collection:

Glyptostrobus europaeus (Brongniart) Heer
Taxodium dubium (Sternberg) Heer
Muscophyllum complicatum Lesquereux
Celastris sp.?

This florule also indicates a late Eocene age".

No outcrops were observed on the east side of Fraser river between the last-mentioned outcrop and Alexandria ferry, but about 300 yards below the ferry, on the same side of the river, a bed of lignite occurs on which an entry had been driven. This coal seam strikes approximately north 20 degrees east, magnetic, and dips at 7 degrees to the southeast. No identifiable fossils were obtained at this point.

On the west side of Fraser river Mr. Doyle pointed out outcrops of the Fraser River formation occurring from about a mile above Doyle's ranch to the same distance below. Two outcrops were seen above Doyle's ranch, one about a mile and the other about half a mile above the cabin.

[1] Reinecke, L.: Op. cit., pp. 16-17.

The outcrop lying farthest up the river showed a strike of south 55 degrees east with a dip varying from 5 to 15 degrees to the southwest, and the second had a strike of south 85 degrees east and a dip of 35 degrees south. The measurements taken on the second outcrop are regarded with considerable doubt, as it was believed that surface movement of the beds had affected their attitude. These occurrences consist of shaly members with considerable carbonaceous material.

In the vicinity of Doyle's cabin a coal seam is partly visible in a shaft above the level of the water. According to Mr. Doyle this seam is exposed at low water in the bed of the river. It strikes about due north and dips to the west at 5 to 7 degrees.

About 1¼ miles below Doyle's ranch an outcrop of sandstone and clay was observed on the bank of the river. According to Mr. Doyle this lies above the coal seam exposed at his cabin. Above the outcrop are two other seams of coal. Here the strike was south 85 degrees east and the dip 5 degrees to the south. A few plant remains were obtained from this locality, but were too fragmental for identification.

The results of drilling by the Cariboo Coal and Clay Company are given by Lay[1] and show that hole No. 1 in 320 feet cut four seams of coal varying from 4 to 14 feet thick; hole No. 2 cut a seam 15 feet thick at a depth of 5 feet, and at 484 feet penetrated a seam 72 feet thick. On the other hand, the bore-hole put down for the oil well, to a depth of 1,400 feet, is reported to have encountered no coal at all. These differences in the logs of the drill holes would appear due to the individual members of the Fraser River formation probably having lenticular shapes, which view is supported by the fact that there is very little correspondence between sections of the formation measured at different localities.

STRUCTURE IN THE VICINITY OF AUSTRALIAN

Owing to the scarcity of outcrops in the vicinity of Australian creek, it is difficult to make a definite statement with regard to structure. The northward change in direction of dip from west to southwest on the western side of Fraser river, and from southeast to northwest on the eastern side of the river, suggests an anticlinal structure with the axis close to the present position of Fraser river. On account of the scarcity of outcrops it is impossible to place the axis of the anticline with any degree of certainty. The opposing dips do not necessarily prove the presence of an anticlinal structure, as they may be due to faulting. There is, however, no evidence that would suggest the presence of a major fault in this area. The fact that a coal seam occurring on the western side of the river was not encountered in the drill hole on the eastern side of the river would suggest that the axis of the anticline at this point has been eroded to a considerable depth.

According to information supplied, this hole passed through 400 feet of surface deposits followed by gravel, sand, and clay for 397 feet. At 797 feet a sand was struck which according to Mr. Patrick gave showings

[1] Lay, D.: Ann. Rept., Minister of Mines, B.C., 1930, p. 172.

of oil and gas. From 810 feet to 1,090 feet the hole passed through what is reported as a heavy conglomerate; chippings of the rock examined by the writer proved to be basalt, but it is quite possible that the chips represented the boulders of a conglomerate. At 1,090 feet a second sand was encountered with showings of gas and oil, from a sample of which Mr. Patrick reported he obtained a small sample of oil with a paraffin base and of 31 degrees Baumé gravity. After passing through this sand the hole penetrated a clay and the difficulties encountered led to the slowing down of the work and its final abandonment for the winter.

OIL AND GAS POSSIBILITIES

The probability of obtaining oil and gas in commercial quantities in any region is dependent upon two conditions: (1) the presence of rocks bearing supplies of oil or gas, and (2) the presence of a structure favourable to the accumulation of these products into pools of sufficient size to be of commercial importance.

Whether the first condition obtains may be told from the character of the rocks, from the experience in wells already drilled, or from the presence of springs of oil or of natural gas. It is commonly accepted by petroleum geologists, as a result of experience in many fields, that petroleum and natural gas are formed by the decomposition of plant and animal remains that have been buried with sediments in the sea. "They are almost never found in commercial quantities in igneous rocks, in metamorphosed rocks or in freshwater sediments not associated with marine strata."[1]

The reason why oil is not formed in freshwater deposits may be, as suggested by Johnson and Huntley[2] that bacterial decay of organic matter in freshwater deposits differs from that which takes place in salt water. Hence, in considering the probability of obtaining commercial supplies of petroleum from any district, the character and origin of the different sedimentary rocks must receive consideration.

The Fraser River formation affords absolutely no evidence of having been laid down in the sea. No marine forms of life have ever been reported from this formation, and though this is negative evidence, and, consequently, not proof, it may be said to strengthen considerably the belief, founded on other evidence, that the formation is entirely continental in origin. Plant remains and fossil insects have been collected from the Fraser River beds at a number of localities. The state of preservation of many of these fossils indicates that they had not been subjected to prolonged transportation, and that the fragments of plants had become entombed close to the site where they grew. In similar beds on Blackwater river Dawson[3] observed two stumps evidently standing where they had grown and now tilted with the containing beds. The recovery of numerous species of insects from the Fraser River beds near Quesnel, in a very perfect state of preservation and all from a single layer[4], affords almost indisputable evidence of the continental origin of the beds in question.

[1] Emmons, W. H.: "The Geology of Petroleum," 1921, p. 1.
[2] Johnson and Huntley: "Principles of Oil and Gas Production," 1916, p. 21.
[3] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1875-6, p. 256.
[4] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1875-6, pp. 258, 266-80.

The evidence afforded by the fossil content of the Fraser River formation is considerably strengthened by the fact that nowhere in the central interior of British Columbia have Tertiary marine sedimentary rocks been found. The absence of marine beds precludes considering the Fraser River formation to be shallow water marine deposits.

The rapid changes from sand to gravel or sand to clay, the irregular forms of the beds, the presence of lignite seams, and of fossil plants and insects, all point to the strata being swamp, lake, or basin deposits. The great variation from one section to another seems to indicate that the rocks were laid down in individual basins.

If this view of the origin of the Fraser River formation be correct, the chances that commercial supplies of petroleum originated in these rocks are not very promising.

It is, however, well known that oil is migratory in character and, consequently, could originate in other rocks and become trapped in favourable structures in the Fraser River beds, so it becomes necessary to consider the other strata of the region to see if these might be considered petroliferous. The next oldest strata are the Lower Volcanics which, since they consist of lava flows and tuffs, cannot be a potential source of oil. Older than these are the Cache Creek rocks, argillites, limestone, and volcanics of, probably, Carboniferous age. These rocks are of marine origin, but they have been highly altered, and are so folded, sheared, and recrystallized that even if they were once petroliferous the oil would have been expelled long before the deposition of the Fraser River beds.

It is not known what rocks immediately underlie the Fraser River beds in the vicinity of Australian. Basalt outcrops about a mile above the mouth of Australian creek on the east side of the river, and though there are no significant outcrops definitely indicating the relative ages of the basalt and the Fraser River beds, it is assumed that the basalt belongs to the Lower Volcanics. Reinecke reports a similar outcrop opposite Australian on the west side of the river. Consequently, it may be assumed that the Fraser River beds are here underlain by basalt.

There is no sign of marine sediments other than the Cache Creek group in this part of Fraser valley, but it must be remembered that much of the area is covered with alluvium and drift so that outcrops are relatively scarce. Farther to the east, in Beaver valley, marine sediments of Mesozoic age are known to occur and part of this formation is reported to carry oil-shale, but there is no evidence that this formation extends west to the part of Fraser valley under discussion.

Marsh gas is nearly always present where vegetable matter is being entombed in sediments or in swamps, and consists essentially of methane (CH_4). Dry natural gas, which is also essentially methane, is formed in much the same way as marsh gas, but occurs in rocks that have been partly or wholly consolidated. It is quite frequently associated with coal seams and its occurrence is not necessarily, nor even usually, an indication of the presence of oil pools. In beds of the character of those of the Fraser River formation it is to be expected that quantities of gas may occur, but if so, its commercial development would depend largely upon the structure of the rocks and the source of supply. No "springs" of natural gas within the area have been reported to the writer; small quantities of gas were reported from the well drilling at Australian, but not in quantities sufficient to be commercial. No analyses are available to show the nature of the gas obtained.

The structure of the rocks in the vicinity of Australian may be considered favourable, as the outcrops suggest an anticlinal structure, but as pointed out before there are not sufficient outcrops to prove definitely that the structure is anticlinal nor to permit tracing the axis of the anticline, if such a structure exists. The internal structure of the rocks is not unfavourable, for sandstone members are present which might form good reservoirs for oil pools if the rocks were oil-bearing, and there are sufficient clay or shale beds to form the necessary impervious covers. From the rock exposures seen and the data obtained from bore-holes, it seems probable that the various members of the Fraser River formation are discontinuous, that is, they probably occur in lenses and pass along their strike into other members of the formation. These lenses themselves would furnish favourable traps for oil if it were present, but, nevertheless, would tend to limit the possibilities because the disconnected character of the lenses would tend to limit the migration of oil or gas and the supply which might be obtained from any one lens would, therefore, be limited. Considerably more information than is available is necessary to establish the internal structure of the rocks and to determine the size of the individual lenses.

As all the evidence points to a freshwater origin for the rocks of the Fraser River formation, and as there is no evidence of the existence of closely associated marine strata, which might have served as a source of oil, it must, therefore, be concluded that the chances of securing commercial supplies of petroleum are not very bright. Favourable structure is only one essential for oil production; it must be accompanied by rocks which are capable of supplying the petroleum.

It may be quite possible that some natural gas will be found in the Fraser River rocks. Again, however, the continental origin of the strata renders it unlikely that large supplies exist, and owing to the probably limited extent of any individual reservoir it is extremely unlikely that natural gas would be obtained in those enormous quantities necessary to justify the large capital expenditures attendant upon its commercial utilization.

MINERAL RESOURCES OF NORTHERN OKANAGAN VALLEY, BRITISH COLUMBIA

By C. E. Cairnes

CONTENTS

Illustrations

INTRODUCTION

The following report is based on field studies in 1931 and brief, local examinations made in the two previous years. It deals particularly with the mining problems of the district and discusses geological conditions only so far as they have a direct bearing on these problems.

The writer is grateful for the many courtesies extended him by residents of the valley, who, either in their official capacity or otherwise, afforded valued assistance and thereby greatly facilitated his work. He is also indebted to his assistants, Messrs. S. S. Holland and H. M. A. Rice, for their efficient co-operation during the 1931 field season.

For upwards of sixty years mining operations of one sort or another have arrested the attention of residents of Okanagan valley, though, on the whole, but few persons were at any one time actively engaged in such developments. From time to time during this long period, as new mineral discoveries were made, new industries planned, or fresh schemes of an allied sort propounded, the district has been temporarily enthused over the prospect that, in spite of earlier disappointments, something might yet be made of its mineral resources.

In the early years placer mining formed the principal, and, for the most part, only, considerable attraction. However, in the mid-nineties, attention was largely diverted to the exploration and development of numerous widely distributed quartz veins carrying, principally, values in gold and, more locally, encouraging showings of silver and silver-lead minerals. More recently exploratory work has been done on a couple of properties carrying a variety of sulphide minerals in which values in copper are of main interest. Aside from purely metalliferous deposits some profit has been won from operations in the non-metallic field. The gypsum deposits at Falkland, on Salmon river, are the most important of their kind in the province. Granite quarries at three localities have supplied building stone and monumental material. Conveniently outcropping bodies of limestone have been utilized for lime and for agricultural purposes. Deposits of clay

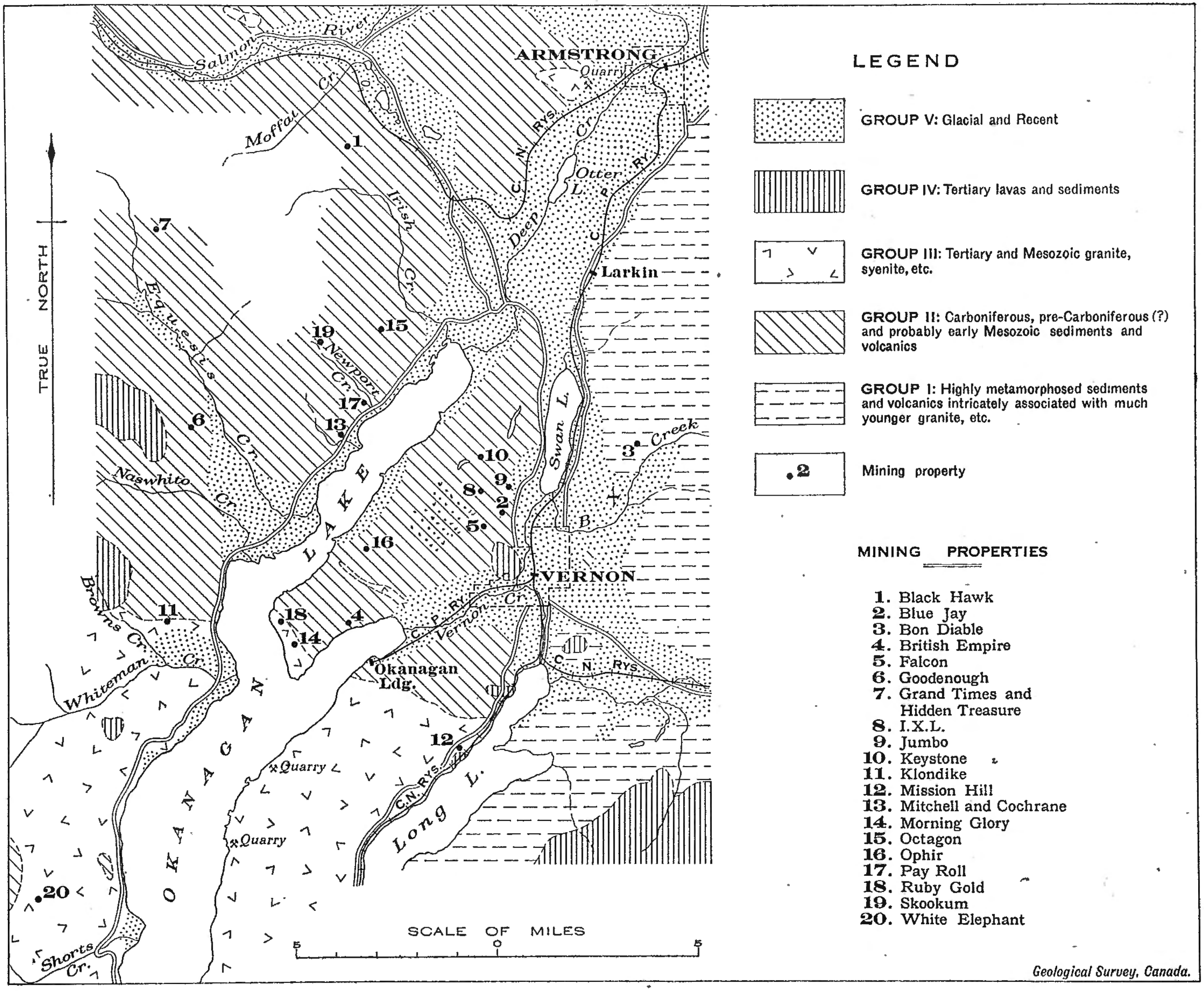


Figure 7. Geological sketch map of part of north Okanagan valley and vicinity, British Columbia.

have provided material for first-class brick. Explorations have disclosed showings of coal in the Tertiary measures and hopes have been entertained that perhaps these or other locations might yet prove a valuable asset. Less well-directed efforts are at present being, and have in the past been, made to investigate the possibilities of the valley as a producer of oil or gas.

GENERAL GEOLOGY

The rock formations of the district may be conveniently grouped in five major divisions and are represented on the accompanying map, Figure 7.

GROUP I

The eastern side of Okanagan valley is largely underlain by a complex of old crystalline rocks, probably chiefly of sedimentary origin, associated with abundant younger granitic intrusives. The older members include a variety of schists, hard quartzitic beds, large and small bodies of crystalline limestone, and other rocks which, in places, are difficult to distinguish from the associated granites intruding them. The latter are, in the main, medium-grained, grey, quartzose rocks, commonly well banded, but in places quite massive. They are intersected by numerous, irregular bodies of coarse-grained pegmatite. The older members of Group I have generally been regarded as Precambrian and have been correlated on Dawson's map[1] with the Shuswap series of Shuswap Lake region. From more recent and detailed studies, however, it seems likely that most if not all of these highly altered rocks are much younger than originally assumed and that they are merely highly altered equivalents of adjacent formations. Their alteration is attributed chiefly to their intimate association with abundant granitic intrusives thought to be contemporaneous with the older and more abundant members of Group III.

Generally speaking, the rocks of Group I have proved unfavourable prospecting ground for mineral deposits, perhaps because at the time when mineralization was taking place in adjoining formations the members of this group stood at temperatures too high to permit deposition of metallic constituents from ascending metalliferous solutions or vapours. The members of this group are not, however, entirely devoid of interest. At points outside of the map-area certain miscellaneous discoveries have been made. Locally, as on the Fifty Cent claim on Mission creek, east of Kelowna and about 3 miles above the junction of Hydraulic creek, large bodies of the gneissic granite have been heavily impregnated with pyrite and are reported to carry low values in gold. Elsewhere, as for example a few miles west of Cherryville, pegmatitic intrusives carry attractive showings of white mica (muscovite) in plates up to 2 inches or more in diameter. Even larger plates occur in a similar deposit near Armstrong.[2] Bodies of metamorphosed limestone here and there (as on Mabel lake) are conspicuously impregnated with graphite. About half-way between Lansdowne and Glenemma[3], the highly altered sediments carry concentrations of garnet and in the vicinity of Armstrong[4] chiastolite has been reported.

[1] Geol. Surv., Canada, Map 604, "Shuswap Sheet."
[2] Ann. Rept., Minister of Mines, B.C., 1927, p. 213.
[3] McEvoy, James: Geol. Surv., Canada, 1891, pt. A, p. 18.
[4] McEvoy, James: Geol. Surv., Canada, new ser., vol. VI, part A, p. 7 (1892-93).

Abundant, small, cyanite crystals were observed in highly metamorphosed mica schists, at an elevation of about 3,200 feet on the ridge north of Glanzier creek between 4 and 5 miles east of Armstrong. Such discoveries, though geologically interesting as indicating the existence of certain conditions, have not proved economically important.

GROUP II

The members of this group occupy wide areas along, and to the west of, Okanagan valley (*See* Figure 7). They comprise a variety of both sedimentary and volcanic formations and in addition are intruded by many dyke-like and less regular bodies of granite and allied rocks. Though for the most part not as severely altered as corresponding members of Group I, they have, nevertheless, experienced great changes; are notably faulted and deformed, and, in places, show transition into rocks similar to those included with Group I. The members of Group II have a general westerly to northwesterly trend. South of Vernon and Equesis (Sixmile) creek the group includes a conspicuous amount of light to dark grey, massive limestone in beds varying from a few feet to several hundred feet thick. In places these limestone beds carry abundant fossils of Carboniferous age. The associated rocks include greenish volcanic tuffs and breccias; green, schistose rocks of less certain origin; and considerable, black, cherty argillite and dark grey to black, rusty weathering, slaty argillites. From Equesis creek northeasterly to near the southern end of Otter lake the formations include a great abundance of fairly massive, greyish green, commonly porphyritic, volcanic rocks—chiefly tuffs and breccias—associated with a variety of sediments which in greater part possess a somewhat ashy or tuffaceous appearance, as though built up in large part of materials ejected from volcanoes and subsequently re-assorted by water action. These sedimentary rocks vary from fine-grained, slaty, and limy sediments to coarse, water-lain tuffs and breccias. To a lesser degree some more typical sediments, including quartzites, slate, and true conglomerates were observed. The coarser fragmental members, including volcanic breccias, water-lain breccias, and conglomerates, carry occasional fragments of limestone, some of which were observed to be fossiliferous and to resemble fragments from the limestone beds previously referred to. The inference is that Group II includes formations of post-Carboniferous, probably early Mesozoic, age.

From the vicinity of Otter lake northward, the members of Group II are chiefly dark grey to black, slaty rocks commonly carrying small, lustrous, dark flakes of ottrelite. Such rocks form the greater part of the hill west of Armstrong and continue in this general direction across Salmon River valley. These slaty, argillaceous rocks appear to underlie the other formations of Group II and for this reason may be presumed to be relatively older. In Dawson's Shuswap sheet they are mapped separately as forming a part of his "Niskonlith series" which was thought to be of Cambrian age. No fossil evidence has, however, been discovered to substantiate this age assignation and, so far as structural relations are concerned, it appears that the members of this belt are conformable with the overlying formations of Group II and, consequently, may represent a considerably later period in the Palæozoic.

The several members comprising Group II contain most of the metalliferous lode deposits in northern Okanagan valley and vicinity. The majority of these take the form of quartz veins carrying gold and an irregular, generally sparse, dissemination of sulphide minerals. In addition, a couple of base-metal, mixed sulphide deposits have received considerable attention. In general, slaty formations of the group are least favourable either for the occurrence or persistence of mineral deposits.

GROUP III

The members of this group are intrusive rocks, chiefly of granitic texture and ranging in composition from granite and syenite to granodiorite or quartz diorite. Even more basic types occur, but are confined to small bodies. Much of Group I is also composed of granitic rocks related in age to granites comprising the greater part of Group III. In Group I, however, the granitic members are so intimately associated with older, highly altered rocks that for present purposes they may be more conveniently mapped and described with them.

The intrusives of Group III comprise members of two distinct ages. The older and more abundant members occupy much of the central part of the country between Long (Kalamalka) and Okanagan lakes. They also form the point between the two arms of Okanagan lake and outcrop extensively in the lower valley of Whiteman creek. Within these areas they are represented chiefly by grey, coarse-grained granite carrying, in places, conspicuous, pinkish crystals of alkali feldspar. Elsewhere, however, and for the most part, they are nearly equigranular rocks in which quartz and feldspar are the abundant mineral constituents and black biotite and (or) hornblende the common dark minerals. In most places these granitic intrusives show evidence of crushing and alteration and locally, as between the two arms of Okanagan lake, they are notably foliated or gneissic. Farther north two small bodies of presumably related granite outcrop, one west of Armstrong and the other north of Salmon river. The former has been quarried to a small extent. Elsewhere within areas otherwise occupied by members of Group II many dykes, sill-like bodies, and others of more irregular shape intrude the older rocks. Many of them have been greatly sheared and altered, so that in places it is difficult to recognize them for what they originally were or even to distinguish them from formations on either side. A type of more than ordinary interest, partly because of its mineralized character and partly owing to its curious appearance, occupies an irregular belt varying up to a mile wide, between the two arms of Okanagan lake north of the main granite contact. This rock is mainly a dark green, heavy rock carrying a large but varying proportion of dark green amphibole in crystals up to 2 inches or more in length. Epidote is, in places, an abundant constituent. In one thin section examined the amphibole (hornblende) is associated with lesser amounts of pyroxene (probably diopside), orthoclase, and acid plagioclase feldspar, and accessory apatite and magnetite. A similar rock outcrops on a small hill near the north end of Long (Kalamalka) lake and another on the south slope of Coldstream valley to the southwest of Lavington, beyond the eastern limits of the map-area. In each instance this rock intrudes conspicuous bodies of limestone and contains many limestone inclusions. This relation suggests that the composition and texture of the intrusive have been markedly influenced by the limy character of the rocks, which it has invaded and partly absorbed, and, therefore, that its discovery may be taken as evidence of the presence of limestone members among the formations intruded by it.

The younger intrusives included with Group III are in part coarse-grained granitic rocks and in part numerous dyke-like bodies of, chiefly, alkaline character. The granitic rocks are characteristically pink or reddish and where so coloured are composed very largely of orthoclase feldspar. Quartz is comparatively scarce and dark minerals, principally biotite, are present in small proportions. Accessory minerals include titanite, sodalite, magnetite, and pyrite. These rocks have, consequently, the composition of syenite and quartz syenite. Where, as in certain places, quartz and plagioclase feldspar become more abundant constituents, the rocks pass into true granites[1] and take on a lighter pink or a mottled pink and white colour. Rocks with the above characteristics occur on either side of the low ridge separating Okanagan and Long lakes. They outcrop along the east side of Okanagan lake for a distance of about 8 miles commencing at a point 2½ miles south of Okanagan Landing and extending inland for a maximum distance of about 2 miles. Granite has been quarried from these intrusives at two places along the lake shore. Similar intrusives form a narrow belt along the west side of Long lake beginning at a point about 3½ miles from the north end. Similar rocks outcrop extensively in the valley of Whiteman creek, west of the area included in the accompanying map, Figure 7.

In addition to these larger bodies of intrusives a host of dyke rocks of presumably related origin intersect the older formations in the vicinity of the main intrusive bodies. They also appear in numbers along the west shore of Okanagan lake and were observed on either side of and between the two arms of Okanagan lake. These minor intrusives form two types, one of light-coloured, chiefly pinkish, and commonly porphyritic dyke rocks, closely allied in composition and appearance with the coarser-grained granitic rocks, and the other of darker (in places slightly pinkish), intrusives, less conspicuously porphyritic than the first type and carrying an abundance of dark minerals, chiefly hornblende. This latter type forms dykes and less regular bodies which have been found intersected by dykes of the first type and, in turn, definitely intrude the older granitic rocks of Group III. A particularly prominent body of the darker type, varying up to 1,000 feet or more in width, cuts across the peninsula between the two arms of Okanagan lake from a little north of the head of the north-east arm.

The older members of Group III are pre-Tertiary, but probably late Mesozoic. The pink syenite and related granitic rocks definitely intrude the pre-Tertiary granites; are, on the whole, more massive and less altered; are quite distinctive in appearance and composition; and bear a close resemblance not only to the pink dykes previously mentioned but also to certain fairly widespread basal Tertiary volcanic flows which, to the south of the map-area (as between Oyama and Okanagan Centre) overlie pre-Tertiary granites. These younger granitic intrusives are, consequently referred with some confidence to the Tertiary era.

[1] *See* later descriptions of this granite in discussion on "Building Stone."

The rocks of Group III are economically important in that the metalliferous deposits of the district are related in origin to them. The mineral deposits are believed to be mainly, if not entirely, connected with the pre-Tertiary or older intrusives. This conclusion is based on the following considerations: (1) mineral deposits are widely distributed within the older intrusives but are not found in the Tertiary granitic rocks; (2) mineral deposits occurring in Group II near the contacts of granitic members of Group III are found in the vicinity of the contacts of the pre-Tertiary rather than the Tertiary components; (3) the mineralized quartz veins, etc., are, in general, broken and faulted to a greater degree than the Tertiary intrusives themselves; (4) these Tertiary rocks rarely carry any appreciable amount of sulphide mineral, whereas such minerals are commonly conspicuously disseminated in the pre-Tertiary irruptives.

GROUP IV

This group consists solely of volcanic and sedimentary rocks of Tertiary age. Such formations are most extensively developed at the higher elevations and outcrop over wide areas to the west and southeast of the map-area. For the most part they are of volcanic origin and include a large proportion of lavas varying greatly in colour, structure, texture, and composition. Intercalated with these lavas at different horizons are bands or beds of fragmental material composed in great measure of volcanic ash and breccia. At rarer intervals these products of vulcanism are interrupted by waterlain sediments varying from coarse conglomerates to fine shale. In places these sediments carry abundant plant remains and, locally, more or less coal. Occurrences of this latter sort have been prospected at different points in Okanagan valley and vicinity, without, however, developing any deposits of present commercial value.

From a metalliferous standpoint these Tertiary rocks have provided little of economic interest and though, on the whole, they are not recommended for prospecting they do present certain interesting possibilities that might be kept in view when prospecting areas in their vicinity.

(1) The oldest Tertiary rocks in both this and adjoining map-areas are sediments, chiefly conglomerates and sandstones, and vary in thickness up to several hundred feet. These sediments are freshwater deposits laid down along stream beds and in lakes. From a study of their characters, it is evident that they accumulated rapidly. It seems probable that where such material was derived from formations carrying gold-quartz veins or other source of free gold, placer deposits would be formed, and although such deposits would now be solid rock they might, in places, be sufficiently rich to pay to mine. Present streams cutting across such ancient placers would doubtless provide a clue both as to the richness and position of the older placers if such exist. Places where basal Tertiary conglomerates were observed and where attempts might some time be made to investigate their possibilities as ancient placer fields, occur in the valley of Shorts creek about 6 miles from its mouth; in the hills west of Okanagan lake between Westside (opposite Kelowna) and the mouth of Trepanege creek; in Trinity hills west of Mabel lake; and in the vicinity and northeast of Enderby.

(2) The prospector might also be advised, when crossing areas underlain by Tertiary rocks, to keep an eye open for possible occurrences of cinnabar (red sulphide of mercury) or stibnite (antimony sulphide) such as characterize deposits on either side of Kamloops lake, particularly in the valley of Copper creek,[1], [2]. These minerals may occur in veins or as disseminated particles in either the Tertiary or adjoining rocks. The commonly associated minerals are marcasite (or pyrite), chalcedony, calcite, and gypsum.

GROUP V

The members of this group are unconsolidated deposits of glacial and stream origin which have accumulated in great thickness and over large areas in Okanagan and Salmon Rivers valleys, and their main tributaries. Up to an elevation of nearly 900 feet above Okanagan lake, and in places even higher than that, the consolidated rocks are largely obscured by water-sorted gravels (sands, sandy silts, and clays associated here and there with slide debris), ill-sorted morainic materials, and fan deposits from tributary streams. The main valleys are flat-bottomed or nearly so and contain lakes of varying size or dry depressions formed probably by the collapse of surface deposits following the melting of underlying remnants of glacial ice. The lower slopes of the main valleys are a series of benches or terraces rising to nearly 900 feet above Okanagan lake and interrupted or modified here and there by tributary streams which have built conspicuous deltas where entering Okanagan lake. At greater elevations stream gravels and other valley alluvium are forming along the creek bottoms, and on the intervening ridges the rock formations may be obscured by poorly sorted or unassorted glacial drift.

The stream gravels and bench materials have provided the gold placer deposits of the district and as such deserve special mention. They have also supplied beds of clay for the manufacture of brick, and quantities of sand and gravel for cement, road metal, etc.

ECONOMIC GEOLOGY

The mining industry in north Okanagan valley and vicinity has been concerned with the following classes of deposits.

A. *Metalliferous Deposits*
   1. Placer mining
   2. Lode mining
      (a) Auriferous quartz veins
      (b) Mixed sulphide deposits
      (c) Magmatic segregations

B. *Non-metallic Deposits*
   1. Gypsum
   2. Building stone
   3. Limestone
   4. Clays
   5. Coal
   6. Petroleum and natural gas.

[1] Dawson, G. M.: Geol. Surv., Canada, Ann. Rept., vol. VII, pp. 340-341 (1896).
[2] Veatch, J. A.: Ann. Rept., Minister of Mines, B.C., 1896, p. 571.

Placer Mining

Though the district has not been, and probably never will be, included among the better known placer fields of the province, placer mining has, nevertheless, occupied local attention more continuously and over a longer period than any other phase of the mining industry and, in fact, is the only phase of metalliferous mining that has yielded any considerable return in proportion to the amounts spent in exploratory and development work. The principal centres of activity to date lie at some distance beyond the boundaries of the map-area, namely: on the South fork of Cherry (Monashee) creek; on the western slope of Monashee mountains, about 40 miles east of Vernon; and on Mission creek about 8 miles east of Kelowna. Little has been done on the latter creek for a great many years. Gold was first found on it in 1861, the creek at that time being called Rivière de L' Anse du Sable (Sandy Cove river). The diggings were visited in 1877 by Dawson who furnished a report of geological conditions under which the placer gold accumulated.[1] On Monashee creek operations have persisted at intervals, from the early seventies to the present. When visited by the writer in the autumn of 1930 encouraging values had been, and were being, found on certain bench leases owned by Hydraulic Mines, Limited, and extending for about 1½ miles above the mouth of the creek, and plans were being formulated for their further development.

Within the map-area placer mining has been conducted with some success on a number of streams tributary to the main valleys. Those of principal interest include Whiteman, Naswhito (Siwash), Equesis (Six-mile), and Moffat. Of these streams the first three occupy prominent valleys draining easterly into Okanagan lake. Moffat creek is comparatively small and empties into a depressed area occupied by several small lakes that have an underground seepage northwesterly into Salmon river. Placer gold has also been found in small quantities along many of the smaller creeks of the area, particularly those draining from the west and south into Okanagan and Salmon River valleys. The valleys of the larger streams are typical of those intersecting the plateau country of British Columbia (Plate I B). They cut deeply across the rock structures and the streams following them flow over rock-bottomed stretches separated by intervals of gentler grade where stream wash has accumulated. In their lower courses the stream beds are flanked by high banks of sorted bench materials rising to heights of several hundred feet (Plate I A). Some attempts have been made to hydraulic these bench materials, but for the most part efforts have been confined to working the creek gravels. On Naswhito (Siwash) creek operations of the latter sort were attempted years before the settlement of Okanagan valley and have continued to attract some attention. The principal producing years of which there is any record extended from 1889 to about 1895, during which period a yearly output of from $1,200 to $2,000 is reported.[2] Since 1914 hydraulic operations have been undertaken by different companies, with some success,[3] at a point about 2 miles from the mouth of the creek. Here bedrock is exposed at the base of about 200 feet of gravels, sand, and clay (*See* Plate I) the lowermost beds comprising several feet of rusty-weathering

[1] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. B, pp. 157-158.
[2] Ann. Repts., Minister of Mines, B.C., 1889-1894.
[3] For details of these operations *See* Ann. Repts., Minister of Mines, B.C., 1915.

gravels. The important values are concentrated near and mostly on bedrock. The disposition of the overlying heavy cover is a difficult problem.

At Moffat creek, on the other hand, encouraging values are reported to have been obtained from the entire deposit of unconsolidated bench materials accumulated near its mouth on either side of the Canadian National railway. Considerable exploratory work including attempts at hydraulic operations was done on this property many years ago by Ross Mahon and others, and some coarse gold is reported to have been obtained. The chief practical difficulties there relate to disposition of waste and to securing an adequate supply of water. At one time it was proposed, and negotiations were in fact put under way, to tap Pinaus lake, in the valley of Equesis creek, by a rock tunnel, to be driven from the upper, southern slope of Salmon River valley, and flume the water from thence to the diggings. The property is owned by John O'Neil, Armstrong, B.C.

Some placer mining has been conducted from time to time on Whiteman, Bouleau, and Equesis creeks. These operations have been chiefly concerned with the recent stream gravels and though hydraulic leases are reported to have been acquired on the two first-mentioned creeks, there is no record of operations of this sort. Nor is any data available as to the output from these creeks except that it was small as compared with that of Siwash creek. Good values are reported to have been obtained locally from Equesis creek, particularly in the vicinity of its junction with Musgrave creek, a northern tributary entering the main stream about 6 miles from its mouth. A little work has also been done on this tributary.

Placer gold has been found in the gravels of Newport (Deep) creek and, in fact, on most if not all of the streams draining the western slopes of the northern Okanagan valley. There are no reports of gold having been found in the streams draining the country east of this valley, though B. X. creek, since it cuts across an area of rocks carrying auriferous quartz veins, should hold gold if any of the streams on this side do.

Lode Mining

Commencing in the nineties, a number of gold-bearing quartz veins were discovered in the vicinity of Vernon and from these many rich samples were obtained and, as a result, much interest was aroused in early exploratory work. Failure, however, to prove any important tonnages of either high-grade ore or profitable mill-feed, led, in a few years, to almost complete cessation of activities. Subsequently, as occasional new discoveries have been made or projects undertaken for the development of old holdings, interest has been partly revived and though in most instances plans have failed to materialize or results have proved disappointing, there appears to be justification for the hope that some development may yet be planned or some further discovery made that will establish the lode-mining industry on a profitable basis.

QUARTZ VEINS

General Remarks

The following table lists properties on which the principal or only mineral deposits are mineral-bearing quartz veins and on which exploratory work has been done.

Name	Owner or agent	Location	References [1]	Remarks
Bachelor No. 1 and No. 2		East of Okanagan Landing	1896, p. 579; 1897, p. 747	Quartz-filled fissure, 3½ feet to 8 feet wide, in granite; mineralized with iron and copper sulphides and free gold
Black Hawk (Peoitch)	A. J. McMullen, Vernon	Head of Irish creek	1899, p. 747; 1900, p. 887; 1902, p. 189; 1919, p. 184; 1922, p. 144	*See* description on following pages
Blue Jay	A. H. Cravan, c/o Hoares (Bankers), 37 Fleet st., London, E.C. 4	1·5 miles NW. of Vernon	1897, p. 609; 1899, p. 747	Crown-granted claim; 4-foot vein of quartz carrying pyrite, arsenopyrite, grey copper, galena, and gold values; workings include a shaft and adit
Bon Diable	Crown	3·5 miles NE. of Vernon on B.X. hill	1897, p. 609; 1899, p. 747; 1901, p. 1125	Crown-granted claim; several small quartz veins and irregular bodies of quartz in a faulted, quartzitic formation; low average values in gold and silver; considerable underground work; occasional rich samples of free gold
British Empire group	V. L. E. Miller, Trinity valley, Lumby, B.C.	Opposite Okanagan Landing	1901, p. 1125; 1902, p. 189; 1903, p. 178; 1905, p. 192; 1906, p. 172; 1925, p. 184; 1927, p. 213.	Group comprises the British Empire, Royal Standard, and Dominion Fraction Crown-granted claims. *See* description on following pages
Cartwright		South from the Ruby Gold claim	1897, p. 609	Vein, several feet wide, of barren-looking quartz
Chance	Crown	About 3 miles south of Lavington	1897, p. 609	Vein of barren-looking, yellow-weathering quartz in a dioritic stock; shaft and crosscut adit; Crown-granted claim

[1] References to Annual Reports, Minister of Mines, British Columbia.

Name	Owner or agent	Location	References[1]	Remarks
Densy group (including Densy Crown-granted claim)	Crown	North of British Empire and west of Three Tramps properties	1897, p. 608; 1899, p. 746	Several narrow quartz veins carrying free gold; one vein 6 feet wide carrying values in copper and gold—several small workings
Falcon	Frank Mitchell, 2064 Penzanie Rd., Foul Bay, Victoria, B.C., and Maude A. McFarlane, Vernon	1 mile NW. of Vernon	1899, p. 747; 1921, p. 191	Crown-granted claim. *See* description on following pages
Grand Times and Hidden Treasure		Grand Times mountain, valley of Equesis creek 450 feet above north-east bank and about 9 miles from the mouth	1898, p. 1129; 1899, p. 747	Body of free-milling, auriferous quartz
Hic Jacet		Probably near Bachelor claims	1898, p. 1130	
Iron Cap		Above (?) British Empire group	1897, p. 609	Two narrow quartz veins carrying a little copper and iron pyrites
I.X.L.	James Bonnau (?)	2 miles NW. of Vernon		*See* decription on following pages
Jumbo[2]	H. J. Blurton, Vernon	2 miles N. of Vernon near Kamloops highway	1928, p. 220; 1929, p. 248	*See* description on following pages

Keystone group		Near Mule lake, 3 miles NW. of Vernon		*See* description on following pages
Klondike group	Wm. Jno. Nelson, Penticton, B.C.	North of Whiteman creek and over a mile west of Okanagan lake	1898, p. 1130; 1899, p. 746	A fractured area at contact of granite and dyke rocks with older sediments; small, irregular quartz veins carrying a little sulphide mineralization and calcite. Klondike a Crown-granted claim
Little Duncan and Panorama	Crown	Newport (Deep) creek	1899, p. 746	Crown-granted claims; white quartz vein 2-5 feet wide carrying pyrite and galena; values in gold and silver with traces of copper
May		South end Armstrong hill, near Round lake	1899, p. 747	White quartz vein; values in gold, silver, and lead
Mission Hill	H. Fallow, *et al*, Vernon	5 miles S. of Vernon on Kelowna road	1928, p. 221	*See* description on following pages
Mitchell and Cochrane group	F. Mitchell, 2064 Penzanie rd., Foul Bay, Victoria, B.C.	Close to highway, 2¼ miles north of Equesis creek	1922, p. 145	*See* description on following pages
Morning Glory group (including Morning Glory and Sarah claims)	Morning Glory owned by Andrew W. Symons. Vernon	Near end of peninsula between the two arms of Okanagan lake	1896, p. 579; 1897, p. 608	Quartz vein on Morning Glory up to 6 feet wide, in granite, carrying free gold, pyrite, chalcopyrite, and galena (?); smaller quartz vein on Sarah, carrying spectacular but spotty showings of free gold; Morning Glory a Crown-granted claim
Octagon group	F. Jewel, H. Alison, and F. Holsinger	Irish creek	1923, p. 161	*See* description on following pages

[1] References to Annual Reports, Minister of Mines, British Columbia.
[2] Note. There is also a Jumbo, Crown-granted claim included with the old Morning Glory group.

Name	Owner or agent	Location	References	Remarks
Pay Roll	H. J. Blurton, *et al*, Vernon	Newport (Deep) creek	1929, p. 247	*See* description on following pages
Polar Star (*See* Zion mountain)		Valley of Shorts creek, on south side of creek about 5 miles from its mouth	1898, p. 1130	
Rex (in Three Tramps group)	Crown	East of British Empire group; at head northeast arm of Okanagan lake	1901, p. 1125; 1905, p. 192	Crown-granted claim; two parallel quartz veins 1 to 1½ feet wide in coarse-grained, amphibolitic intrusive; quartz carries iron and copper sulphides; principal values in gold and copper
Ruby Gold group (including Ruby Gold Crown-granted claim)	Crown	North of the Morning Glory	1897, p. 608	Vein of milky-white quartz 10-12 feet wide carrying iron pyrites—veins break up into stringers at bottom of 30-foot shaft—free gold found in vein; several small, barren-looking quartz veins
Skookum	H. J. Blurton, Vernon	At the head of Newport (Deep) creek	Recent discovery; 1931, Prelim. Rept., p. 37	*See* description on following pages
Swan Lake group		East of Swan lake—near highway to Kamloops	1897, p. 609	A number of exposures of barren-looking vein quartz
Three Tramps group (*See also* Rex claim)	Crown	East of British Empire group	1897, p. 609; 1899, p. 746	Three Tramps, a Crown-granted claim; aside from vein quartz the associated country rock, a dark green, coarse-grained, hornblende-rich, dioritic formation carries local concentrations of iron and copper sulphides

White Elephant group (including White Elephant Crown-granted claim)	Archie P. Clark, R.R. No. 1, Vernon	North of Shorts creek and 2 miles west of Okanagan lake	1921, p. 192; 1921, p. 196; 1922, p. 144; 1923, p. 159; 1924, p. 140; 1927, p. 213; 1928, p. 220; 1929, p. 248; 1930, pp. 207–208	*See* description on following pages
Yellow Rose	Isabella Nancy Knight and John Somerville, c/o John Somerville, Vernon	Adjoins White Elephant claim to the north	1924, p. 140	Crown-granted claim
Zion Mountain group		Shorts creek — between the two main forks	1907, p. 128	Developed by the late E. H. Love; narrow quartz vein carrying $2 to $5 in free-milling gold values

42433—6

The quartz veins on the various properties bear, on the whole, a close resemblance to each other. The quartz is mostly a massive, milky-white, semi-vitreous type carrying little trace of mineralization. Individual veins may, however, contain either a sparse or a liberal impregnation of sulphides. In places the quartz may be quite vuggy, in part as a result of the leaching out of sulphide minerals and in part owing to incomplete filling of the vein fissures by the quartz. On the whole the smaller veins are better mineralized than the larger, though in places, as on the Keystone group, heavy sulphide mineralization was noted across a vein several feet wide. Veins vary in width from a few inches to 100 feet but rarely exceed 10 feet. Their length is seldom in proportion to their widths, partly owing to faulting, which has been particularly severe. As a consequence vein outcrops can rarely be traced for more than a hundred yards or so, because they either pinch out or are faulted. In general, the veins are sharply defined against the enclosing formations and though they may pinch and swell there is comparatively little evidence of silicification of, or gradation into, the wall-rocks. The latter may, however, show some alteration and commonly carry disseminated sulphides, chiefly pyrite cubes, for some distance away from the veins. Many veins strike north to northeast, but the majority strike west to northwest and in this respect coincide more or less closely with the structural trend of the members of Group II with which they chiefly occur. So far as could be determined all the quartz veins were introduced at about the same time, though some veins or bodies of quartz appear to have formed under higher temperature conditions than others, notably, for example, the quartz at the White Elephant mine. On the Jumbo claim a group of north-south stringers are intersected by an east-west vein. At other places veins following different directions unite to form single veins. At no place did the character of the quartz or its mineralization appear to bear any relation to the trend of the veins.

Description of Properties

The following notes deal with a number of properties on which exploratory and development work has been done within the last ten years or so. For details as to amount of development work, assay values, etc., the reader is referred to the Annual Reports of the Minister of Mines for British Columbia, as listed in the tables above.

Black Hawk Group. On this property a quartz vein, 5 feet wide, strikes north to northwest, and intersects greenish volcanic rocks and minor, slaty sediments of Group II.[1] The principal exposures lie nearly 2,000 feet above and less than a mile west of the Canadian National railway and about a mile southeast of Moffat creek. The vein is probably continuous for several hundred yards. It is visibly mineralized with pyrrhotite, chalcopyrite, pyrite, and galena and, in places, carries much calcite. Samples taken by the Resident Engineer at a number of points indicated gold values varying from 0·20 to 0·56 ounce a ton. Further work should be so planned as to prove the length of the vein and to ascertain values at a depth of at least a few feet below the surface. If a large tonnage of $5 to $10 ore were thereby proved, the property would be well worth further attention.

[1] *See* earlier discussion of this group of rocks.

British Empire Group. Considerable work has been done on this property and a small tonnage of ore has been extracted and milled. The group is one of several occupying much of the peninsula between the two arms of Okanagan lake. The end of this peninsula is underlain mainly by foliated, grey granite or granodiorite intersecting, towards the north, a belt of sediments composed chiefly of black, cherty argillites, slaty rocks, and abundant limestone. The strata of this belt, within which the British Empire workings lie, strike about north 55 degrees west and dip steeply in part to the northeast and in part to the southwest. The belt is about one-half mile wide and on the northeasterly flank is in contact with that curious amphibolitic intrusive, referred to in a previous section of this report,[1] as probably deriving its peculiar texture and mineral composition from its contact with bodies of limestone. This intrusive carries disseminated sulphide minerals; is intersected by mineralized quartz veins; and is believed to be the source of the mineralization on the British Empire and adjacent properties[2]. It, in turn, as well as the older rocks, is intersected, both to the north and south of the British Empire workings, by persistent dykes of grey to slightly pinkish, feldspar porphyry, up to several hundred feet wide. These dykes project like ribs above the surrounding rocks. They are believed to be of Tertiary age and, therefore, of post-mineral age.

The workings on the British Empire group lie between 250 and 500 feet above and not far from the shore of Okanagan lake, opposite Okanagan Landing. The lowermost adit, about 450 feet long, is a crosscut intersecting several quartz veins up to a few inches in width and striking in a general northerly direction. Short drifts have been run along each of these and, towards the face, a raise extended up to, probably, the next adit level about 175 feet above. At this upper adit an outcropping quartz vein 1½ feet wide strikes nearly north and is vertical. A third adit (?), now inaccessible, lies at about the same elevation as the last, but some 350 feet to the north of it. The country rocks are chiefly dark grey or black argillites and slate containing a number of narrow, brownish-weathering bands of a fine-grained, carbonated rock.

The vein quartz carries sparsely disseminated pyrite and chalcopyrite and the adjoining wall-rocks are abundantly impregnated with well-formed cubes and octahedra of iron sulphide. Values are chiefly in gold which is largely free-milling, but partly carried in the sulphides.

A 5-stamp mill was erected on the lake shore in 1903. A small tonnage of ore was treated and is reported to have given $27 a ton in gold on the plates. Concentrates were stated in 1905 to carry about $50 a ton in gold. The mill was closed down in 1906 after a 120-day run. The results of this test are not known.

No further work is reported until 1925 and the years immediately following when further attempts at production were made by A. W. Symons. Symons first built an arrastra operated by horse power, but subsequently installed a small Ross mill. Some success was attained in the first but little in the second venture.

The conditions obtaining on the British Empire group are much like those encountered or believed to exist on the several other nearby properties. The showings do not, individually, warrant large expenditures,

[1] *See* p. 69.
[2] *See* notes in above table on the Rex and Three Tramps properties.

because gold values, though locally spectacular, are spotty and average values over any considerable body of vein matter appear to be too low to warrant extensive development work. Furthermore, the quartz veins though numerous are mostly small and scattered, and individually are faulted or split into a number of small, unworkable stringers. Their character at depth has received but slight investigation, but the available evidence does not suggest that the veins as regards continuity and values materially change. Possibly the only way the quartz veins in this section may be mined at a profit is by the various property owners pooling their interests in a single, local organization. The second step should be to sample carefully the individual veins and the sampling of the surface should be checked by samples from depths of at least a few feet. If the sampling indicated a total tonnage, conservatively estimated, sufficiently large and of high enough value to warrant mining and the erection of a small mill, the mill should be erected and the pockets of ore should be mined, the mining being conducted as if there were no expectation of finding or developing more or larger pockets of pay ore than were disclosed at the surface.

Falcon Claim. An open-cut and a couple of shafts on this claim have developed a quartz vein, about a foot wide, striking a few degrees east of north and dipping 30 degrees west. This vein intersects argillaceous and tuffaceous sediments of Group II and is of interest partly because of the high gold values that have been obtained from selected samples and partly because of the considerable amount of disseminated arsenopyrite both in the vein and in the adjoining wall-rock. Other minerals include chalcopyrite, pyrite, a little galena, and free gold. Average values do not appear to have been sufficient to encourage further development of so small a vein.

I.X.L. Group. An incline shaft on this group is at an elevation of about 2,200 feet, and is situated about 900 feet above and 1½ miles west of the south end of Swan lake. The shaft is 20 feet deep and follows a 6-inch quartz vein striking north 75 degrees east and dipping 45 degrees northwest. A smaller quartz vein joins it on the hanging-wall side. The veins intersect platy, argillaceous sediments which strike nearly east and dip 50 degrees north. The veins are composed of brownish stained, vitreous quartz carrying a sparse dissemination of iron sulphides. Values are not known.

Jumbo Claim. This claim is located in a field a few hundred yards west of the Vernon-Kamloops road and about 2 miles north of Vernon. On the property a number of narrow quartz veins are exposed by the workings which include two shallow shafts, two short, inclined adits, and 250 feet or more of surface trenching. The veins follow two principal directions, one group striking about east and dipping south at 65 degrees or so and the other trending more nearly north and standing nearly vertical. In one open-cut a series of north-south, quartz veins and stringers are intersected by an east-west vein and gold values to date have been found chiefly in the latter. The veins intersect sedimentary members of Group II represented here by black, platy argillite or slate and a more massive, grey or greenish grey rock of tuffaceous appearance carrying numerous small fragments of argillite. The rocks have a general northwesterly strike, but their structure is complicated by faulting. A body of the black, slaty rocks immediately north of the workings has, for example, apparently been thrust southerly at a small angle, over more massive, tuffaceous beds in which the vein deposits occur.

The veins appear to distinctly favour the more massive rocks and either pinch out or are faulted off where they encounter the slaty types. They vary in width from a fraction of an inch to about 4 feet, individually show great irregularity, and as exposed would not average more than a foot in width.

The most northerly of the east-west veins has been traced for about 70 feet to a place where it is cut off by the thrust previously referred to. This vein is of white, semi-vitreous, highly fractured quartz which, in places, is quite drusy. It carries visible free gold and sparsely disseminated pyrite. On what may be the faulted westerly continuation of this vein a shaft and trench expose a width of from 6 inches to 2 feet of vein quartz carrying some free gold and conspicuous lumps of native sulphur. Small quantities of sulphur were also noted in the more northerly workings. This mineral appears to have been produced by a slow decomposition of the iron sulphides present in the quartz. Pyrite also occurs, as cubes, impregnating the wall-rocks, a feature characteristic of most of the mineralized quartz veins in the district. In the black slates these iron cubes reach a diameter of half an inch or more.

Though mineralization of an attractive character has been found on this property the veins are small and discontinuous. They are, doubtless, of the same age as many other veins occurring in a belt that extends westerly to and across the northwest arm of Okanagan lake in the vicinity of Newport (Deep) creek. Other properties in this belt include the Blue Jay, Falcon, I.X.L., Keystone, Pay Roll, and Skookum.

Keystone Group. On this group, situated about midway between Swan and Okanagan lakes, several exposures of vein quartz have been found and a little work has been done on some of them. At a point near the northeast end of Mule lake an open-cut exposes some copper-stained vein quartz carrying a little chalcopyrite. This vein strikes a few degrees north of west and is vertical. About 1,400 feet to the northeast another vein, 3 feet wide, is heavily mineralized with pyrite and carries a little sphalerite. It is exposed for only a few feet, but may join, about 100 yards to the northwest, a large exposure of sparsely mineralized vein quartz having a width of between 50 and 100 feet. About 500 feet in a northeasterly direction from the heavily mineralized vein-showing an open-cut and short incline have been made on a quartz vein up to 3 feet wide, striking about north 35 degrees east and dipping 30 degrees northwest. This vein carries a little pyrite and galena.

No attempt has yet been made to correlate these various vein exposures nor to trace them for any considerable distance. They intersect chiefly sedimentary members of Group II including dark argillites and grey to greenish grey, tuffaceous beds, the whole assemblage striking west to northwesterly and dipping principally to the northeast. Locally the veins show encouraging mineralization and include at least one unusually large exposure. Values are not known.

Mission Hill Group. This group lies on either side of the Vernon-Kelowna road about 5 miles south of Vernon. The rocks here are chiefly grey, granitic rocks carrying some included material and overlain to the south and southwest of the workings by small bodies of Tertiary lava. Exploratory work has investigated the character and continuity of several exposures of vein quartz appearing at intervals above and west of the road over a distance of about a mile. At these exposures the quartz forms bodies up to several feet wide, but owing to the drift cover and more especially to the irregular shapes of the bodies and the faulting to which they have been subjected they are not traceable individually for more than a few yards. The outcrops, in fact, appear to represent a series of disconnected veins and lenses of quartz occupying fractures and to some extent replacing the wall-rocks.

The principal showing of quartz lies a few yards west of the road and has been excavated at a number of places. It is a lens-like mass several yards wide, carrying sparsely disseminated pyrite and chalcopyrite. This mass is intersected by an adit 200 feet long driven from the east side of the road about 50 feet below the outcrop. At the adit level the quartz occurs mainly as a group of irregular stringers and small lenses carrying disseminations, streaks, and bunches of sulphides, chiefly pyrite. The granitic wall-rocks are also impregnated with sulphide. Some calcite occurs in vugs in the quartz. About 2,500 feet west to northwest of the adit and 200 feet above it, is a short exposure of a quartz vein 6 feet wide striking north 55 degrees west and dipping 60 degrees northeast. The vein lies between much decomposed walls of granite and carries a sparse dissemination of iron sulphide and galena. Another showing of quartz occurs about 450 feet west of the last, but contains very little mineralization. Other vein outcrops were also observed on the property.

The vein matter is believed to be related to the grey granite in which it occurs and in this respect is doubtless connected with a number of other occurrences of vein quartz occurring within a belt, a mile or so wide, that lies on either side of the southern contact of a large area of granitic rocks (Group III) with older formations (Group II). A number of old workings lie within this belt between Long (Kalamalka) and Okanagan lakes and on some of these, as for example the old Bachelor and Hic Jacet claims, attractive gold values are reported to have been found. To what extent these values apply to average and not to specially picked samples or to large or small bodies of quartz is not known. Two samples taken by the Resident Engineer from outcrops on the Mission Hill group assayed: gold, 0·02 ounce; silver, 5·1 ounces; gold, trace; silver, 1·6 ounces.

Mitchell and Cochrane Group. On this property a large open-cut immediately above the road along the west side of Okanagan lake exposes two parallel quartz veins 6 to 8 feet wide and 2 feet apart. The veins strike nearly east, dip steeply to the south, and intersect argillaceous sediments which in this vicinity strike about north 65 degrees west and dip at low angles to the southwest. The veins have been traced for 200 feet or more. They carry disseminated sulphides including pyrite, galena, chalcopyrite, and sphalerite. According to the Resident Engineer a "sample of some of the sorted ore from the smaller of the two veins ran: silver, 9 ounces; lead, 15 per cent. Samples taken from the larger vein, consisting of quartz impregnated with iron pyrites, yielded no appreciable values in gold and silver". In the vicinity of these workings several other, small quartz veins were observed. Both veins and adjoining wall-rocks carry pyrite, less chalcopyrite, and traces of other sulphides.

Octagon Group. The workings on this group are about 2,000 feet above Okanagan lake on the southwest slope of the valley of Irish creek. Here an open-cut and a short adit have opened up a quartz vein 6 to 7 feet wide striking northeasterly and dipping at an angle of about 30 to 35 degrees. The vein is sparingly mineralized with argentiferous grey copper and carries a little galena, sphalerite, and pyrite. Copper stains occur at the surface and along fractures in the quartz. The vein intersects a massive, grey dyke of feldspar-quartz porphyry.

Pay Roll Group. On this group of six claims, staked in the valley of Newport (Deep) creek, a number of quartz veins have been discovered. The main exploratory work has been confined to one that outcrops along the southwest bank of the creek about 400 feet above Okanagan lake. When visited in the autumn of 1930 this vein had been exposed for a length of at least 700 feet[1] and a vertical range of nearly 100 feet. In this distance the vein maintains a fairly uniform width, averaging from 2 to 3 feet. It strikes nearly east and dips south at an angle of 45 degrees, conforming approximately with the attitude of the enclosing rocks. The latter vary from rather schistose argillaceous sediments to more massive, quartzitic, limy, and possibly tuffaceous types. The sediments are intersected by dykes of grey, feldspar porphyry, mainly, it is believed, of post-mineral age. The vein is composed of banded, white quartz carrying appreciable sulphide mineralization, chiefly galena, with, towards the west, chalcopyrite. Mineralization is most pronounced near the hanging-wall of the vein where the quartz is also more vuggy. The hanging-wall is followed for several yards by a narrow seam of yellowish, oxidized, lead ore of which a sample taken by the writer and assayed by the Mines Branch, Ottawa, contained 20·99 per cent lead, and silver at the rate of 45·50 ounces a ton. A sample of similar material taken by the Resident Engineer is reported by him to have assayed: gold, 0·04 ounce; silver, 35·5 ounces, and lead 40·4 per cent. The body of the vein carries much lower values. A sample taken near the east end where the vein is 26 inches wide was assayed by the Mines Branch and reported to carry: trace gold; 0·72 ounce silver a ton; 0·83 per cent lead; 0·03 per cent zinc. Another sample, taken by the Resident Engineer, at a point farther west and across a width of 2 feet 6 inches, gave: trace gold; 6 ounces silver; 1·6 per cent lead.

Other exposures of mineralized quartz veins were observed on the property near the summit of the ridge on the north side of the creek. At an elevation of about 3,050 feet an outcropping vein has an exposed width of about 100 feet and strikes northwesterly parallel with the bedding of the enclosing sedimentary rocks. This vein is mostly massive and sparingly mineralized, but in places carries galena, sphalerite, and pyrite. A little native sulphur was also noted. The vein probably carries a little free gold. An assay return of $22, mostly gold, is reported to have been obtained from this property and composite samples are stated to have

[1] It is reported that it has since been stripped for another 600 feet.

yielded from $2 to $3 in gold. Galena, where present, carries approximately an ounce of silver to one per cent lead. Another exposure of vein quartz, possibly a continuation of the last-mentioned vein, was picked up on the left side of the creek near the bottom of the valley. Here the vein is exposed for a width of several feet and, in places, is well mineralized with galena and carries considerable sphalerite, and a little pyrite and chalcopyrite. Drusy cavities in the quartz contain a conspicuous amount of native sulphur, a feature that has already been noted in the veins on the Jumbo claim near Swan lake.

Skookum Claim. This claim, situated near the head of Newport creek at an elevation of about 3,850 feet, is accessible by a trail 2½ to 3 miles long. On it several parallel or nearly parallel veins have been discovered. These veins vary from 2 to 6 feet in width, but are of unknown length, sufficient work not having been done to establish their continuity. They strike a few degrees north of west, stand almost vertically, and in these respects conform closely with the wall-rocks which in the vicinity of the main showings are principally argillaceous sediments varying from black, slaty types to more massive, chiefly grey, fragmental beds possibly of volcanic origin. These sediments are in contact, a little to the northwest of the showings, with a body of volcanic breccia which appears to rest unconformably on the sedimentary formations.

Comparatively little work has yet been done on this property. At the discovery camp, an open-cut exposes two quartz veins or two portions of one vein, 3 feet apart and 4 and 6 feet wide, respectively. The quartz is mineralized with disseminated pyrite, chalcopyrite, grey copper, galena, and free gold. One sample across the 6-foot vein is reported by the owner to have assayed about $16 in gold and 170 ounces silver to the ton. Several other samples from selected portions of the various veins are stated to have given from $12 to $20 in gold; from 35 to 144 ounces in silver; traces or very small percentages of lead, and appreciable antimony and copper. The high silver values are apparently associated with some sulphantimonide of copper, probably argentiferous grey copper or freibergite. Gold can be panned from each of the veins, and some very spectacular specimens of gold-bearing quartz have been obtained from them.

White Elephant Group. This property is situated 2 miles west of and about 2,300 feet above Okanagan lake. It is accessible by a road 4½ miles long, which branches off from the main highway along the west side of the lake, at a point a mile north of Shorts creek or 36 miles from Vernon.

The property is of unusual interest because of the nature of the deposit and the extended attempts that have been made to develop it. The White Elephant claim, within which the workings lie, was staked in 1921 and soon afterwards acquired under bond by American capitalists. During the spring and summer of 1922 it is reported that some 300 tons of ore, averaging about 1½ ounces in gold and ½ ounce in silver, were shipped. Work was discontinued in the latter part of the year. In the autumn of 1924 the property was taken over by Okanagan Premier Mines, Limited, of Victoria, and further development work done, though no production is recorded. Following a period of idleness, a third company, Pre-Cambrian Mines, Limited, with headquarters in Seattle, bonded the property and installed a small flotation mill. A small tonnage of concentrates was produced. Values, however, were not satisfactory and the company has turned its attention to investigating the character and extent of the mineralization at greater depths.

The mineral deposit occurs in a granite body that occupies an extensive area in the lower valley of Shorts creek and from there northward to and for some distance beyond Whiteman creek. This intrusive is a fairly massive, coarsely crystalline, equigranular, grey to slightly pinkish, hornblende-biotite granite. It is correlated with the older granites of Group III.

The discovery on the White Elephant claim consisted of a body of vitreous, highly fractured, white quartz 60 feet or more long and about 50 feet wide, striking a few degrees east of north and dipping at about 50 degrees east. This quartz body is surrounded by the granite, good outcrops of which can be seen close to the workings. At 35 feet below the surface, the quartz body is 36 feet wide and has been drifted on for 70 feet without encountering granite at either end. Work has been done below this level, but these lower workings were inaccessible when visited by the writer and there is little available information concerning them.

The quartz is mineralized in a peculiar fashion. A large part of it is almost completely barren of visible minerals.[1] However, within the first 12 feet or so of either wall, streaks, bunches, and lenses of pyrrhotite occur. Some of the lenses are as much as several feet thick. These pyrrhotite masses contain a network of narrow, fine-grained, dark greenish yellow, vein-like bodies composed mainly of minute pyrite grains, but with some interstitial quartz and tiny, irregular quartz veinlets. The pyrite grains are arranged in a series of almost microscopic rows parallel with the sharply defined, pyrrhotite walls. Similar, narrow, pyritiferous bodies lie along the contact of the pyrrhotite masses with the surrounding quartz and generally show a less regular contact with the quartz than with the pyrrhotite. The mode of occurrence and finely granular character of this pyrite and its intimate association with quartz suggests that it consolidated from a gel that occupied fractures in the previously consolidated pyrrhotite and the semi-consolidated quartz. In other words, it appears that although all the vein material had been introduced at or about the same time and from the one source, the pyrrhotite and most of the quartz had precipitated before the pyrite gel had consolidated.

Other minerals in the deposit include a bismuth telluride (tetradymite), chalcopyrite, and (?) free gold. No free gold was positively identified in the specimens examined, but it is reported that specimens were discovered, during initial operations on the property, in which flakes of native gold were interleaved with plates of the telluride mineral. The latter is the most interesting of the metallic constituents of this deposit. It is a tin white, very soft, mineral occurring either in massive form, somewhat resembling steel galena, or in tabular, foliated masses showing perfect basal cleavage. The flat surfaces of such masses are tarnished and, in part, filmed with chalcopyrite and (?) free gold. The telluride occurs as particles and small masses disseminated through the quartz without, it appears, any particular relation to the pyrrhotite bodies. A polished surface of one specimen was examined under the microscope. In this specimen (*See*

[1] The writer was informed that some scheelite had been found associated with the quartz in the outcrop.

Figure 8) the telluride replaces pyrrhotite, pyrite, chalcopyrite, and quartz and near the contact with these minerals holds abundant, small, irregularly shaped inclusions of them (Figure 8). Elsewhere in the telluride are swarms of extremely minute bodies of a yellow mineral, probably chalcopyrite, but too small to identify. The textures presented by both the pyrrhotite and chalcopyrite inclusions in the telluride minerals have that curious pseudo-eutectic appearance described and illustrated by Lindgren[1] as characteristic of replacement processes. Tiny veinlets of chalcopyrite lie within the pyrite bands, or along minute fractures in the pyrrhotite. Microscopic particles of the same sulphide also occur in quartz veinlets within the pyrite bands. These relations suggest that the chalcopyrite was among the last minerals and the telluride (tetradymite) the last to form in this deposit.

It is significant that the pyrrhotite bodies, as a whole, carry low to negligible values in gold, whereas the quartz in the vicinity of the pyrrhotite may provide high assay returns. This feature is partly explicable on the basis of the order of consolidation of the several vein constituents. The pyrrhotite appears to have been the first to be deposited and the telluride mineral (tetradymite) the last, with, doubtless, considerable overlap among the intervening constituents including quartz, pyrite, and chalcopyrite. Pyrrhotite and quartz probably commenced deposition at about the same time, but considerable of the latter still remained in solution after all the pyrrhotite had crystallized out. Part of this remaining silica formed a gel with iron sulphide within and around the periphery of the pyrrhotite masses and eventually was deposited in the banded form previously described. Towards the close of the period of consolidation of this gel, deposition of the remaining minerals hitherto held in solution commenced. These included chalcopyrite, any remaining quartz, and last of all, tetradymite. Probably, also, any free gold was deposited in these closing stages, though no direct evidence of this was obtained. These later minerals were deposited wherever space permitted, principally within the main quartz body. There was an apparent tendency for them to form near the pyrrhotite masses, though not actually in them, as these masses afforded little space for mineral deposition. The highly fractured character of both quartz and pyrrhotite now evident in this mineral deposit is a result of deformation subsequent to mineralization, and is accordingly not believed to have any bearing on the occurrence or association of minerals or values.

As the minerals in this deposit are of primary origin and have come from depth it would seem that gold values should persist with depth. On the other hand, the fact that the gold values seem to be associated principally with the tetradymite and the deduction that this telluride mineral was among the latest if not the last of the metallic constituents to be deposited and might, in consequence, be expected to concentrate in the upper portions of the deposit suggest that gold values may also be found to decrease with depth.

The origin of the mineral deposit is referred to the enclosing granite which is pre-Tertiary, probably late Mesozoic. This granite is considerably altered and sparingly mineralized near its contact with the

[1] Lindgren, Waldemar: "Pseudo-Eutectic Textures"; Econ. Geol., vol. XXV, No. 1 (1930).

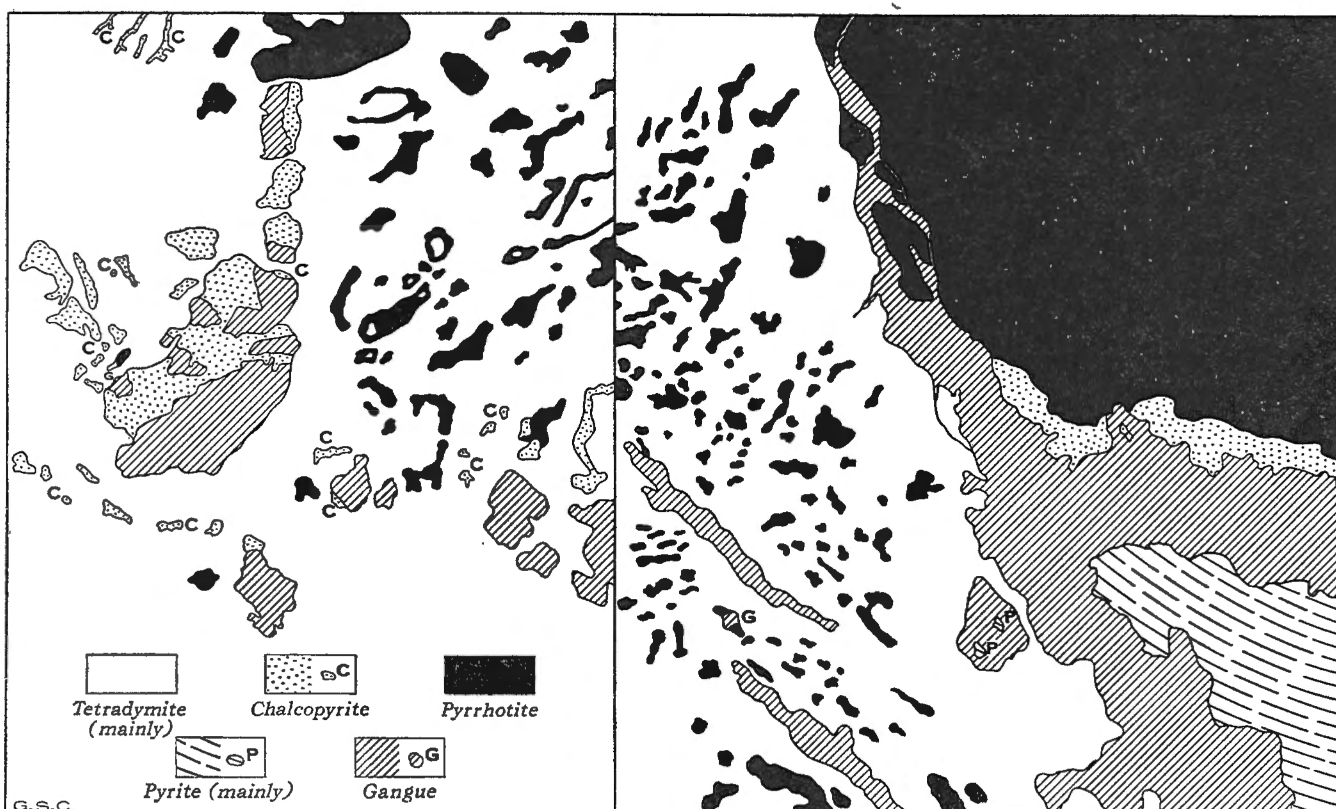


Figure 8. Camera-lucida sketches of ore from White Elephant mine, Okanagan valley, British Columbia. Magnification 150 diameters.

quartz outcrop. Both it and the mineral deposit are intersected by a narrow, low-dipping, dark dyke, presumably of Tertiary age, related to volcanic rocks which here and there overlie the granite unconformably.

A number of other properties have been staked either adjoining or in the vicinity of the White Elephant group. These were not examined, but are reported to contain well-defined, mineralized quartz veins occurring in the granite and in an adjoining belt of sediments farther west.

Conclusions with Respect to Vein Quartz Deposits in this District

In previous pages considerable has been said regarding the location, number, size, mineralization, and contained values of the quartz veins in the area under discussion. It has also been indicated that although considerable work has been done on these veins this work has lacked concentration and at only two or three places has been carried to the point of production. Nor has this production amounted in any instance to more than a few tons and the proceeds to more than a slight return, in comparison with amounts expended in exploration and development. On most of the properties, however, the slight amount of work has been purely exploratory. On many of the claims some encouragement has been afforded this work by the discovery of free gold, the occurrence of heavy sulphide concentrations, the receipt of high assay returns on selected samples, or the unusual size of certain vein outcrops. But in no single instance does it seem that the exploratory work has proved the existence of a body of quartz of sufficient size and average value to pay to mine. In at least many cases it has been realized that either the richer veins or richer portions of veins were too small or the bulk of the vein matter too low grade to warrant further development. Production on a small scale such as has been attempted, is burdened by initial costs for exploratory and development work, for surface and underground equipment, and for overhead expenses. In general, the smaller the scale of operations, the larger, in proportion, will be the expenses. It appears to the writer that the suggestions offered as affording a possible plan of development of veins on and in the vicinity of the British Empire group might well be applied to a larger area including most of the properties referred to in this report. The first step would be the pooling of resources by the various property owners. The next step would be a careful sampling of the showings on these properties. Doubtless as a result of careful sampling many veins and many claims could be abandoned as worthless and it is even conceivable that in the end it would appear that further attempts at development or production on any one property would be inadvisable. On the other hand, the sampling might indicate that at certain localities there were important bodies of quartz carrying sufficient average values to warrant further consideration. Knowing approximately what such values were one could then estimate what the total cost of mining, milling, transportation, etc., must be limited to in order to afford a margin of profit.

COMPLEX SULPHIDE DEPOSITS

Deposits of this type are of limited occurrence in the district, but have received considerable attention on two properties situated on either side of the northwest arm of Okanagan lake.

Goodenough Group[1]

This group, owned by H. J. Blurton, Vernon, B.C., is situated on the ridge between Naswhito (Siwash) and Equesis (Sixmile) creeks about 3½ miles directly west of Okanagan lake. It is nearly reached by a branch road that leads off from the highway along the west side of the lake at a point a little north of Naswhito creek. Most of the workings lie between 1,300 and 1,800 feet above lake-level.

The property has had a long history, having been staked and restaked a number of times under different names and explored by various individuals and organizations. Interest has been maintained by the extent and variety of mineral deposition rather than by assay values. Exploratory work has been largely devoted to attempts to delimit the area of mineralization.

The mineralization has been produced at the contact of a body of grey granite with overlying sedimentary and volcanic rocks. The granite has been partly unroofed in the vicinity of the workings, but higher up the hill to the west and northwest disappears beneath a heavy cover of older rocks. It is a light grey, medium-grained, massive granite in which the original, dark constituents, chiefly biotite, have been completely altered to secondary minerals, principally chlorite.

The granite is included with the older members of Group III. The pre-granitic rocks comprise greenstones, limestone, and some argillaceous sediments and are included with the formations of Group II. The greenstones are probably, in the main, old volcanics, but in part are secondary rocks formed by contact metamorphism of limestone. The latter are highly altered at the granite contact, but elsewhere, as on a prominent knoll a little northwest of the mineralized area, form conspicuous outcrops of nearly pure, grey limestone carrying abundant fossils of Carboniferous age.

Workings include six or more shallow shafts; three or more adits, one of which is 200 feet long; many open-cuts; and several hundred feet of surface trenching. They are scattered over an area about 1,200 feet long and 800 feet broad in which occur many exposures of iron and copper-stained rocks.

The various showings reveal a general similarity in mineralization and in the alteration of the associated rocks. Both phenomena are suggestive of high-t mperature conditions involving recrystallization of the older rocks and their replacement by mineralizing gases and solutions. In these respects the limestone and limy members of the invaded rocks have suffered most complete transformation, being now composed largely of lime-silicate minerals, principally epidote and garnet, associated with more or less crystalline calcite and metallic minerals.

The principal metalliferous constituents are pyrrhotite, pyrite, magnetite, and chalcopyrite in order of relative abundance. Of these the copper sulphide is most important economically. It occurs in part as tiny

[1] Ann. Repts., Minister of Mines, B.C., as follows:
1899—p. 746—"I.O.U., Gem, Buckthorn, and Copper Queen."
1900—pp. 886-887, "Porteous Camp."
1902—p. 189—"Gale, Dawson, Blue Bell, and Phoenix."
1904—p. 228—"Gale group."
1921—p. 191—"Queen group."
1924—p. 140—"Goodenough group."
1929—p. 247—"Goodenough group" (Okanagan Copper Co.).

veinlets intersecting the other minerals, and in part as disseminations, irregular streaks, and small masses associated in varying proportions with other minerals. Pyrrhotite oxidation has furnished much of both the reddish oxide and whitish iron-sulphate stains observed at the various showings. It is a particularly prominent constituent of the mineralized greenstones in which it occurs in forms varying from minute disseminations to masses of nearly solid sulphide. Magnetite occurs in masses associated chiefly with pyrite and chalcopyrite. Pyrite is disseminated through the older rocks and the granite. Copper carbonate stains and soot-like decomposition products are common wherever chalcopyrite is present. A little galena was also noted. The mineralization is connected in origin with the granite and occurs mainly within a zone along the contact of this intrusive body. It is principally confined to the overlying older rocks, though in places the granite itself is sparingly mineralized. At most if not all the showings the mineralized zone appears to be shallow because it is largely confined to the rocks covering the granite and this cover is shallow. Information gained from many operations to date suggests that mineralization has tended to follow fractures or shear zones striking north to northeasterly and that beyond the zone of contact influence there is a change from mixed sulphide ores with comparatively little quartz gangue, to quartz veins carrying a sparse dissemination of metallic minerals. It may eventually be shown that other structures within the roof rocks, such as folds having a general northwesterly trend parallel to the main axis of deformation of the pre-granitic rocks, have exerted an important influence on the mineral concentration. It would greatly enhance the prospects of the property if it could be proved that the granite roof lies at workable depths where the cover of older rocks is thicker, particularly beneath the limestone belt to the northwest. In such case, the possibilities for the development of deposits of substantial thickness should be exceptionally good.

In spite of the amount of surface or near-surface work and the great number of showings, the property is difficult to evaluate. Many samples taken at different times and by different persons indicate values in copper of rarely less than 1 per cent, more commonly ranging from 1 to 8 per cent, and, for selected material, much higher than this. Assays also generally show values in gold and silver averaging about 0·03 ounce and 0·05 ounce a ton, respectively. Such values combined should be attractive if a large tonnage could be definitely proved. The property seems to be one where geophysical methods of prospecting could be employed to advantage and where systematic drilling should be attempted in order to obtain a better idea of average values and of average thickness of the mineralized contact zone.

Ophir Group[1]

This property, comprising seven claims, held by location, is owned by Joe St. Laurent, Falkland, B.C., *et al.* It is on the east side of the northwest arm of Okanagan lake about 6 miles from the head of the lake and 15 miles by road from Vernon.

The property was originally staked in the summer of 1923 by Wm. Brent of Vernon and was known for some time as the Brent property.

[1] Ann. Repts., Minister of Mines, B.C., 1923, p. 161; 1925, p. 184; 1926, p. 200; 1927, p. 213; 1928, p. 220.

The initial discovery was made on the side of the hill nearly 300 feet above the lake shore. Here some high-grade copper ore was discovered in a shear zone striking northwest and dipping 60 degrees to the northeast. This shear zone has a maximum width of about 50 feet and conforms with the structure of the enclosing formations. The latter are chiefly dark grey, argillaceous, more or less slaty or schistose rocks, but include along the course of the shear zone a narrow but persistent band of quartz-sericite schist. The latter is a white or cream-coloured, lustrous, highly micaceous rock which has been involved in most of the deformation affecting the associated, argillaceous beds and probably is a highly altered quartz porphyry dyke or sill.

Exploratory work, including several open-cuts and trenches, has proved the continuity of the shear zone for 800 feet and a vertical depth of over 200 feet. Mineralization is not equally distributed along or across this zone, but is mainly confined to widths of, at most, a few feet. From developments to date, however, it would seem that the entire width of the shear zone may be regarded as potential ground within which, at intervals along either the strike or dip, important mineralization may occur.

The minerals present include pyrite, chalcopyrite, sphalerite, and galena in about this order of abundance. Zinc silicate (calamine) has also been reported and a number of secondary minerals have formed in small quantities from the iron and copper sulphides. Pyrite occurs disseminated through both the rich and lean portions of the shear zone irrespective of other minerals. Chalcopyrite is more restricted and is most conspicuous in the lowest, main open-cut where it occurs in part as bands or lenses, an inch or so wide, of solid or nearly solid sulphide, and in part disseminated through the adjoining quartz-sericite schist wall-rock across a total mineralized width of about 4 feet. A sample taken by the Resident Engineer in 1925 across 2 feet of such material assayed: gold, trace; silver, 0·2 ounce a ton; copper, 4·3 per cent. Subsequent development work at this point opened up about 4 feet of higher grade copper ore. Sphalerite is abundant in the main, upper open-cut situated 155 feet above and 400 feet southeast of the lower workings. Here a trench 75 feet long follows a well-mineralized band, about 3 feet wide, in the shear zone, from which band a carload of ore has been extracted and was reported by Mr. St. Laurent (September, 1929) to assay $43 a ton in combined gold, silver, and zinc values. A sample across the trench was obtained in 1928 by the Resident Engineer, and assayed: 0·06 ounce gold, 2·4 ounces silver, 1·6 per cent copper, 2 per cent lead, and 21 per cent zinc a ton, and indicates in a general way the proportions of copper, lead, and zinc sulphides present. The zinc blende occurs partly massive and partly in disseminated form, associated with galena, pyrite, and chalcopyrite, replacing the schistose country rock. At the southeast end of the trench the mineralized width pinches to a few inches; attempts to pick it up again in a couple of trenches farther southeast have not been successful, though the shear zone itself is persistent. Similarly, a long trench intermediate between the upper and lower main showings does not show any appreciable concentration of sulphide minerals. This latter trench may not have been extended far enough to the northeast.

Such work as has been done demonstrates the continuity of the shear zone, but indicates that the important mineralization is confined to shoots of as yet unproven dimensions and containing quite different proportions of sulphide minerals. The discoveries to date, and the possibility that the shear zone may contain other and larger ore-bodies than have yet been found, give some hope that the property may yet become a producer of base metals.

The mineralization is connected in origin with the granitic rocks such as outcrop farther south between the two arms of Okanagan lake. In the immediate vicinity of the Ophir property a number of porphyritic, grey to somewhat pinkish, intrusive bodies outcrop and might be supposed to have some bearing on the mineralization. They are, however, almost certainly of Tertiary age and are consequently considered to have been intruded in post-mineral times.

MAGMATIC SEGREGATIONS

Chrome-Vanadium Group[1]

This property, owned by A. H. Raymer and associates of Kelowna, B.C., is situated at the headwaters of Nicola river at an elevation of 4,800 feet above sea-level. It is accessible from Okanagan lake by road and trail up the valley of Lambly (Bear) creek and thence over the divide between Osoyoos and Kamloops districts via a pass 5,850 feet high on the south flank of White Rocks mountain. The distance by this route is about 19 miles, of which the first 7 are by road. The property may also be reached by road and trail up Nicola river from Douglas lake, a distance of about 23 miles.

Interest in the Chrome-Vanadium group is centered chiefly on the occurrence of segregated chromite in a belt of serpentinized peridotite which extends across Nicola valley in a general north 25 degrees west direction. This belt was followed to the southeast of the river for over half a mile and in the opposite direction for about a mile and picked up again over a mile farther northwest. In this total distance the belt maintains a remarkably straight course and an apparently steep dip. On either side of Nicola river it has an observed width of about 400 feet and is doubtless somewhat wider, as its northeast contact is nowhere exposed. On the southwest side the belt is in contact with, and apparently intrudes, both granitic rocks and argillaceous sediments. In shape, structure, and contact relations this belt resembles a broad dyke and such it is presumed to be.

This chrome-bearing dyke is composed mainly of dark green serpentine which commonly weathers a deep orange-red, but in places is coated instead with a thin, semi-transparent, whitish, talcose film. The serpentine has resulted from the alteration of an intrusive composed very largely of olivine. Microscopic studies reveal different stages of alteration ranging from those in which abundant small grains of olivine occur in a meshwork of serpentine to others in which no traces of unaltered olivine remain. Other minerals present include partly to completely altered crystals of pyroxene, talc, chlorite, magnetite, asbestos, and chromite. The chromite is dark brown and almost opaque in thin section. It is an abundant constituent at one locality. At most other places the rock carries disseminated magnetite occurring either in crystals or in lumps and small,

[1] Ann. Rept., Minister of Mines, B.C., 1929, p. 249.

irregular streaks. At different places the serpentine was observed to contain small veinlets of cross-fibre asbestos varying in thickness from that of a mere thread to ¼ inch. Where shearing or slickensiding is pronounced, lenses of partly developed, slip-fibre asbestos have formed. In a comparatively narrow, steeply inclined belt of this sort, however, important deposits of asbestos are hardly to be expected. Small lumps and stringers of pearl grey, semi-transparent talc are abundantly scattered through some sections of the peridotite belt.

The principal discovery was made less than 100 yards southeast of, and a few feet above, the left bank of the river, at a point nearly 450 feet from the southwest contact of the serpentine belt. Here a small segregation of high-grade chromite ore was discovered and, apparently, mostly dug out. It occurred in part as closely spaced kidneys of chromite ½ inch to one inch in diameter, and in part as a heavy dissemination of small, granular aggregates occupying up to 75 per cent or more of the rock volume. The enclosing rock is a dull green, massive, partly serpentinized dunite in which some further alteration to talc and chromiferous chlorite has occurred. Little or no magnetite appeared to be present. Though not of itself economically important, this discovery suggests the possibility of other occurrences in this serpentinized belt. Little clue is furnished as to where to look for such deposits. The rock in the belt is a type that under favourable conditions might prove a valuable source of both chromite and asbestos and, perhaps, rarer minerals such as platinum. The belt should, consequently, be followed in both directions and particular attention paid to it at places where it either widens materially or changes in its general structure or appearance. In its southeasterly course the belt should, if continuous, cross streams tributary to Okanagan lake. It might, in consequence, be a good plan to prospect some of these larger tributary valleys, such as that occupied by Trepanege creek, for this rock and to try panning the stream gravels at or immediately below the place where the creeks cut across it. Any heavy, black sand obtained by panning should be examined for chromite and platinum. The former can be distinguished from any magnetite present by the fact that it is not noticeably magnetic and forms a brown powder when crushed. Platinum on the other hand is more metallic looking and much heavier than either magnetite or chromite, is not magnetic, and is malleable. The discovery of appreciable amounts of either chromite or platinum in such creek gravels would at once suggest further prospecting in that vicinity.

The small chromite deposit on the Chrome-Vanadium group is, judged from descriptions, very similar in type and origin to those at present exciting some interest in Clinton mining division, on Scottie creek and vicinity.[1]

PROSPECTING AREAS

Two areas in which it appeared that more prospecting might be done to advantage were noted during the past summer.

One of these areas occupies a portion of the northern slope of the valley of Shorts creek, about 9½ miles from Okanagan lake. A rapid survey of this section indicated a considerable body of old rocks, such as

[1] Ann. Rept., Minister of Mines, B.C., 1930, pp. 198-200.

might be included with Group II, intruded to the east, west, and south by a large body of grey to slightly pinkish granite. The older rocks include abundant limestone with which is associated fine-grained, quartzitic, and argillaceous sediments. Viewed from the bottom or the south slopes of the valley, these old sediments could be seen to occupy a V-shaped area narrowing to about half a mile wide in the vicinity of Shorts creek and broadening towards the north. The following interesting features were noted: (1) all or nearly all members of the V-shaped area are reddish weathering as the result, apparently, of oxidation of sulphides; (2) much limestone is present, a rock which under favourable circumstances is susceptible to important mineralization; and (3) the contact of these sediments is with a large body of intrusive granite of a similar type to that which elsewhere in the district is connected with mineral deposition.

The other area is a tract of country of uncertain dimensions, including White Rocks mountain[1] on the divide between the headwaters of Lambly (Bear) creek and Nicola river. The underlying rocks are chiefly granitic types, principally distinguished by the occurrence of abundant, conspicuous, peculiarly shaped crystals of orthoclase feldspar varying from a fraction of an inch to several inches in length, but unusually narrow in proportion to their length. Otherwise these rocks vary from white to dark grey or greenish in colour and from true granites to, on the whole, intrusives having more nearly the composition of quartz syenite and syenite in which dark green amphibole (hornblende?) may be abundant and quartz relatively scarce. Other essential minerals include microcline, microperthite, and sodic plagioclase feldspars. Accessory and secondary minerals are sphene, epidote, chlorite, magnetite, and sulphides.

This body of alkaline, granitic intrusives occupies at least several square miles. It is of economic interest by reason of the many places where it was observed to carry conspicuous disseminations of pyrite, chalcopyrite, and, more locally, magnetite. As a consequence of the copper sulphide, rock outcrops are, in places, stained with copper carbonates. The sulphides are original constituents of the intrusive mass, are relatively abundant, and point to this area as a particularly favourable one to prospect for more concentrated mineral occurrences, preferably in the vicinity of the granitic contacts with bodies of older formations.

Non-Metallic Deposits

GYPSUM

Falkland Deposits[2]

A discussion of the non-metallic resources of northern Okanagan valley and vicinity would be hardly complete without at least some reference to the well-known gypsum deposits at Falkland, owned by Gypsum, Lime, and Alabastine, Canada, Limited. These were formerly known as the Salmon River deposits and were first staked about 1894. No pro-

[1] For description of route to this mountain, *See* report on the Chrome-Vanadium group of claims.
[2] McEvoy, Jas.: Geol. Surv., Canada, Ann. Rept., vol. VIII, pt. A, p. 37 (1897).
Cole, L. H.: Mines Branch, Dept. of Mines, Ottawa, Pub. No. 245, "Gypsum in Canada," 1913, pp. 91-95.
Cole, L. H.: Mines Branch, Dept. of Mines, Ottawa, Pub. No. 714, "The Gypsum Industry of Canada," 1930, pp. 58-63.
Ann. Repts., Minister of Mines, B.C., 1925, p. 189; 1930, p. 197.

duction was attempted until 1926, following the construction of the Kamloops-Kelowna branch of the Canadian National railway. The deposits are on the northern slope of Salmon River valley between 500 and 1,000 feet vertically above the railway at Falkland, 44½ miles by rail southeast of Kamloops and about 28 miles by rail northwest of Vernon. They are worked from quarries and the product is carried by a gravity aerial tramway to a 200-ton storage bin at the railway terminal. From there it is mostly shipped to the company's plants at Port Mann, B.C., and Calgary, Alta., but some is sold in the raw state.

The references listed above, and especially Mr. Cole's reports, include full particulars with respect to the location, history, size, and composition of the Falkland gypsum deposits and also give details on mining and milling methods and on the industrial uses to which the manufactured products are put. The deposits occur in lens-shaped masses within a belt of greenish and greenish grey, massive to quite schistose rocks of, chiefly, volcanic origin. This belt has a general northwest strike and about 14 miles from Falkland forms the southern end of Armstrong mountain to the west of the south end of Otter lake. To the northeast this belt of volcanic rocks is in contact with a wide zone of probably older, dark grey to black, slaty, argillaceous, ottrelite schists. Such rocks form the greater part of Armstrong mountain and farther northwest occupy the summit of the mountain to the north of, and about 2,500 feet above, Falkland.

The formations of the "volcanic" belt, as developed in the vicinity of Falkland, are, with the exception of the gypsum deposits, very similar to those occurring over wide and extended areas to the southeast across and beyond the present map-area. They include: (1) massive greenstone, representing volcanic lavas and flow-breccias, and containing numerous, conspicuous, dark green crystals of hornblende; (2) greenish, volcanic tuffs and breccias showing, in places, evidence of stratification, and grading into tuffaceous sediments composed in part of volcanic ash and in part of contemporaneous, sandy, limy, and argillaceous materials; and (3) bodies of crystalline or semi-crystalline limestone. This limestone forms a series of lens-shaped masses elongated along the general trend of the enclosing formations and not uncommonly showing good bedding structures. Such associations were observed on either side of Salmon River valley within a few miles west of Falkland; at numerous places in the vicinity of Vernon; in Coldstream and Creighton valleys to the east of Vernon; and on the western slopes of Monashee mountains in the valleys of Monashee creek and its tributaries.

At Falkland the geological associations of the gyspum deposits are exactly similar to those of the limestone occurrences at the many localities referred to above and the analogy is rendered even more complete by the discovery of limestone in and bordering one of the larger gypsum lenses.[1] Referring to this feature Cole states, "The gypsum has a capping of badly weathered limestone . . . . . Along the edges of the (gypsum) deposits residual pinnacles of limestone still remain standing . . . . . The limestone in these masses carries minute particles of gypsum through it."

[1] *See* photo and description in Cole's report, 1913.

BUILDING STONE

Three granite quarries (*See* Figure 7) have been opened up in the northern Okanagan valley, two on the east side of Okanagan lake a few miles south of Okanagan Landing and a third about 2 miles west of Armstrong, close to the Canadian National railway. The two quarries on the lake are in a coarse, pink and white granite which forms part of a body of Tertiary, granitic rocks. These quarries are fully described by Parks[1] from whose report much of the following information has been obtained.

The more northerly (Benjamin Lefroy) quarry, about 4 miles south of Okanagan Landing, is 50 feet long with a maximum face of 20 feet. Distinct sheeting is not shown, but the upper part of the face is cut by close-set, arching partings conforming to the contour of the hill. A strong set of vertical joints runs north and south. Other vertical joints cross in a southeasterly direction. Though the site gives no promise of yielding really large blocks, the stone has a good rift and grain and is practically devoid of knots or flaws.

The stone is a dull, light reddish granite, lacking in "liveliness". It is rather coarse in grain, with feldspar crystals up to 8 mm. in diameter. Quartz is much less abundant than the feldspar and the dark mineral, biotite, is in relatively small amount. The microscope shows large orthoclase crystals in a semi-decomposed condition, some plagioclase, biotite, and a few grains of olivine. The specific gravity of the rock is 2·643. This rock has been employed to good advantage in the construction of such buildings as the railway station, post office, and Hudson's Bay Company store in Vernon and the Church of England and the Royal Bank at Kelowna. The Vernon post office shows a uniform and pleasing pinkish tint without any sign of knots, flaws, or iron-staining.

The more southerly quarry, about 6 miles south of Okanagan Landing, is operated by the Vernon Granite and Marble works, and was opened up subsequent to the Lefroy quarry, about 1910. It is about 75 feet long, parallel to the shore, about 50 feet wide, and 30 feet deep.

The sheeting is irregular and poorly developed at the north end. Near the middle, at the top of the face, the sheets seem to dip east at about 30 degrees. The main joints strike north 20 degrees west, dip 85 degrees westerly, and are widely spaced, thus permitting the quarrying of large stone. The rift of the granite is vertical at north 15 degrees east and is, therefore, not parallel to the main jointing. In the rear of the present workings some good outcrops were observed and doubtless many others could be found in the region.

The granite in this quarry is, on the whole, brighter, fresher, and somewhat coarser than that obtained from the Lefroy property. Its mineral constituents are quartz, orthoclase feldspar, in crystals up to 10 mm. long, plagioclase, in less amount, and black mica or biotite with a little green chloritic matter. A little pyrite was also observed, but does not appear to have formed any rust spots.

Much of the production from this quarry was used for the court house in Vernon. Small amounts have been used for monuments, chiefly for bases. The court house is a splendid building with a pleasing, slightly

[1] Parks, W. A.: Mines Branch, Dept. of Mines, Canada, "Building and Ornamental Stones of Canada," vol. V, pp. 66-70.

pinkish colour: it shows less disfiguration due to knots, veinlets, etc., than most of the granite structures in British Columbia. The building bears the date 1914.

The Lumsden quarry near Armstrong is in a body of medium to fine-grained, light grey granite. This stone has a good rift and grain, and is worked with facility. Unfortunately, it contains an undue amount of pyrite, with the result that all cut stone becomes badly spotted after a short period of weathering. A small amount of this stone has been used for monumental bases. It was employed for the base of the Bank of Montreal building, Vernon.

LIMESTONE

The older formations of the north Okanagan valley, included in Groups I and II, contain an abundance of limestone. Most of this limestone occurs within two broad and roughly parallel belts striking in a general west to northwesterly direction across the valley. The southern belt is the larger and, on the whole, contains the greater number of large, readily accessible, limestone deposits. This belt crosses Okanagan valley in the vicinity of Vernon and includes a great number of prominent limestone exposures within a short distance of that town. Prominent outcrops also occur: around the head of Long lake; between the two arms of Okanagan lake; and in the valley of Naswhito (Siwash) creek.

The other belt crosses Okanagan valley a little to the north of the map-area, between the towns of Armstrong and Enderby. Probably the most conspicuous body of limestone in this belt occurs near the head of and on the north slope of Glanzier creek, about 5 miles west of Armstrong. Other prominent exposures occur: to the south of this creek; on Knob hill, 2½ miles northwest of Armstrong; and in Salmon River valley a few miles west of Falkland.

The limestone of these belts is mostly crystalline or semi-crystalline and varies in colour from nearly pure white to shades of grey. Much of it is comparatively free of impurities and seems to be nearly pure calcium carbonate.

Some of these limestone bodies have been utilized in a small way for the manufacture of lime. One quarry, on Kendry (Christian) creek (lot 989) near the main valley bottom, about 3 miles east to northeast of Armstrong, was opened by Land Limes, Limited, on a vertical band of grey, fairly pure, crystalline limestone about 25 feet wide. A plant was installed to crush the stone for use in agriculture, the product having the trade name of "Decalion". This plant has not been in operation for several years.

The great abundance and unusually convenient situation of limestone bodies in these northern sections of Okanagan valley suggest that special effort should be made to utilize them for one or more of the extraordinary number of industrial uses[1] that limestone products have.

CLAY

Glacial and post-Glacial clay and silt are abundant in Okanagan valley and have been employed to some extent in the manufacture of brick. Probably the most successful and prolonged effort of this sort

[1] Gouge, M. F.: Mines Branch, Dept. of Mines, Canada, "Limestone in Industry," Pub. 719, pp. 43-53

was made about a mile north of Enderby, on a branch line of the Canadian Pacific railway about 25 miles south of Sicamous and 9 miles north of Armstrong. Here the Enderby Brick and Tile Company developed a clay bed forming part of the Shuswap River terrace. This was a stratified, calcareous, yellow clay[1] strongly impregnated with iron oxide, somewhat silty, and containing an abundance of mica scales. The bed is replaced laterally by sand. It made a good, hard, red brick of which some 331 M were kilned in 1920[2]. The product was shipped south as far as Kelowna and east along the main line of the Canadian Pacific railway to Revelstoke.

A number of years ago a brick plant was operated at Vernon near the junction of the Coldstream and Long Lake roads. This plant is reported to have manufactured brick from a section several feet thick, of rather silty, banded, glacial clays, an exposure of which may be seen in an old pit on the north side of the Coldstream road.

In 1920 the Lakeside Clay Products Company, Limited, was formed[3] to work a clay deposit near Okanagan Landing. During the summer a plant was installed for production of brick and some kilns fired. It was the intention of the company to manufacture drain and hollow tile as soon as developments warranted. Some good tile were made from samples of the clay, but, so far as could be learned, no production is recorded.

COAL

The question as to whether economic deposits of coal might not be found in northern Okanagan Lake district is one that has not only aroused some interest, but has resulted in the expenditure of considerable time and money in exploratory work. For many years it has been common knowledge that the Tertiary sedimentary rocks of the district carry some coal. After visiting a number of reported occurrences and discovering others, it appears to the writer that in most instances the deposits are seams varying from a few inches to over a foot in thickness, composed of alternating thin layers of coal and sandstone or shale. In other instances, the so-called coal seams are merely strata containing abundant, partly to completely, carbonized fossil remains of plants. In neither case are the deposits of commercial value, but the first type may represent horizons which elsewhere hold thicker, more valuable coal seams. At two localities where considerable exploratory work has been done, special conditions seem to have obtained, and although in one case the occurrence must be labelled as of doubtful, and the other as of even less possible, value they each warrant further discussion.

Shorts Creek Coal Property

This property, comprising about 6 square miles of land, held under the Coal Licence Act of 1910[4], is owned by Jas. Forester, Vernon, B.C. It is situated on the northern slope of the valley of Shorts creek, a western tributary of Okanagan lake, and is accessible by 4 miles of road and 3 miles of trail from the highway along the west side of the lake. The

[1] Ries, H., and Keele, J.: Geol. Surv., Canada, Mems. 24 E-25, pp. 118-120.
[2] Ann. Rept., Minister of Mines, B.C., 1920, p. 169.
[3] Ann. Rept., Minister of Mines, B.C., 1920, p. 169.
[4] Holden, Jas.: Private Report, June 27, 1913.

workings, comprising one inclined adit and two open-cuts, lie at an elevation of about 3,500 feet above sea-level or between 1,100 and 1,350 feet above the bottom of Shorts Creek valley.

In the vicinity of the coal property, Shorts creek occupies a prominent, deeply incised valley with steep to, in places, nearly perpendicular walls rising to plateau levels nearly 3,000 feet above the valley floor (Plate I B). This valley has exposed a basin of Tertiary rocks which include the coal measures and which rest unconformably on pre-Tertiary formations. The latter are chiefly granitic intrusives on the west and still older formations, mainly sediments, on the east side of the Tertiary basin. This basin provides one of the most complete sections of Tertiary formations in the district. A splendid view (Plate I B) of it is afforded from the edge of the plateau on the south side of Shorts Creek valley, from which position the general structure and composition of the basin can readily be observed. The basal member is a coarse conglomerate, 100 to 200 feet thick, composed entirely of detritus from pre-Tertiary rocks and is well exposed in the bottom of the valley on either side of Shorts creek about 6 miles from its mouth. This conglomerate is overlain by from 2,000 to 3,000 feet of volcanic rocks, chiefly lavas, but including ash rocks and breccias which, in part, are waterlain and show good bedding structures. The lavas vary in appearance, but are principally reddish or purple and often highly vesicular or amygdaloidal. These volcanic members floor the valley west of the conglomerate bed for over a mile to where the underlying, older, granitic rocks are exposed. At this point the volcanics extend up the northern slopes of the valley for 1,000 feet or more, vertically, to the base of the sedimentary series containing the coal showings. These sediments have a maximum thickness estimated at 500 feet. They are chiefly rather coarse, greenish sandstones interbedded with dark, shaly strata containing plant remains and with beds varying from coarse agglomerates, carrying large, angular fragments of lava, to fine-grained ash beds. The sediments are intruded by wide dykes of basalt representing feeders to overlying lava flows. The latter, together with greenish grey, pyroclastic beds, form nearly perpendicular cliffs rising to the plateau level. This upper series of volcanic rocks continues south across the valley of Shorts creek to form the peaks of Terrace and Sheep mountains. The underlying, coal-bearing measures might, in consequence, be searched for around the base of these high hills at an elevation of about 5,000 feet.

The workings on this property develop what is apparently a single coal-bearing zone situated within 100 feet or so of the base of the sediments. In its explored and more accessible sections this zone has a fairly uniform strike of a few degrees north of east and dips northerly at from 20 to 25 degrees. It has been opened up at three places, the two end workings being over 200 yards apart. The lowest and most westerly working is an inclined adit following the coal zone for a distance of about 75 feet on an average dip of 25 degrees to the north or into the hill. At the portal this zone is exposed as a seam of impure coal from 3 to 3½ feet thick, including many thin, bony or shaly partings. The coal itself is dried and cracked by exposure, and is very fragile. Underground, the character of the seam improves as depth is gained. Near the face of the adit a little drifting has been done, but, owing to water, a proper examination of the lowest parts of these workings could not be made. A sample (No. 342) was taken on the west side of and towards the bottom of the incline, across 16 inches of what appeared to be about the maximum thickness of the best coal—the entire seam at this point being 4 feet or more thick. A selected specimen of good looking coal (No. 343) weighing about 2 pounds was also obtained at this point. This coal is fairly clean and is black and lustrous, though containing dull streaks and inclusions of bony material. Owing in part to deformation and in part to exposure it is quite friable, breaking into small fragments when touched with the hammer. However, material on the dump indicates that some sounder coal was encountered near the bottom of the incline. Analyses of the samples referred to above were made at the Fuel Testing Laboratories of the Mines Branch, Ottawa. The results indicate a high percentage of ash. The coal is rated as impure bituminous.

Analyses

Sample No.		1 (342)	2 (343)	3	4
Proximate analysis:					
Moisture	%	2·8	1·8	1·5	
Ash	%	30·1	37·1	47·1	7
Volatile matter	%	28·4	25·7	23·1	29
Fixed carbon (by difference)	%	38·7	35·4	28·3	64
Ultimate analysis:					
Sulphur	%	0·4	0·4	....	
Calorific value:					
Calories per gram gross		5,690	5,240		
B.T.U. per lb. gross		10,240	9,440		
Fuel ratio, fixed carbon/volatile matter		1·35	1·40	1·25	
Coking properties		Poor	Poor		

Samples 1, 2, and 3 were analysed in the Fuel Testing Laboratories, Mines Branch, Ottawa. Samples 1 and 2 were collected by the writer from the incline adit and are those already referred to. Sample No. 3 was collected by K. D. Woodworth, Kelowna, B.C., from the same working and forwarded to Ottawa for analysis. Sample No. 4 is reported to have been analysed by C. P. Hill, Hillcrest, Alta., about 1913. It was obtained from this property and evidently represents carefully selected rather than representative material.

The outcrop of this seam could not be traced westerly from the adit mouth for more than a few yards and a short distance farther the sediments are crossed by volcanic rocks representing a large feeder to overlying lavas. Still farther west the strata abut against underlying, pre-Tertiary, granitic rocks. In the opposite direction within 300 yards of the incline adit, and at elevations of about 100 and 200 feet, respectively, above it, are two open-cuts exposing the coal seam. At the lower exposure the seam has a maximum thickness of about 7 feet and at the second 8 or 9 feet. At both places the coal occurs as a series of narrow beds intercalated with numerous thin layers of shale. The whole is considerably deformed and fractured.

The sediments can be traced for half a mile or more to the northeast of the most easterly open-cut, and in this distance appear to decrease to about half their maximum thickness. Still farther northeast they are exposed in steep, inaccessible bluffs. The position at which they reach the plateau level was not determined, owing to paucity of rock exposures, nor were any outcroppings of coal observed beyond the more easterly open-cut, though such may be present.

Enderby Coal Mines, Limited

Over twenty-five years ago an outcrop of coal was discovered in a steep gulch east of Shuswap river about 8 miles north of Enderby. This discovery at "Coal gulch" resulted, about 1905, in the formation of a company, Enderby Coal Mines, Limited, to acquire and explore a considerable tract of land in that vicinity. Experts were called to examine these holdings and on their advice an expensive program of tunnelling, drilling, and surface work was undertaken, partly in Coal gulch and partly in Logan gulch, a neighbouring valley to the south. The results were disappointing and operations were discontinued in 1908. It was, however, the opinion of those principally interested that failure to discover any important body of coal was a result of unfortunate delays, incompetent service, and inadequate funds for satisfactory exploration, rather than to a lack of value of the holdings.

The writer visited both Coal and Logan gulches in the autumn of 1930 and in 1931 spent a couple of days in examining the geological sections exposed in their vicinity.

At Enderby, Shuswap river swings sharply from a westerly to a northerly course. Within the angle so formed hills rise abruptly to an elevation of about 3,000 feet above the river, where they meet a gently rolling upland. The eastern slopes are, in places, quite precipitous, and are scored by a series of steep-walled gulches, including those already referred to.

The basement rocks composing these hills are chiefly granitic and metamorphic rocks of the Shuswap type. Granitic types predominate and include principally grey, banded (gneissic) rocks and white, coarse-textured, pegmatitic granite. Other members include: bands of lustrous mica-schists; bodies of crystalline limestone; and masses of massive to schistose greenstones of volcanic origin. From Enderby northward for some 4 miles and east of Shuswap river for about 2 miles, these old basement rocks are overlain unconformably by Tertiary sediments and volcanics. The general section as exposed on the westerly facing slopes is as follows. At the foot are exposed rocks of the Shuswap type. Above them is an assemblage, about 100 feet thick, of Tertiary sediments, chiefly conglomerate, with traces of coal, representing the coal-bearing horizon opened on Coal gulch. These sediments are overlain by about 1,000 feet of sediments of another type, interrupted at one point by a thick lava flow and followed, in places at least, by a series of normal sediments bearing traces of coal and, perhaps, 15 to 20 feet thick. Above them lie about 500 feet of volcanic rocks with here and there at the top another minor development of normal sediments.

Coal Gulch Section

For some 1,500 feet above Shuswap valley, the rock formations intersected by Coal gulch are old basement rocks of the Shuswap type. These are mostly granitic, but include towards the top a considerable body of greenstone. Within a few feet vertically above the uppermost greenstone exposure, a coarse conglomerate is exposed, and represents the basal formation of the Tertiary section at this locality. This conglomerate is composed of well-rounded cobbles and boulders up to 2 feet or more in diameter, derived entirely from pre-Tertiary formations, and resembling the underlying basement rocks. Within 100 feet or so farther up the bed of the gulch, the conglomerate boulders become much smaller and are associated with a little sandy material. At about this point are situated the lowermost of three closely spaced adits, representing the old workings on Coal gulch. None of these workings was accessible, but the surrounding drift and heavy brush had been partly cleared away and shallow trenches dug to expose the bedrock. This is mainly conglomerate mixed with a little sandstone and containing clay-like seams a few inches wide along which it appeared that some movement had occurred. Resting on such a seam a few inches of coal containing bony material had been exposed, and at another point a small, isolated block of coal was found incorporated in the conglomerate. A few pieces of coal, not in place and probably obtained from the workings, were also observed near the portal of one of the adits. Aside from the above, no coal was noted although recent work had fairly well exposed the underlying rocks in the vicinity of and for a distance of 100 feet or so above the old workings to where the next formation is encountered. In view of the thickness of coal, amounting to several feet, discovered at this locality and developed by the old workings, the present meagre showings are disappointing, though no better than might be expected in such a geological environment. Regardless of how thick the coal was at the original discovery the following conclusions were reached: (1) There is no room for any lateral extension of the coal in the conglomerate beds on either side; (2) The thicker portions of the coal deposit have already been extracted; (3) The deposit was probably lens-shaped and formed under special conditions in an otherwise unfavourable environment; (4) The conglomerate body at this locality has been downfaulted with respect to formations higher up the gulch and, consequently, any continuation of the coal deposit must be looked for higher up the hill; but, owing partly to the unfavourable character of the enclosing and overlying rocks and partly to their highly faulted and brecciated condition, the possibilities of finding any considerable body of coal are very limited. The character and geological associations of the coal deposit in this gulch strongly suggest that the deposit was formed locally from vegetable matter, carried down an early Tertiary stream course and trapped by some obstruction until eventually covered by gravel and sand. The isolated block of coal observed in the conglomerate illustrates this mode of origin, as it was originally a fragment of wood buried in the gravels.

The faulting that has involved the lowermost Tertiary sediments is well illustrated in exposures above the workings in Coal gulch. One hundred feet or so to one side of the uppermost adit, and only a few feet vertically above it, the conglomerate is in contact with, and apparently dips under, a sedimentary formation of unusual characters. At first glance it appears to be the Shuswap type of granitic rocks such as compose much of the basement on which the Tertiary lies, but on closer examination it is seen to be a chaotic mass of mainly angular fragments of such granitic rocks. In places higher up the sides of the gulch, similar rock is in contact with cliff-like masses of the basement rocks, seemingly in place, but generally so crushed and brecciated that it may be quite difficult to distinguish them from the sediments composed of accumulated fragments. Rocks of these two types outcrop on either side of the valley up to a point about 300 feet above the workings. At this elevation conglomerate again appears, is much the same as that in which the coal deposit was found, and is, in fact, regarded as a faulted portion of the same bed. This conglomerate continues up the hill for a maximum height of about 100 feet. Above it, through a thickness of about 50 feet, there are still rounded boulders and pebbles, but the bulk of the material is a granitic breccia similar to that observed just above the coal workings. This breccia in turn is overlain by a grey or greenish grey, to, in places, purplish, lava flow 100 feet thick. This lava is in part quite massive and in part, particularly towards the top, highly vesicular and amygdaloidal. Above it again and extending to over 800 feet above the workings are cliffs of the same granitic breccias, but containing here and there, in the mass of angular fragments of all sizes, occasional rounded or semi-rounded pebbles or cobbles.

At about 850 feet above the workings or 2,300 feet above Shuswap valley, the granitic breccias are overlain by a well-defined flow breccia, light grey to pinkish, and having about the composition of rhyolite. This flow breccia carries occasional fragments of the underlying rocks and has a thickness of about 200 feet. It grades upwards into a massive, greenish grey lava which continues to the top of the main valley wall and has a thickness of nearly 300 feet. This lava forms perpendicular cliffs showing well-fluted columnar structure and affording a conspicuous topographic feature as viewed from the lower Shuswap valley. Resting on this lava, a short distance south of the head of Coal gulch, is a fine conglomerate composed of detritus from the underlying volcanic rocks.

Logan Gulch Section

The section of rock formations revealed farther south, on Logan gulch, is very similar to that in Coal gulch. At the old camp where drilling operations had been conducted years before, about 500 feet above Shuswap valley, the rock formations are not exposed, but, since it is reported that drilling encountered some coaly material, doubtless include a continuation of the conglomerate horizon seen in Coal gulch. On the nose of the ridge on the north side of the gulch, and extending from 600 to about 1,350 feet above the camp, outcrops are almost continuous and for the most part are cliffs of crushed basement rocks and bodies of fragmental rock or breccia composed of angular detritus from these basement formations. Towards the top of the section these breccias include considerable crystalline limestone. At 850 feet above the camp is a belt of vesicular lava representing the flow encountered 400 feet above the workings in Coal gulch. Higher still, at the base of the upper series of lavas, 1,350 feet above the camp, are a few feet of well-bedded sandstone and fine conglomerate containing here and there along the strike, coal less than an inch thick. These beds strike about north 50 degrees east and dip from 20 to 35 degrees to the southeast. They were not observed on Coal gulch and may be missing there. These upper coal-bearing sediments are overlain conformably by a thick accumulation of volcanic lavas representing the southerly continuation of those lavas that form the high cliffs at the head of Coal gulch.

Other Localities

South of Logan gulch, within a couple of miles of Enderby, the hill was examined on its western and southern slopes and much the same succession of rocks encountered as revealed in the two gulches. In this direction, however, the rocks dip gradually towards the main valley bottom. Near Bousfield's ranch, for example, flow breccias representing the base of the upper series of volcanic rocks lie 900 feet above the valley bottom; within the western limits of Enderby, outcrops of the basal conglomerate of the Tertiary series appear, and south of the bend in Shuswap river the upper volcanic flows outcrop in the bottom of the valley.

Conclusions

To appreciate the value and meaning of the several occurrences of coal, it is essential that these occurrences be considered in relation to some of the main events of Tertiary time. The Tertiary era commenced with the elevation of the land surface. As a result of this uplift the erosive powers of the streams were greatly increased. It seems probable that a valley existed in the vicinity of the present Spallumcheen and Shuswap River valleys and that as a result of vigorous erosion it was rapidly floored with water-lain gravels, sands, and mud, which accumulated in abundance at the mouth of the larger tributary streams. Most of the finer material, however, seems to have been swept from both the tributary and main valleys by the rapid streams, leaving principally gravel deposits of irregular thickness and distribution. Such conditions were not conducive to the formation of coal. A certain amount of vegetable drift would, no doubt, be lodged with the gravel and sand and, locally, might accumulate and on subsequent burial ultimately change to coal or coaly material mixed with rock sediment as seems to be exemplified by the deposit in Coal gulch.

This period of erosion and deposition was terminated by a series of catastrophic events, connected with violent volcanic activity and also, it is thought, with contemporaneous granitic intrusions. It was a period of much faulting, during which a broad zone of weakness developed along, approximately, the present course of Okanagan valley. The old basement rocks, on which lay the recently deposited Tertiary sediments, were badly shattered and many faults developed which entirely disrupted both old and young formations. The main valley seems to have been largely developed by a series of down-faulted blocks, leaving the eastern wall exposed as a succession of steps with vertical or steeply dipping walls of highly fractured basement rocks with patches of Tertiary sediments remaining on top. Disintegration of these walls, assisted by gravity and probably by continued earth movements, rapidly developed large slides and talus slopes composed chiefly of ill-sorted, angular fragments from the broken basement rocks with scattered boulders, pebbles, etc., from the overlying sediments. Such talus slopes, with projecting outcrops of the shattered basement rocks, form those unusual-looking exposures of fragmental and brecciated rocks that now occur over a vertical range of several hundred feet in Coal and Logan gulches. These processes were interrupted temporarily at one stage by the eruption of a lava flow about 100 feet thick.

Following this period of rapid adjustment to sharp changes in the surface topography, came an interval of comparative quiet when normal water-lain sediments were formed along the valley bottoms and in lakes and streams at various elevations. The thin section of coal-bearing sediments noted in Logan gulch at the base of the upper lavas is believed to have formed locally as a lake deposit at this time. The period of sedimentation was cut short by a second important, though less violent, interval of volcanic eruption during which the several hundred feet of lavas and flow breccia, such as now form the steep cliffs at the heads of Coal and Logan gulches, were extruded.

Subsequent local geological history has involved : (1) the formation of an uppermost or third series of sediments such as those composed of volcanic detritus observed at the head of Coal gulch; (2) tilting and moderate deformation of the upper lavas and underlying rocks; and (3) further erosion and modification by water and ice of the present Shuswap, Spallumcheen, and Okanagan valleys.

Coal has been found in two horizons of sedimentary rocks in the Tertiary section as exposed in the hills east of the lower Shuswap River valley and north of Enderby. The upper horizon is too thin to provide coal deposits of workable dimensions and the tiny seams discovered in it in Logan gulch are of no commercial significance. This upper formation gives no promise of thickening appreciably and thereby providing room for substantial coal deposits.

The original coal discovery in the basal conglomerate in Coal gulch must have been lens-shaped and a result of peculiar local conditions at the time of its formation, though to some extent its form has been modified by subsequent faulting and distortion of the enclosing conglomerate.

It is quite unlikely that commercial deposits of coal will be discovered along this slope of Shuswap valley, for even though local occurrences of good coal be found, the possibility of their continuing for any considerable distance without serious disruption is beyond all reasonable expectation. This conclusion is rendered more emphatic by the fact that the coal-bearing formation as exposed in Coal gulch is not such as might under the best of structural conditions be expected to contain commercially valuable deposits. The best that can be hoped for is the fortuitous discovery of small deposits situated so conveniently as to afford a small local supply for domestic consumption. Prospecting for such occurrences should be confined to the vicinity of exposures of conglomerate and associated sandstone beds.

Conditions along the west side of Spallumcheen and Shuswap River valleys are, from such exposures as were seen, no more suitable for coal deposits than those on the opposite side, but include a similar group of rocks with a similar geological history. An outcropping body of conglomerate within the southwest corner of the town of Enderby seems to have formed part of the same conglomerate belt as that containing the coal in Coal gulch. The Enderby conglomerate rests on highly brecciated basement rocks including, about half a mile to the north, a body of reddish granite whose shattered outcrops have supplied considerable excellent road metal. In the opposite direction, and about 2 miles south of Enderby, outcrops of shattered granitic and greenstone basement rocks and associated slide or talus debris are overlain by a body of vesicular, grey-green lava which is probably a continuation of the lava seen 400 feet above the workings in Coal gulch.

PETROLEUM

A special report by the writer on the "Oil Possibilities of the North Okanagan Valley, B.C." was released for the public press in August, 1930. The report pointed out that geological conditions in this valley were quite unfavourable for the accumulation of either oil or gas and in consequence it was hoped that any further expenditures would be avoided. Encouraged, however, by favourable reports, the Okanagan Oil and Gas Company of Kelowna established a drill site on the south side of Mission creek about 6 miles southeast of Kelowna. The well was spudded in on November 27, 1930, and drilling has been in progress since that time. When visited in August, 1931, the well was down some 1,700 feet and at the time of writing is reported to have been continued to 2,355 feet. The Kelowna well is sunk within a mile of the southern edge of a tongue of Tertiary sediments that extends up the valley of Mission creek for about 7 miles east of Okanagan lake. These sediments are freshwater, probably lacustrine, deposits carrying plant and insect remains of late Eocene or possibly later Tertiary age. As exposed in the valley of Mission creek they comprise interbedded grey and greenish sandstones, fine conglomerate, and dark grey to black, shaly rocks containing in places abundant plant remains and a little coal. Less than a mile south of the well these Tertiary sediments are in contact with hornblende granite-gneisses of the Shuswap type. North of Mission creek they are in part overlain by Tertiary volcanic lavas, but elsewhere their contact is with crystalline and metamorphic rocks and is mostly obscured by drift. Westerly the Tertiary sediments probably extend to and across Okanagan lake, widening out in this direction to form a belt 10 miles wide on the west side of the lake. Though dipping mostly from 10 to 30 degrees, these sediments as exposed in the valley of Mission creek are locally greatly deformed and broken, a feature suggesting a faulted relationship with the adjoining pre-Tertiary formations.

A few samples obtained from the well at reported depths of about 1,700, 2,170, and 2,355 feet are of granitic rock, being composed chiefly of fragments of quartz, feldspar, and hornblende and containing considerable limy material. The latter is calcite derived in part from decomposition of the feldspar, but may be largely residual material from limy formations that with other rocks have been transformed to granite. A specimen of hornblende granite-gneiss, obtained, for example, about 3 miles farther up the valley of Mission creek, carries appreciable calcite and, in places, effervesces quite freely with acid.

It is of interest, in connexion with the study of the geology of Mission creek and vicinity, to refer to Dawson's early report[1] and map[2] based on

[1] Dawson, G. M.: Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. B, pp. 157-158.
[2] Dawson, G. M.: Idem, Geol. map of a portion of the Southern Interior of B.C., 1877.

investigations made in 1877. Dawson visited Mission creek in that year and paid particular attention to its geology, in view especially of the interest being taken at that time in placer operations on this creek. The map published on a scale of 8 miles to an inch is too small to adequately represent the narrow belt of Tertiary sediments up Mission creek so these have been included with the overlying Tertiary lavas in one general colour. In his report, however, Dawson draws a cross-section of the formations in the valley of Mission creek showing a few hundred feet of Tertiary sediments overlying a basement complex of much older crystalline and metamorphic rocks. Neither Dawson nor subsequent geologists working in this field have been able to discover evidence of any Cretaceous formations in this or neighbouring parts of Okanagan Lake district. Nor for that matter, do the Cretaceous formations widely exposed elsewhere in British Columbia contain any such considerable beds of limestone and limy sediments as those indicated by the Kelowna well drill log. Limestone is, in fact, a distinctly rare constituent of the Cretaceous rocks of the province. Similarly, the Tertiary sediments exposed either in Mission creek or at numerous other localities in the district nowhere have been observed to carry more than negligible amounts of limy material. It follows, in consequence, that the abundant limy strata reported in the company's drill log as encountered in the lower 1,000 feet or so of Kelowna No. 1 well are almost certainly of pre-Cretaceous age and, as such, are quite readily correlated with deposits of limy rocks and conspicuous limestone beds occurring either in the late Palæozoic formations of the valley or their granitized equivalents. Such deposits are included with members of Groups I and II in the classification adopted in this report. There is no possibility that either the metamorphosed formations comprising these groups or the overlying, relatively insignificant body of Tertiary sediments contain appreciable amounts of either petroleum or natural gas. Traces of such substances might be encountered in drilling almost any series of sediments containing remains of organic life, but only under special conditions, none of which is applicable to the formations of Mission creek and vicinity, can any significant accumulation of oil or gas occur.

BORINGS FOR WATER, OIL, AND GAS IN BRITISH COLUMBIA

By W. A. Johnston

(Chief, Division of Pleistocene Geology, Water Supply, and Borings)

Collection of samples and records from wells drilled for oil, gas, and water in British Columbia was continued in 1931, but comparatively little drilling was done. Considerable interest has been shown in the possibilities of obtaining well water for irrigation purposes in Okanagan valley and at other places. There appear to be good prospects of obtaining water in basins occupied by Tertiary sediments and lavas at many places in British Columbia, but geological investigations are necessary to determine this question. Records of borings that have been made in these basins are of great value in this connexion but are few in number. A case in point is the Kelowna well being drilled in search of oil and gas. Water is reported to have been struck in this well at several horizons. The Water Supply and Borings Division maintains a laboratory equipped for the purpose of examining samples and endeavours to obtain as many records as possible of wells that are put down in search of oil, gas, or water. These records have a positive as well as a negative value; they show that in some places, for example, water can be obtained by drilling to a certain depth and in other places that there is little or no use in drilling. Bags, for the collection of samples, and report forms will be sent on request, and persons who intend to have wells drilled are asked to advise the division so that, before the actual drilling begins, arrangements may be made to obtain samples and records.

In 1931 drilling for oil and gas was done at Australian, in Cariboo district, by the Cariboo Oil and Gas Company, Limited. A number of samples and a driller's log were received from this well. These showed the interesting fact that the Tertiary sediments extend to a depth of about 600 feet. The Tertiary basin which extends along Fraser river for some distance above and below Australian has been described by L. Reinecke.[1]

Drilling by the Okanagan Oil and Gas Company in Kelowna district is reported to have reached a depth of about 2,265 feet.

Pacific Petrol Products started drilling for oil and gas at Dorr; eight samples from depths of 40 to 140 feet were received from the well.

In Sumas area the Sumas Gas and Oil Company continued drilling. Ten samples from depths of 779 feet to 864 feet from No. 2 well were received.

In Sage Creek area a second well was begun by the Crow's Nest Glacier Company.

On Lulu island, in Fraser River delta, the International Pipe Line Company have drilled the third and fourth wells to a depth of about 900 feet. These wells are in the Recent delta of the Fraser and the Recent unconsolidated materials may extend nearly to this depth. Some gas has been obtained, but there is trouble in screening off the soft, unconsolidated, fine sands. The geology of the area is described in Memoir 135, Geological Survey, Canada.

[1] Geol. Surv., Canada, Mem. 118.

OTHER FIELD WORK

Geological

E. J. LEES. Mr. Lees, under the supervision of H. S. Bostock, completed the topographical and geological mapping of the Laberge 4-mile quadrangle (latitudes 61° to 62°, longitudes 134° to 136°), Yukon. A report and map are being prepared.

W. E. COCKFIELD. Mr. Cockfield commenced the geological mapping and studying of a 1-mile quadrangle (latitudes 52° 30′ to 52° 45′, longitudes 121° 30′ to 122°), Cariboo district, B.C. Further field work is required before a report or map can be prepared.

J. F. WALKER. Mr. Walker completed the geological mapping and studying of Salmo 1-mile quadrangle (latitudes 49° to 49° 15′, longitudes 117° to 117° 30′), B.C. A report and map are being prepared.

C. S. EVANS. Mr. Evans commenced the geological mapping and studying of Cranbrook 1-mile quadrangle (latitudes 49° 30′ to 49° 45′, longitudes 115° 30′ to 116°), B.C. Further field work is required before a map or report can be prepared.

Topographical

R. BARTLETT. Mr. Bartlett commenced topographical mapping of Teslin 4-mile quadrangle (latitudes 60° to 61°, longitudes 132° to 134°). About one-third of the area was done.

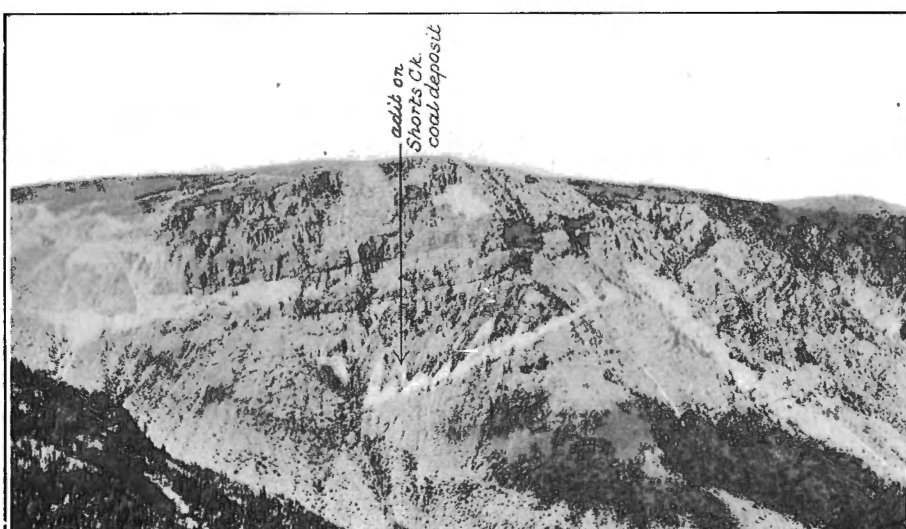
W. H. MILLER. Mr. Miller concluded surveys in Portland Canal mining area. Enough information has been obtained for compilation of a 4-mile map of the whole group of mineralized areas—Anyox, Alice Arm, Salmon River, Marmot River—that comprise the Portland Canal mineral area. A series of 1-mile sheets, partly contoured, will also be prepared.

A. C. T. SHEPPARD. Mr. Sheppard completed topographical mapping of Cranbrook 1-mile quadrangle (latitudes 49° 30′ to 49° 45′, longitudes 115° 30′ to 116° 00′), including an extension in the northwest corner to include several mineralized localities. A 1-mile sheet will be prepared. Mr. Sheppard also supervised and assisted other topographical field parties in British Columbia and Alberta.

A. C. TUTTLE. Mr. Tuttle topographically surveyed the remainder of Crowsnest 1-mile quadrangle (latitudes 49° 30′ to 49° 45′, longitudes 114° 30′ to 115° 00′). About half of this area, which contains important coal mines, had previously been mapped and the results published as the Blairmore sheet, the boundaries of which do not conform to the present unit system of 15 minutes latitude by 30 minutes longitude. The Crowsnest sheet is now in course of preparation.

PLATE I

A. Bench materials composed of clay, sand, and gravel, in the valley of Naswhito (Siwash) creek about 2 miles from its mouth, at the site of recent hydraulic placer workings. (*See* page 73.)



A. A portion of the north slope of Shorts Creek valley showing a basin of Tertiary rocks which includes the Shorts Creek coal measures. (*See* page 73.)

INDEX

Note. All places mentioned are in B.C., unless otherwise stated.

The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are four parts, A, B, C, and D. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.