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Summary Report, 1922, Part A

CONTENTS

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SUMMARY REPORT, 1922, PART A

EXPLORATIONS IN SOUTHERN YUKON

By W. E. Cockfield

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INTRODUCTION

In reviewing the published descriptions of the mineral deposits of Whitehorse, Wheaton, and Conrad districts, it was found that wherever the genesis of these deposits has been established it is attributed to the intrusion of the Coast Range batholith. It was, consequently, considered advisable to map the eastern edge of these granitic rocks in order that prospectors might know more precisely the location of the zone, adjacent to these rocks, in which ore-bodies are likely to occur. With this in view, the writer commenced mapping such parts of the area lying between longitudes 134 and 136 degrees and latitudes 60 and 61 degrees as had not already been mapped.

Of the area assigned, considerably more than half is now completed. A reconnaissance map of this part, on the field scale of 2 miles to the inch, to show the drainage and geology, is compiled and waiting for the additional field information to complete the area. During the course of the field work the writer was ably assisted by N. T. Ellis, T. D. Guernsey, and R. H. B. Jones, all of whom performed their duties in a capable and satisfactory manner.

TOPOGRAPHY

The area lies along the junction between Yukon plateau and the Coast range[1] and contains parts of both these provinces. The Coast range in general is an irregular complex of peaks and ridges that possess little symmetry other than a rough alignment on a northwesterly trending axis. It has everywhere a jagged and precipitous aspect, and consists of rugged or even needle-like summits, knife-edged crests, and sharply incised valleys. The summits stand at elevations of from 5,500 to 7,500 feet.

The Yukon plateau is an upland surface standing at an elevation of 5,000 to 5,500 feet. Into this surface the streams have cut to depths varying from 1,500 to 4,000 feet, giving a very irregular topography. The summits of the unreduced ridges lying between waterways are the remains of a gently rolling plain, which is broken only here and there by isolated residuary masses that rise above the general level. This surface is apparently an uplifted and dissected peneplain.

[1]For a discussion of the physiographic provinces of Yukon, *See* Cairnes, D. D., "Wheaton District", Geol. Surv., Can., Mem. 31, 1912, pp. 9-11.

GENERAL GEOLOGY

The area under discussion lies along the eastern edge of the Coast Range batholith, and practically the entire area is believed to be underlain at some depth by the granitic rocks of this batholith, isolated bodies of which outcrop at intervals to the eastward of the main boundary. In addition to these granitic rocks the area contains numerous other rock types, including igneous, sedimentary, and metamorphic varieties which range in age from the Precambrian to the Tertiary or Quaternary. In the central part of the area the plateau surface corresponds very closely with the original roof of the batholith, so that remnants of the former roof of this igneous body are still preserved. In addition there are numerous masses of the rocks invaded by the granites which remain as inclusions in the granites. Farther west these masses gradually become less numerous and disappear, having most likely been removed by erosion.

Table of Formations

Era	Period	Formation	Lithological characters
Quaternary......	....	Superficial deposits.	Gravel, sand, clay, soil, muck, volcanic ash, ground ice, slide rock, and morainic materials
		Wheaton River volcanics	Rhyolite, granite porphyry, and related volcanics with their tuffs and breccias
Tertiary........	....	Chieftain Hill volcanics	Andesite, basalt, and related rocks with their associated tuffs and breccias
	Cretaceous to Jurassic	Coast Range intrusives	Granitic rocks ranging from granite to diorite with associated porphyritic phases
	Probably Lower Cretaceous	Perkins volcanics...	Andesite, diabase, basalt, with associated tuffs and breccias
Mesozoic........	Lower Cretaceous or Jurassic	Laberge series......	Argillite, metargillite, shale, sandstone, conglomerate
	Jurassic............	Tantalus conglomerate (Kootenay?)	Conglomerate and sandstone with seams of coal
Palæozoic	Triassic to Carboniferous.......	....	Crystalline limestone
			Cherty quartzite, black slate, biotite, slate, and limestone
	Devonian?..........	....	Pyroxenite and peridotite
Precambrian....	....	Mt. Stevens group (Yukon group?)	Sericite and chlorite schists, mashed basic and semi-basic volcanics, gneissoid quartzite, hornblende gneiss, and crystalline limestone

The oldest rocks known to occur in the area are included in the Mt. Stevens group, a series of sericite and chlorite schists, mashed basic volcanics, gneissoid quartzites, hornblende gneiss, and crystalline limestones. These represent remnants of the roof of the Coast Range batholith or inclusions in it and are really a complex of both igneous and sedimentary rocks which have suffered prolonged dynamic metamorphism. These are probably equivalent to the Yukon group [1] and are thought to be Precambrian in age.

More recent than the Mt. Stevens group are certain pyroxenites and peridotites which occur only on the southern part of Tally-Ho mountain. These are thought to be related to similar rocks in other parts of Yukon and in northern British Columbia, and are believed to be of Devonian age.

Outcropping along parts of Windy arm and Tagish lake is a series of sedimentary rocks; cherty quartzite, black slate, biotite slate, and limestone. They extend toward Atlin lake, and are followed by limestone, generally crystalline, from which occasional fragments of fossils are obtained. This limestone may be referred either to the Upper Carboniferous or to the Triassic.

In Mesozoic time a considerable thickness of sediments was deposited in this part of Yukon territory, and although a large part of these have been removed by erosion, in the central part of the map-area they are still preserved, and have an aggregate thickness of from 5,000 to 6,000 feet. No complete section of these beds has been obtained. The lower conglomerate series (Tantalus conglomerate) has a thickness of about 1,000 feet and on the basis of fossil evidence is referred to the Kootenay. It is coal-bearing in the lower part. The Laberge beds consist of argillites, metargillites, shales, sandstones, arkoses, tuffaceous conglomerates, and bedded tuffs, and these have been referred to the Lower Cretaceous. Much of the material forming these beds is of igneous origin. In certain parts of the district the division into Tantalus conglomerate and Laberge series has not been carried out, as both were included in the one group, the Tutshi series, by earlier investigators.

Contemporaneous with these sediments, and possibly in part more recent than they, is a series of volcanic rocks, chiefly andesites, diabases, and basalts, with their associated tuffs and breccias.

Following the volcanics are the Coast Range intrusives, which present a number of rock types ranging from granite to diorite or gabbro. These rocks have dominantly a granitic habit, and granodiorite is the prevalent rock type. The Coast Range batholith, apparently, represents an igneous complex formed by a long and probably intermittent period of intrusion. Pebbles of granodiorite identical with that of the Coast range are very numerous in the Laberge beds; yet even the uppermost of these beds are invaded by Coast Range rocks. This would point to several periods of intrusion with intervals during which sufficient time elapsed to permit of the cooling and erosion of the intrusives.

The Tertiary and Quaternary are represented by two types of volcanic rocks, the earlier consisting of andesites and basalts with their associated

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

tuffs and breccias. Some of these flows appear to be quite recent, having been poured forth since the rivers have cut approximately to their present depths. They may consequently be Pleistocene or even Recent in age. These are followed by rhyolites, quartz porphyries, and related rocks which occur only as dykes and small surface flows.

Overlying all the consolidated rock formations there is a mantle of superficial deposits including sand, gravel, clay, soil, muck, ground-ice, volcanic ash, slide rock, and morainal materials. This mantle covers all the valley bottoms and in addition extends over large parts of the valley walls and upland surface.

ECONOMIC GEOLOGY

The mineral deposits of the Conrad, Whitehorse, and Wheaton districts have in large part already been described[1]. Briefly stated, the mineral resources, excluding coal, may be grouped into four classes as follows:

I. Contact metamorphic deposits. Chiefly copper.
II. Gold-silver deposits.
III. Silver-lead deposits.
IV. Antimony-silver deposits.

CONTACT METAMORPHIC DEPOSITS

The contact metamorphic deposits include all the properties of the Whitehorse copper belt, and also the Fleming mineral claim on Carbon hill, Wheaton district. These deposits, in the first case, occur in altered limestones close to, or in direct contact with, the Coast Range granodiorites; and in the second case, in hornblende gneiss at the contact with the same intrusives. There can be no doubt as to the close genetic connexion between the ore-bodies and the intrusion of the Coast Range batholith, this connexion being apparent even on the most casual examination.

GOLD-SILVER DEPOSITS

The gold-silver deposits include the properties on Stevens, Wheaton, and Tally-Ho mountains, Gold hill, Becker creek, and the Big Thing mine on Windy arm, all of which have been described,[2] and also the Midnight group to be described later. Discussing the genesis of these deposits Cairnes says in part: "It is, therefore, apparent that if these deposits are associated with any of the igneous materials of the district, these must be the Jurassic granitic rocks. In the field the veins appear to be everywhere

[1]McConnell, R. G., "Whitehorse Copper Deposits," Geol. Surv., Can., Sum. Rept., 1900, pp. 49A–52A.
"Windy Arm District", Geol. Surv., Can., Sum. Rept., 1905, pp. 30-32.
Cairnes, D. D., "Explorations in a Portion of Yukon South of Whitehorse", Sum. Rept., Geol. Surv., Can., 1906, pp. 24-30.
"Report on a Portion of Conrad and Whitehorse Mining Districts, Yukon", Geol. Surv., Can., pp. 13-23.
McConnell, R. G., "Report on the Whitehorse Copper Belt", Geol. Surv., Can., 1909.
Cairnes, D. D., "Wheaton River District", Geol. Surv., Can., Sum. Rept., 1909, pp. 51-57.
"Wheaton District, Yukon Territory", Geol. Surv., Can., Mem. 31, 1912, pp. 85-147.
"Wheaton District," Geol. Surv., Can., Sum. Rept., 1915, pp. 43-49.
[2]Cairnes, D. D., "Wheaton District", Geol. Surv., Can., Mem. 31, 1912, pp. 87–113.
Geol. Surv., Can., Sum. Rept., 1917, p. 36.

intimately associated with these intrusives so that the genetic relationship between them appears certain." The majority of these veins occur in a belt 2 to 3 miles wide closely paralleling the eastern boundary of the Coast Range batholith.

SILVER-LEAD VEINS

The principal silver-lead properties which have been described are the Union and Nevada mines, Wheaton district,[1] and the Montana, M and M, Venus, and Dail Fleming group of Windy Arm district.[2] The Mascot group is described in this report. The genesis of these deposits appears to be somewhat uncertain. They have been attributed to igneous rocks of different ages, but the probability seems to be that they owe their origin to the phenomena attending the latest stages of the intrusion and cooling of the batholith.

ANTIMONY-SILVER DEPOSITS

The most important of the antimony-silver claims are the Porter group and Goddell group on Carbon hill, and the Morning claim and Evening claim on Chieftain hill. These have all been described[3] and their origin is ascribed to heated waters ascending from the cooling mass of the Coast Range batholith.

This review will serve to show the importance of the Coast Range batholith in connexion with the ore deposits of the district. It may also be pointed out that the majority of the ore-bodies occur in connexion with outlying bodies of granite rather than with the main mass of the batholith, although there are many exceptions. It may also be laid down as a general rule that the main mass of the batholith away from its borders is not likely to have been the seat of ore deposition, except possibly where there are inclusions of the older intruded rocks.

Only three properties were visited by the writer during the past summer. These included both gold-silver and silver-lead veins. The silver-lead vein visited lies on the Mascot group at the head of a small tributary to Watson river. The vein occurs practically on the divide between Berney creek and Watson river. The property is owned by E. Johnson and M. Watson of Carcross, but was bonded to J. Moore Elmer of the Slate Creek Mining Company during the winter of 1921-22. A small amount of prospecting was done on the claims, but the option was abandoned in the spring of 1922.

The outcrop is visible along a cliff face for about 2,000 feet. The vein varies considerably in strike, dip, and thickness, being in some places 20 feet thick and in others less than 1 foot. At the foot of the cliff an adit was driven 200 feet on the vein. It was filled with water and ice at the time of the writer's visit, and consequently only the surface features could be examined. According to information supplied by J. M. Elmer the vein pinched to 6 inches towards the end of the tunnel and the values dropped

[1]Cairnes, D. D., "Wheaton District", Geol. Surv., Can., Mem. 31, 1912, pp. 129-139.
[2]Cairnes, D. D., "Report on a Portion of Conrad and Whitehorse Mining Districts, Yukon," Geol. Surv., Can., 1908, pp. 14-18.
Sum. Rept., Geol. Surv., Can., 1917, pp. 36-44.
[3]Cairnes, D. D., "Wheaton District", Geol. Surv., Can., Mem. 31, 1912, pp. 113-129.

to $7 a ton in gold and silver. Assays from the outcrop, it is claimed, show values of from $15 to $30 a ton in gold and silver. Below the mouth of the adit the vein is 6 feet wide, but it narrows to less than 2 feet inside the portal. The country rock is a diorite (Coast Range intrusives) and near the deposit is a large inclusion of schist (Mt. Stevens group). The writer took a grab sample across the 6-foot width of the vein immediately below the entrance to the adit. This was assayed and found to contain:

Gold	0·11 oz. per ton
Silver	1·45 "
Lead	(not determined)

Though the results obtained so far from the prospecting of this property have been unsatisfactory it must be remembered that only a small part of the vein has been explored by underground workings, and these workings do not extend under the widest parts of the vein as shown on the surface. The possibility of finding paying ore-shoots on the property has not been exhausted.

The deposit is somewhat unfortunately situated with regard to transportation. There is no road to the property, and the nearest point on the railway is Robinson, about 45 miles distant. A road could easily be constructed up Watson river to the property, or from the end of Wheaton River wagon road at Carbon hill up Berney creek, but in either case the distance to the railway would be about the same.

MIDNIGHT GROUP

The Midnight group is situated on Midnight gulch, a tributary to Wheaton river, about 8 miles above its mouth. The property is readily accessible from Carcross by a boat across lake Bennett to the mouth of Wheaton river, whence a trail leads to the claims.

The Midnight group consists of six claims, the Midnight, Midnight No. 1, Midnight No. 2, Anna Frances, Guardsman, and Harrison, owned by Matthew Watson and E. Johnson, of Carcross.

The workings consist of three short adits and a large number of open-pits or trenches. Two of these adits are situated close to the camp on the Midnight No. 1. The third is situated on the Midnight No. 2 near the crest of the hill and is known as the "old showing." In addition there are a number of open-pits situated on the Midnight, Midnight No. 1, and Midnight No. 2.

The showings are all very similar in character so that only typical ones need be described. On the Midnight claim there is some trenching known as the "lower workings". Here a dyke of granite porphyry is shown cutting schists of the Mt. Stevens group, and the dyke itself contains some inclusions of schist. Close to the hanging-wall of this dyke is a small dyke of basalt that cuts the granite porphyry, and, near the foot-wall, another dyke 7 feet wide of the same material. The width of the granite porphyry dyke is 50 feet. The granite porphyry is very much altered and, apparently, silicified. Under the microscope it shows large crystals of feldspar in a micrograniti c groundmass. The feldspar is highly altered to sericite. Running through both the feldspar crystals and the groundmass of the rock are small veins of quartz which are taken to represent secondary silicification. The infiltration of secondary silica was probably accompanied by deposition of the ore minerals, pyrite, galena, and occasional specks of native gold visible to the naked eye. The gold occurs both with the sulphides and also in the quartz when the sulphides are absent.

There is a similar occurrence at the "old showing" on the Midnight No. 2 claim. Here a dyke of granite porphyry 25 feet wide cuts the Perkins volcanics. The dyke is well silicified and carries seams of quartz containing pyrite, galena, and free gold. The two adits situated near the camp show, apparently, two-cross seams, but these are not well exposed. Both of the seams are considerably leached and decomposed. Colours of gold may be obtained by panning this material.

Adjoining the Midnight group are a number of claims, but on only two of these, the Gladys S and Sarah J, owned by T. Brooks, has any work been done. The occurrences here are similar to those already described.

These porphyry dykes have been traced for considerable distances by means of surface pits and trenches. They are, apparently, broken by a series of more or less parallel cross-faults, which would require further stripping and an accurate survey of the property to work out. There would, however, be no question of the tonnage available if it could be demonstrated that the values were persistent over the width of the dykes. A rough sampling of the property indicates, however, that the values in gold are not maintained over the mass of the dykes, even where silicification is complete, but are confined to small portions where either gold or sulphides are visible. These portions form only a very inconsiderable part of the whole deposit. It, therefore, remains to be demonstrated whether these portions carry sufficient values to form ore-shoots. This can be done only by further stripping and systematic sampling. The writer is inclined to regard those points where cross-faults or cross-seams intersect the main dykes as the most probable locations of ore-shoots.

The second gold-silver property visited lies on the eastern slope of mount Reid, near the junction of Berney creek and Wheaton river. The property is situated about 5 miles beyond the end of Wheaton wagon road, or 36 miles from Robinson. There are two claims, the Grandview owned by A. Birnie, and the Rambler by C. I. Burnside.

The vein is situated in a small gulch tributary to Skookum gulch, and the workings consist of a number of trenches. At the time of the writers' visit the gulch was largely filled with snow so that very little could be seen of the deposit. The country rock consists of the Perkins andesites, which at this point form an inclusion in the Coast Range granodiorites. The vein is first exposed on the shoulder of the mountain near the top of the small gulch. About 500 feet below this is a small open-cut in which the vein is partly exposed. At the upper workings the surface trench has been filled in with slide rock. The lower workings, however, show a vein 3 feet in width with gouge on either side. The vein at this point is almost vertical. Mineralization consists of galena, pyrite, stibnite, and arsenopyrite in a gangue of quartz. The vein has been exposed on the surface over a distance of 1,000 feet by means of pits, but most of these were filled with slide rock.

COAL

Coal is known to occur at several localities in the area under discussion. Seams occurring on Coal creek near Dugdale and Idaho hill have already been described[1]. The coal occurs in the Jura-Cretaceous Tantalus conglomerates, in or immediately below which have been found all the valuable coals so far discovered in southern Yukon. It is quite probable that other seams exist in addition to those described by Cairnes. There is, however, at present no demand for coal in southern Yukon, and prospecting for it is consequently not being carried on.

[1]Cairnes, D. D., "Report on a Portion of the Conrad and Whitehorse Mining Districts, Yukon" Geol. Surv., Can., 1908, pp. 20-21.
"Wheaton District", Geol. Surv., Can., Mem. 31, 1912, pp. 145-147.

COAST AND ISLANDS OF BRITISH COLUMBIA BETWEEN DOUGLAS CHANNEL AND THE ALASKAN BOUNDARY

By V. Dolmage

CONTENTS

INTRODUCTION

The season of 1922 was spent in making a geological map of the coast of British Columbia between Douglas channel and the Alaskan boundary. This work completes the geological mapping of the British Columbia coast which was begun at Vancouver by O. E. LeRoy[1] in 1905, continued by J. Austen Bancroft[2] in 1907, by R. P. D. Graham[3] in 1908, by R. G. McConnell[4] in 1912, and by the present writer[5] in 1921, and 1922.

That part of the coast examined in 1922 extends from Estevan island, latitude 53, to the head of Portland canal, in latitude 56, a distance of almost exactly 200 miles. The British Coumbia-Alaska boundary extends the full length of Portland canal. The entire shoreline, including all the inlets and islands of this district except Queen Charlotte islands, was examined, and most of the known mineral occurrences within 4 miles of the shore were visited. Several days were spent in examining the Hidden Creek mine at Anyox. The mapping was confined chiefly to the shoreline, but was extended over the entire area of all the islands less than 5 miles across. The geology was plotted on the marine charts published by the British Admiralty. Much of the mapping was done on charts on a scale of approximately 4 miles to the inch. These are fairly accurate except for parts of the seaward shores of the outer islands, which were sketched from only a cursory examination. However, the area lying between Ogden channel and the entrance to Portland inlet is covered by three large scale, recent charts which are accurate and complete and were of great assistance in the work.

The writer wishes to express his thanks to H. S. Munroe, general manager of the Granby Consolidated Mining, Smelting, and Power Company,

[1]Geol. Surv., Can., Pub. No. 996, 1908.
[2]Geol. Surv., Can., Mem. 23, 1913.
[3]Geol. Surv., Can., Sum. Rept., 1908, p. 38.
[4]Geol. Surv., Can., Sum. Rept., 1912, p. 63.
Twelfth Inter. Geol. Cong., Guide Book No. 10, 1913. Geol. Surv., Can., Mem. 32, 1913.
[5]Geol. Surv., Can., 1921, pp. 22A–49A.

at Anyox, for permission to examine the Hidden Creek mine and for placing at his disposal the maps, plans, and reports of the mine. Thanks are also due to Mr. John Flewin, of Port Simpson, for assisting the writer to examine the many mineral deposits near Maple bay, Portland canal, and for supplying much general information regarding the northern part of the district. W. S. Dyer ably assisted the writer throughout the season, and for a short time took charge of the shoreline mapping.

Previous work had been done in various parts of this area by H. Carmichael and W. F. Robertson of the British Columbia Bureau of Mines, and by R. G. McConnell of the Geological Survey, Canada. Carmichael[1] examined the mineral deposits of Portland Canal district and of Observatory Inlet district in 1906 and 1909. In 1910, Robertson[2], Provincial Mineralogist of British Columbia, examined the mineral deposits in the Portland Canal district. In 1910 and part of 1911, McConnell[3] mapped the Portland Canal district. In 1911, he[4] mapped the shores of the northern part of Observatory inlet, examined the Hidden Creek mine, and made a reconnaissance trip across the Coast range to Nass valley. In 1912, McConnell examined the Surf Inlet mine[5] on Princess Royal island and the shores between Surf inlet and Prince Rupert and in the same year made a reconnaissance along the Grand Trunk Pacific railway[6] from Prince Rupert to Hazelton. In 1913, he made a further examination of the Hidden Creek mine[7] in Observatory inlet. Certain other parts of the district are also described in Guide Book No. 10 of the Twelfth International Geological Congress. In 1916, J. M. Turnbull examined and reported on the section of territory surrounding the head of Alice arm, for the British Columbia Bureau of Mines[8]. The adjoining territory of southeastern Alaska is described in a report on the Ketchikan and Wrangell mining districts by Fred Eugene Wright and Charles Will Wright[9].

GENERAL CHARACTER OF DISTRICT

The district is very similar to that of the section lying to the south and described in the writer's report of the previous season[10]. The climate is, for such latitudes, rather mild but very wet. The population is much larger than in the district to the south. The city of Prince Rupert with a population of slightly over 6,000 is the largest community, but there are also the large villages of Anyox and Alice Arm in Observatory inlet, and of Stewart on Portland canal and there are many canneries about the mouths of Skeena and Nass rivers. Whereas lumbering is the principal industry

[1]Carmichael, H., Ann. Rept. of Minister of Mines, B.C., 1906, pp. H 61; 1909, pp. 59.
[2]Robertson, W. F., British Columbia Bur. of Mines, Bull. No. 2, 1910.
[3]McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1910, p. 59.
McConnell, R. G., Geol. Surv., Can., Mem. 32, 1913, p. 1.
[4]McConnell, R. G., Geol. Surv., Can., 1911, p. 41.
McConnell, R. G., Geol. Surv., Can., Mem. 32, 1913, p. 73.
[5]McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1912, p. 63.
[6]McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1912, p. 55, Twelfth Inter. Geol. Cong., Guide Book No. 10.
[7]McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1913, p. 55.
[8]Turnbull, J. M., Ann. Rept. of Minister of Mines, B.C., 1916, p. K 53.
[9]U.S. Geol. Surv., Bull. 347, 1908.
[10]Dolmage, V., Geol. Surv., Can., Sum. Rept., 1921, p. 23A.

farther south along the coast, in this section it is relatively unimportant and is greatly exceeded by both fishing and mining.

The shoreline is irregular, though less so than in the district to the south. Several large channels, such as Principe, Grenville, and Wark, strike north 45 degrees west, which is parallel to the general trend of the coast and also to the principal geological boundaries. Of these channels, the most remarkable is Grenville channel, which maintains a perfectly straight course for over 50 miles, and with its steep sides, clear channel, and great depth, is one of the best inland steamboat channels in the world. Portland canal and Observatory inlet parallel one another in a northerly direction and are more or less transverse to the trend of the coast-line and the geological contacts. The former is about 90 miles long and is one of the grandest fiords on the coast. Nass and Skeena rivers, two of the largest on the British Columbia coast, enter the sea in this district. For some distance from the coast they occupy fiords similar to all the others except that they have been filled by sediment deposited by the river. These fiords, also, cut across the general trend of the geological formations.

Almost the entire area is occupied by the Pacific system of the Cordilleras of Canada. This system is a great range of mountains extending along the mainland shore of British Columbia from Fraser river far into Alaska. It was formerly known as the Coast range and has been described by Dawson[1] and Bancroft[2]. These mountains occupy over 90 per cent of the area (Figures 1 and 2), and in the eastern part they reach elevations of 7,000 feet. Towards the west they become gradually lower until a line is reached just east of Banks and Estevan islands, where the mountains end abruptly and west of which lies a rolling lowland, with elevations generally less than 100 feet. The lowland has a width of from 10 to 30 miles and is composed of numerous islands some of which are hundreds of square miles in area.

GENERAL GEOLOGY

This district is chiefly occupied by the quartz diorites and granodiorites of the Coast Range batholith, a number of large masses of older rocks such as greenstone, argillite, crystalline limestone, and schists, which form inclusions in the batholith. The inclusions range from a few feet to over 100 miles in length and have a marked tendency to form long, narrow bands roughly parallel to the trend of the coast, and to the axes of folding. The rocks younger than the batholith consist of many relatively small dykes varying in composition from lamprophyre to rhyolite, a few small areas of stratified sands and boulder clay, and one very small area of recent volcanic rocks.

[1]Dawson, G. M., "Report on the Northern Part of Vancouver Island and Adjacent Coast", Geol. Surv., Can.

[2]Bancroft, Austen J., Geol. Surv., Can., Mem. 23, p. 13.

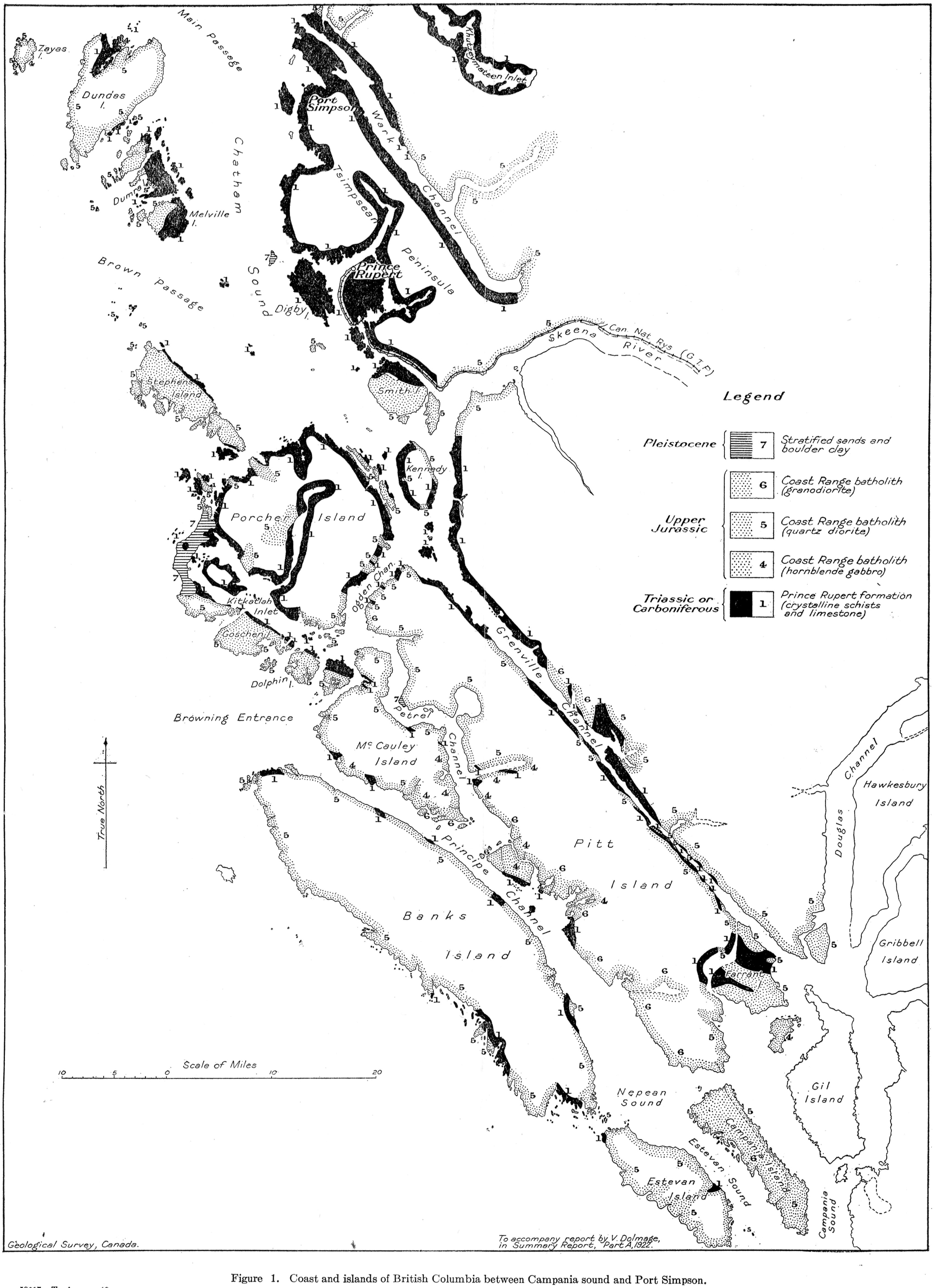

Figure 1. Coast and islands of British Columbia between Campania sound and Port Simpson.

58617—*To face p. 10.*

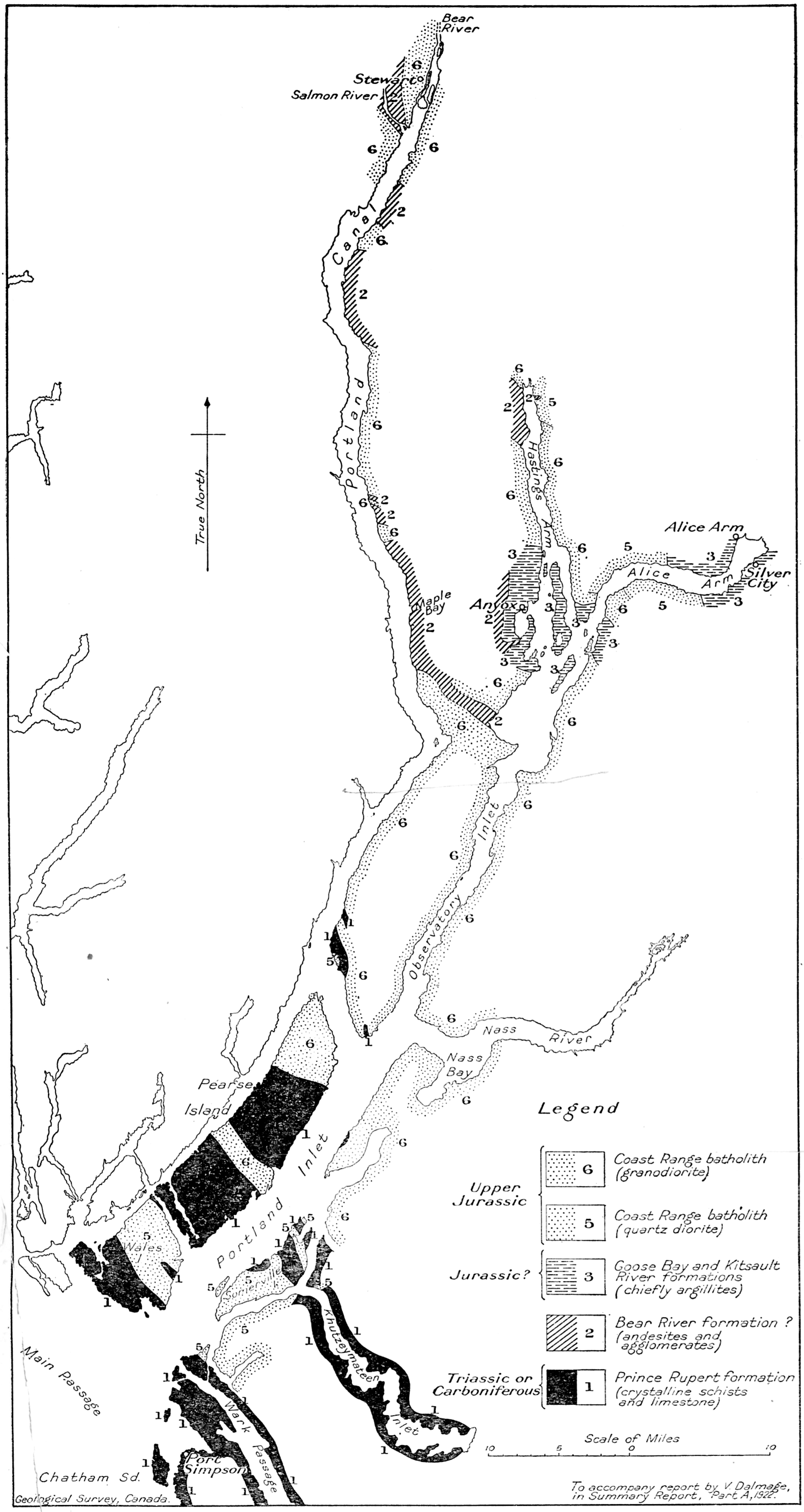

Figure 2. Coast and islands of British Columbia between Port Simpson and Stewart.

58617—*To face p. 10.*

Table of Formations

Age	Name of formation	Lithological character
Recent		Volcanic breccia
Pleistocene		Stratified sands, gravels, and boulder clay
Post Jurassic to Late Tertiary		Lamprophyre to rhyolite dykes
Upper Jurassic	Coast Range batholith	Granite, granodiorite, quartz diorite, and hornblende gabbro
Jurassic?	Kitsault River formation	Argillites, fine sandstone, conglomerate, arkose, and tuffs
Jurassic?	Goose Bay formation	Argillites, fine sandstone
Jurassic?	Bear River formation (McConnell's)	Massive and fragmental greenstones
Triassic or Carboniferous	Prince Rupert formation	Hornblende-garnet-quartz-biotite schists, greenstones, and limestones

PRINCE RUPERT FORMATION

The Prince Rupert formation is composed of highly metamorphosed crystalline schists with, near the base of the exposed sections, some greenstones, schistified pyroclastics, and narrow bands of limestone and dolomite. The formation was named by McConnell in 1912.[1] These rocks occur in three fairly large, well-defined bands and also in a number of small isolated patches widely scattered in the western part of the district (Figure 1). The largest of the three bands extends from the southern end of Grenville channel far into Alaska. It has a maximum width near Prince Rupert of over 20 miles. It strikes north 40 degrees west, which is roughly parallel to the trend of the coast as well as to the other bands of schist. The second band lies 6 to 10 miles to the northeast. It outcrops along both shores of Kutzeymateen inlet and strikes across Somerville and Pearce islands into Alaska. The third band lies still farther northeast and, in this district, is confined to Pearce island, but extends many miles into Alaska.

The rocks composing this formation are of the following types, beginning with those in the upper part of the formation: quartz-biotite schist; hornblende-muscovite-garnet schist; biotite-garnet-quartz-feldspar schist; crystalline limestone and dolomite; pyroxenized limestone; chloritic schist; schistified volcanic breccia.

The largest mass of limestone occurs on the northwest corner of Smith island. Here, beds several hundred feet thick outcrop along the shores of a narrow inlet which penetrates the island southeastward for 3 miles, parallel to the strike of the limestone. Thick beds of limestone occur also on Porcher island and along the west shore of Grenville channel. Several beds of dolomite were observed on Banks island just opposite Anger island.

The greenstones and schistified volcanic breccias and flows are confined to Dunira and Melville islands. These rocks, however, are much less metamorphosed than the other rocks of this formation and may possibly belong to a younger formation.

[1]Geol. Surv., Can., Sum. Rept., 1912, p. 60.

The bedding as well as the schistosity of the rocks strikes northwesterly, parallel to the general trend of the shoreline and the geological boundaries. The average strike is about north 40 degrees west, but it varies locally from north 50 degrees west to north 50 degrees east. The dips are mostly to the northeast, but in the vicinities of Wark channel and Kutzeymateen inlet closely folded synclines occur.

In what appears to be a continuation of these schists and limestones, 60 miles north of this district, in Alaska, fossils were found in the limestone. These were so poorly preserved that their age could not be satisfactorily determined, but they are thought by E. M. Kindle[1] to be Upper Palæozoic or probably Triassic.[2]

GOOSE BAY FORMATION

The Goose Bay formation consists of a series of metamorphosed argillites and other fine sediments which occurs on both sides of Observatory inlet in the vicinity of Anyox. It was named by R. G. McConnell[3] after the small bay on which Anyox is situated but which has since had its name changed from Goose bay to Granby bay.

The formation has a maximum width of about 8 miles and maximum length, in a north-south direction, of about 10 miles. Except on the west, where it is in contact with greenstone, it is completely surrounded by the granodiorite of the Coast Range batholith in which it forms an inclusion.

The contact with the greenstones lies a mile or so west of Anyox and is of great importance, because on it is situated the great Hidden Creek copper mine.

The formation consists of highly metamorphosed black, brown, and grey, well-bedded sediments, which are steeply folded along axes trending in a northerly direction. They consist of argillites, fine grey argillaceous and carbonaceous sandstones, and a few thin beds of impure limestone. Near the greenstone contact there is much faulting, and the sediments are extensively mashed.

The most abundant variety is a black, very fine-grained, bedded and banded sediment composed of nearly equal proportions of quartz, biotite, and a black opaque substance that is presumably carbonaceous material. A little feldspar is sometimes found, and considerable talc and iron sulphide. Brown varieties with less carbon and more biotite, and grey varieties, in which muscovite is abundant, are also found. The quartz forms from 20 to 40 per cent of these rocks and occurs in the form of small interlocking equal-sized grains. Pale brown biotite is nearly everywhere abundant. It is frequently segregated in thin parallel lamellæ forming a fine banding. In many places these highly micaceous sediments are conspicuously spotted with closely spaced spots from one-half to one-fourth of an inch in diameter. The spots consist of pure black mica much coarser than that forming the lamellæ. A large amount of opaque material was observed in the thin sections. Microscopic examination of polished specimens showed this to consist chiefly of pyrrhotite, pyrite, and carbonaceous material, with a

[1]Kindle, E. M., "Notes on the Palæozoic Faunas and Stratigraphy of Southeastern Alaska", Jour. Geol., vol. XV, No. IV, May-June, 1907.

[2]Wright, F. E. and C. W., U.S. Geol. Surv., Bull. 347, p. 56.

[3] McConnell, R. G., Geol. Surv., Can., Mem. 32, pp. 82.

small amount of chalcopyrite, magnetite, and in places a few flakes of graphite. In the brown varieties a small amount of hematite was found.

A few beds of fine, dark grey sandstone and still fewer and thinner beds of impure limestone are intercalated with the metamorphosed argillites. As shown by the presence of the pyrrhotite, pyrite, graphite, and probably much of the biotite and some of the quartz, these rocks have been intensely thermally metamorphosed, but only very locally have they been sheared to form slates. Close to the Hidden Creek mine and other sulphide deposits the rocks have been nearly completely silicified by metasomatic and pneumatolitic actions.

There is considerable doubt as to the age of the Goose Bay formation. No fossils were found in it and correlation must, therefore, be made on lithological similarities. McConnell[1] was inclined to the view that these argillites are a part of the Bitter Creek[2] formation of Bear River district. Because, however, of their close proximity to the Kitsault River formation, which outcrops in Alice arm 6 miles to the east, and also their close lithological similarities, the writer prefers to consider them as part of this formation, which is probably of Lower Jurassic age. From the descriptions of these two formations it will be noted that the Goose Bay is much the more highly metamorphosed, but this difference is probably because it forms a relatively small inclusion in the Coast Range batholith, whereas the Kitsault River formation lies outside the batholith.

BEAR RIVER FORMATION

This formation consists of massive and fragmental greenstones with a few interbedded layers of fine, argillaceous tuff and impure limestone. It occurs in three large bands or inclusions in the batholith, crossing Portland canal in the vicinity of Maple bay, Round point, and Salmon river. The widths of these three bands are respectively 8 miles, 5 miles, and $3\frac{1}{2}$ miles. They have much greater but unknown lengths. The formation consists chiefly of so-called greenstones which in reality are hornblende schist. There are also thick, massive flows of coarse andesite, some chlorite schist, a few thin beds of quartz-biotite schist, argillaceous tuff, and impure limestone.

The hornblende schists consist largely of fibrous hornblende varying from deep greenish blue to almost colourless. Small amounts of quartz, andesine, labradorite, biotite, and chlorite constitute the remainder. The quartz shows evidence of crushing, and the feldspars are greatly altered to sericite. They probably represent metamorphosed andesites and tuffs.

The less altered and more massive andesites are medium to fine-grained porphyries in which andesine forms the phenocrysts as well as much of the groundmass. Hornblende constitutes the remaining part of the rock and is probably largely a product of metamorphism. The biotite schists and tuffs occur chiefly near Maple bay and are described in connexion with the Maple Bay copper deposits.

These rocks are steeply folded along axes trending north by west and somewhat parallel to the trend of the contacts of the various bands.

[1]McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 82.
[2]McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 12.

They are clearly older than the Coast Range batholith, which intrudes them, but their relation to the Goose Bay formation is somewhat obscure. Several large faults occur along their contact, and in the vicinity of the contact the argillites are intricately folded and mashed. In places, the greenstones appear to intrude the argillites; elsewhere the argillites appear to overlie the greenstone. No fossils were found and their correlation with the Bear River formation described by McConnell[1] is based on lithological similarities and geographic proximity.

KITSAULT RIVER FORMATION

Sedimentary rocks similar to those at Granby bay outcrop continuously along both shores of Alice arm for the last 6 miles of its length, their contact forming the eastern boundary of the Coast Range batholith. These sediments extend east for an unknown distance and up Kitsault river beyond the limits of exploration. They are fine, argillaceous sediments thinly bedded and steeply folded, but are considerably less thermally metamorphosed than the Goose Bay argillites.

These rocks have been studied in the Kitsault River district by Hanson[2] who favours correlating them with the Nass formation, which occurs in the Salmon and Bear River districts, and also was named by McConnell[3]. In Kitsault River area Hanson[4] found in these rocks fossils which determined their age as Upper Mesozoic, very probably Jurassic.

COAST RANGE BATHOLITH

The Coast Range batholith is the main geological feature of the British Columbia coast region from Fraser river to Alaska. It occupies more than half of the district here considered, the remainder being occupied by the inclusions of the older rocks mentioned above. The batholith is, however, narrower, and the bands of older rocks are somewhat wider, than they are farther to the south, and farther north in Alaska the batholithic rocks finally disappear entirely.

The batholith is composed of light-coloured, medium coarse, crystalline rocks chiefly of the composition of quartz diorite. Large sections, however, consist of granodiorite and there are also small amounts of granite, quartz-monzonite, diorite, and hornblende gabbro. Quartz diorite and granodiorite form over 90 per cent of the total exposed bulk of the batholith. These two rocks are very similar in appearance and the one often merges into the other, making it difficult to map the two types separately. However, the granodiorite, granite, and quartz-monzonite have sharp intrusive contacts with the gabbro. They are lighter coloured, often having a pinkish tinge, and contain more biotite and less hornblende than the quartz diorites. Using these criteria, an attempt was made to map the granodiorite, granite, and quartz-monzonite under one colour, the quartz diorite and diorite under another colour, and the gabbro under a third. A large number of specimens were taken from all parts of the area and

[1]McConnell, R. G., Geol. Surv., Can., Mem. 32, p. 14.
[2]Hanson, Geo., Geol. Surv., Can., Sum. Rept., 1921, p. 11 B.
[3]McConnell, R. G., Geol. Surv., Can., Mem. 32, pp. 17 and 64.
[4]Hanson, Geo., op. cit., p. 11.

microscopically analysed. As a result it was found that the boundaries established in the field required only minor alterations, and they are shown on Figures 1 and 2.

As shown by the map the granodiorite occupies almost all the territory adjacent to Portland canal and Observatory inlet; also the greater part of Campania island; small areas on the west side of Pitt island; parts of Anger and McCauley islands; and a large area on the east side of Grenville channel north of Klewnuggit inlet. These more acid types show a general tendency to lie towards the central part of the batholith, but there are exceptions to this. The gabbro occupies much smaller areas, which are irregularly scattered through the batholith and seem to be related to inclusions of basic schists.

Quartz diorite is the most abundant variety, not only of this district, but of the whole batholith. It is a medium coarse, holocrystalline rock varying in colour from grey to nearly white. It consists essentially of plagioclase ranging from oligoclase to labradorite, of from 10 to 40 per cent of quartz, hornblende, and biotite, with usually a little augite and some orthoclase. The common accessories are apatite and sphene. The former is invariably present in small but constant amounts, whereas the quantity of sphene varies greatly, sometimes being very abundant. Hornblende is usually more abundant than biotite, but frequently these minerals are about equal. The hornblende found in the northern part of the batholith has a strong pleochroism varying from a deep bluish green to almost a clear yellow and has extinction angles up to 25 degrees though usually not greater than 17 degrees. Orthoclase is almost invariably present, but seldom forms more than 2 per cent of the rock.

The granodiorite, which is the next most abundant rock type, closely resembles the quartz diorite, and the two rocks often merge imperceptibly into one another. On the whole, however, the granodiorites are lighter in colour and sometimes are slightly pinkish. They consist of the same minerals as the quartz diorite, and are distinguished from the latter only by a higher proportion of orthoclase, ranging from 8 per cent to 20 per cent, usually a higher proportion of biotite, and less hornblende. The quartz and orthoclase are frequently intergrown to form micropegmatite. The granodiorite along Portland canal and Observatory inlet is particularly high in potash feldspar, usually having over 12 per cent and an average of 20 per cent. At a few localities in this vicinity and also on Campania island specimens were taken which contain nearly equal proportions of potash and soda-lime feldspars and are, therefore, quartz-monzonites.

The gabbros are very subordinate in amount. They are black to dark grey, and are quite irregular in grain, but mostly rather coarse, with hornblendes up to 2 inches in length. In most cases they have a gneissic structure and in two localities on Finn island they were found to grade into a biotite-hornblende-quartz-schist similar to the Prince Rupert schists.

In composition they are irregular. They consist essentially of hornblende, biotite, magnetite, and labradorite, with in places augite, epidote, andesine, and quartz. The hornblende forms large elongated crystals having, in thin section, a pale blue-green to yellowish colour and often containing a large amount of black opaque dust which is probably magnetite.

They have extinctions up to 18 degrees. The quartz is in places rather abundant and forms intergrowths with the hornblende. It is the writer's opinion that some at least of the gabbro represents more or less assimilated inclusions of quartz-hornblende schist.

The Coast Range batholith is of great economic importance. It is well known that most of the mineral deposits of the coast region had their origin in the magma which formed this batholith.

YOUNGER DYKES

Everywhere throughout the district the batholithic and older rocks are cut by numerous dykes of all sizes up to several hundred feet in width and of a wide variety of composition. They vary considerably in age, but probably are all younger than the ore deposits, which were formed after the partial consolidation of the batholith. They have had absolutely no metamorphic effect on the rocks they cut. They invariably have chilled margins and many of them are spherulitic and even glassy. They are so numerous that in the Hidden Creek mine, at Anyox, over one hundred separate dykes have been mapped. Though some of them are left in position to act as supporting pillars, many more of them have to be mined, and have thus considerably lowered the grade of the ore. On the bare glaciated slopes of the granodiorite mountains these dykes can be seen for miles in great numbers cutting the granodiorite in all directions. They consist of a large variety of rock types ranging from acid quartz porphyries, granites, and syenites through diorites and andesites to kersantites. Some of the varieties identified are malachite, vogesite, garganite, and kersantite.

PLEISTOCENE DEPOSITS

At several places along the shores of this district fairly thick deposits of fine sands, clays, gravels, and boulder clay were observed. The most important of these localities are: the west side of Porcher island, Granby bay, at a point on the east shore of Petrel channel, on Tugwell island, and along the shore between Tugwell island and Port Simpson.

These deposits vary in thickness from 20 feet up to 200 feet. They cover only small areas and are confined to small basins. The largest areas are those on the west shore of Porcher island and on Tugwell island and the adjacent mainland. The deposits consist of fine gravel, very fine clayey sandstones, and sandy clays, all finely stratified, and in places showing crossbedding. Interbedded with these are thick deposits of fine, bluish clay through which are scattered boulders some of which are tons in weight. These clays are true boulder clays and are conclusive evidence that the deposits were formed during the Glacial period. Small marine shells in the bedded sands indicate that the deposits were formed in the sea. These deposits are now found at elevations of over 200 feet and it follows, therefore, that since Glacial times the region has been uplifted to this extent.

RECENT VOLCANIC BRECCIA

Though volcanic rocks of Post Glacial age are found at several places in Alaska immediately north of this district, and were also found by the writer[1] at several localities in the district to the south, only one occurrence of such rocks was found in the district here considered. This occurrence occupies only a few hundred square yards on the west side of the most northern point of Pearce island, and a thickness of only 20 feet is exposed.

The rock consists of a light greyish green, fine-grained matrix filled with pebbles ranging from a small fraction of an inch up to a foot or more. The pebbles consist of granodiorite, and quartz diorite, related to the Coast Range batholith; gneiss and schist belonging to the Prince Rupert formation; fragments of reddish and brownish tuff of unknown origin; and many fragments of porphyrite which were undoubtedly derived from the late dykes that are so abundant in the district. The matrix is a fine aggregate of a large number of minerals including quartz, oligoclase, andesine, orthoclase, hornblende, chlorite, uralite, sericite, calcite, and micropegmatite.

The age of this breccia is not positively known, but, since it contains fragments of some of the more recent dykes, it must be, at least, very late Tertiary and probably even much younger.

ECONOMIC GEOLOGY

The district represented in Figures 1 and 2 has important deposits of copper, smaller deposits of silver, one of gold, and one of molybdenum. It is adjoined on the north by the rich Salmon River and Bear River districts, and on the northeast by the rich silver-producing district about the head of Alice arm.

COPPER

Hidden Creek Mine. The largest deposit of copper is that of the Hidden Creek mine at Anyox, owned and operated by the Granby Consolidated Mining, Smelting, and Power Company. This is the largest copper deposit in British Columbia and is at present producing nearly 3,000,000 pounds of copper per month. A very excellent and complete report on the deposit had, shortly before the writer's visit, been finished by J. Austen Bancroft, formerly assistant general manager of the company. This report, and the geological maps accompanying it, were kindly placed at the writer's disposal. With the help of these, and the observations made during several days on the premises under the guidance of F. E. Patton, the company's mining engineer, a good knowledge of the deposit was obtained. The following report is largely a restatement of facts from Bancroft's report, with a few observations by the writer.

The mine is situated about 1 mile north of Granby (formerly Goose) bay, on the west side of Observatory inlet just at the junction of Hastings and Alice arms. A smelter with a daily capacity of 3,000 tons is situated on the shore of Granby bay. The ore, which is very high in sulphur, is smelted directly in blast furnaces by a process of partial pyritic smelting without previous roasting or concentrating. The matte from the blast furnaces is blown to blister copper in converters and the blister copper is shipped to the Nichols Chemical Company, New York, where it is refined.

[1]Dolmage, V., Geol. Surv., Can., Sum. Rept., 1921, p. 29 A.

The ore-bodies are well to the centre of a large body of greenstones and metamorphosed argillaceous sediments which forms an inclusion in the Coast Range batholith. The contacts of the inclusion with the batholith lie about 4 miles to the north and 5 miles to the south of the principal ore-bodies. The contact between the greenstones and argillaceous sediments lies about 1½ miles northwest of Granby bay. The greenstones lie to the west and extend to Portland canal and beyond. The ore-bodies lie on or adjacent to the contact between the greenstone and argillites. This contact has a northeasterly trend, but is exceedingly irregular owing partly to faulting. The dip of the contact is almost vertical in the upper levels, but flattens considerably in the lowest workings. Owing to its irregularity, also to the highly folded and mashed condition of the argillites in its vicinity, and to the intense hydrothermal alteration, the true nature of this contact is difficult to determine. In places, such as on Bonanza creek, the greenstones and argillites are faulted together. At Maple bay, 7 miles to the west on Portland canal, the greenstones are interbedded with similar argillaceous sediments. In Bear and Salmon River districts, what appear to be the same greenstones are overlain by argillites. The greenstones, though massive in places, are fine grained, and, where less altered, have the appearance of andesites. They are, moreover, interbedded in many places with true volcanic breccias and seem to form a part of a volcanic series. Bancroft, however, found the greenstones crosscutting the argillites and also found inclusions of the argillites in the greenstones, from which he concluded that the greenstones are younger rocks which have intruded the argillites.

The so-called greenstones are really hornblende schists. Throughout the whole inclusion they are highly metamorphosed, and consist of 70 per cent to 90 per cent of a pale green hornblende, of a fibrous nature but with higher indices of refraction than actinolite. The other minerals found in the rock are chlorite, andesine, orthoclase, quartz, biotite, talc, epidote, and, in many places, small amounts of pyrite. Near the ore-bodies much more quartz is present, and Bancroft found also actinolite, tremolite, calcite, sphene, and leucoxene.

The argillites, also, of this inclusion are highly metamorphosed, and consist chiefly of biotite, quartz, pyrite, and pyrrhotite, with a considerable amount of carbonaceous material. In the vicinity of the ore-bodies, however, large quantities of talc, sericite, and quartz are present. In places silicification is almost complete. Interbedded with the metamorphosed argillites are thin beds of coarse and fine-grained, greyish sandstones, and a few thin beds of limestone.

The Coast Range batholith which surrounds the inclusion and which occupies most of the territory in the vicinity of Portland canal and Observatory inlet, is composed of granodiorite in which quartz forms about 40 per cent, biotite and hornblende about 10 per cent, and feldspar 50 per cent of the rock. The feldspar consists of one-third orthoclase and microcline and two-thirds oligoclase and oligoclase-andesine.

At 3,200 feet northwest of the mine there is a band of coarse diorite about 250 feet wide, striking north 20 degrees to 50 degrees east, and lying nearly parallel to the greenstone-argillite contact.

The only other rocks in the vicinity are the numerous dykes already mentioned. As these were virtually all injected after the deposition of the ore they have no significance as to its origin; but their abundant presence in the ore-bodies has a distinct tendency to lower the grade of the ore, since most of them have to be mined.

There are seven ore-bodies. Numbers 1 to 5 are clustered close together about the apex of a spur of greenstone about 2,500 feet square which juts out into the argillites in a northeast direction. The sixth ore-body lies 1,300 feet to the southwest on the southeast side of the above-mentioned spur of greenstone. Another ore-body, which is really a separate deposit, but is owned by the same company and known as the Bonanza, is situated 3½ miles to the south on Bonanza creek and 3,200 feet from the shore of Granby bay. This deposit is also on a contact between the argillites and a small mass of greenstone less than a mile in diameter.

Ore-bodies 1, 4, 5, and 6 lie on the contact of the argillites and greenstones, where the argillites are much crumpled and the greenstones are especially schistose. Numbers 1 and 5 have developed where the turn in the strike of the greenstone-argillite contact is most abrupt. These ore-bodies are richer where the slate contact overhangs the ore. Ore-bodies 2 and 3 and Bonanza lie in the greenstone, where it is especially schistose, and 2 and 3 are so situated that at the time of their deposition they were probably roofed by slate.

The following dimensions will give some idea of the sizes of the ore-bodies. Ore-bodies 1 and 5 have a combined length on the 530-foot level of about 1,240 feet, with an average width of 150 feet. Number 3 is a faulted block of Number 2 and they have a combined length of 750 feet with a width of 240 feet. Number 4 ore-body lies chiefly above the 530-foot level. It is triangular in plan with a length on the 760-foot level of 560 feet. The present workings extend over a vertical range of 800 feet and diamond drilling has proved the ore-bodies to extend still deeper. They have a maximum size in cross-section on the 530-foot level, below which there is a gradual decrease in size which becomes more marked below the 150-foot level and is coincident with a sudden flattening of the greenstone-argillite contact.

There has been developed up to date in ore-bodies 1, 2, 3, 4, 5, 6, and 7, 13,215,000 tons of high-grade ore, averaging 2·14 per cent copper, and 1,534,000 tons of low-grade ore, carrying 0·94 per cent copper. The Bonanza deposit contains 488,800 tons of 2·49 per cent ore and 577,300 tons of 0·64 per cent ore.

The chemical composition of the ore is very well shown in the following tables which are averages of a great many determinations.

High-grade Ore

Ore-body	Gold in oz. per ton	Copper %	Insoluble %	Silica %	Iron %	Sulphur %	Alumina %	Magnesia %	Lime %	Silver in oz. per ton
No. 1.....	0·013	2·08	26·1	22·7	29·8	30·1	4·6	1·2	5·0	0·40
No. 2....}	0·006	2·11	37·6	31·4	26·0	18·2	10·3	3·8	3·2	0·25
No. 3....}	0·002	1·83	48·4	39·4	21·7	8·1	11·5	6·6	1·8	0·11
No. 4.....	0·008	1·71	8·9	7·0	41·5	31·6	1·9	0·5	9·0	0·79
No. 5.....	0·012	2·81	17·9	16·5	34·1	33·3	1·6	n.d.	5·2	1·00
No. 6.....	0·010	2·44	42·3	31·1	27·1	22·0	9·1	n.d.	4·8	0·63
Bonanza...	0·006	2·49	35·2	27·6	26·0	17·8	10·1	6·3	2·0	0·28

Low-grade Ore

Ore-body	Gold in oz. per ton	Copper %	Insoluble %	Silica %	Iron %	Sulphur %	Alumina %	Magnesia %	Lime %	Silver in oz. per ton
No. 1.....	0·004	0·71	40·6	35·9	23·6	21·1	5·9	2·0	5·4	0·14
No. 2....}	0·002	0·69	42·8	34·2	24·2	16·2	10·8	4·7	3·4	0·08
No. 3....}	0·002	0·69	50·0	42·2	22·0	7·8	11·5	6·4	1·4	0·11
No. 4.....	0·002	0·54	9·0	6·8	40·7	36·1	2·2	1·5	7·6	0·25
No. 5.....	0·003	0·66	45·8	41·5	24·8	19·0	5·1	n.d.	3·3	0·25
No. 6.....	0·003	0·74	62·3	55·8	14·6	9·6	10·1	n.d.	3·6	0·19

The total ore shipped from 1918 to 1921 inclusive from ore-bodies 1, 2, 3, 5 yielded 0·008 oz. of gold and 0·49 oz. of silver to the ton.

The mineralogical composition of the gangue and ore is comparatively simple and very constant. The gangue consists of silicified argillite and greenstone averaging 50 per cent silica. Scattered among the sulphides as loose individual grains are found biotite, hornblende, actinolite, epidote, quartz, and calcite; quartz, hornblende, and calcite being by far the most abundant. The hornblende of this ore is of a much darker colour than that of the greenstone. The calcite is present in small disseminated grains, and seldom occurs as late veinlets cutting the ore, in the manner so common to most of the copper deposits of the Pacific region.

The common metallic minerals are pyrite, pyrrhotite, chalcopyrite, zinc blende, magnetite, and arsenopyrite. These constitute nearly 100 per cent of the ore, but Bancroft found also small amounts of galena, and the writer found in some high-grade ore from the Number 1 ore-body, on the 530-foot level, a small amount of native silver, associated with some arsenopyrite, and a very small amount of a soft grey mineral which is almost certainly argentite. Number 4 ore-body is different from the others. It is composed almost entirely of pyrite, in the form of small crystals less than one-sixteenth of an inch in size, cemented with calcite. Surrounding this central mass is a shell of nearly pure pyrrhotite. The copper content is so low that this ore is sold as pyrite ore.

In general the pyrite, arsenopyrite, and magnetite were deposited earlier than the pyrrhotite, zinc blende, and chalcopyrite, but in two specimens veinlets of pyrite were found cutting the pyrrhotite and chalcopyrite. The three sulphides—chalcopyrite, zinc blende, and pyrrhotite—were deposited simultaneously. The small amount of argentite occurs as rounded blebs of microscopic size in the chalcopyrite. Its age was not indicated but it was probably precipitated at the same time as the chalcopyrite. The native silver occurs in a similar manner and is probably of the same age.

Some specimens from each of the ore-bodies were assayed for copper, gold, silver, and zinc, to find the association of the various metals and minerals. The results of these analyses are as follows:

Ore-body	Copper	Gold	Silver	Zinc
1	0·48	0·004	0·12	0·4
1	0·8	0·010	0·30	0·7
1	2·10	0·007	0·38	trace
1	2·30	0·017	0·16	0·2
1	0·70	0·007	0·17	1·7
1	1·07	0·007	0·28	1·3
1	2·70	0·012	0·60	0·2
1	2·90	0·018	1·04	1·8 Pyrrhotite ore
1	2·98	0·005	0·45	0·2
1	3·80	0·005	0·92	1·1
2	0·65	0·002	0·04	0·4
2	3·32	0·002	0·08	0·5
3	1·14	0·001	0·05	0·2
3	1·50	0·001	0·06	0·3
4	0·4	0·006	0·37	trace
4	1·12	0·007	0·32	0·6
4	1·40	0·003	0·51	0·3
4	2·62	0·016	1·62	1·1
5	0·2	0·003	0·13	trace
5	0·7	0·003	0·17	4·4
5	0·8	0·003	0·44	0·6
5	3·01	0·016	0·96	2·2
5	5·90	0·025	1·99	1·6

These analyses give no indication as to how the gold and silver are associated, but it seems clear from the writer's study of polished sections that the silver was deposited in the form of silver minerals during the time that the chalcopyrite and zinc blende were being deposited. The higher gold values are associated with high copper values, which appears to imply that the gold is associated with the chalcopyrite. But this is contrary to the general experience in other mines of the coast region, where the gold is found in the pyrite either as submicroscopic particles or in solid solution.

Regarding the origin of these ores it is Bancroft's opinion that they were formed by the replacement of greenstones and argillites by solutions that began to circulate towards the close of the intrusion of greenstones, and continued during the advance and cooling down of the Coast Range batholith. He considers the possibility of there being two periods of silicification, one related to the greenstone intrusion, and a later and more extensive one related to the invasion of the batholith; but says that the field evidence is in favour of one prolonged period of silicification and mineralization. This would involve a tremendously long period of time for the formation of these deposits. There is no doubt, however, that the great bulk of the metal of these deposits, as of all the deposits of the coast region, originated in the Coast Range batholith.

The immediate future for the Hidden Creek mine looks very bright. The costs are fairly low and the price of copper is much improved. The cost in May, 1922, of one ton of ore delivered at the smelter was $0.949 with labour at the following prices:

Unskilled labour	$3.30 a day
Blacksmiths and carpenters	5.00 "
Shift bosses	5.75 "
Foreman	6.40 "
Miners	4.25 "
Muckers	3.85 "

Two hundred and eighty-four labourers were then employed, consisting of over fifteen different nationalities.

The ore reserves on July 1, 1922, were:

Ore-body	High grade		Low grade	
	Tons	Copper per cent	Tons	Copper per cent
1	3,866,000	1·94	672,000	0·87
2	2,305,000	1·87	269,000	0·96
3	1,188,000	1·82	427,000	1·00
4	139,000	1·90	55,000	1·20
5	1,047,000	2·90	111,000	0·90
6	255,000	2·44	....	....
Total	8,800,000	1·97	1,534,000	0·94
Bonanza	488,800	2·49	....	....

This reserve will last at the present rate of production for about thirteen years.

Outsider Group and Adjoining Claims. At a place known as Maple bay on the east side of Portland canal about 30 miles from its head and 7 miles due west of Anyox, there are several groups of copper claims situated in the same inclusion of greenstones as the Hidden Creek mine. The best known and most developed of these is the Outsider, from which about 16,000 tons of 2·9 per cent ore was shipped in 1906 and 1908. It has recently been bonded by the Granby Consolidated Mining, Smelting, and Power Company, of Anyox.

This deposit and the others in the vicinity of Maple bay were described by G. A. Clothier in the Annual Report of the Minister of Mines of British Columbia for 1921.

The Outsider group is situated at the northern end of Maple bay at an elevation of about 1,000 feet and the other groups extend a mile to the south at elevations of from about 1,000 to 3,000 feet. All the showings are reached by trails which are, excepting at the lower end, in fairly good condition.

These claims are among the first located in the Portland Canal district. In 1896 Lieutenant Mosier of the United States Navy discovered the showing which is now known as the Bluebell. He did not make any attempt to develop it and in 1899 it was restaked by John Flewin, of Port Simpson. The claim now known as the Eagle was at that time staked by Mr. Collison, a missionary from Nass river. These two claims along with others were combined into one group, the Bluebell, which is owned by Mr. Collison, Wm. Noble, of Stewart, and others. In 1900, John Flewin located the Comstock group which lies to the south of the Bluebell. It was Crown-granted in 1912 and is still owned by Mr. Flewin.

The Outsider group was located in 1904, and in 1906 was acquired by the Brown Alaska Company, which at that time owned and operated a smelter at Hadley, on Kasaan peninsula, Prince of Wales island, Alaska.

This company developed the property, and during 1906-1908 shipped 16,000 tons of 2·9 per cent ore to the Hadley smelter. Soon after this the company failed and the mine was acquired by Martin Woldson and associates of Spokane, Wash., who several months ago bonded it to the Granby Consolidated Mining, Smelting, and Power Company.

In 1913, the Granby Company took an option on this property along with all the other claims in the vicinity of Maple bay. The option was extended until 1916, when work was commenced. A townsite was surveyed and cleared, several miles of tram-line were built, a wharf was constructed, and a tunnel was driven on the Starr claim adjoining the Outsider group. From this tunnel about 4,000 tons of heavy sulphide ore, high in pyrrhotite, was shipped to Anyox. Considerable diamond-drilling was also done, but in 1917 the property was abandoned and the tracks and machinery were removed.

All the copper deposits at Maple bay occur under geological conditions very similar to those at the Hidden Creek mine, which is only about 7 miles distant. The copper occurs in the same inclusion of greenstone and associated rocks. The contacts of the inclusion with the Coast Range granodiorite lie 4 miles north and 4 miles south of Maple bay. The greenstones at Maple bay are, however, less massive than those at Anyox and are interbedded with many layers of argillaceous tuff and micaceous schist. The ore-bodies occur in large replacement quartz veins which lie between the bands of greenstone and metamorphosed tuffs. The strata strike north 10 degrees to 35 degrees east and dip from 40 to 85 degrees to the southeast.

The most abundant rock is a green hornblende schist exactly similar to the greenstone of the Hidden Creek mine except that it occurs in relatively thin beds interstratified with tuffs. Other beds of greenstone, particularly those near the veins, are altered chiefly to chlorite and to a less extent to sericite. They consist, in their present state, of crushed grains of quartz, oligoclase, andesine, chlorite, zoisite, sericite, talc, and in a few cases small amounts of albite were found. The primary ferromagnesian minerals have completely disappeared; the feldspars have remained fairly fresh. Several beds of micaceous and carbonaceous schists occur near the beach of Maple bay. These consist of a fine-felted network of light brown biotite and colourless fibrous hornblende in a still finer-grained mass of quartz and feldspar, chiefly the former. Closely associated with this type is a similar rock consisting of a fine mixture of quartz, feldspar, carbonaceous material, and a small amount of talc and hornblende, with no biotite. Hornblende schist constitutes the foot-wall of almost all the veins; the hanging-wall is mostly a chlorite-sericite schist, high in quartz and feldspar, which probably represents a metamorphosed tuff.

The Outsider mine consists at present of four tunnels at elevations of 925 feet, 1,100 feet, 1,150 feet, and 1,200 feet respectively. These run parallel to the strike of the greenstones and also the strike of the vein, and pass through an ore-body from 200 to 400 feet long. Most of the ore between the 1,100 and the 1,200-foot levels was stoped out by the Brown-

Alaska Company. The lower tunnel, however, is in heavy sulphide ore, and the last 400 feet of the 1,100-foot tunnel follows a well-defined vein carrying small, scattered patches of copper ore. The width varies from 8 to 20 feet and the tenor of the ore varies from 2 per cent to 4 per cent copper with combined gold and silver values of about $1 to the ton. The best grade of ore is in the foot-wall.

The ore consists chiefly of chalcopyrite and pyrrhotite in a gangue of quartz and country rock. Small amounts of pyrite and zinc blende are also present. In the oxidized parts limonite is plentiful and in places the pyrrhotite is altered to a later sulphide which is either pyrite or marcasite, but which is not present in appreciable quantities.

The tunnel on the Star claim is in a vein consisting chiefly of pyrrhotite and quartz but with low values in copper. The average width of this vein is 5 or 6 feet.

On the Eagle claim of the Bluebell group, which is about half a mile southeast of the Outsider and at an elevation of 3,000 feet, a small tunnel has been driven 40 feet. It runs north 40 degrees east following a silicified and mineralized band that lies parallel to the structure of the greenstones. Three bands of rich sulphide-pyrrhotite and chalcopyrite occur in this zone, having widths of 12 inches, 15 inches, and 24 inches respectively. In a deep gulch to the north a similar band of quartz 10 feet wide is exposed, which carries small bunches of metallic sulphides, chiefly zinc blende with a little chalcopyrite.

On the Anaconda and other groups there are five of these parallel bands of quartz in the greenstone, that range from 5 to 100 feet in width. One has been traced by open-cuts and trenches for 3,000 feet or more. They are composed chiefly of fine-grained quartz approaching chert in places and having a banded structure parallel to the greenstones. They seem to be completely silicified bands of country rock. In these bands of cherty quartz there are irregular masses of clear glassy quartz from which veins run in all directions. The metallic sulphides occur in greatest abundance in these areas of clear quartz, but some also occur in the cherty quartz.

The only metallic minerals are chalcopyrite, pyrrhotite, pyrite, and zinc blende. Chalcopyrite is much the most abundant of these minerals. Pyrrhotite is common, but pyrite and zinc blende are rarely seen in hand specimens. However, the metallic minerals are not plentiful and the ore at best is not high grade. The silicified zones are not metallized, even sparsely, throughout the exposed surfaces, but only in certain irregular areas which are often widely spaced. Some of these areas are of considerable size and might on development prove to be commercial ore-bodies.

It seems reasonable to suppose that these copper deposits were formed by mineralizing solutions which originated in the Coast Range batholith, rose through the schistose greenstones, and deposited their mineral content where conditions favoured precipitation. If this theory be correct the ore may be expected to continue downward for a great distance and may even increase in grade. However, the absence of any large masses of pyrrhotite, and the presence of such large quantities of quartz, are not, in this region, favourable indications of the presence of large copper deposits.

Bald Mountain Group. A group of copper claims known as the Bald Mountain group, owned by the International Copper Company, has been well described by A. C. Garde[1].

This property includes thirty-two Crown-granted claims situated on Bald Mountain range in the northern part of Porcher island. The showings which are at elevations of from 100 to 1,000 feet are conveniently reached by an excellent 2-mile trail from Jap inlet, which is an almost perfect harbour for small craft. For the first 1½ miles the trail crosses a muskeg and is planked.

This part of Porcher island consists of banded gneiss, micaceous schist, and chloritic greenstone interbedded with bands of limestone that are seldom more than 150 feet wide. These rocks strike north 50 degrees west and extend southeast through Gibson island into Grenville channel. They form a part of the Prince Rupert formation. To the west of the group of claims they are cut by a large mass of granodiorite and quartz diorite which extends northwest through Prescott and Stephens islands. These intrusives probably also underlie the ore deposits and it is highly probable that metals of these deposits were deposited by solutions originating in the magma of the granodiorite and quartz diorite. Towards the northeast of the ore-bodies there is a large pegmatite dyke 15 to 20 feet wide, composed chiefly of quartz, pink feldspar, and biotite, but it has probably no relation to the ore-bodies. The feldspar forms a high proportion of the dyke and is chiefly microcline.

The ore-bodies occur in bands in the schists and gneiss. These bands are now composed chiefly of garnet, pyroxene, and calcite with copper-iron and iron sulphides. They very probably represent original bands of limestone which have been completely metamorphosed. These bands as well as the schists strike north 60 degrees west and dip 60 degrees northeast. Although many lenses of ore were found not one of them is more than a few feet long. The widest showing occurs on the Entente Cordiale claim. It has a width of 74 inches but has not been traced along the strike for more than a few feet.

The gangue minerals found are red garnet, pale green augite, greenish black hornblende, calcite, quartz, and, embedded in the quartz, are large idiomorphic crystals of oligoclase-andesine. The metallic minerals are pyrite, pyrrhotite, chalcopyrite, and zinc blende. The showings on the Entente Cordiale are said to contain small values in gold and silver, but no silver minerals were detected.

Samples from the 12-inch paystreak on the Little Bull claim assayed gold 0·04 ounce, silver 1·0 ounce, copper, 4 per cent. A dump of 20 tons of ore from a 25-foot shaft yielded a sample carrying over 3 per cent copper and $1.50 in gold and silver.[2]

The ore in these showings is of fairly good grade and the showings are plentiful. The ore is certainly primary and for that reason may be expected to continue downwards. According to Mr. Garde's report the 25-foot shaft on the Little Bull claim showed that ore-body to widen with depth. However, all the ore-bodies so far discovered are rather small in area and are far apart.

[1]Rept. of Minister of Mines, B.C., for 1916, p. 50 K.
[2]Minister of Mines, B.C., 1916, p. 51.

Jitney Group. Three copper claims, called the Jitney group, owned by R. G. Frizzell and associates, of Prince Rupert, are located on the north end of Porcher island half a mile east of the northern end of Jap inlet. The deposit is in a low, marshy place only a few feet above sea-level.

The ore occurs in a considerably sheared greenstone and is composed chiefly of pyrite, pyrrhotite, and chalcopyrite. The greenstone consists of chlorite, andesine-labradorite, quartz, apatite and—in the neighbourhood of the sulphide veins—considerable common green hornblende with a little calcite and an extra amount of quartz.

A small tunnel and some open-pits expose a body of ore about 1 foot wide of nearly solid sulphide. A small inclined shaft exposes another ore-body 18 inches wide of solid and disseminated sulphide. The ore was not traced for any distance along the strike. From the tunnel 4 tons of ore was shipped to Anyox and is said to have yielded about $50 worth of copper and a slight amount of gold and silver. This is a small but a fairly promising showing. The ore is very similar in appearance to that of the Hidden Creek mine.

GOLD

On the northwest side of Porcher island, near Surf point, there are a number of small gold-bearing quartz veins. They are included in three groups of showings, one on the Patterson-Gillett group owned by Frank Patterson, a second group on the Eagle claim owned by Joe Dawson, and a third group on the I.X.L. claim owned by A. E. Wright and partner, of Prince Rupert. The Patterson-Gillett group and the Eagle claim are described by G. A. Clothier in the Annual Report of the Minister of Mines of British Columbia for 1919. The I.X.L. group was only recently staked. In 1917, the Patterson-Gillett group was under option to the Bellmont-Surf Inlet Mines, Ltd., who did considerable exploratory development work but dropped the option the same year.

All these showings occur on the northwest slopes of the Bell range of mountains and are less than 3,500 feet distant from an excellent harbour just south of Surf point. They are at elevations ranging from 125 to 450 feet and are reached from the harbour by an easy trail which passes for most of the distance through open muskeg country.

This part of Porcher island is underlain by a wide band of quartz diorite belonging to the Coast Range batholith. Just northwest of the Patterson-Gillett group there is a wide band of greenstone older than and intruded by the quartz diorite, and belonging to the Prince Rupert formation. A few very small inclusions of greenstone occur on the I.X.L. group, one of which adjoins a mineral vein. All the mineral veins except the one on the Eagle claim lie in the quartz diorite. The greenstones consist chiefly of pale green, fibrous hornblende with small amounts of quartz, andesine, chlorite, and talc.

The quartz diorite is a grey, medium-coarse, fresh rock consisting essentially of andesine, quartz, biotite, and a large amount of dark bluish green hornblende. There is less than one per cent of potash feldspar. Accessory minerals are apatite and sphene, the latter being quite abundant in places. Near the veins the quartz diorite is sheared and considerable sericite and epidote are present.

On the Patterson-Gillett group there are six more or less parallel quartz veins. They vary in width from 3 feet down to a few inches. The greatest length to which any vein has been proved is about 300 feet. At a distance of a few hundred feet on an adjoining claim a crosscut tunnel was driven with the apparent object of tapping this vein. This tunnel in the first 15 feet crosses three small quartz veins, each only a few inches wide and carrying almost no sulphides. Fifty feet from the portal a 4-foot quartz vein was penetrated which also is devoid of sulphides and consequently carries no gold. It was drifted on to the east for 40 feet and in places small amounts of sulphide were discovered. Seven feet beyond the drift there is another quartz vein a foot wide that contains much pyrite. Eight feet farther is still another quartz vein 17 inches wide and also containing much pyrite. This is probably the continuation of the main vein exposed in the open-cuts to the west. In a large open-cut to the south there is still another vein exposed for a vertical range of about 30 feet. It is heavily pyritized and a systematic sample from the dump carried 0·35 ounce in gold, 1·02 ounce in silver per ton, and traces of copper.

Still another showing consists of a large, irregular mass of quartz veins 15 feet to 20 feet wide. These veins were so irregular in attitude and width that their strike could not be taken. The quartz on the surface is only sparingly pyritized. This same quartz mass is reached by a tunnel 30 or 40 feet lower which runs for 60 feet in a south 80 degrees east direction. From a small raise and shaft a quantity of ore was taken and after hand-sorting was shipped.

Several other small shipments of hand-sorted ore have been made from these showings. One shipment of 20 tons yielded 3·76 ounces of gold and 1·8 ounces silver per ton. As this shipment carried 40 per cent insoluble material it is evident that by milling the ore, concentrates of a much higher grade could be obtained.

On the I.X.L. group three small similar veins occur. The highest one is at 576 feet. It is about 1 foot wide, is exposed for about 50 feet, and carries only a small amount of pyrite. It strikes north 85 degrees west and dips south 80 degrees. At elevation 480 feet, and a short distance to the west there is a vein 3½ feet wide exposed for only a few feet. This vein appears to strike about 60 degrees west and dips 85 degrees southwest. It carries considerable pyrite, especially in the altered rock fragments included in the vein quartz. At elevation 300 and still farther west, a vein 6 to 8 inches wide and well pyritized is exposed, striking north 70 degrees west, and dipping 85 degrees north. On a map of this property supplied by Mr. Wright, the owner, there is another vein marked and labelled "big quartz vein". This was not found by the writer. The veins on this property have not been sampled, but, being so closely situated to the Patterson-Gillett veins and having the same appearance and composition, it is likely that the pyrite in them is auriferous.

The gangue of these veins consists almost entirely of milky quartz, medium fine to very fine grained. In the quartz are frequently found small masses of sericite which were originally fragments of quartz diorite. Considerable sericite of a similar origin is also found along the margins of the quartz veins. A very small amount of chlorite and ankerite was also found. Pyrite is the only metallic mineral visible to the naked eye. Under the microscope, minute quantities of chalcopyrite are seen. No gold or silver minerals were visible in any of the specimens examined.

The similarity of these veins in mineral composition, metallic content, and geological associations to those of the Surf Inlet[1] mine, 90 miles to the south, is extremely close and most striking. As at Surf inlet, the gold is present in the pyrite in either submicroscopic particles or in solid solution. The chief difference between these and the Surf Inlet veins is one of size, the latter being much larger.

On the Eagle claim a tunnel follows for about 15 feet in a south 60 degrees east direction an indistinct silicified and mineralized zone which appears at this distance to be faulted off. A small crooked tunnel running approximately north 30 degrees east from this point appears to be a fruitless attempt to find a continuation of the mineralized zone. This deposit is in sheared greenstone, and not, as in the case of the others, in quartz diorite.

SILVER, GOLD, AND MOLYBDENUM

There are several deposits lying east of Anyox and chiefly in the vicinity of Alice arm, which are characterized by the following minerals: pyrite, arsenopyrite, pyrrhotite, chalcopyrite, galena, zinc blende, and tetrahedrite. Most of them also contain native silver, one contains much ruby silver, and two of them have molybdenite, one in sufficient amount to give it value as a molybdenite deposit.

The Golkish is situated on the shore of Deep bay 3 miles south of Anyox. It is owned and operated by the Golkish Mines, Limited, under the management of H. Heidman. The deposit is worked primarily as a supply of siliceous flux for the smelter at Anyox, but it also carries small amounts of gold and silver. In 1921, 9,203 tons of ore were shipped which yielded 3,518 ounces of silver and 943 ounces of gold.

The deposit[2] consists of a quartz vein averaging about 6 feet in width and lying in black argillite parallel to the bedding planes. The strike of the argillites and vein is north 5 degrees to 10 degrees east and the dip about 52 degrees to the east. Its close proximity to the shore and to the smelter, the extreme regularity of the vein, and the steep uniform dip make mining and transportation costs very low.

The vein consists almost entirely of milky-white quartz with a few small streaks of argillite and small bunches of metallic minerals irregularly scattered through it. The argillites consist of argillaceous and carbonaceous material, considerable quartz, biotite, and a small amount of talc. Pyrrhotite and pyrite are freely disseminated throughout the argillites and a small amount of magnetite is also present. The small bunches of metallic minerals in the vein consist of the following minerals named in the order of abundance: zinc blende, galena, pyrrhotite, pyrite, arsenopyrite, tetrahedrite, chalcopyrite, native silver, native gold, electrum, an

[1]Dolmage, V., Geol. Surv., Can., Sum. Rept., 1921, p. 30 A.
[2]Clothier, G.A., Ann. Repts., Minister of Mines, B.C., 1920 and 1921.

unknown mineral in microscopic quantities probably polybasite. All these minerals except the last are plentiful enough to be seen easily with a hand lens.

The pyrite and arsenopyrite were deposited before the other minerals. They are in places intimately intergrown so that the colour of one merges almost imperceptibly into that of the other. In other places the pyrite forms shells around the arsenopyrite grains. In the latter case the pyrite is of later origin, but very probably most of the two minerals were deposited at the same time. Of the other minerals, pyrrhotite and zinc blende seem to be the earlier. The galena, chalcopyrite, tetrahedrite, silver, gold, and electrum show no structure which indicates that any one was earlier than any other, and it seems probable that they were deposited during the same general period of metallization. The native silver is generally found in the galena as rounded blebs, and the gold occurs both in the galena and in the quartz.

The Molybdenum Mining and Reduction Company has developed to a small extent a molybdenite property on the north shore of Alice arm about 4 miles from the village of Alice Arm. A small power plant and concentrating mill are situated on the beach and are connected by an aerial tram 4,075 feet long with the mine which is situated at an elevation of 1,100 feet. This deposit is fully described by J. M. Turnbull[1] and briefly described by R. G. McConnell.[2] Though discovered several years ago it made its first and only shipment in 1916, when 383 tons of ore carrying 2 per cent molybdenite were shipped. Since then almost no work has been done on the property.

The deposit consists of a number of nearly parallel quartz veins occurring in a series of argillite, arkose, and argillaceous sandstones which form a part of the Kitsault River formation as defined by Hanson.[3] The argillites at this point strike in a northwest direction and dip vertically. At the northern end of the deposit there is a wide band of pink aplite striking northeast into which the vein merges. The argillites are cut by a great many lamprophyre dykes which strike more or less parallel to the veins. The dykes are for the most part younger than the veins. The eastern contact of the Coast Range batholith lies slightly less than a mile to the west of the deposit.

The veins are exposed in the steep gulch of a small stream for an horizontal distance of about 800 feet and from an elevation of 1,100 feet to 1,425 feet. In the creek at the lower workings three persistent quartz veins are exposed which contain numerous films of molybdenite lying parallel to the vein walls. A system of tunnels, with a total length of several hundred feet, exposes several bands of quartz carrying small amounts of molybdenite and one large, highly mineralized vein 10 feet wide. A short winze was sunk on this ore-body and a raise was driven 30 feet to the surface, both of which are in good ore. In the creek above these workings, the veins are exposed continuously for 400 feet or more, but no high-grade ore was found. In the upper workings almost no molybdenite

[1]Turnbull, J. M., Ann. Rept. Minister of Mines, B.C., 1916, pp. 66-68 K.
Turnbull, J. M. and Gwillim, J. C., Can. Mun. Res. Com. Final Report, pp. 128-131.
[2]McConnell, R. G., Geol. Surv., Can., Mem. 32, pp. 93.
[3]Hanson, G., Geol. Surv., Can., Sum. Rept., 1921, pp. 11 A.

is present, but its place is taken by considerable amounts of other metallic minerals carrying fair values in silver, zinc, and lead. The amount of commercial ore of this class so far exposed is, however, small.

The veins exhibit an interesting change in composition as they approach the above-mentioned body of aplite. In its lower parts the large vein consists entirely of quartz and molybdenite with a few veinlets of pyrite. Farther north it becomes increasingly feldspathic. As the body of aplite is approached the proportion of feldspar in the veins exceeds that of quartz and the vein becomes an aplite dyke. The feldspar consists chiefly of albite and albite-oligoclase with a lesser amount of orthoclase, all of which are intensely sericitized. Four hundred feet from the lowest workings the large vein consists of quartz, feldspar, and molybdenite, the last in thin parallel bands similar to those in the lower workings. At the uppermost workings very little molybdenite is present, but other sulphides are fairly abundant. These form veinlets of solid sulphides an inch or so in width, bordered on either side with quartz and calcite. The sulphides of these veinlets also have a banded arrangement, with the pyrite towards the centre and the arsenopyrite on the sides. The metallic minerals present named in their order of abundance are zinc blende, pyrite, arsenopyrite, galena, chalcopyrite, native silver, and, in places, small amounts of molybdenite.

The pyrite and arsenopyrite were deposited first, and probably at the same time, as both minerals are closely intergrown. Closely following these came zinc blende and some of the chalcopyrite. Then followed a period of intense crushing in which the zinc blende, pyrite, and arsenopyrite were fractured. These fractures were then filled with quartz, calcite, chalcopyrite, tetrahedrite, galena, and native silver. Some crushing also followed the deposition of the galena as its crystals are frequently much bent. The native silver occurs in the same veinlets with galena, chalcopyrite, tetrahedrite, and quartz, and also as rounded blebs in the galena and in the pyrite. These structures and the entire absence of any other minerals characteristic of secondary enrichment lead the writer to conclude that the native silver is of primary origin like the other metallic minerals with which it is associated.

Esperanza. The Esperanza[1] is a group of silver claims situated about half a mile northwest of Alice Arm, and west of Kitsault river. It is at an elevation of 520 feet and reached by a well-graded trail which branches off the Dolly Varden railway.

It is one of the oldest properties in the Alice Arm district and for a long time was known as the Roundy property, after Frank Roundy, the original owner. It has since changed hands several times and at the time of the writer's visit was owned by Mr. Elge who has since sold it.

As this property is described at length on page 46, a complete description of the geology and workings will not be repeated here. The deposit consists of quartz veins in argillites of the Kitsault River formation, and is similar in many respects to the Golkish deposit.

For purposes of comparison with the other deposits and because of its unusual interest the mineralogy of the deposit will be described here.

[1]The deposit is described by J. M. Turnbull in the Annual Report of the Minister of Mines of British Columbia for 1916. It is also referred to by G. A. Clothier in the subsequent Annual Reports for 1918 to 1921 inclusive.

The minerals present, named in order of abundance, are: zinc blende, galena, freibergite, ruby silver, pyrite, pyrrhotite, chalcopyrite, native silver, and polybasite. All except the native silver and polybasite can be seen in the hand specimens.

All the sulphides are later than the quartz except some of the pyrite. Pyrrhotite and arsenopyrite were not found replacing the pyrite, but all the other minerals do replace it. This indicates that the pyrite, arsenopyrite, and pyrrhotite are earlier than the other sulphides and were probably deposited during the same period. Zinc blende was observed as veinlets in the pyrite and is, therefore, in part at least later, but pyrrhotite and chalcopyrite were found in finely disseminated particles in the zinc blende, suggesting simultaneous deposition. The galena, freibergite, some of the chalcopyrite, ruby silver, and native silver, occur in veinlets cutting the zinc blende and are, therefore, in part later in origin. Most of the freibergite is, however, the same age as most of the galena. There are no indications that the polybasite, native silver, and ruby silver are later than the galena and freibergite with which they are associated. Smooth, rounded particles of galena, native silver, and ruby silver are found in the freibergite, and rounded areas of the native silver, ruby silver, freibergite, and polybasite are found in the galena. All the structures suggest that these minerals were deposited about the same time.

The similarity of this deposit to the Golkish, both in composition and geological associations, is very marked, the one main difference being that much ruby silver is found in the Esperanza and is absent from the Golkish.

Lynx Group. The Lynx group,[1] which is a re-stake of the Cariboo group, is a low-grade molybdenite deposit carrying values in silver, lead, and zinc. It is situated on the north fork of Lime creek about 4 miles by trail from the east side of Alice arm. The cabin is at an elevation of about 2,000 feet. The property is owned by Miles Donald and associates, of Alice Arm.

The deposit occurs in a very highly altered band of granodiorite which cuts the Kitsault River sediments. The granodiorite is well exposed in the canyon of the creek, and extends for several hundred yards both above and below the workings, which consist of a tunnel and several open-cuts. In its present highly altered state the granodiorite has a pale greenish colour, is medium coarse grained, and quite soft. It consists of feldspar almost completely sericitized, quartz, calcite, muscovite, chlorite, and disseminated sulphides. The muscovite frequently contains numerous fine needles of hornblende arranged in a reticulate pattern. The rock, probably, is related to the Coast Range batholith. Lying to the northeast about 2 miles and at a considerably higher elevation are some large flows of basalt several hundred feet thick. These are much younger than the granodiorite and it is hardly probable that the mineral deposits are related in any way to them.

The granodiorite contains disseminated molybdenite and numerous veinlets of quartz and calcite which also carry small amounts of molyb-

[1] Turnbull, J. M., Ann. Rept. of Minister of Mines, B.C., 1916, p. 66.
Clothier, G. A., Ann. Rept. of Minister of Mines, B.C., 1921, p. 47.

denite associated with zinc blende and other sulphides. The molybdenite occurs in the granodiorite, but in amounts too small to constitute an ore of molybdenum. There are, however, numerous small quartz and sulphide veinlets which carry silver values. Most of these veinlets are exceedingly small, but in a tunnel which the owners have driven recently, veins of sulphide several inches in width were discovered. These consist of quartz, calcite, and a large amount of zinc blende, with smaller amounts of galena, tetrahedrite, and chalcopyrite. Silver is reported to be present.

Roundy Creek. A silver deposit on Roundy creek, a few miles to the south, occurs on a contact between argillite and altered granodiorite exactly similar to that just described. This deposit belongs to Mr. Morley, of Alice Arm, and is situated at an elevation of 2,200 feet and only about 1½ miles from the beach. It is reached by a good trail 3½ miles in length starting from Silver City, which is on the east shore of Alice arm, less than a mile from its head. The deposit is described by G. A. Clothier.[1]

The rocks in the vicinity are very poorly exposed. Both argillites and highly altered granodiorite are exposed in the few scattered workings, but the direction of the contact could not be determined. The main eastern contact of the Coast Range batholith lies not very far to the southeast, and a large band of granodiorite is reported to lie just east of the deposit.

The veins cut both formations and though fairly numerous are small, none exceeding 8 inches in width. They contain a large proportion of metallic minerals. A grab sample taken by Clothier assayed $2 to the ton in gold and 142·5 ounces of silver. The gangue consists of quartz and calcite. The metallic minerals named in order of abundance are zinc blende, pyrrhotite, galena, arsenopyrite, pyrite, chalcopyrite, and native silver. The pyrrhotite, arsenopyrite, and pyrite were deposited first and are replaced by zinc blende, chalcopyrite, galena, and native silver. The silver occurs in small blebs in the galena.

All the minerals are cut by calcite veinlets which are quite numerous. In one specimen some very minute veinlets of pyrite or marcasite were observed cutting the pyrrhotite. These were visible only under high magnification.

SUGGESTIONS TO PROSPECTORS

The proximity of some of the mineral deposits to the contacts of the Coast Range batholith, such as, for example, the Lynx group, the Molybdenite group, and Morley's claim on Roundy creek, suggests that their metallic content originated in the batholith. This view is strengthened by the large number of deposits in other parts of the Coast district, which are similarly situated with reference to the contacts of the batholith, and also by the absence of other igneous rocks in sufficient amounts to be possible sources of these rich accumulations of metals. It is now the belief of all those who have worked in this region that the mineral deposits were formed by solutions emanating from the magma of the batholith.

In pointing out to prospectors the importance of working along the

[1]Ann. Rept. of Minister of Mines, B.C., 1921, p. 48 G.

contacts of the batholith, attention should also be drawn to the fact that many of the deposits are 5 or more miles from any known contact and either inside or outside the batholith. The two large low-grade copper deposits of the British Columbia coast, the Britannia and the Hidden Creek, are situated in shear zones in large inclusions in the batholith and the Hidden Creek deposit is 4 miles from the nearest exposed contact of the batholith. The deposits at Maple bay are very similar and are similarly situated. There are, however, some copper deposits at the head of Kitsault river which lie east of the batholith. Within the batholith itself, and in no way related to other rocks, are found the pyrite-gold deposits such as Surf Inlet and Surf Point, and the former, which is an exceedingly rich deposit, is many miles from any known contact. Outside the batholith are found the rich silver-gold deposits such as the Premier and the rich silver deposits, such as the Dolly Varden and Esperanza. The two first are in volcanic rocks and are much larger and richer than the last type which is found in the argillaceous sediments.

RECONNAISSANCE BETWEEN KITSAULT RIVER AND SKEENA RIVER, B.C.

By George Hanson

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1922 the writer carried on a geological reconnaissance in the area between Kitsault river and Skeena river. The area reconnoitred embraces the Alice Arm district and extends south-southeast, as a narrow belt which crosses Nass river at Aiyansh. From this point, it lies in the drainage basins of Tseax and Kitsumgallum rivers and eventually reaches Skeena river at Terrace. The possibility of the discovery of petroleum in commercial quantities in Kitsumgallum valley was to be investigated, and a general idea of the economic geology of the whole area was to be obtained. Although the contemplated reconnaissance was not finished, some information was obtained and is embodied in the present report. The sketch maps (Figures 3 and 4) accompanying this report are approximately correct lithologically, but of doubtful accuracy with respect to the age of the formations.

Previous geological surveys in the area included detailed work in upper Kitsault valley, and a reconnaissance of Alice arm, Nass river, and Skeena river[1], and brief field examinations described in the Annual Reports of the Minister of Mines, British Columbia.

[1]Dawson, G. M., "Report of an Exploration from Port Simpson on the Pacific Coast to Edmonton on the Saskatchewan, Embracing a Portion of the Northern Part of British Columbia and the Peace River Country", Geol. Surv., Can., Rept. of Prog., pp. 1 B-177 B, 1879-1880.

McEvoy, James, Geol. Surv., Can., Ann. Rept., 1892-1893, pp. 13 A-16 A.

McConnell, R. G., "Geological Section along the Grand Trunk Pacific Railway from Prince Rupert to Aldermere, B.C."

Geol. Surv., Can., Sum. Rept., 1912, pp. 55-62.

McConnell, R. G., "Portions of Portland Canal and Skeena Mining Divisions, Skeena District, B.C.", Geol. Surv., Can., Mem. 32, 1914.

Hanson, Geo., "Upper Kitsault Valley, British Columbia", Geol. Surv., Can., Sum. Rept., 1921, pt. A, pp. 7-21.

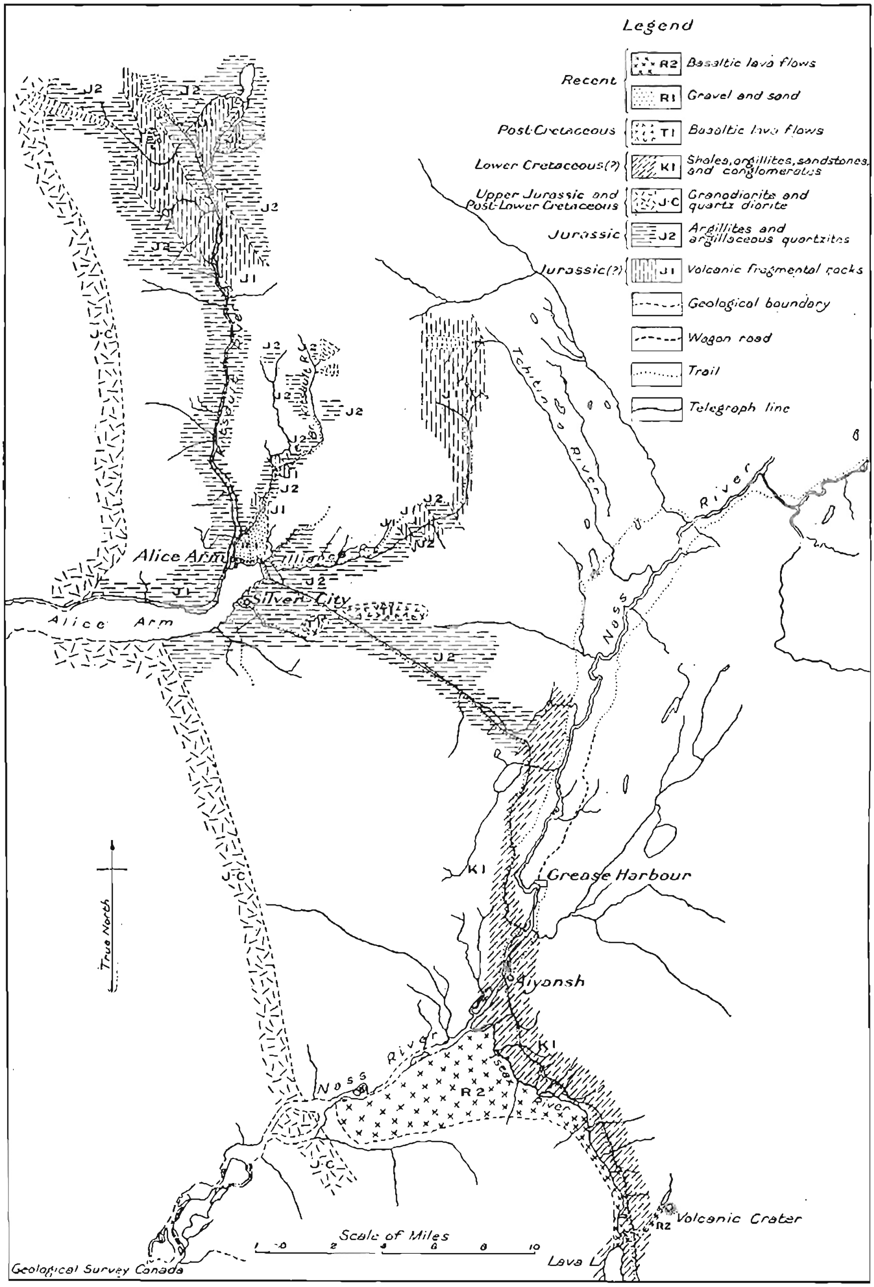

FIGURE 3. Geology between upper Kitsault valley and Lava lake, Cassiar district, B.C.

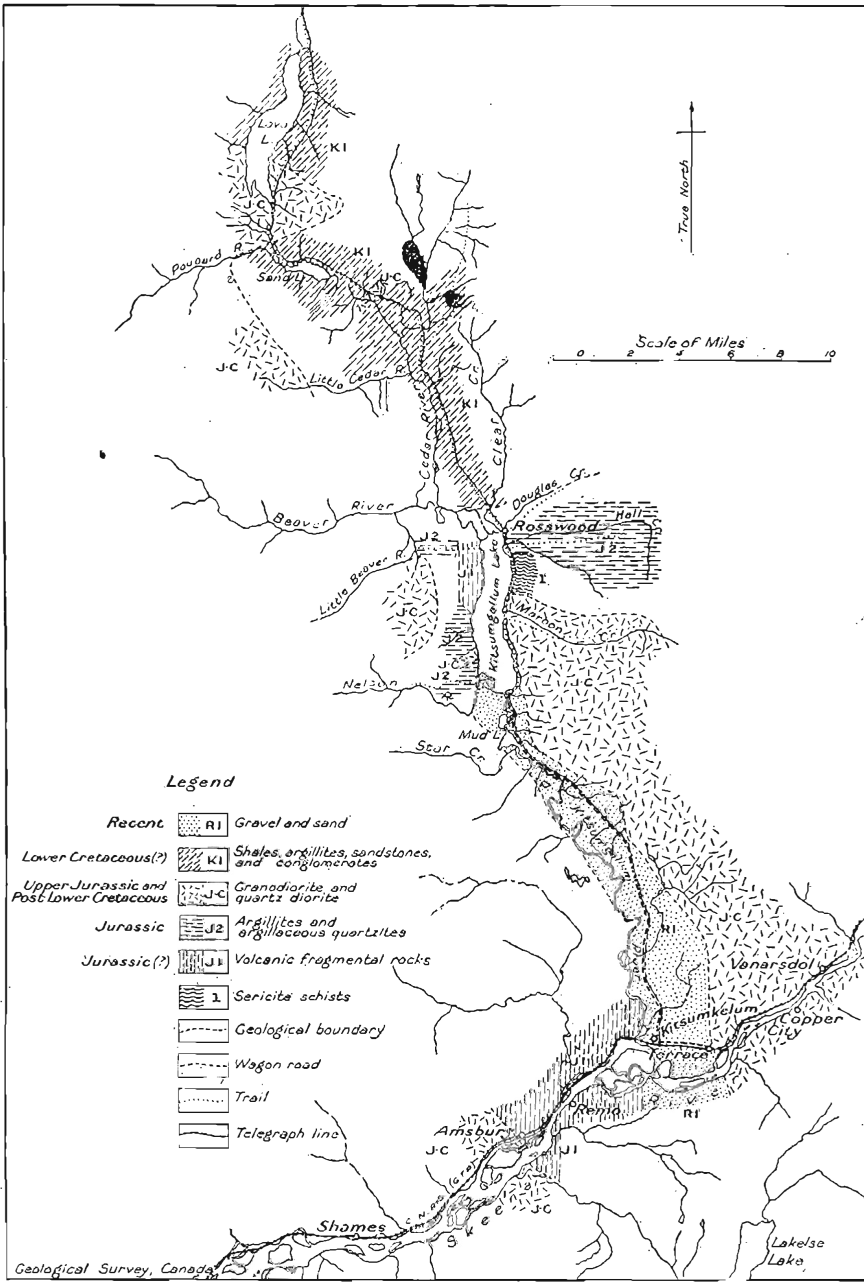

FIGURE 4. Geology between Lava lake and Skeena river, Coast district, B.C.

R. W. Goranson rendered very able assistance in the field. The writer wishes to express his indebtedness also to the various agents in charge of the cabins along the Government telegraph line, for their many courtesies; to the prospectors, and to G. F. Monckton and others, for helpful information.

GENERAL CHARACTER OF THE AREA

LOCATION AND MEANS OF ACCESS

Alice Arm is a small town situated at the head of Alice arm, a branch of Observatory inlet, and is a regular port of call for steamers of the Union Steamship Company of British Columbia; a boat service is maintained as well three times a week between Alice Arm and Anyox. The more remote parts of the arm can be reached by trails along the larger streams.

Aiyansh, 35 miles up Nass river from Mill Bay—which is on the estuary of Nass river—is a port of call for the Union Steamship Company. A boat service is maintained twice a month between Aiyansh and Mill Bay. A foot trail follows the telegraph line through Alice Arm and Aiyansh.

Terrace is a small town on the Canadian National railway, 94 miles inland from Prince Rupert. A trail suitable for packhorses follows the telegraph line between Aiyansh and Terrace.

RELIEF AND DRAINAGE

The whole area lies along the eastern border of the Pacific system of the Coast mountains, and although the topography in general resembles that of the Pacific system, it has also several points in common with that of the Interior system. The arm north of Alice Arm is characterized by jagged peaks somewhat less rugged than those typical of the region farther west, and seldom rising more than 6,000 feet[1]. The main valleys have steep sides, and the streams occupying these valleys have steep grades. The tributaries are in their infancy and are simply small streams tumbling down the mountain sides. Glaciers are present at the heads of the main streams and most of the tributary creeks.

The region lying between Alice arm and Nass river is a plateau. The surface rises fairly steeply from Alice arm and from Nass river to about 2,200 feet, and the intervening area ranges in elevation from 2,100 to 2,500 feet. The origin of this flat upland surface appears to be, in the main, the result of Tertiary erosion. The erosion surface is covered locally by horizontal flows of basaltic lava, and this lava may have aided in the formation of the plateau by filling up hollows.

The Nass-Skeena district differs in many ways from the Alice Arm district. The Tseax-Kitsumgallum valley is bordered on the west by the mountains of the Pacific system. From Nass river to Lava lake the mountains to the east were not seen. From Lava lake to the foot of Kitsumgallum lake some of the mountains to the east are higher than 7,000 feet. The rocks in this part of the district have a westerly strike, and the region is drained by tributary streams flowing west to Kitsumgallum river and east to Skeena river. The mountains with crumbly knife-edge summits lie between the

[1]Elevations referred to mean sea-level.

tributary streams and consequently have a westerly trend. Above 5,200 feet the mountain slopes are steep, but between 4,000 and 5,200 feet the surfaces are smooth and rounded, and the slope is gentle. The mountain slopes higher than 4,000 feet apparently represent a Tertiary erosion surface that has been modified by continental glaciation. It is interesting to note that the present timber-line practically coincides with the lower edge of the gently sloping surface.

Below the 4,000-foot contour the mountain slopes are the steep sides of stream valleys. The tributary valleys were formed during Tertiary time by water erosion and were, perhaps, deepened by alpine glaciers during the Pleistocene. The most noticeable difference between the drainage in this part of the area and in the Pacific system proper is to be seen in the tributary valleys. In the Pacific system, these valleys are as a rule small, and the grade is approximately the slope of the mountain side; but in the region under discussion the tributary streams have large valleys 3,000 feet deep, where the grade corresponds to that of the main streams of the Pacific system. In fact some of the tributary streams of Kitsumgallum river, notably Beaver river, are navigable for over 12 miles from their mouths for canoes and motor boats. In the lower reaches of the larger tributaries the streams meander through flat-bottomed valleys.

The Tseax-Kitsumgallum valley is a large, broad valley, 1 to 4 miles wide. The bottom of this great depression is approximately 550 feet at the divide between Tseax and Kitsumgallum rivers. The valley joins Nass valley but crosses Skeena valley and continues to Kitimat arm. McConnell believed that it represented an old valley of erosion possibly robbed by the Skeena[1]. The writer did not examine the valley through its whole extent, but is of opinion that formerly the water of upper Nass river flowed through this valley, was joined by the water of the upper Skeena at Terrace, and reached the sea at Kitimat arm. Nass and Skeena rivers, below their junctions with this main valley, may have eroded headward sufficiently to rob the valley of its waters before the Pleistocene; in any case, when the glaciers disappeared the robbery was accomplished.

Alpine glaciers moved along this valley as well as westward to the coast along Nass and Skeena valleys. Glacial erosion was not very extensive along Tseax-Kitsumgallum valley, but glacial grooves and truncated mountain spurs are present and a scouring action is exemplified at Kitsumgallum lake, which fills a rock-scoured basin. Glaciers are absent from this part of the area except on the upper slopes of the highest mountains.

Several lakes lie in Tseax-Kitsumgallum valley. Lava lake, 7 miles long, was formed a few hundred years ago through the agency of a lava flow that dammed Tseax river. Sand lake is a small lake which has been formed by damming of Tseax river by detritus brought into the valley by Poupard river. Kitsumgallum lake, 6½ miles long, fills a basin scoured out by glaciers. It was formerly much larger, but the upper end of the lake has been filled up with silt carried by streams entering the head of the lake. The two small lakes below Kitsumgallum lake have been separated from the main lake by detritus deposited by streams entering the valley from the east and west.

[1]Geol. Surv., Can., Sum. Rept., 1912, p. 55.

GENERAL GEOLOGY

The rocks in the area are in the main of Jurassic age. They have been severely folded in most places and intruded by granitic rocks of the Coast Range batholith, which now forms the western border of the area. The region to the north, east, and south, immediately adjoining the area, has not been explored geologically. The Jurassic formations are overlain by Cretaceous sedimentary rocks which have been intruded by granitic dykes and stocks. Unconformably above the Cretaceous lie isolated patches of Tertiary sedimentary rocks and lava flows. Pleistocene glacial debris is found locally; recent gravels and clays are found along the main valleys; and a recent lava flow perhaps 300 years old is present in the central part of the area.

The rock formations in the area have been classified tentatively as follows:

Table of Formations

Time	Formation	Lithology
Recent	Lava flows, stream deposits, marine clays	Basaltic scoria and lava, stratified gravel, sand, and clay
Pleistocene	Glacial deposits	Till, boulders
	Unconformity	
Tertiary	Sedimentary rocks, lava flows and dyke rocks	Poorly consolidated sandstones and shales; basaltic lava flows and dykes
	Unconformity	
Post-Lower Cretaceous	Stocks, dykes	Granitic intrusive rocks
Lower Cretaceous (?)	Skeena formation(?)	Shaly argillites (coal seams), sandstones, and conglomerate
Upper Jurassic	Coast Range batholith	Granodiorite, quartz diorite
Jurassic	Sedimentary rocks Volcanic rocks	Argillites, argillaceous quartzites Volcanic fragmental rocks and porphyrites
Pre-Jurassic	Schistose rocks	Sericite schists

PRE-JURASSIC

The sericite schists in the table on page 40 are believed to represent the oldest formation in the area. They are exposed on Kitsumgallum lake and extend eastward in a band one mile wide. The formation is important in that it contains mineral deposits. It is made up chiefly by the minerals sericite, quartz, epidote, and garnet, and has originated through the regional and contact metamorphism of a sedimentary rock. Shearing has obliterated most traces of former bedding planes, but it appears that the formation, though severely contorted, dips in a northerly direction and underlies the Jurassic sedimentary rocks farther north.

JURASSIC

Volcanic rocks of probable Jurassic age are exposed on the Kitsault, northeast fork of Kitsault, and Illiance rivers. They consist chiefly of massive purple and green tuffs and breccias. They are believed to correspond in age to McConnell's Bear River formation in Bear and Salmon River districts and to parts of the Kitsalas and Hazelton formations along Skeena river. In the upper Kitsault valley these rocks are massive and heavy bedded, and structures are difficult to ascertain, but on Illiance river they consist in the main of stratified water-deposited tuffaceous material containing many water-worn pebbles. South of Alice Arm, Jurassic volcanic rocks are not found until Kitsumgallum lake is reached, where the rock is exposed on the west shore of the lake. Here the formation is again massive and hard and devoid of apparent structure.

The Kitsalas formation outcrops along the Canadian National railway between Amsbury and Kitsumgallum river. The age of the formation has not been ascertained, but McConnell has placed it tentatively in the Triassic.[1] The formation is a heavy-bedded, structureless volcanic rock purple and green in colour. It probably extends northward along the west side of Kitsumgallum river. The volcanic rocks on Kitsumgallum lake correspond lithologically, and probably belong to the Kitsalas. A narrow band of the rock extends eastward on the east side of Kitsumgallum lake, apparently overlying the sericite schists and underlying the sedimentary rocks exposed at the north end of the lake. In Alice Arm district the green members of the series are important in that they contain numerous mineral deposits. In the Kitsumgallum section, however, the formation consists chiefly of the purple members, and apparently contains no mineral deposits.

The Jurassic sedimentary rocks are more widespread than the volcanic rocks. In the Alice Arm district they are mainly argillites. On Kitsault and Illiance rivers they are argillites; on the northeast fork of Kitsault river, quartzites are conspicuous and in the region southeast of Alice Arm coarse-grained sandstones and quartzites are common. On Kitsumgallum lake the rocks are quartzites and argillaceous quartzites. The formation extends eastward from the lake and apparently continues to Skeena river, to become there the Hazelton formation. Leach says in regard to the Hazelton group, "There seems to have been from south to

[1]Geol. Surv., Can., Sum. Rept., 1912, p. 59.

north a gradual transition from rocks of purely volcanic origin (chiefly porphyrites) to aqueous deposits such as those on Sixmile and Ninemile mountains near Hazelton."[1] These Jurassic rocks do not outcrop in the valley between Nass river and Kitsumgallum lake, but it seems likely that the series is continuous and that the argillites of Alice Arm district and the quartzites of Kitsumgallum lake are of the same age. Numerous mineral deposits are found in the rocks of the Hazelton group, particularly in the harder formations.

LOWER CRETACEOUS

Rocks believed to be of Lower Cretaceous age are exposed along Nass river and in the valley between Nass river and Kitsumgallum lake. From Kitsumgallum lake northward for 6 miles the rocks are coarse sandstones and fine-grained conglomerates lying with gentle northerly dips. Between this area of sandstone and Nass river the rocks are shales and shaly argillites containing a few coal seams.

The conglomerates and sandstones are not very hard and the rock breaks around pebbles and sand grains. The conglomerate contains pebbles of chert, quartz, and argillaceous quartzite, cemented by calcite. A thin section of the sandstone showed the rock to be even grained, although the grains were irregular in shape. The grains consist of quartz, chert, and feldspar, and the cement is calcite. Twisted and bent flakes of biotite and muscovite are present. Alteration products are sericite and chlorite.

The shales and shaly argillites to the north appear to overlie the sandstones and conglomerates, but the contact was not seen. The shales are fine-grained black rocks sufficiently fissile to cleave readily in the direction of the bedding planes. No marine fossils were found in the formation, but plant remains associated with coal beds were seen in a few places. The fossils have not yet been identified. It is plain that the formation is not as a rule closely folded, but the presence of numerous faults and dykes indicates some complexity of structure which could not be determined owing to the covering of drift and timber. The dip of the rocks is vertical in a few places, but in general it is less than 45 degrees.

INTRUSIVE ROCKS

Granodiorite of the Coast Range batholith outcrops along the western side of the area. From Alice Arm to the northern edge of the mapped area the eastern contact of the granodiorite has a northerly trend. At Alice Arm the contact swings eastward and between Alice Arm and Nass river the trend is south-southeast. Throughout this extent the contact is regular, no outlying stocks are found, and granitic dykes are seldom if ever seen.

From Nass river to Skeena river the contact has in general a south-southeast trend, but is very irregular; large spurs project eastward and northward from the main contact; outlying granite stocks occur; and granite dykes are fairly common. North of Nass river small lamprophyre dykes are very plentiful, whereas in the district between Nass river and Skeena river, although such dykes are present, they are of rare occurrence.

[1]Geol. Surv., Can., Sum. Rept., 1909, p. 63.

The granodiorite in the Alice Arm district has hitherto been considered as of Upper Jurassic age. Between Nass river and Skeena river, however, outlying stocks, associated granitic dykes, and what appear to be spurs from the main batholith, are intrusive into sedimentary rocks believed to be of Lower Cretaceous age. No fossil evidence is available to prove the age of the supposed Lower Cretaceous sedimentary rocks, but the rocks contain coal seams, and resemble those of the Skeena formation (Lower Cretaceous) to the north and east.

Thin sections from the main body of granodiorite and from the associated spurs show that the rock is very uniform from one end of the area to the other. It ranges in composition from granodiorite to quartz diorite. It contains quartz, varying amounts of orthoclase, plagioclase, ranging in composition from oligoclase to andesine, biotite, hornblende, apatite, magnetite, and varying amounts of titanite. Products of alteration are sericite, calcite, chlorite, and epidote.

The granitic dykes are as a rule pink. A thin section of one of them shows that the rock consists chiefly of plagioclase and hornblende, but quartz is rare. The alteration products, which are rather plentiful, are chlorite, sericite, and calcite. The thin section contains a good deal of prehnite in interstitial spaces between primary minerals.

TERTIARY

Lava flows covering an area of several square miles are exposed a few miles southeast of Alice Arm. The lava is in horizontal beds 10 to 50 feet thick, making a total thickness of several hundred feet, and it overlies the older sedimentary rocks unconformably. Thin sections show that the rock contains phenocrysts of enstatite and labradorite in a finer-grained groundmass consisting of plagioclase, augite, enstatite, olivine, and magnetite. Amygdules of calcite occur. The plagioclase phenocrysts are approximately of the composition $Ab_{35}\,An_{65}$, but the plagioclase of the groundmass is somewhat more acid and occurs in long slender laths. Augite and olivine are rare. The rock in its more basic facies is a basalt, but in general it is more properly named enstatite andesite. The lava is quite solid and massive and breaks into rude hexagonal pillars. Near the lava flows are several basaltic dykes, and it is probable that the lava flowed out onto the surface from these dyke feeders. The age of the lava has not been determined, but is probably Pleistocene or Tertiary.

On the north bank of a creek bed northeast of Lava lake, poorly consolidated sediments are underlain by lava flows. The creek bank at this point is a cliff 400 feet high and this is the only place where the rocks were examined. The area covered by the rocks is probably very small. The lava flows are vesicular in places and approximately 100 feet thick. A thin section of the lava shows it to be an enstatite andesite; the plagioclase laths seen in the section are of the composition of andesine. A basic dyke cuts the lava but does not penetrate the overlying sediments. The sediments are friable sandstones, shaly sandstones, and conglomerates. The pebbles and boulders in the conglomerate consist of vesicular lava, granite, slate, argillite, and quartz. The formation dips northward at an angle of 30 degrees. No fossils were found here, but from the general appearance of freshness and imperfect consolidation of the rocks it is concluded that they are of Tertiary age.

PLEISTOCENE AND RECENT

Although scattered glacial boulders are found over the whole area, boulder clay is not common. Local areas of boulder clay 50 feet thick were noted on Kitsault river, and its northeast fork, Cedar river, and Douglas creek.

Sediments and hard rocks of Recent age are plentiful. Terraces are present along the Nass, Tseax-Kitsumgallum, and Skeena valleys, and at the head of Alice arm. The terraces along the valleys do not extend more than about 200 feet above the present streams and represent gravels deposited along the stream beds and left as terraces by deepening of the channels. Some of the gravels at Terrace were deposited as delta deposits in a larger body of water such as a larger stream, an arm of the sea, or a lake. At Alice Arm a flat extends inland 2 miles from the head of the arm. It rises 50 feet in this distance and at its inner edge east of the northeast fork of Kitsault river is surmounted by three terraces, the highest of which is 275 feet. The flat was formed by sediment carried by streams entering the arm, but whether the terraces represent sea beaches, or whether they are river terraces formed along the northeast fork of Kitsault river is not known.

Marine clays of Recent age occur along Bear river at an altitude of 400 feet. Similar clays, but devoid of fossils, occur at the same elevation on Salmon river, Kitsault river, and its northeast fork. Clay beds are present in the gravel terraces at Terrace, but it is not likely that these are marine. The clay in the terraces is in thin beds layered with gravel, and dips gently downstream. On the terrace north of the town of Terrace there are at least two of these clay beds; the upper one is about 3 feet thick and lies about 50 feet below the top of the terrace; the main bed is at the base of the terrace. The top of each clay bed is a water horizon. As the clay is impervious, groundwater flows through the pervious gravels along the top of the clay bed.

The youngest solid rocks in the area occur along the valley between Lava lake and Nass river. This is a lava flow 20 miles long covering an area of 20 to 25 square miles, and is the youngest lava flow so far recognized in British Columbia. The Indians on Nass river believe that the flow came down about 200 years ago, but it is probable that the lava is not less than 300 years old. The stream poured out of a crater situated northeast of Lava lake and on the south side of a creek flowing westward to Tseax river. The lava dammed the creek and thus formed a small lake in the valley. The molten rock then flowed down the creek bed, reached Tseax river and dammed that stream, forming Lava lake. The flow from this point followed the Tseax valley, becoming several miles wide on reaching Nass river. Had the flow been restricted to a narrow channel on its way to the Nass, doubtless it would have dammed that river, but the volume of lava was then spent and Nass river forms the northern boundary of the flow.

There is no evidence to show that there was more than one eruption of lava, but after the lava had escaped from the crater, scoria was erupted, building up a small cone around the main crater. After a period of quiescence sufficient to permit the formation of a level floor in the crater, there was a further explosion resulting in a smaller scoria cone and crater within the larger earlier crater.

The lava was not examined along the Nass nor on the lower part of Tseax river, but wherever it was seen it occurs, not in a flow with an even surface, but as lava fragments. Occasionally there are areas 50 feet long, which represent part of the original surface of the flow and which are fairly level, but almost all the rock is in fragments 15 feet or less in diameter. The lava flowed along creek and river valleys, and it may be that explosions from superheated steam had a good deal to do with the breaking up of the solidifying lava. In places the flow is well crystallized, but in general it contains a good deal of glass. The rock is vesicular and dark brown to black. Thin sections show that it is an enstatite andesite. The main part of the flow is devoid of vegetation, but trees have grown up along its margin and on the scoria cones.

STRUCTURE

The structure over the central part of the area seems to be a large syncline striking in an easterly direction and plunging to the east. From Rosswood northward to a few miles north of Lava lake, the prevailing dip of the rocks is northward at angles of 10 degrees to 45 degrees. At Aiyansh the dip is steep in a southerly direction, and along Nass river the rocks are commonly vertical or dip steeply either to the north or south. It would appear, however, that easterly trending structures are local and have been aided in their development by spurs projecting eastward from the Coast Range batholith. The syncline is apparently a local downwarp or cross-fold in formations having a northwesterly strike and northeasterly dip.

ECONOMIC GEOLOGY

The area under discussion lies along the eastern border of the Coast Range batholith. It is 95 miles long, and, naturally, contains several types of mineral deposits. Most of those in upper Kitsault valley have been described recently,[1] and will not be again described here. The mineral deposits could be divided into groups on a basis of form or mineral content, but it is more convenient here to describe the few that were examined according to the locality in which they occur. All of them were formed by ascending mineral-bearing solutions emanating from some underlying source—probably the Coast Range batholith and associated outlying stocks. In a few instances the primary mineral deposits thus formed have been modified by superficial agencies. In addition to metallic mineral deposits, coal seams occur in the area.

ALICE ARM DISTRICT

This district has undoubted economic possibilities. The mining of high-grade silver ore appeals to the prospector, because ore can be mined with practically no outlay of capital. A prospector cannot, however,

[1] Hanson, George, "Upper Kitsault Valley, B.C.", Geol. Surv., Can., Sum. Rept., 1921, pp. 7–21.

afford to build wagon roads, or even pack trails, for the purpose of taking out his ore; consequently, wagon roads through the more promising mining districts would be of very great aid.

Mining might also be carried out on a moderately large scale, and lower grades might be used, if the ore were concentrated instead of being shipped direct. This might be done by a company controlling several properties within easy reach of the mill. There are a few properties with good surface showings and others where hopes of discovering good ore seem well founded. A few of these properties may develop into mines.

Excepting the properties in the upper Kitsault valley described last year, only two properties in the Alice Arm district have shipped ore. These are the Esperanza and the La Rose. The La Rose has made two shipments amounting to 33 tons, carrying 0·12 ounces gold and 235 ounces of silver per ton. The Esperanza has made small shipments for a number of years, the ore containing up to 0·2 ounces gold and about 200 ounces silver per ton.

Homeguard. This property is located 14 miles from Alice Arm on the east side of Kitsault river. The ore consists of large boulders up to 30 feet in diameter that lie in mixed talus and morainal matter. They contain disseminated chalcopyrite, pyrite, and galena. The good grade of ore in the boulders has instigated search for the source. The boulders probably came from a belt of rocks known locally as the "copper belt". The western contact of this belt crosses Kitsault river between Homestead and Miner creeks, and if the direction of contact were projected for a mile it would cross the Homeguard; consequently, it is expected that the ore zone will be found very close to the boulders. Little is known of the structure or the persistence of the ore zones in the copper belt, and, therefore, very careful study of any surface exposures should precede underground exploration.

La Rose. The La Rose mine is located on the west side of Kitsault river about 6 miles from Alice Arm. The mineral deposit is a narrow quartz vein in a country rock of argillite, and contains rich silver ore.

Esperanza. This property was one of the first to be staked in the area and is located one mile from Alice Arm. The vein is narrow, contains rich silver minerals in a quartz gangue, and lies in a country rock of argillite.

R. W. Goranson, who assisted the writer in the field, has given the following description of the mine:

Esperanza mine is situated on the steep eastern slope of Kitsault River valley, about one mile north of the town of Alice Arm. The main adit of the mine is at an elevation of 460 feet. This property is now operated by a syndicate of Anyox men.

The country rock consists of black argillite which strikes north 25 degrees west, and dips to the west at 45 degrees. Three lamprophyre dykes, the largest 15 feet wide, are later than a major period of faulting, but are cut by a still later series of faults.

An undulating fault which strikes about 5 degrees east of north and dips east at 45 degrees, has acted as the channel and place of deposition for the ascending ore solutions. The vein varies from 3 feet to a mere streak in width, 8 inches being a good average width. It has been faulted by later normal faults which strike mostly northwest and dip to the southwest. Since the vein dips with the hillside, sufficient depth should be ascertained before doing any extensive mining, because movement along these later faults could very easily throw the lower block out enough to cause it to be removed with the eroded part of the mountain. This would mean the loss of the lower part of the rich silver zone down to the valley bottom. The southern extension of this vein, still undeveloped, will make good prospecting ground.

The main fault, being a zone of weakness, has been subjected since the deposition of the ore to minor movements which have made it a good watercourse. Minor fissures, which include gash, bedded, and minor fault veins, almost undisturbed since the formation of the mineral veins, are not rich in silver minerals.

The vein contains quartz, pyrite, arsenopyrite, and a little siderite 200 feet above the main adit. The economically important minerals are argentite, pyrargyrite, polybasite, a little native silver, galena, and sphalerite. In places the vein material is roughly banded, parallel to the walls. The best ore is in the narrow part of the vein where gouge is plentiful.

The paragenesis appears to be quartz, pyrite, sphalerite, galena, and the silver minerals. The ruby silver, pyrargyrite, is the most plentiful of the valuable minerals.

Carbonaceous matter, present as graphite in the gouge, may have played an important rôle in the precipitation of these silver sulphides.

PROPERTIES ON NORTHEAST FORK OF KITSAULT AND ILLIANCE RIVERS

On the northeast fork of Kitsault river the San Diego and Red Bluff properties lie in a fine-grained grey rock apparently of sedimentary origin, but similar in many ways to the "copper belt" rocks farther north. The properties farther upstream lie in sedimentary rocks that are chiefly argillites of the Jurassic sedimentary series.

On upper Illiance river the tuffaceous sediments and tuffs have a north to north-northwest strike. On the east and also on the west side of the river the rocks dip gently to the west, but in a zone which is followed by the stream they dip steeply to the west. There appears to be a sharp flexure in the formation, the west side having moved downward in relation to the east side. Along the flexure the rocks are sheared and along this sheared zone ore solutions have ascended and formed a number of mineral deposits. The Bellevue, United Metals, Silver Bell, and half a dozen other mineral properties, have been staked along this zone. The mineral zone is strongly defined and may contain rich and perhaps extensive shoots of ore. The mineralization is of the silver-lead type. The Monarch is one of the few properties which have been staked on Illiance river outside this main zone. It is located at the headwaters of the river in a country rock of tuff. The mineral deposit is a quartz vein containing silver-bearing grey copper. The vein strikes north and dips west. Two blocks of the vein offset by a cross-fault are exposed, and to trace the vein and to obtain a better idea where it will be encountered at depth, surface work should be done.

A number of mineral claims have been staked in the area between the northeast fork of Kitsault and Illiance rivers, but this locality was not visited.

PROPERTIES ON LIME AND ROUNDY CREEKS

The Cariboo is one of the groups of mineral claims in the region southeast of Alice Arm. The country rock is argillite and sandstone intruded by numerous sills and dykes of granitic material. The whole is extensively weathered. Molybdenite is present over a zone several hundred feet wide, but no commercial body has been exposed. Assays show gold and silver values, and these metals are probably contained in pyrite, galena, and other minerals, disseminated through the rocks and quartz veins. It is interesting to note that immediately northeast of the property, lavas cover the older rocks. If the lava flows are of pre-Pleistocene age it is likely that products of Tertiary weathering such as secondary mineral deposits will not have been scoured off by Pleistocene glaciers in the area immediately surrounding the lava flows.

NASS-SKEENA DISTRICT

A different type of mineral deposit is found in this district. Some of the properties are of the silver-lead type, but the majority are gold deposits. Coal also is found in this part of the area. Only a few of the mineral claims were visited and none of those west of Tseax-Kitsumgallum valley was seen. The metallic mineral deposits here are chiefly narrow quartz veins where mining in a small way may be possible. There may be, also, large low-grade mineral deposits, but unfortunately, development has not proved the existence of any of this type. The future of coal mining in the district remains in doubt and no workable tonnage has been proved. Drilling for oil will evidently not prove to be a successful venture.

Silver Dollar. This property, formerly known as the Iona, is located in the main valley 12 miles north of Rosswood. The property is covered with drift that has not been cleared sufficiently to expose the trend and size of the ore-body, but from present developments it would appear the good ore is present in small shoots. One of the open-cuts exposes grey copper ore rich in silver. The country rock is argillite.

Relief. Located on Egan creek, a tributary of Cedar river, 8 miles northeast of Cedar River crossing. Two other claims, the Blue Grouse and Hunter, adjoin the Relief. A good deal of surface work has been done on the Relief in tracing a quartz vein for a distance of 1,000 feet. The country rock is argillite intruded by granitic dykes. The vein outcrops on the left bank of Egan creek and dips under the creek. In some places the vein is 8 feet wide, but in most places the hanging-wall is under water, and the width could not be determined. The gangue minerals consist of quartz and calcite, and the metallic minerals, which are confined within a width of 3 feet along the foot-wall, are chalcopyrite and galena.

Sunlight. Located at an altitude of 3,800 feet, 4 miles east of Rosswood on the north side of Hall creek. The country rock is argillaceous quartzite intruded by granitic dykes. The vein varies in width from 2 to 12 feet, but in several places it is split up into numerous closely-spaced gash veins over a greater width. The mineralization consists of pyrite, galena, and zinc blende, in a gangue of quartz, and the metal sought for is gold.

Bear Group. Located south of Hall creek, 5 miles from Kitsumgallum lake. A narrow bed vein of quartz lies in country rock of argillaceous quartzite and contains good gold ore. The strike of the vein is east-northeast and the dip is to the south. The vein is honeycombed on the surface through the oxidation of sulphides.

Treadwell Group. Located on the east shore of Kitsumgallum lake. The country rock is a quartz-sericite schist. The ore zone strikes east and dips north, paralleling the shearing planes of the enclosing rock. The lateral extent of the ore-body is not known and it is, therefore, impossible to obtain a clear idea of the merits of the property. The metals sought for are copper and gold, and the ore is rich enough to warrant careful exploration of the strike, length, and width of the zone.

PLACER GOLD

Douglas creek was worked in the early years of placer mining in British Columbia, and the creek still yields wages to a few men. The quantity of gold now taken out is not great, but gravel benches on the lower reaches of the creek and on the shores of Kitsumgallum lake near the mouth of the creek, might be tested to ascertain whether the gravels could be worked profitably on a large scale.

COAL

Coal seams on the banks of Cedar river were described in 1914[1]. The seams outcrop on the steep banks of the river, but are in many cases covered by small landslides. Some of the coaly material was obtained, but only from the weathered parts of the seams, and this material was chiefly graphite. Similar material was obtained from poorly exposed seams on Little Cedar river. If the material obtained can be used as evidence at all it tends to show that any coal found will be anthracite and will probably contain a good deal of graphite and schungite.

PETROLEUM

One of the principal purposes of the writer's visit to the Kitsumgallum valley was to inquire into the possibility of finding petroleum in commercial quantities. No evidence was found to indicate the presence or former presence of petroleum in the valley. The sericite schists, Jurassic volcanic and sedimentary rocks, and the granitic rocks of the Coast Range batholith, need not be considered as probable containers of commercial petroleum. The shaly argillites of probable Cretaceous age remain. These rocks have been intruded by dykes and small stocks, and in some places are faulted and steeply folded. Marine fossils are scarce if they are present at all. No seepages and no residues from the former escape of oil were found. The absence of any evidence favouring the presence of petroleum, and the unfavourable geological evidence combine to discourage search for petroleum in the valley.

[1]Brewer, W. M., "Skeena Mining Division", Ann. Rept., Minister of Mines, B.C., 1914, pp. K 108-K 109.

KISPIOX VALLEY

A few days were spent in the Kispiox valley to investigate the probability of petroleum in commercial quantities. Although the time spent was brief it was sufficiently long to convince the writer that there is a dearth of any favourable indications.

Kispiox river heads in the divide between Nass and Skeena rivers, and flows in a southerly direction, joining Skeena river 8 miles north of Hazelton. Rocks of Cretaceous age are exposed on the Kispiox and Skeena north of the junction.[1] It is not known how far up the Kispiox the Lower Cretaceous rocks extend, but black shales are present as far as 50 miles from Hazelton, the most northerly point reached on this visit. As no break in the sedimentary series was noted, these shales are probably of Lower Cretaceous age. Gentle folds and dome-like structures are present, but the shales appear to be devoid of fossils. No evidence was found to indicate that petroleum existed in the rocks. Until positive indications of the presence of petroleum are discovered, the idea of drilling for oil should not be entertained.

[1]Malloch, G. S., Geol. Surv., Can., Sum. Rept., 1911, pp. 78-90.

ALBERNI AREA, VANCOUVER ISLAND, B.C.

By J. D. MacKenzie

CONTENTS

Illustration

INTRODUCTION

Alberni canal is a narrow fiord extending in a northeasterly and northerly direction more than halfway across Vancouver island from its west coast. The depression, which below sea-level is occupied by the waters of the canal, continues northward and then northwestward as the Somass and Stamp River valleys. At the head of the canal there is a low uneven area, rising gradually to the eastward in a distance of 2 or 3 miles to a height of about 500 feet. Above this elevation the slope suddenly increases, and the lowland is abruptly surmounted by the steep, rugged western slopes of the Beaufort range. Southward, the area of lowland occupies a depression parallel to Alberni canal. In this direction the lowland rises and narrows, until it is merged in the hills bordering China Creek valley. Underlying this topographic depression is a basin of Upper Cretaceous sediments, whose lesser resistance to erosion has caused the lowland to form. The surrounding, steep mountains are composed of much more resistant, pre-Cretaceous rocks. The area shown on the map as underlain by Upper Cretaceous rocks is approximately 30 square miles.

In connexion with the investigation of the Nanaimo series, as the Upper Cretaceous coal-bearing rocks of southeastern Vancouver island are termed, the Alberni area was visited for purposes of comparative study. The largest single area of Upper Cretaceous rocks on southern Vancouver island, outside of the Comox-Nanaimo-Cowichan basin, occurs in this district, and it has long been known that seams of coaly shale occur in these sediments. A particular interest attaches to the investigation of the Alberni area, therefore, in that it throws some light on the probabilities for the occurrence of workable seams of coal in this basin. Six days were spent in field work, during five of which Mr. J. E. Gill acted efficiently as assistant.

There are two towns in the area. Port Alberni, with a population of about 1,200, is at the head of navigation on the canal, and Alberni, with about 600 inhabitants, is situated at the end of the canal, where Somass river enters, less than 2 miles north of Port Alberni. There are a number of scattered farming settlements in the rolling, fertile country northward and northwestward from the head of the canal.

The area may be reached in several ways, the most convenient of which is by motor road from Nanaimo, 53 miles from Port Alberni. The Esquimalt and Nanaimo railway runs a train three times a week from Parksville Junction, and the "Princess Maquinna" of the Canadian Pacific Railway Coast Steamship Service makes regular calls at Port Alberni on her trips up and down the west coast of Vancouver island from Vancouver and Victoria.

Sawmilling, logging, fishing, and farming are the principal industries of the district. There is a large amount of excellent timber, principally fir and cedar, in the vicinity, and the splendid stand of magnificent trees along the Island highway west of Cameron lake, just east of the area reported on, is well known. In the canal, the salmon and herring fisheries are of much importance. Stream and lake fishing attract many tourists and sportsmen in the summer season.

PREVIOUS WORK

No detailed examination of the Alberni area has been made by officers of the Survey until the present time. However, in 1909, C. H. Clapp outlined the boundaries of the basin in connexion with a reconnaissance of southern Vancouver island.[1] The shores of Alberni canal and Barkley sound have been studied by V. Dolmage, who has also examined the whole of the west coast of Vancouver island north of Barkley sound.[2]

The "Geology of the Nanaimo Map-Area"[3] and "The Coal Measures of Cumberland and Vicinity, Vancouver Island"[4], are two publications containing material of some interest in connexion with the Upper Cretaceous rocks of the Alberni area.

TOPOGRAPHY

The area surrounding the head of Alberni canal exhibits two strongly contrasted types of topography. One of these is the topography developed on the area underlain by the Cretaceous sediments, and the other is formed in the areas of pre-Cretaceous rocks. The first type is a generally low, irregular surface, for the most part below 400 feet in elevation, with moderate slopes and no pronounced hills. Seen from an elevation it appears nearly flat, but there are considerable minor diversities of surface. The second type consists of steep, rough hills rising abruptly above the low-lying Cretaceous area, these hills being formed of pre-Cretaceous volcanic rocks. A transition between the two types of surface occurs in the pass over which the Alberni-Nanaimo road runs, and this pass is also utilized by the railway. Here, the basal Cretaceous sediments are found at elevations up to 1,500 feet, from which height the land underlain by them slopes downward to the lower country. The principal elevation within the low-lying area itself is formed by a ridge of pre-Cretaceous rocks that project through the Upper Cretaceous sediments. It runs in a direction a few degrees west of north along the Esquimalt and Nanaimo

[1] Clapp, C. H., Geol. Surv., Can., Mem. No. 13, 1912, pp. 132-135, and Map No. 17 A.
[2] Dolmage, V., Geol. Surv., Can., Sum. Repts., 1918-1919.
[3] Clapp, C. H., Geol. Surv., Can., Mem. 51, 1914.
[4] MacKenzie, J. D., Bull. Can. Inst. Min. and Met., June, 1922.

railway in the north-central part of the area. Northward, near the large bend in the railway, this ridge flattens into the surrounding lowland, of which the even surface here is enhanced by a veneer of stratified sand and clay.

The contrast between the generally even lowland carved on the Upper Cretaceous sediments and the steep, rough upland formed by the pre-Cretaceous metamorphosed volcanic rocks is most vividly seen in the northeastern part of the area. There the Beaufort range rises steeply in a rugged rampart running in a straight line northwesterly for miles. Against this rampart the flat floor of the valley stops suddenly, and the high wall starts up with scarcely any transition zone. Even more pronounced, but perhaps less evident, is the contrast between the towering cliffs of mount Arrowsmith, the highest point in southern Vancouver island, which rises to an elevation of nearly 6,000 feet, and the low area of sedimentary rocks at the head of the canal.

The origin of these two types of topography seems due obviously to differential erosion acting on rocks of markedly differing resistant powers. The hard, tough, massive, meta-volcanic and plutonic pre-Cretaceous rocks survive the action of processes that soon wear down the soft, incoherent, laminated, Upper Cretaceous sediments.

GENERAL GEOLOGY

Table of Formations

Age	Formation	Lithology
Pleistocene and Recent..	Superficial deposits...............	Glacial till, and stratified, unconsolidated gravel, sand, and clay. Marsh and delta deposits
	Unconformity	
Tertiary (?)............	Intrusive (?) porphyry...........	Probably quartz diorite porphyry
	Intrusive Contact (?)	
Upper Cretaceous........	Nanaimo series...................	Shale, sandstone, and conglomerate; carbonaceous and coaly shale; thin coal seams
	Unconformity	
Upper Jurassic, and, possibly, Lower Cretaceous	Saanich granodiorite.............	
	Intrusive contact	
Lower Jurassic and Triassic.....................	Vancouver group..................	Meta-volcanics, argillites, and schist

The detailed classification of the formations of the Alberni area is as given in the above table, but from the point of view of this report they fall naturally into three divisions: (1) Pre-Upper Cretaceous; (2) Upper Cretaceous; and (3) Post-Upper Cretaceous. Of these the Upper Cretaceous rocks are the most important and will be given the most consideration here. The other formations will be described in less detail, sufficient only to indicate their general characteristics and their relations to other occurrences of similar rocks on Vancouver island.

PRE-UPPER CRETACEOUS ROCKS

Vancouver Group

The rocks of the Vancouver group are well exposed in the rugged mountains already described as surrounding the lowland underlain by the Cretaceous sediments. In particular they can be studied in cuts on the Alberni-Nanaimo highway, east of its summit; in numerous cuts along the Esquimalt and Nanaimo railway; at the highway bridge over Somass river; McCoy creek; and along Sproat river above and below the bridge on the road to Great Central lake.

For the most part the rocks of the Vancouver group are of volcanic origin. They are dark greenish and bluish, dense, hard, tough rocks of effusive and pyroclastic types, possibly with some intrusives. On the shore of the canal, 150 yards south of the old slope south of the Port Alberni wharves, an outcrop of typical agglomerate of the Vancouver group occurs. It consists of sharply angular, irregular, unsorted fragments of dense and porphyritic, vesicular lava, ranging from $\frac{1}{8}$ inch to 8 inches in size, set in a matrix of smaller fragments of similar material. In a railway cut about a mile northwest of the summit there are outcrops of fine, wavy, laminated argillites overlying a purplish micaceous schist, the whole overlain apparently conformably by a rock resembling a sheared tuff. These strata strike north and south and dip 60 degrees west. Less than a mile to the northwest along the railway, similar rocks strike north 20 degrees west and dip 85 degrees northeast. It is possible that these relations indicate a steep, closely folded syncline in the pre-Cretaceous rocks.

East of the summit on the railway, and also around the headwaters of Roger creek, are greenish-grey to black, very dense, hard, siliceous flaggy argillites. They are greatly contorted, fractured, and faulted.

Ordinarily it is difficult to detect any sign of bedding in the massive volcanic rocks of the Vancouver group. They are, however, greatly jointed, fractured, and sheared, and minor slips and faults are commonly observed. The structural relations to the younger rocks of the area will be given in connexion with the description of those rocks.

These rocks can be traced continuously eastward across the island until they join lithologically similar rocks of the Vancouver group on the east coast. They have also been correlated, by Clapp, with the Vancouver group.[1]

[1]Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912, Map 17 A.

Saanich Granodiorite

A small point on the shore of Alberni canal less than half a mile south of the wharves at Port Alberni is formed of a whitish weathering, fine to medium-grained granitic rock consisting essentially of plagioclase and quartz, with subordinate hornblende and biotite. This rock also forms the steep hill bounding the Cretaceous basin on the southwest. It is mapped by Clapp[1] as Saanich granodiorite, and as no detailed study has been made of it in connexion with the preparation of this report, that classification of it is given here. The relation between the Saanich granodiorite and the Vancouver group is not exposed in this area, but it is known to intrude the Vancouver rocks elsewhere. It is considered to be of Upper Jurassic, and possibly Lower Cretaceous age.

UPPER CRETACEOUS ROCKS

Nanaimo Series

The Upper Cretaceous rocks of the Alberni area form a basin, the outlines of which follow in general those of the topographic lowland described above. These outlines can most readily be understood by reference to Figure 5. The rocks consist of various conformable sediments which are markedly unconformable on the older formations, and which have been folded into a syncline, complicated by subsidiary folds and faults.

Basal Conglomerate. In most places where the basal sediments have been observed they are conglomerates, though occasionally a sandstone or even a shale appears to be the basal member. The conglomerates are grey or greenish grey, consisting of rounded to sub-rounded pebbles of the subjacent pre-Upper Cretaceous rocks, which are usually volcanics, though, as already noted, argillites and granodiorite also occur. The conglomerates are variable in texture; the pebbles range from a fraction of an inch to several inches in size, and the proportion of pebbles to matrix is variable. At the base, angular boulders up to 2 and 3 feet across have been noted. Gradations between conglomerates, grits, and pebbly sandstones occur. Individual beds range from a few inches to a score or so of feet in thickness.

The largest area of conglomerate caps the divide in the pass over which the Alberni-Nanaimo road and the railway run. The subjacent rocks are here siliceous argillites, volcanics, and schist, and there are many pebbles of these rocks in the overlying sediments. The conglomerate underlies the ear-like area of some 2 square miles projecting eastward from the main body of the Upper Cretaceous rocks. Near its eastern boundary it has southeasterly dips up to 10 degrees. The dip flattens farther to the west, and westerly and northwesterly dips prevail toward its western boundary, where it finally disappears beneath the overlying shales. Associated with this conglomerate are some very siliceous sandstones, in beds up to 10 feet thick, which are virtually wholly composed of clear quartz grains. In a cut on the Nanaimo road, about a mile west of the summit and within a few feet of the base of the measures, beds of coarse, greenish conglomerate alternate with lenticular beds up to a foot thick, of purplish, maroon, and claret-coloured coarse sandstones. These red beds are noteworthy because strata of this colour are very rare in the Nanaimo series.

[1] Loc. cit.

In McCoy creek, a quarter of a mile above the Sproat Lake road, a basal conglomerate of very irregular texture is exposed lying on dark green, hard, volcanic rocks of the Vancouver group, which, it is evident, here formed part of an irregular surface. In the hollows of this pre-Upper Cretaceous surface the pebbles and boulders of the volcanics accumulated, and were consolidated to form a basal conglomerate. Above, in the bank, are coarse arkosic sandstone beds composed largely of debris of the older volcanic rocks.

In thickness this basal conglomerate member ranges from a few inches to more than 300 feet, the latter thickness being found south of the summit on the Alberni-Nanaimo road.

The relation of this basal conglomerate to the pre-Upper Cretaceous rocks is clearly pronounced unconformity. The older rocks are vastly more metamorphosed; they dip at higher angles; their strike is discordant in several places with that of the conglomerate; they are much more broken, jointed, and sheared, and, as already described, the conglomerate is largely formed of detritus derived from them. The relation of the conglomerate to the overlying shales and sandstones is not so evident, because the relative softness of the latter rocks causes their contacts with the conglomerate to be obscured. The general relations observed, however, leave no doubt that the conglomerate underlies the shale and sandstone that make up the great bulk of the Upper Cretaceous rocks of the Alberni basin. Apparently the conglomerate does not form a continuous sheet at the base, but was collected only in the deeper hollows of the basin, or in other localities where coarse sediment was readily supplied. Local, lenticular sheets of conglomerate thus occur, varying in thickness and area with local conditions at the time of their formation. This state of affairs is similar to that obtaining in the Comox and Nanaimo basins of the Nanaimo series on the east coast of Vancouver island.

Sandstone. Besides the sandstone interbedded with the conglomerate, other sandstones occur in several parts of the area, always near the base, and in places where the basal conglomerate is thin or absent. In railway cuts 1 to 2 miles southeast of Bainbridge station beds of massive quartzose, olive grey, grey, and whitish sandstones and grits overlie coarse arkosic grits and conglomerate made up of fragments of the pre-Upper Cretaceous volcanic rocks upon which the whole is unconformable. These strata strike north 50 to 60 degrees west, parallel to the Beaufort range, and dip 45 to 60 degrees southwest.

About a mile north of Alberni station, sandstones at the base of the measures are exposed in railway cuts. Here there are massive and flaggy beds, coarse, greenish grey, and calcareous, and interstratified with sedimentary breccias composed of angular fragments of the underlying volcanic rocks, averaging a quarter of an inch across. The strata here strike north 20 degrees west, parallel to the low ridge of underlying volcanic rocks that rise above them to the northeast, and they dip up to 10 degrees off the flank of this ridge to the southwest.

In a low ridge forming the northeast wall of the valley of the small creek bounding the area underlain by sediments on the south, about a mile southeast from the wharves at Port Alberni, somewhat over 10 feet of brownish weathering, calcareous, coarse to medium flaggy sandstone strikes about north 60 degrees east and dips 15 degrees northwest. This sandstone is full of impressions of stems and other obscure plant markings, and one 6-inch layer is crowded with pelecypod internal moulds, the species of which have not yet been determined. These were the only fossils discovered in the area, except fragments of shells that have been noted occasionally in the sandstones. This sandstone is near the base of the measures, and is probably one of the bands recorded in the log which is given on page 64 of the drill hole put down in 1878. Of the 154 feet of strata sectioned by this hole, various bands of sandstone up to 40 feet thick account for 104 feet.

On the shore south of the wharves at Port Alberni, about 10 feet of green, fine, flaggy and shaly sandstone, containing dense, hard, brownish-weathering calcareous bands, is well exposed. The strike is north 75 degrees west and the dip 15 degrees northeast, dipping under the bank of shale exposed in the cliffs farther south.

Shale. With the exception of the areas occupied by conglomerate and sandstone as noted above, the whole of the sedimentary area is underlain by shale. The best and most continuous exposure is in Roger creek and its tributary, Fourmile creek, which together give a fairly complete section of the Upper Cretaceous basin. The shale is also well exposed in a cliff southward for over a quarter of a mile from the Port Alberni wharves, where it overlies the sandstone occurring there. Shale is also found in Dry creek; in cuts and as debris along the Alberni-Nanaimo road; in the headwaters of Cherry creek, and farther down the same stream; and it is reported from various excavations in Port Alberni. For the most part, however, the shale does not outcrop, and the area underlain by it is drift covered.

The characteristic rock of this shale member of the Nanaimo series is a black, dense, homogeneous, very fine-grained mud rock, occurring in massive beds, as much as 15 feet thick. This massive shale is well exposed in Fourmile creek, near the eastern edge of the sedimentary basin, and it can also be seen in a cutting on the Alberni-Nanaimo highway, where it affords an excellent example of pronounced concentric weathering. Toward the western half of the basin, the shale, though still dominantly black and massive, contains thin sandstone interbeds. A striking exposure of them is found in Roger creek, where a bank 60 to 80 feet high extends for 150 yards along a curve of the stream, exhibiting a large number of even, regular, continuous, fine, greyish sandstone bands, running the whole length of the exposure. They range from ½ inch to 2 inches thick, and are spaced from 3 inches to 3 feet apart in the shale.

In the cliff exposure along the shore south of the Port Alberni wharves, the shale is stained and rusty, and the bedding lamination has been accentuated by weathering. Yellowish and buff-weathering, very hard and tough calcareous and siliceous concretions, from 1 inch to 6 inches, are occasionally found in the shale, usually concentrated in certain beds. Many of these concretions were broken open in a search for fossils, but none was found.

Two vertical sandstone dykes, 1, 2, and the other 4, inches thick have been observed cutting the shale on Fourmile creek.

Two samples of this shale were collected and sent to the ceramics laboratory of the Mines Branch for testing. The following report thereon has been supplied by Mr. Howells Frechette:

"Laboratory number 785 = Field number 1347.

From a borrow-pit in shale on Alberni-Nanaimo road, about 3 miles from Alberni, B.C. Upper Cretaceous (Nanaimo Series).

This is a hard, dark grey shale, non-calcareous, rust films on some fragments.

Fusion temperature: cone 5 (1230° C.).

When ground and tempered with 14·5 per cent water it is low in plasticity and could not be used alone for making hollow-ware.

Wet moulded bricklets behaved as follows:

Bricklet	Air shrinkage	Firing temperature	Fire shrinkage	Total shrinkage	Water absorption	Colour	Body
	%		%	%	%		
1.....	4	Cone 09 (970°C)..	0	4	15	Pinkish buff, scummed.	Strong, fairly hard
2.....	4	" 09 (970°C)..	0	4	15	" " "	" "
3.....	4	" 06 (1030°C)..	0	4	14½	" " "	" hard
4.....	4	" 03 (1090°C)..	½	4½	13	Light buff, scummed...	" "

Two bricklets were made by the semi-dry press method, and on firing gave the following results:

Bricklet	Firing temperature	Water absorption	Colour	Body
		%		
1.........	Cone 06 (1030°C)....	14	Light pinkish buff....	Fairly hard, friable on edges
2.........	" 03 (1090°C)....	13	Pinkish buff..........	Hard, friable on edges

In order to use this shale for brickmaking it should have a plastic clay added to it and some re-agent to prevent scumming.

Laboratory number 786 = Field number 1349.

From bank of Puntledge river, in city of Courtenay, B.C. Shale from Trent River formation of the Nanaimo series.

Fusion temperature: cone 3 (1190°C).

When ground and tempered with 15·5 per cent water it has fair plasticity and will flow through a hollow-ware die.

Wet moulded bricklets behaved as follows:

Bricklet	Air shrinkage	Firing temperature	Fire shrinkage	Total shrinkage	Water absorption	Colour	Body
	%		%	%	%		
1.........	5	Cone 09 (970°C)...	1	6	12	Buff........	Hard, strong
2.........	5	" 09 (970°C)...	1	6	12	"	"
3.........	5	" 06 (1030°C)..	1	6	12	"	"
4.........	5	" 03 (1090°C)..	6½	11½	3	Dark brown	Very hard, strong

Two bricklets were made by the semi-dry press method and on firing gave the following results:

Bricklet	Firing temperature	Water absorption	Colour	Body
		%		
1.............	Cone 06 (1030°C)....	13	Reddish buff.......	Hard and strong
2............	" 03 (1095°C)....	4	Brown..............	Very hard and strong

This shale is suitable for the manufacture of building-brick and hollow fireproofing by the plastic process and for dry pressed face brick."

The general relations and attitudes of the exposures of the shale indicate that it is conformable on the sandstone and conglomerate already described. It is probably intruded by the porphyry described below, and it is unconformably overlain by the Pleistocene and Recent superficial deposits. If younger members of the Nanaimo series formerly existed in this area, there is now no evidence of them.

The shale has been deformed both by folding and faulting, but a consideration of the features produced by these forces will be deferred until the structural geology of the area is described.

No undisturbed section of this shale has been found that would afford evidence as to its thickness. The folded section on Fourmile and Roger creeks, referred to above, indicates that there is in this area a thickness of at least 1,200 feet, and possibly more, though the total present thickness is not likely to be over 2,000 feet. There is no doubt that erosion has removed a considerable thickness of strata from this area, leaving only a part of that originally present, but how much has been removed is only a matter of conjecture. The question of the thickness of the measures will be further discussed when their structure is considered.

The sedimentary rocks just described, pending the definite evidence to be obtained when the fossils obtained from them will be determined, are tentatively correlated with the Upper Cretaceous Nanaimo series of the east coast of Vancouver island. This correlation is based on the lithology of the sediments, their degree of induration and deformation, their relations to the rocks of the Vancouver group and to the younger formations. The basal conglomerate in particular is identical in type and in its relations to the underlying rocks, with the basal conglomerates of the Nanaimo series.

The sandstones and shale are generally closely similar to, and are indurated to the same degree as, the rocks of the Nanaimo series. The presence of coaly shale is another point of similarity. The deformation is relatively of the same order of magnitude as that suffered by the Nanaimo series, and similar effects have been caused by it. It is concluded that these sediments are a separate basin of the Nanaimo series, a conclusion which agrees with that of Clapp.[1]

There is no direct evidence, however, to indicate with what particular formation of the Nanaimo series these sediments of the Alberni basin should be correlated. Though the Alberni and the Comox basins are now separated by an axis of pre-Cretaceous rocks, they may well have formed a single basin originally. The occurrence of the basal conglomerate on the highest part of the divide between the two basins suggests this. The thickness of at least 1,200 feet that is indicated for the shale in the Alberni basin affords some ground for the suggestion that it is possible that this shale is the analogue of a thick shale formation occurring on the east coast of the island, and well exposed in French creek and in Little Qualicum river, only 8 or 9 miles east of the Alberni basin. In Little Qualicum river dense, very black, massive carbonaceous shale has a resemblance to that of Roger creek. On French creek, it is reported that more than 1,800 feet of shale was penetrated by a drill without passing through the formation, and another hole was 1,100 feet deep. Homogeneous shale formations of this thickness are unknown in the Nanaimo series, except at this locality, so it is possible that these two thick shale formations are to be correlated. Thin streaks of coal are reported on good authority from the shale on French creek. This is another similarity to the rocks of the Alberni basin.

It would be of much interest with respect to the possibilities of workable coal in the Alberni area if this question could be definitely settled. The drill holes on French creek, mentioned above, did not find any coal seams. The strata penetrated by the drill are almost certainly stratigraphically beneath the Comox formation which contains the coal seams of the Cumberland area, and are very different from it lithologically, so it is not to be expected that they would contain coal.

The question of the correlation of the rocks of the Alberni basin can be summarized by stating that they are almost certainly members of the Nanaimo series, and possibly belong to an horizon immediately below the Comox formation of the Comox area.

POST-UPPER CRETACEOUS ROCKS

Tertiary Intrusive (?) Porphyry

Nearly 2 miles from Port Alberni, and about ¼ mile south of China Creek road, a hilly ridge rises a few score feet above the surrounding country, which is probably largely underlain by shale. On this ridge are numerous massive outcrops of a light grey, speckled porphyry. The phenocrysts are plagioclase, which occurs in sharply crystallized equidimensional grains up to one-eighth inch across, set in a dense matrix.

[1]Clapp, C. H., Geol. Surv., Can., Mem. 13, 1912, p. 135.

The rock is not greatly broken by joints, and though badly weathered it is clearly not metamorphosed. This porphyry does not in the least resemble any of the volcanic rocks of the Vancouver group, but it is much like a porphyry which intrudes the Comox formation of the Nanaimo series at Anderson hill, near Cumberland, and which has been termed by Clapp a dacite.[1] Though the contacts and relations of the Alberni porphyry are not exposed, its appearance and lithology strongly support the inference that it is to be correlated with this intrusive near Cumberland, which is probably of Tertiary age. In composition it is probably a diorite or quartz diorite porphyry. In mode of occurrence it is probably intrusive, and the shape and distribution of its outcrops suggest that it may be a sill, or an irregular body with sill-like characteristics.

Superficial Deposits

Till. Till, or boulder clay of glacial origin, occurs in numerous exposures in the area examined. It is well exposed near the wharves at Port Alberni, in railway cuts near Alberni, and in Roger creek. An extensive sheet apparently forms much of the surface cover south of Roger creek, and also forms the principal surface deposit above the 400-foot contour throughout the area.

Stratified Drift. North of Roger creek, and exposed in many road cuts, ditches, and stream banks, the surface covering is largely stratified drift. It consists of well-bedded yellow sand, gravel, and clay, the two first frequently false bedded, and variable in nature. A distinctive, yellowish, tough, silty clay, markedly resistant to the weather, is frequently exposed in banks of this stratified drift. This clay resembles greatly a similar material noted on the east side of the island in the vicinity of Cumberland.

These stratified beds are clearly waterlain sediments, and have evidently been hastily accumulated in shallow basins of deposition. No careful study has been made of them, but they have been observed to an elevation of about 400 feet, and are unconformable on top of the till. Their appearance and relations indicate that the sediments composing them were derived from the till, and washed into lakes caused by glacial damming, or into estuaries when the land stood lower than at present. It is possible that these stratified beds are to be correlated with the Wreck Bay formation[2] of the west coast of Vancouver island.

STRUCTURAL GEOLOGY

It is ordinarily difficult to detect evidence of structure in the pre-Upper Cretaceous rocks of the Alberni area, beyond the fact that they have been recrystallized, compressed, shattered, sheared, and jointed. Mostly, they are massive volcanics, in which metamorphism has destroyed any evidences of their original attitudes. Along the eastern rim of the

[1]Clapp, C. H., Geol. Surv., Can., Sum. Rept., 1911, p. 95.
[2]Dolmage, V., Geol. Surv., Can., Sum. Rept., pt. B, 1919, p. 16.

Upper Cretaceous basin, however, argillites and schists which are apparently conformable with the massive volcanic members strike northerly and northwesterly, and dip at high angles both to the northeast and southwest. As they are unconformable under the deformed Upper Cretaceous rocks, it is evident that they have been deformed more than once.

In spite of the meagre exposures of the rocks of the Nanaimo series, a considerable amount of information has been obtained concerning their structure. They form an elongated syncline, complicated by one principal anticline and other lesser folds, and by some faulting. The principal elongation of the area is northwesterly, and the basin extends from across the valley of China creek on the south, where it is relatively narrow, northwesterly to within 5 miles of Comox lake, a total distance of over 30 miles. Within the area covered by Figure 5 the sediments dip southwestward from their northeastern contact, and northeastward from their southwest boundary. As already described in detail, the boundary of the basin is an unconformity.

The best evidence bearing on the internal structure of the Upper Cretaceous basin is to be seen in Roger creek, and its tributary, Fourmile creek, which together give a nearly continuous series of exposures across the sedimentary area. From the information afforded by these outcrops the section on Figure 5 has been constructed. This section illustrates the most reasonable conception of the underground structure of the basin, and though it is, perhaps, not correct in every detail, it certainly illustrates the general structure of the basin in this locality, and also the degree of deformation that the measures have undergone.

In upper Fourmile creek black massive shale strikes north 45 degrees west, and at first dips 5 degrees or less to the southwest. Farther down the creek, the strike remains constant, but the dip gradually increases for half a mile, until it is almost vertical. Dips of from 60 to 70 degrees southwest then prevail for another quarter mile, until the creek takes a right-angle turn to the northwest. For the next quarter mile along this course similar high southwest dips prevail. The stream then swings back to a southwesterly course, and for about 300 yards the shale, which here contains a few sandstone banks, lies in pronounced minor open folds, several of which are well exposed in the bed and banks of the creek. A few score yards above the junction of Fourmile and Roger creeks a normal fault, striking nearly north and south and dipping 75 degrees east, with a downthrow on the east, is well shown in the bank of the stream. This fault is also exposed in Roger creek. The amount of downthrow of this fault is not known, but it marks a significant displacement of the measures, for westward from it the measures are less disturbed and lie in undulating open folds, with a general strike of north 60 degrees west, and dips not exceeding 30 degrees.

The relations summarized above are illustrated by the section on the accompanying map. There are no distinctive strata or horizon markers of any kind that can be used with assurance to interpret the structure, so that at least two interpretations of the dips east of the fault are possible, of which the more likely one is shown in the section.

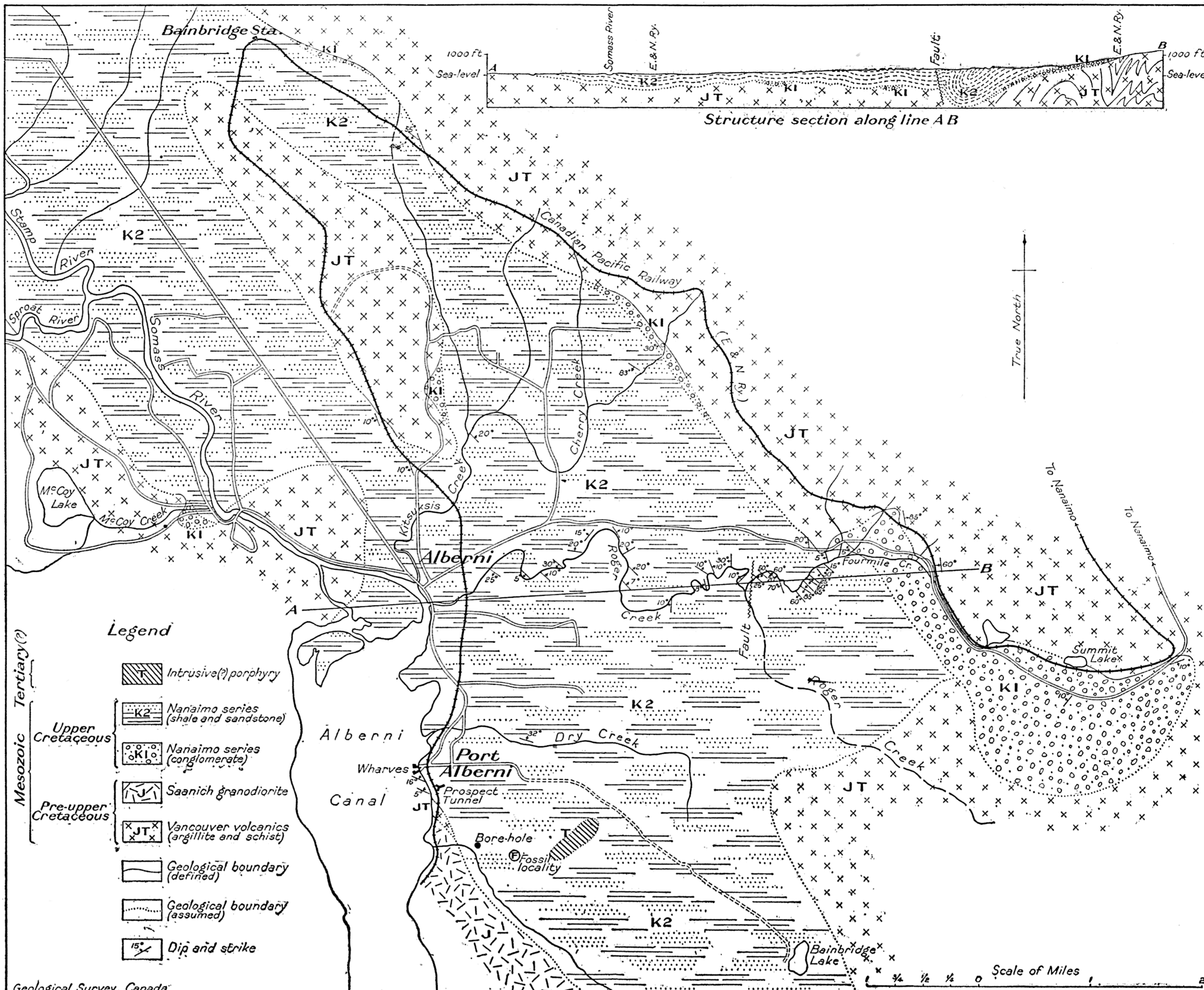

FIGURE 5. Geological map of the Alberni area, Vancouver island, B.C.

58617—To face p. 62.

The zone of steep southwestward-dipping strata on Fourmile creek is considered to be the southwest limb of a closely folded syncline, of which the flatter strata farther east form the northeast limb. This interpretation indicates a thickness of about 1,200 feet for the shale. The other possible interpretation is to consider the dips in Fourmile creek as representing a gradually steepening homocline cut off on the west by the fault already described. In this case a thickness around 2,000 feet is required for the shale. On the whole there is little to choose between these two interpretations; they both indicate an unusually thick shale formation for the Nanaimo series, and a pronounced deformation of the eastern part of the basin.

Westward of the fault there is less difficulty in interpreting the attitudes seen in the stream. They obviously represent moderate folding which has disposed the measures in two synclines, of which the eastern one is cut off by the fault near the junction of Fourmile and Roger creeks. These two synclines are separated by a low anticline. A mile or so to the northwest of the position of this section, on the strike of the axis of this anticline, the underlying pre-Upper Cretaceous rocks emerge in the low ridge described above. This anticlinal ridge is flanked on either side by synclines of Upper Cretaceous rocks. West of Bainbridge station the ridge disappears under the covering of stratified drift, and the anticline which causes its emergence plunges probably northwestward carrying the pre-Upper Cretaceous rocks again beneath the veneer of the sediments of the Nanaimo series.

ECONOMIC GEOLOGY

COAL

In the remaining section of this report the evidence for the supposed occurrence of workable seams of coal in the Alberni basin will be stated, and then it will be discussed in the light of the known geologic data that have been accumulated concerning the occurrence of coal in the Nanaimo series, in this as well as in other districts. The historical information is derived from a report on the Alberni area made to the Hon. Wm. Sloan, Minister of Mines for British Columbia, by Mr. George Wilkinson of Victoria, formerly Chief Inspector of Mines in British Columbia, in May, 1922. The following statements are essentially as given in Mr. Wilkinson's report:

"The first prospecting on this property was done by the Alberni Land Company, who employed one Archibald Muir to supervise the work. A drill was put down in the southerly part of lot 1, on the banks of a small stream which is locally known as Coal creek. This drill hole was put down to a depth of approximately 155 feet, at which point it penetrated the pre-Upper Cretaceous volcanic rocks, having passed through the coal measures. Seven seams of coal and shale mixed, running from 1½ to 6 feet in thickness, were penetrated by this drill hole. It was started on November 21, 1877, and finished September 21, 1878, but there was a period when work on the hole was suspended. The type of machine used in drilling this hole is not known.

Mr. Swayne, Manager of the Alberni Land Company, very kindly allowed me to look through the records of the early developments, and to copy the log of the drill hole, which is given below:

Thickness of strata	Nature of rock	Depth
Feet		Feet
6	Shale and coal mixed	6
1	Sandstone	7
4	Shale	11
1	Sandstone	12
1½	Coal mixed with shale	13½
5½	Sandstone	19
1½	Shale and coal	20½
2	Sandstone	22½
3	Shale and coal	25½
1	Sandstone	26½
1	Shale and coal	27½
2	Sandstone	29½
1 8/12	Shale and coal	31 2/12
1 4/12	Shale	32½
1½	Sandstone	34
2½	Shale	36½
½	Sandstone	37
3	Shale	40
2	Sandstone	42
1	Shale	43
1/12	Coal	43 1/12
2	Shale	45 1/12
½	Sandstone	45 7/12
3	Shale	48 7/12
½	Sandstone	49 1/12
2/12	Clay	49 3/12
2/12	Coal	49 5/12
2 5/12	Sandstone	51 10/12
2	Shale	53 10/12
4/12	Clay	54 2/12
1 2/12	Sandstone	55 4/12
2	Light shale	57 4/12
½	Soft shale	57 10/12
½	Hard shale	58 4/12
2	Shale	60 4/12
4	Sandstone	64 4/12
6	Shale	70 4/12
½	Sandstone	70 10/12
2	Shale and coal	72 10/12
1 11/12	Sandstone	74 9/12
1	Shale	75 9/12
6 3/12	Sandstone	82
4½	Conglomerate	86½
7½	Grey sandstone	94
1	Light shale	95
39 5/12	Light sandstone	134 5/12
1 6/12	Freestone	135 11/12
½	Light shale	136 5/12
17	Grey sandstone	153 5/12
½	Soft stone	153 11/12
4/12	Quartz and granite	154 3/12

After the prospecting in 1877 and 1878, there does not seem to have been any more work done until 1911 and 1912. During this period a slope was driven on a seam that outcropped in a railway cut of the Esquimalt and Nanaimo railway about a quarter of a mile south of the wharves at Port Alberni. This slope is said to have been driven in some 200 feet, and it is reported that the seam is about 3 feet thick. No records or sections of the seam were kept. It was not possible to locate any of the men who worked in this slope, so any information gathered about it is only hearsay. The work was done under the supervision of the late Archibald Dick, formerly a Government Inspector of Mines. The slope is located about 1,500 feet in a northwesterly direction from the drill-hole that was put down in 1878, and is no doubt in one of the seams that was penetrated by the drill-hole. It is now full of water, caved at the entrance, and inaccessible, so no first hand information could be obtained regarding it, but some samples of the coal were obtained by digging into the old dump at the entrance to the slope. Although this dump has been exposed to the elements for 10 years, the coal shows no signs of weathering, being firm in structure, clean, and of a bright lustre.

An analysis made by the British Columbia Government analyst gives the following composition for samples "A" and "B".

Analyses of Coal from Prospect Tunnel at Port Alberni

	Sample "A"	Sample "B"
Moisture	0·9	0·6
Volatile comb. matter	4·9	12·8
Fixed carbon	72·1	72·3
Ash	22·1	14·3
	100·0	100·0 "

The lower part of the cliff of shale into which the old tunnel was driven is now covered by talus, and there is no trace of the seam that caused the prospecting. As Mr. Wilkinson states, there is no definite information obtainable about this seam. The dump in front of the opening is formed largely of black, carbonaceous shale containing very numerous plant markings which have been changed to coal, as well as thicker coaly lenses ranging from $\frac{1}{32}$ inch to $1\frac{1}{4}$ inch in thickness, and up to 12 inches long by 4 inches wide. They are bright, hard, light "glance" coal, and break with a cubic fracture. A smaller dump beside the first consists of carbonaceous shale with a higher proportion of coaly lenses. Pieces of bright glance coal up to 2 inches thick can be found in this shale, and it is probably material of this sort that is represented by the analyses quoted above from Mr. Wilkinson's report. There is nothing on these dumps to indicate how much, if any, of the reported 3 feet of thickness of the seam consists of coal.

The analyses do not resemble any of the coals known from Vancouver island, and represent coals of an anthracitic variety—a higher class of coal than one would expect from an inspection of the coal on the dump.

The evidence for the occurrence of workable coal seams in the Alberni basin may be summarized as follows:

The fact that the sedimentary rocks of the area are almost certainly members of the Nanaimo series, which in part is coal bearing on the east coast of Vancouver island.

The occurrence of seven seams described as "shale and coal" ranging up to 6 feet in thickness, and discovered in the bore-hole of which the log is given above.

The occurrence of two seams of coal, one 2 inches and the other 1 inch thick, in the hole.

The occurrence of the seam in the railway cut on which the prospect tunnel was driven.

It remains to examine critically this evidence in order to decide on the probability of the occurrence of workable coal in the Alberni area.

Coal occurs in several localities on the east side of Vancouver island, but these occurrences can all be referred with a high degree of certainty to three zones of coal-bearing strata. These zones in descending order are: (1) the Comox formation, which is coal bearing in parts of the Comox basin; (2) the Newcastle formation, containing the Newcastle and Douglas seams of the Nanaimo area; and (3) the Wellington seam of the Nanaimo area.

These three relatively restricted zones contain all the workable seams now known on southern Vancouver island, though coal does not everywhere occur in these zones. The remainder of the Nanaimo series is thoroughly known both from numerous natural exposures and many bore-holes, but except for the zones mentioned it is barren of coal.

Unless, therefore, the Alberni rocks can be correlated with one of the three coal-bearing zones of the Nanaimo series, the fact that they belong to that series is not of itself significant as indicating a probability of coal. It has been shown above that the only correlation that can be even suggested between the Alberni strata and those of the Nanaimo series indicates that the shales at Alberni are equivalent to a shale formation on the east side of the island that is below the coal-bearing Comox formation, and which, furthermore, has been proved barren of workable coal by bore-holes.

Even when all due allowance is made for the supposedly crude nature of the tools with which the bore-hole of 1878 was put down, it can hardly be considered that the nature of the seams passed through is much better than the "shale and coal" recorded in the log. The hole is not a deep one, and thicknesses of strata of as little as one inch are recorded singly, with other thicknesses stated to inches in several instances. Though possible, it is not at all likely, that if a thick seam of pure coal had been penetrated it would have escaped attention. It may safely be assumed that drillers of 50 years ago were as anxious to find coal as are their descendants of today.

The evidence from the log of the hole, therefore, is that several zones of shale with streaks of coal were passed through. As the log records separate thicknesses of coal of 2 inches, and even of 1 inch, it is a fair inference that the streaks of coal in the shale were less than an inch in thickness.

The uncertain value of thin coal seams as indicators of thicker seams in any given area has been well summarized by G. A. Young[1] in his report on coal seams in Gloucester county, New Brunswick, and what Young says of the Carboniferous in Gloucester country is equally applicable to the Cretaceous of the Alberni area. The thin coal seams of this area indicate merely that geologic conditions when they were formed were only partly favourable to the formation of coal seams. They do not indicate either the presence or absence of thicker seams of coal.

Pretty much the same sort of considerations apply to the occurrence of the seam on which the prospect tunnel was driven. It is probable that this seam is one of those recorded in the log of the 1878 drill hole. If not one of these, the material on the dump, the fact that there is no record of a workable seam having been found, that the prospecting operations were abandoned and the workings have been allowed to cave, indicate that it was of similar nature, and not a seam of workable thickness.

This consideration of the evidence bearing on the question leads to the conclusion that up to the present neither the natural exposures nor the prospecting operations have afforded definite indications of workable coal seams in the Alberni area. It is not impossible that such seams do exist, but there is no evidence of their presence. Their existence can be definitely ascertained, or their absence demonstrated, only by a core drill of not less than 2 inches in diameter in the hands of a competent driller. Before such expensive means of prospecting are resorted to, it would be well to ascertain the character of the seam on which the prospect tunnel was driven, by clearing away the talus which has obscured the exposure. The top seam in the old bore-hole could be uncovered at probably relatively small expense. By these operations some of the points discussed above as matters of inference could be speedily decided, and just so much more information would be available for those who might consider the financing of a bore-hole to test the measures finally.

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[1]Young, G. A., Geol. Surv., Can., Sum. Rept., 1920, pt. E, p. 4 E.

PLACER MINING IN CEDAR CREEK AREA, BRITISH COLUMBIA

By W. A. Johnston

CONTENTS

Illustrations

INTRODUCTION

The discovery in the autumn of 1921 of placer gold near Cedar creek in the Cariboo district, British Columbia, caused a rush of prospectors to the area in the spring of 1922. Considerable prospecting was carried on throughout the area during the spring and early summer in an attempt to extend the known area of placer ground, but by midsummer most of the prospectors, disappointed in their search for gold, had left the area. No important new discoveries were made outside the original area, but mining and prospecting in the vicinity of the original discovery resulted in the finding of pay gravels which are much richer than, and of different character from, those originally found. This discovery was made late in the summer, and has served to revive interest in the area, and to show that the deposits are of considerable importance. The fact, also, that the pay gravels are found at a high level above the bottoms of the present main valleys renders the occurrence of exceptional interest, for few, if any, similar occurrences were formerly known in the region. Prospecting for placer gold, and placer mining have been carried on in this general region, intermittently, since 1859, but nearly all the prospecting has been confined to the bottoms of the present valleys and to buried channels and benches not far above the present drainage. The finding of rich pay gravels at a high level near Cedar creek gives encouragement to the belief that other similar occurrences will be found when the region is thoroughly prospected.

The writer examined and mapped the Cedar Creek area in September, 1922. Acknowledgments are due to Mr. Colin Muir, Major M. S. Day, Mr. R. N. Campbell, Mr. E. G. Stevens, Mr. J. E. Graham, and other mining men and prospectors for information regarding placer mining operations and prospecting in the area. J. A. Maguire acted as assistant and fulfilled his duties efficiently.

GENERAL CHARACTER OF THE DISTRICT

ACCESSIBILITY

Cedar creek is a small stream flowing into Quesnel lake from the east about 3 miles above the old dam at the foot of the lake. The lake is situated in the south-central part of Cariboo district. A road, passable for automobiles, runs from Williams Lake station on the Pacific Great Eastern railway to the dam, where a townsite has been laid out and a new post office, named Likely, has been established. The road passes through Quesnel Forks at the junction of the north and south forks of Quesnel river, and thence along the north side of the south fork to the dam, the distance from Williams Lake to the forks being 64 miles, and from the forks to the

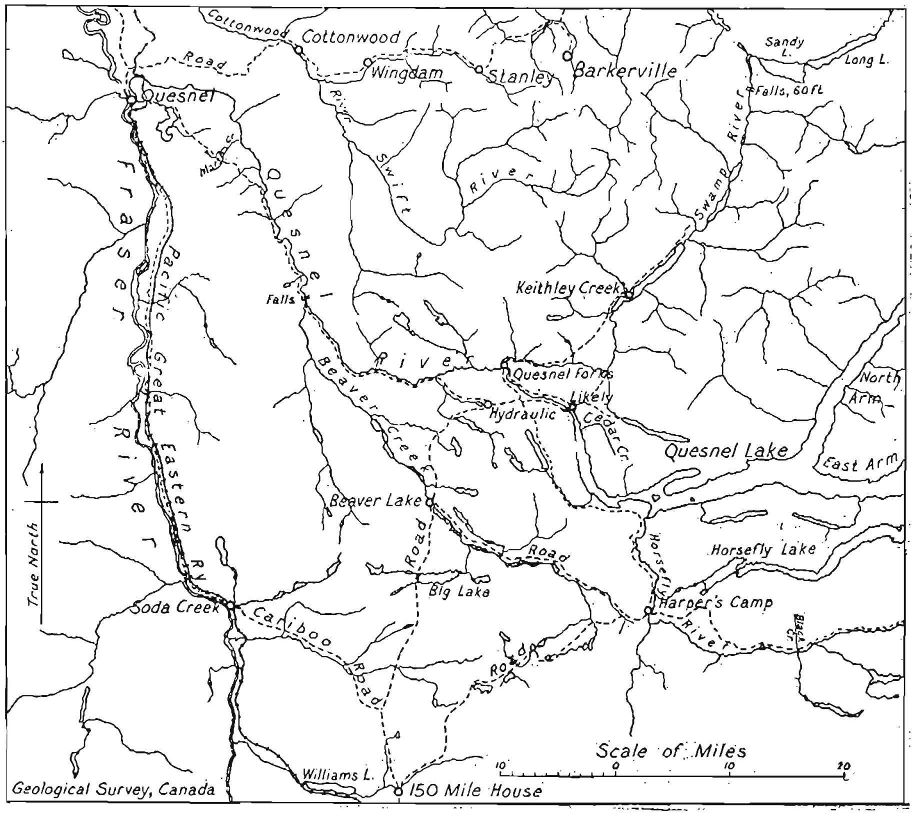

FIGURE 6. Quesnel Forks district, showing location of Cedar creek.

dam 7 miles. Another road, which ends on the south side of the river at the dam, runs from near Bullion, 4 miles from the dam, and is shorter than the road via Quesnel Forks, but there is no bridge across the river at the dam and the Forks road is generally used. Boats are employed for transportation from the dam to the delta at the mouth of Cedar creek, and a wagon road is being built from the delta up to the mines. An hotel, a general store, and a number of residences have been built at the townsite and along the shores of the lake, and there are a number of motor boats on the lake.

CLIMATE

Records of climatic observations[1] at Bullion are available from 1897 to 1905. Bullion is situated on the west side of the South fork of Quesnel river, about 6 miles northwest of Cedar creek. Climatic conditions are similar at the two places, except that on the upland near Cedar creek the snowfall is, probably, somewhat greater, and the rainfall slightly less, because of the greater altitude. It should be noted that the records are for a period of only 8½ years. A period of at least 10 years is necessary to afford an approximately correct estimate of the true mean temperature and precipitation. This is especially the case in Cariboo district because of the wide variation in climatic conditions from year to year. The amount, given below, of the mean precipitation, may vary from the true mean as much as 15 or 20 per cent. The variation of the mean temperature, as given, from the true mean, is probably not so great, since temperature conditions from year to year do not vary as much as precipitation.

The mean annual temperature at Bullion is 40 degrees, being 4 degrees higher than that of Winnipeg in southern Manitoba, and 9 degrees less than that of Vancouver. The temperature extremes throughout the year are greater than at Vancouver, because of the inland situation of the area, but not as great as at Winnipeg or at other places in the Great Plains. The mean temperature for July is 59 degrees, whereas at Winnipeg it is 66 degrees and at Vancouver 63 degrees. The mean temperature at Bullion for January, the coldest month, is 20 degrees, whereas at Winnipeg it is −4 degrees and at Vancouver 35 degrees. Temperatures as low as −28 degrees and as high as 95 degrees (in June or August) have been recorded. Extreme high or low temperatures persist for only short periods in the year. In some years frequent thaws occur throughout the winter. In other years few thaws occur in December, January, or February and most of the snowfall remains until March or April.

The average annual precipitation (rainfall and melted snowfall) at Bullion is 24 inches, and varies from 17 to 30 inches. At Barkerville, north of the area, it is 34·5 inches. Precipitation is well distributed throughout the year, but is slightly greater in summer than in winter, the monthly average for June, July, and August being 2·3 inches. June is the wettest month, the average rainfall being 2·8 inches.

The average winter's snowfall is 92 inches, that of Barkerville being 185 inches. It varies greatly from year to year. In the winter of 1897-98 it was 142·6 inches; in the winter of 1904-05 it was only 44·0 inches. The snow comes as a rule in November and lasts until April.

PHYSICAL FEATURES

The topography of the Cedar Creek area is in general similar to that of the Quesnel River and western part of the Quesnel Lake districts. The present stream valleys are, for the most part, narrow and deep and steep-sided. Some of the valleys, in their upper parts—for example, Cedar Creek valley—are broad and flat-bottomed, and parts of the upland about 1,000 feet above the lowest parts of the main valleys are nearly level.

[1]Reports of the Meteorological Service of Canada, Toronto, Ont.

This shows that streams formerly flowed at about the level of the upland and that the present valleys have been cut down below the old drainage level, probably because of uplift of the region. The general altitude of the upland surface in the Cedar Creek area is about 3,200 feet, the altitude of Quesnel lake being 2,250 feet as determined by Amos Bowman in 1885. In places only small remnants of the old plain-like surface at a high level are preserved; in other places they are quite extensive. Isolated hills and ridges—for example, Spanish mountain east of the headwaters of Cedar creek—rise 1,500 feet or more above the plateau level. These hills are erosion remnants, and prove that a great thickness of the bedrock has been worn away. The recognition of the old plain-like surface at a high level is of importance in prospecting for placer gold, for it is reasonable to suppose that parts of the channels of the ancient streams would be preserved and that they may be gold-bearing. The plateau in this region is quite distinct from that of Barkerville area, in the north-central part of the Cariboo district, which is about 3,000 feet higher.

Cedar creek for about $1\frac{1}{2}$ miles up from the delta at its mouth is a narrow, V-shaped rock gorge. It has a gradient of over 600 feet in $1\frac{1}{2}$ miles.

In places the gorge is 400 feet deep. The sides are not vertical, but in most places are too steep to be climbed easily. In its upper part the creek flows in a broad flat-bottomed valley, which extends southeast for several miles, and is nearly parallel to the lower part of Quesnel lake. The creek divides in the broad, upper part of its valley, one branch heading in a small pond near the southeast side of the valley, and the other extending towards Spanish mountain, which lies between the valley and Spanish Lake valley on the east. A broad, nearly flat-topped ridge, forming a remnant of the old plain-like surface, lies between the wide upper part of Cedar valley and Quesnel lake on the west. The ridge for a mile or so south of Cedar creek is 900 to 1,000 feet above Quesnel lake, and is about 100 feet above the lowest part of the broad valley of Cedar creek on the east. The ridge is about 1 mile from the lake and rises gradually towards the south, where it passes into a high hill near where Quesnel lake turns towards the east. North of Cedar creek the summit ridge is somewhat lower and declines towards the north, but rises again near Poquette creek, 3 miles north. Small tributaries of Cedar creek, on one of which the recent discovery of placer gold was made, have low gradients in their upper, and very steep gradients in their lower, parts. The upper parts of the tributary valleys are mostly shallow trenches in the drift deposits, and have no visible rock rims. The broad upper part of Cedar valley continues south to the head of Hemlock creek, a tributary of Quesnel lake, and occupies a narrow, deep valley somewhat similar to the lower part of Cedar creek. The summit valley at the heads of the two creeks is broad and flat bottomed and contains a number of small marshes and ponds.

A delta and alluvial fan at the mouth of Cedar creek represent the amount of material eroded by the creek since the disappearance of the glacier from Quesnel Lake basin. The inner part of the delta or the alluvial fan, near where the stream issues from the rock gorge, is about 70 feet above the level of the lake. The outer part of the delta is nearly at lake level. The outer edge of the delta falls away steeply into the water, which has a maximum depth of 50 to 55 feet in the channel opposite the end of the delta.

The area is well timbered with white spruce, western cedar, western hemlock, balsam fir, lodgepole pine, aspen and balsam poplar, paper birch, and alder and willow. Trees 2 to 3 feet in diameter are common, but most of the trees are smaller. Windfalls occur in places, but the timber, generally, is green. The dense underbrush and fallen trees render travel difficult except where trails have been cut.

HISTORY OF MINING

Cedar creek was prospected, and mined to some extent, in the early days of placer mining in Cariboo. It was first ascended by a prospecting party in 1862, but—apparently because of the important discoveries in the deep ground of Williams creek, early in that year—was abandoned until 1865. The discovery of Cedar creek is credited to J. E. Edwards, one of the prospectors of the famous Aurora claim at the mouth of Conklin gulch, a tributary of Williams creek. Bancroft states[1] "The Cedar Creek diggings proved to be valuable, yielding steadily as well as largely for some time. The Aurora claim, with flumes and sluices costing $8,000, yielded, mostly in 1866, $20,000; the Moosehead claim, costing $2,000 to open, paid $7,000 the first year; the Barker claim, also located in 1866 and costing $7,000 to open, paid $2,000 in a year; and the Discovery claim was yielding, in September 1866, $15 to $20 a day at a point where it was shallow. In August 1867, the Aurora was paying 100 ounces a week, and other claims from $10 to $20 a day to the man". All these claims were, apparently, in the bed of the creek in its lower part above the delta. G. M. Dawson states[2] that in 1886 the creek was largely in the hands of Chinese miners, who worked it for several years by the hydraulic method on a fairly large scale. From 1883 to 1891 the creek produced from $2,000 to $6,300 a year.[3] The total production of the creek is not definitely known: it probably did not exceed $100,000. Only the lower part of the creek was found to be gold bearing and, judging by the old workings, little or no gold was found above the junction of the small tributary on which the recent discovery was made. In a few places, benches up to about 100 feet above the creek were worked, particularly on the north side of the creek about 1 mile from the mouth. There are no records of gold having been found on Hemlock creek, but Poquette creek has been mined for many years. The bars and flats along the North fork of the Quesnel produced large amounts of placer gold in the early days, and the benches have been known since the sixties to be gold-bearing, but the lack of an adequate supply of water prevented their being worked except on a small scale. On the west side of the North fork, about halfway between the Forks and the outlet of the lake, is the well-known Bullion property, a deep buried channel mined for many years by Hobson and associates. The dam at the foot of the lake was built in 1898 by the Golden River Quesnel Company for the purpose of holding back the waters of the lake and mining the bed of the river. It was partly demolished in 1921.

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[1]Bancroft's Works, vol. XXXII, "History of British Columbia", p. 488.
[2]Geol. Surv., Can., Ann. Rept., vol. III, pt. II, 1887-88, p. 125 R.
[3]Ann. Repts. of Minister of Mines, B.C.

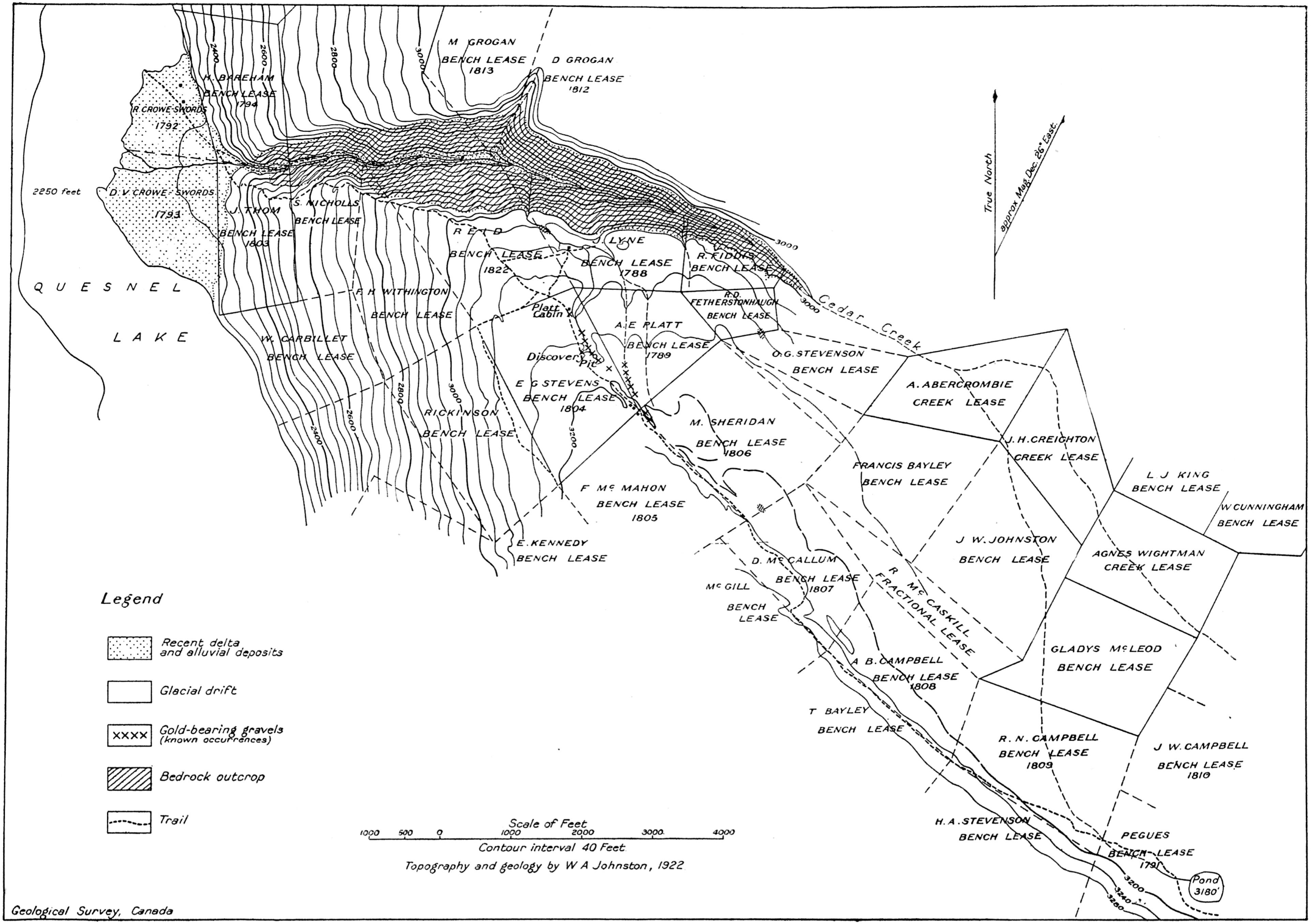

FIGURE 7. Placer deposits, Cedar creek, Cariboo district, B.C.

58617—To face p. 72.

The recent discovery of placer gold was made by two propectors, A. E. Platt and John Lyne. It is stated that Lyne was told by John Likely, an old time prospector of Cariboo now living at Kamloops, B.C. (after whom the new post office has been named), that gold had been found in the early days at about the locality where Platt and Lyne made their discovery. However, if gold was known, in the early days, at high levels above the creek, the occurrence apparently was not considered to be of importance. The discovery, or rediscovery, by Platt and Lyne, was made in a shallow draw or depression near the head of a small stream flowing into the canyon of Cedar creek from the south and about one-half mile south of Cedar creek. The discovery pit is 910 feet above Quesnel lake and 550 feet above Cedar creek at the point where the tributary creek joins it. It is distant from Cedar Creek landing about 1½ miles, but is less than a mile in a direct line from the lake. The discovery draw is on the east side of the summit ridge, but is only a few feet lower than the actual summit. Since the original discovery, gold-bearing gravels have been found at a number of points for about 2,000 feet along the course of the supposed channel. Almost all the area has been staked, the placer claims consisting of creek and bench leases having a maximum area of 80 acres. Some of the claims and the location of the gold discoveries are shown in Figure 7.

GENERAL GEOLOGY

BEDROCK

The bedrock is well exposed in the canyon of Cedar creek for about 1½ miles above its mouth. A few small outcrops occur on the upland, and small patches of the bedrock have been uncovered by placer mining operations in the discovery draw.

The rocks are mostly, if not entirely, volcanic and consist of interbedded flows and fragmental rocks. In places they are highly vesicular and amygdaloidal. The rock at the discovery draw is an amygdaloidal andesite porphyry[1]. The rocks are somewhat altered and are deformed by folding and faulting. The bedding is mostly massive and is not well shown because of the jointed, shattered, and weathered character of the rock. A massive, firmly-cemented conglomerate outcrops at the outlet of Quesnel lake and in places along the west side of the lake between Cedar creek and the dam. It probably overlies unconformably the series of volcanic rocks exposed on Cedar creek.

Fossils collected by Bowman in 1885, on the south shore of Quesnel lake, near Hazeltine creek and at Big Wheel flat, 2 miles below the outlet of Quesnel lake, showed that the rocks at these places are probably of Lower Cretaceous age[2]. Bowman mapped the rocks in the vicinity of the lower part of Quesnel lake, including the Cedar Creek area, and along the North

[1]Microscopic examinations of rock specimens were made by V. Dolmage, of the Geological Survey.

[2]"Report on the Geology of the Mining District of Cariboo, British Columbia," Ann. Rept. Geol. Surv., Can., 1887, pt. C, p 19 C.

fork of the Quesnel as Mesozoic. Part of the series was considered by him to be definitely Lower Cretaceous and a part older and possibly Jurassic. As Bowman's work was largely reconnaissance, and as no special study of the rocks of the Quesnel district has been made, little is definitely known regarding the age of these volcanics and their relationship to older and younger rocks in the region.

SURFACE DEPOSITS

The unconsolidated deposits overlying the bedrock consist of Recent (post-glacial) alluvium, glacial drift formed during the Ice Age immediately preceding the present period, and gold-bearing gravels, parts of which are pre-Glacial (Tertiary).

The Recent deposits have been formed mainly by streams eroding the drift deposits, and, to some extent, the bedrock. The delta of Cedar creek represents the material eroded by Cedar creek, and deposited in the lake since the disappearance of the glaciers from the region. The great size of Cedar Creek canyon as compared with the delta, and the presence of glacial drift in places on the sides of the canyon, show that it was not entirely cut in post-Glacial time. It was, probably, formed in part during the Ice Age, by streams issuing from the ice, and may be in part inter-glacial or even pre-Glacial. It is generally held that only 10,000 to 20,000 years have elapsed since the disappearance of the glaciers of the Ice Age, and this is not sufficient time for much weathering or erosion of the bedrock. The Recent gravel deposits formed in the beds of the streams are in places gold bearing, but, except where the streams have eroded older gold-bearing gravels, they are not likely to be of much importance. The Recent gravels, formerly mined in the bed of Cedar creek, derived their gold probably mainly from erosion of pre-Glacial gold-bearing gravels which had been caught up in the glacial drift, and only in small part from erosion of the bedrock or of pre-Glacial gravels in place. The gold in the bench deposits at Quesnel dam and along the South fork of the Quesnel was mainly derived in the same way.

The glacial drift consists in part of boulder clay, formed by the grinding and plucking action of the glaciers and deposited when the ice melted. A part consists of rudely stratified gravels deposited by streams issuing from the ice. The boulder clay rarely contains any gold, but, in places, may contain masses of gold-bearing gravels caught up by the ice. The glacial outwash gravels are not gold bearing except where they have been formed, in part at least, by erosion of older gold-bearing gravels.

Glacial drift occurs abundantly from lake level up to altitudes of at least 3,300 feet. It forms a blanket over most of the area, and, because of its irregular deposition and water-holding capacity, renders prospecting difficult. The glacial drift on the upland in the vicinity of the discovery draw forms low ridges and knolls separated by shallow depressions that are frequently undrained. The drift is uneven in thickness, and the character of the surface gives little or no indication of the character of the surface of the bedrock, for a hill of drift may overlie a depression in the bedrock, or vice versa. The maximum thickness of the drift on the upland, as shown by shafts, is at least 35 feet. It may be more in places but it probably averages less.

The presence of glacial drift at high levels shows that the whole area was, at one time, covered by the ice-sheet, but the presence of pre-Glacial gravels beneath the drift on the upland shows that comparatively little erosion of the bedrock, at least in places, was accomplished by that sheet. This is, probably, because when the ice-sheet was thick enough to completely fill the valleys and to cover the upland it was nearly stagnant because of its low surface gradient. The main avenue of drainage of the ice was by way of the Quesnel Lake trough, and there is evidence that considerable erosion of the bedrock in the lake basin was accomplished by the ice. The sides of the lake would be remarkably straight if the Recent deltas were removed; the banks rise steeply and are steeper in their lower than in their upper parts, and the tributary valleys are hanging, that is, they are not graded to the bottom of the main valley. These features are characteristic of valleys that have been widened and deepened by glacial erosion, and are not characteristic of stream-eroded valleys. It is, therefore, probable that the Quesnel Lake basin was partly formed by ice erosion, and, therefore, it is not likely that gold-bearing gravels will be found in the bed of the lake.

Terraces cut in the drift deposits along the sides of Quesnel lake occur near the mouth of Cedar creek and at various places between the creek and the outlet of the lake. They are found at various levels up to about 400 feet above the lake. They are not continuous and are much better defined in some places than in others. They were, probably, formed by streams flowing along the edge of the ice at the time when the lake basin was partly filled by a glacier. The terrace gravels are, in places near the outlet of the lake, gold-bearing. The gold was, probably, derived from gold-bearing gravels included in the drift, and was concentrated in the terrace gravels as the result of stream erosion of the drift. The bench deposits near the outlet of the lake, and along the North fork for some distance below the outlet, are mainly coarse gravels that are concentrates formed by the wearing away of a considerable thickness of drift by the powerful stream issuing from Quesnel lake.

The glacial drift, except near the surface, which is mostly reddened by weathering, is distinguished from the older gravels by its greyish colour and unweathered character, and by the occurrence in it of foreign boulders and glacially striated and faceted stones and boulders. The boulder clay is unstratified and is a heterogeneous mixture of rock fragments of various sizes and shapes in a matrix of fine silty or clayey material. Its clayey character renders it very retentive of water so that even on steep slopes the groundwater level is usually near the surface. Dense vegetation also helps to retain the moisture and although, in the autumn, the surface over most of the area is quite dry, water is usually found in shallow excavations.

ECONOMIC GEOLOGY

PLACER DEPOSITS

Placer gold occurs in different ways, and varies somewhat in character, at different places in the area. In the discovery pit only a small thickness of muck and broken and partly disintegrated bedrock overlies the solid bedrock, the gold occurring in the broken bedrock and in crevices in the solid bedrock. The gold is coarse and nuggety and not greatly worn. Gold has been found at various places in the discovery draw for about 500 feet downstream from the head. It is mostly on or in the bedrock. In places there is an overburden of several feet of barren glacial drift, and where the boulder clay is tight on the bedrock the gold is absent. Several test pits sunk in the lower part of the draw failed to show pay gravels, but a 13-foot shaft on the left bank just below Platt's cabin showed good values in gravels beneath or in the boulder clay. The gravels are apparently glacial outwash or reworked ancient stream gravels, for they are only slightly weathered. A drive was run from the shaft for 18 feet into the bank. Mr. Muir, Superintendent of the Cedar Creek Mining Company, stated that good prospects were found both in the shaft (except near the surface), and in the drive. The discovery draw ends abruptly about 800 feet above Platt's cabin at a low ridge of drift 20 feet high. Farther up stream, near the Platt-Stevens line, a small marsh occurs, and here also gold has been found in test pits. On the Platt ground it occurs at intervals in a shallow draw in the drift deposits for a distance of about 400 feet. The overburden of glacial drift is 6 to 10 feet deep and the pay gravels are 1 to 5 feet thick. Gold was being mined here in September at the rate of 2 to 3 ounces a rocker a day. The pay gravels are yellowish or red because of the presence in them of oxidized clay. They appear to be, in part at least, re-sorted, probably by glacial waters. Finer gold is found in the surface wash farther down the draw, and is probably the result of concentration from the drift by Recent streams. Gold has also been found in test pits in a continuation of the draw into the Sheridan ground. A series of small depressions or channels extends along the north side of the trail leading to the pond in which one branch of Cedar creek heads. They occur along the slope of the southwest side of the broad upper part of Cedar valley and are thought by the prospectors to mark the continuation of the gold-bearing channel. This supposition is not universal, for it is evident from a study of the map that a broad channel extends southeast at about the same level as that of the known gold occurrences. Small prospects are said to have been obtained at one or two places along the supposed course of the channel above the Sheridan claim, but apparently the finds so far are not of much importance. It cannot be said, however, that the area has been thoroughly prospected.

Mining development and prospecting during the summer resulted in the discovery of a body of remarkably rich gravels on the left bank of the Discovery draw about 600 feet above Platt's cabin (Plate I). The pay gravels rest on bedrock and are overlain by 1 to 10 feet of barren glacial drift and muck. They are reddened by the presence of clay, derived probably from weathering of fragments of the country rock included in the gravels. Most of the gravel is angular, but some worn pebbles occur. No glaciated stones were seen in the gravel. The bedrock is fairly smooth, but is soft and easily excavated. It is apparently not glaciated. The pay gravels average about 3 feet in thickness and were exposed by mining operations for a width of 25 feet and shown by test pits to extend for a distance of at least 70 feet. Subsequent operations have shown that they have a width of at least 50 feet. They trend northwest, and into the bank on the west side of the draw. The gold is well distributed through the gravel. In places little if any occurs on or in the bedrock. In other places it is found in cracks and crevices in the bedrock to a depth of 2 feet.

Cedar Creek delta also was prospected to some extent for placer gold, and early in 1922 it was proposed by the Del Ecuador Company to install a dredge. A number of test pits were sunk in the delta down to about water-level. It is reported that only low values in fine gold were found. There is no doubt that a certain amount of gold occurs here, for the delta has been formed by the material brought down from Cedar valley, which is known to have been gold-bearing for a distance of about one mile above the delta. The gradient of the stream is steep and in times of flood the volume and current of the stream are sufficiently great to transport fine gold. On the other hand it is improbable that much gold occurs below water-level, for it would be deposited as soon as the current of the stream was slackened by the still waters of the lake. The bedrock beneath the delta may be below dredgeable depth and it is unlikely that gold will be found on bedrock, because of the effects of glacial erosion. Furthermore, a part of the materials forming the surface of the delta is tailings which contain no appreciable amounts of gold, and the delta is heavily timbered. It is doubtful, therefore, whether dredging would be a profitable undertaking. At least, borings should be made to test the delta before dredging is undertaken.

Character of the Gold

The gold found in the discovery draw and in the workings on the west side of the draw is coarse and nuggety and as a rule not greatly worn. The pieces average perhaps 2 or 3 cents in value but nuggets up to $3\frac{3}{4}$ ounces have been found. The gold is mostly dark red, apparently due to a surface film of iron oxide. Many of the nuggets are irregular in shape; the protuberances are somewhat rounded or worn and the depressions frequently contain fragments of quartz embedded in the gold. Others are well worn. There is, therefore, no doubt that the gold is placer gold in the sense that it has suffered some transportation and wear after being released from the parent vein.

The gold found on the Platt ground is finer than on the discovery ground. The pieces average about six to the cent and are fairly uniform in size. Much of the gold is flattened and worn. The worn character and fairly uniform size indicate transportation and sorting by streams, at least to some extent.

The assay value of the gold from the Stevens ground varies from $17.05 to $17.16 an ounce. The assay value of the finer gold from the Platt ground varies from $16.99 to $17.21. A few nuggets nearly silvery white have been found. They are high in silver and probably approach electrum in composition. Small nuggets obtained by prospectors from bench deposits near Poquette creek were thought by them to be platinum, but proved on examination to be alloys of silver and gold.

Mining Operations

Some prospecting and mining were done on the discovery ground and on adjoining properties in the autumn of 1921 and during the winter, but little was done in the spring of 1922, partly because of litigation. Owing to faulty location on the part of A. E. Platt, who staked the discovery ground, the actual discovery proved, when the claims were surveyed, to be on E. G. Stevens' claim. The dispute was finally settled by Stevens retaining the ground and receiving half the gold that had been taken out. In April, 1922, six of the original claim owners, E. G. Stevens, F. McMahon, Mike Sheridan, Dan McCallum, and the Grogan Bros. pooled their interests and later bonded their claims to the Cedar Creek Mining Company of Vancouver, of which Mr. F. S. Munson is president and Mr. Colin Muir superintendent. This company began mining operations on July 1 and employed about thirty men in building a road to bring in machinery, erect buildings, and in mining and prospecting. Later, the working force was increased to about seventy men. Owing to the scarcity of water all the mining up to the end of September was done with rockers. About the end of September two pumps were installed, storage dams built, and the water used repeatedly for sluicing, the water being pumped up through 300 feet of 6-inch pipes by a 4-inch centrifugal pump. A fortnight's severe weather at the beginning of December prevented sluicing, but it was resumed during the latter part of December and part of January. Most of the mining by the Cedar Creek Mining Company has been confined to the discovery draw and adjacent ground on the left bank on the Stevens claim, but some prospecting has been done on the Sheridan claim. Mining was begun in August on the Platt claim which Messrs. R. McCaskill and R. Wright have bonded. Ten men under the direction of Mr. R. N. Campbell were employed. Rockers only were used as the water supply was limited. Work had already been done on the Platt claim during the previous autumn and winter. Prospecting at other places in the area was being carried on by a few individual miners. Numerous pits and shafts, the deepest about 35 feet, prospect the area at widely separated points, but in many places the gold-bearing ground was found to be deep, and as soon as the level of the groundwater was reached—usually only a few feet from the surface—the prospectors found they could not control the water, even, in some cases, with the aid of a small pump operated by a gasoline engine. Prospecting is also being carried on during the present winter of 1922-23. It is reported that values averaging about $1 a yard for a depth of 12 feet have been found by Mr. Finlayson, whose claim is about 4 miles up the Cedar Creek valley, and that some small values have been found on the Rickinson lease. On the Platt ground drifts are being run and a dump is being piled up for washing in the spring. It is stated by Mr. R. N. Campbell that the pay gravels are 4 feet thick and are increasing in value as the left rim is approached.

Output of Gold

The production of gold by the Cedar Creek Mining Company from July 1, 1922, to January 16, 1923, amounted to $133,922 (the gold being reckoned at $17 an ounce). The output from December 16, 1922, to January 16, 1923, was 2,180 ounces, the result of six days rocking and the remaining time sluicing. For this output 300 cubic yards were handled, giving an average value of $120 per cubic yard for a depth of 6 feet. In the six days from October 25 to October 30, 697 ounces, 10 pennyweights, 16 grains were produced with three rockers. The production on the Stevens' ground in May and June, 1922, amounted to $2,838, and in the autumn of 1921 and following winter $4,100, of which Platt took out $3,400 and Stevens $900. The production of the Platt ground is not definitely known.

Source of the Gold

The remarkable richness of the gravels on the Stevens ground and the fact that they lie on bedrock beneath the glacial drift show that they are pre-Glacial in age. The concentration of such large quantities of gold in the gravels could have been accomplished only by the gradual weathering and wearing away by streams of considerable quantities of the country rock and, presumably, of the veins in which the gold was originally contained. The erosion and weathering which freed the gold from the parent rock could not have been the result of glaciation, for glaciers erode either by grinding the bedrock into a powder, which is carried away by streams, or by plucking out masses of the rock which become included in the ice and are transported by it. Furthermore, the concentration of the gold in the gravels must have been accomplished before the glaciers came into existence. It is possible that the gold-bearing gravels have been moved somewhat from their original position by the action of the glaciers, but since they are not mixed with the glacial drift and rest on an unglaciated rock surface they could have been transported by the ice only a short distance, if at all.

The coarseness and angularity of much of the gold shows that it was not transported by streams far from its original source. It would be impossible for streams having as low a gradient as the ancient streams had, to transport nuggets weighing 1 to 3¾ ounces. The presence of quartz in some of the nuggets suggests that they were derived from quartz veins.

No quartz veins are known in the immediate vicinity of Cedar creek, but few rock outcrops occur except in the canyon of the creek. Quartz veins, which are reported to be gold-bearing, occur in the vicinity of Poquette creek 3 miles north of Cedar creek. Some prospecting and development work was done during 1922 by John Creagh on a small vein outcropping on the north side of Cedar creek about 1 mile above its mouth. The mineral of the vein is mainly pyrrhotite, but contains also galena, chalcopyrite, zinc blende, and pyrite. The gangue is small in amount and is mainly calcite and chlorite. A sample from the dump, assayed by the

Mines Branch, Department of Mines, was found to contain: gold 0·20 ounce a ton and silver 1·06 ounces a ton. There was no platinum. It is evident, therefore, that gold-bearing veins occur in the area and it is probable that the placer gold was originally derived from these veins. A mineral location, covering parts of the Stevens and Platt placer leases, has been made by K. C. Laylander and associates, who believe that the placer gold is residual and was derived directly from the weathering of lodes. No mineralized veins in the bedrock have been uncovered in the placer mining operations near the discovery draw, but only a small part of the bedrock has been exposed.

The fact that the rocks in the Cedar Creek area, which are quite different in character and age from those of Barkerville area to the north, contain mineralized veins, is of interest as showing the possible occurrence of other placers derived from the wearing away of these rocks and of workable lode deposits. It does not necessarily follow, however, that rich placer deposits indicate the presence of workable lode deposits, for the placer gold may be the result of concentration from the weathering and wearing away of a large amount of vein material, which contained comparatively little gold per ton of vein material.

Water Supply

The question of an adequate supply of water for mining purposes is of considerable importance for the mining of both the rich gravels and the low-grade gravels. At present only sufficient water is available for rockers and desultory sluicing. The rich gravels can be profitably mined in this way, but would be more economically mined if a better supply of water were available. Considerable bodies of low-grade gravels, which would pay well for hydraulicking if sufficient water were available, are known to occur and excellent facilities for disposal of the tailings are provided by the canyon of Cedar creek. Little can be said regarding the possibilities of obtaining an adequate supply of water, however, as no thorough investigation has been made. Good supplies are available in Johnston creek and Rapid river, 10 to 15 miles to the east, but whether the divide at the head of Spanish lake is too low to permit of the water being brought across it at a sufficiently high level is not known. The summit level of the valley of Cedar creek near its head is a few feet below the highest part of the workings on the Platt and Sheridan claims. If water were brought across the valley from the east, it would have either to be siphoned across or flumed over at a high level, in order to provide sufficient head for hydraulicking at the workings. A small supply would be obtainable for part of the workings by bringing a ditch from the ponds in the upper part of Cedar Creek valley. A large supply could be obtained by extending a ditch around the highland area lying between the broad valley at the head of Cedar creek and Quesnel lake on the east, and by means of storage reservoirs conserving the run-off, which is most abundant in the spring.

Summary of Conclusions

The rich pay gravels being mined on the west side of the discovery draw are older than the glacial drift. They are distinguished from the glacial drift by their reddish colour and weathered character. They appear to be in place, but this is open to question. If they are in place they indicate the occurrence of an old stream channel at the level at which they lie. The continuation of the channel, therefore, should be looked for at about the same level. It is possible that the pay gravels extend through the greater part of the Stevens claim, for the ground is only gently sloping. If so, and provided the present values hold, they may contain upwards of a million dollars in gold. It is not to be expected that they extend towards Cedar creek and Quesnel lake much beyond the Stevens claim, for here the ground drops away rapidly. The ancient valley probably extended from the Stevens ground towards the present outlet of Quesnel lake and nearly coincided with the present valley of the lake in its lower part from Cedar creek to the outlet. In this stretch the ancient valley was first lowered by stream erosion and was later deepened by ice erosion, so that the gold which it contained became mixed with the drift, and was later concentrated by stream action in the bars and benches near the outlet of the lake. Above the Stevens claim the ancient valley probably extended along the west side of the broad upper part of Cedar valley, the main part of the valley being below the level of the gold occurrences. On the other hand, it is possible that the gold-bearing gravels have been moved to some extent by the glacial ice that moved across the region. The general direction of ice movement in the area is not definitely known, but judging by observations in the region lying to the north it was towards the southwest or across the upper part of Cedar valley. This movement, however, was slight, the main movement being in the direction of the Quesnel Lake valley, toward its outlet. The failure to find pay gravels along the valley above the lower part of the Sheridan claim may be due to lack of prospecting, or to the effects of glaciation, or to the fact that the ancient gravels are gold-bearing only in places. Whether the gold-bearing gravels that are being worked are in place can be definitely determined only by observing, during mining operations, whether the bedrock is glaciated, whether the gold extends down into the bedrock, and whether the pay gravels are mixed with the drift. It cannot be said that the upper part of the supposed channel has been thoroughly prospected. This can, probably, be done only by drilling, because of the difficulties—in sinking -of controlling the water. Since rich pay gravels occur at a high level above the present drainage in the Cedar Creek area and since occurrences of this sort were not known, nor looked for to any great extent, while this general region was being prospected for placer gold, intermittently since 1859, the Cariboo district is evidently still worth prospecting.

BEDROCKS AND QUARTZ VEINS OF BARKERVILLE MAP-AREA, CARIBOO DISTRICT, B.C.

By W. L. Uglow

CONTENTS

INTRODUCTION

The fabulous richness of the placers which have been mined from restricted sections of the creek valleys of the Barkerville district since 1860 naturally directed attention towards the source of the gold, and led to the exploration of the very prominent quartz outcroppings as the probable mother lode. For fifty years prospectors, miners, and geologists have sought, with little success, to discover the source of the gold. The writer was instructed to devote the field season of 1922 to a systematic survey of the bedrock geology of the area to ascertain, if possible, whether a solution of this problem might be obtained.

Three and one half months were spent in the field, efficient assistance being rendered by C. O. Swanson and G. C. Lipsey. During the latter part of the season, Mr. Swanson was in charge of the areal mapping.

A full report on this area is in course of preparation in co-operation with W. A. Johnston who investigated the placer deposits. Only a brief outline of the geology and of the results of the work is, therefore, given here.

PREVIOUS WORK

The first systematic investigation of the rocks, veins, and placers was carried out by Amos Bowman[1] in 1885–1886. W. Fleet Robertson made an exhaustive study of the veins and placers in 1902.[2] In 1918 and 1919 B. R. MacKay[3] undertook a reconnaissance geological survey of the district, and in 1920 D. A. Nichols completed a topographical base map covering about 225 square miles on a scale of 3,000 feet to 1 inch. In 1921 W. A. Johnston[4] commenced a detailed study of the placer deposits. The annual reports of the Minister of Mines for British Columbia from 1874 to the present give further information relating to the mining operations.

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[1]Geol. Surv., Can., Ann. Rept., 1887, pt. III.
[2]Ann. Rept. of Minister of Mines, B.C., 1902.
[3]Geol. Surv., Can., Sum. Repts., 1918, 1919, pt. B.
[4]Geol. Surv., Can., Sum. Rept., 1921, pt. A.

GENERAL GEOLOGY

The area consists of an uplifted and deeply dissected plain-like surface of erosion. The uplands maintain a fairly uniform level, varying between 5,800 and 6,500 feet, sloping downwards towards the west. The streams have incised their valleys to depths of 2,000 to 2,500 feet into the plateau surface. The country is well timbered, mainly on the valley slopes; timber-line is about 6,500 feet. The flat and rolling uplands are covered with drift so that in only a small proportion of the area is bedrock actually exposed.

Table of Formations

Period	Series	Formation	Lithology
Jurassic ?		Mt. Murray sills and dykes	Diabase, diorite
Intrusive contact			
Carboniferous	Bear River[1]		Chert, argillite, crinoidal limestone, basic volcanic flows and breccias, basal conglomerate
Unconformity			
		Proserpine dykes and sills	Quartz porphyry Felsite
Intrusive contact			
Precambrian ?	Cariboo		Quartzite, quartz pebble conglomerate, micaceous quartzite, sericite schist, quartz slate, black graphitic slate, argillite, limestone

CARIBOO SERIES

This series underlies about nine-tenths of the map-area, occupying all except its northern part. It consists of a series of regionally metamorphosed sediments whose upper members are argillaceous and calcareous, and whose lower members are arenaceous or derivatives therefrom. These rocks were called the Cariboo schists by Dawson, Bowman, and others, but within the Barkerville area true schists are present only to a small extent.

[1]Not R. G. McConnell's Bear River series of the Portland Canal district.

PROSERPINE DYKES AND SILLS

Large numbers of buff and brownish-weathering fine-grained to medium-grained intrusive rocks occur in the Cariboo series. They do not all belong to one intrusive period, as some of them are partly schistose, whereas others are granitoid and cut across the regional structures. All are considerably replaced by siderite and ankerite, so that their petrography is in many cases obscure. Their field relations afford the best evidence of their igneous origin. The less altered types are quartz porphyries and felsites.

Owing to the scarcity of exposures, it was found inadvisable to attempt to map these rocks separately.

BEAR RIVER SERIES[1]

Slide mountain, mount Murray, mount Greenberry, mount Howley, and mount Guyet, and the country northeast of a line joining them, are underlain by the Bear River series of conglomerate, argillite, crinoidal limestone, chert, and basic volcanics. There are no schists in the series; the rocks preserve their original bedding structures and show an absence of foliation due to regional metamorphism. Lithologically they resemble the Cache Creek group of Dawson[2], but there are no cherty quartzites. There is primary chert, however, in thinly-bedded form, associated with indurated fissile shale or argillite.

Fossils collected from mount Greenberry and Two Sisters mountain were submitted to E. M. Kindle, who states that he is reasonably sure they are of Carboniferous age.

The rocks of this series are separated by a marked unconformity from the underlying Cariboo series. This unconformity has been located at various points along an extent of 15 miles. In the basal conglomerate there are many boulders of medium to coarse-grained acid igneous rock, which indicate a pre-Carboniferous period of intrusion.

MOUNT MURRAY SILLS AND DYKES

Diabase sills are very abundant in the cherts and argillites of the Bear River series. There is a very large number of them, and they vary in thickness from a few inches up to several hundred feet. The sills are so widespread, with lit-par-lit injection structure through the cherts and argillites, that it was found impossible to map them separately on the scale of 3,000 feet to 1 inch.

Dykes of diorite and hornblende porphyrite, which are believed to occupy the feeding fissures for the sills, are found cutting the Cariboo series.

[1]Not R. G. McConnell's Bear River series of the Portland Canal district.
[2]Geol. Surv., Can., Ann. Rept., vol. VII, pt. B, pp. 37-49.

STRUCTURE

The structure of the area is simple and consists of an anticlinorium, in which both series of rocks are involved. The main axis of the fold strikes north 55 degrees to 65 degrees west and crosses the map-area through mounts Burdett, Agnes, Pinkerton, Amador, and Nelson. On the southwest flank of the anticlinorium the beds dip from 10 degrees to 50 degrees southwest, but on the northeast side the dips vary up to 90 degrees. The softer and less competent beds of the Cariboo series are intimately folded between the more competent quartzites, in which folding of an open character prevails. The rocks of the Cariboo series are much more severely deformed than are those of the Bear River series. This indicates a period of folding between the times of the formation of the two series.

Zones of shearing striking nearly parallel to the axis of the fold cut across the map-area. Cross-range fractures and faults striking north 15 degrees to 25 degrees east are exceedingly common and pass through all the rocks of the area. They are so closely spaced in many cases as to produce a fracture cleavage in this direction in the argillites.

ECONOMIC GEOLOGY

QUARTZ VEINS

Descriptions of the various veins on which exploration and development work has been done are given by Bowman[1], W. Fleet Robertson[2], Macpherson[3], and others and need not be repeated here. The history of quartz mining activity is given in the various Annual Reports of the Minister of Mines for British Columbia from 1876 to the present.

The following classification and vein relationships are the outcome of the season's work[4], and are here given only in summary form.

"A" Veins. These veins constitute one of the most conspicuous features of the camp. They are mostly large bodies of white quartz up to 100 feet wide, and of unknown length. They are especially prominent in a broad zone of shearing which strikes about north 35 degrees to 40 degrees west, nearly parallel to the trend of the formations. This zone, which varies in width from one-quarter of a mile to one mile or even more, has been traced from Round Top mountain on the southeast to Sugar creek on the northwest—a distance of over 25 miles. The quartz outcrops conspicuously on the grassy uplands of the plateau surface—in places standing as much as 10 feet in relief. It seems probable that individual bodies of quartz in this zone are discontinuous and lenticular, but the country rock in their vicinity is mostly well charged with small bunches and stringers of quartz of the same character.

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[1]Geol. Surv., Can., Ann. Rept., 1887, pt. C.
[2]Ann. Rept. of Minister of Mines, B.C., 1902.
[3]Min. and Eng. Record, vol. XXIV, 1919.
[4]Uglow, W. L., "Quartz Veins of Barkerville, Cariboo District, B.C.", Bull. C.I.M.M., Nov. 1922, pp. 1165–1175.

These veins are abundantly intersected by crossing closely-spaced fractures, so that the quartz is exceedingly friable and even tends to break into plate-like pieces. This fact and the *en echelon* or step-like arrangement of adjoining lenses indicate that these veins are of pre-shear-zone origin; that is to say, after their formation, they were involved in the stresses that formed the shear zone.

Veins of this class are only sparsely mineralized with sulphides. In places, they appear to be quite barren, whereas in other places they are impregnated with pyrite, which is found as a rule in cubical development. Other sulphides are typically absent. The country rock in the vicinity of the pyritized parts of the veins is mostly richly studded with pyrite crystals.

No primary or originally free gold was found in these veins. Assays of the white quartz which constitutes most of the vein material show no gold; and of the pyrite, the only other mineral present in quantity, show from traces up to about half an ounce of gold per ton. These results practically eliminate the large quartz "blow-outs" as possible producers.

"B" Veins. The "B" veins are inconspicuous features of the district, but they are, apparently, those with which the precious metals are predominantly associated and to which mining developments will be confined. The cross-fractures and cross-faults mentioned above intersect and pass through the "A" veins. These northeasterly-trending fractures are mostly sealed with quartz, perhaps only of the thickness of a sheet of paper. Quite commonly, however, the quartz fillings are 12 to 15 inches wide, varying up to 5 feet. In many places series of multiple veins occur, consisting of parallel veins close together.

The quartz of the "B" veins being massive and unsheared is easily distinguishable from that of the "A" veins. The margins of these veins are characterized by narrow comb-like bands of siderite and ankerite which are weathered to a yellow or dark brown near the surface. The veins are commonly well mineralized with galena, pyrite, and arsenopyrite, with minor amounts of sphalerite, barite, and scheelite. The sulphides in many cases carry high gold values. Selected samples of arsenopyrite, for example, assayed as much as 135 ounces of gold to the ton of pure mineral.

Intersections of the "A" and "B" Veins. Veins of the "B" type are post-shear-zone in origin. They crosscut the foliation of the schistose quartzites and are not involved in any shearing. They are found cutting through and meeting the "A" veins. From a study of these intersections it is inferred that mineralizing solutions travelling along the "B" set of joint fissures not only mineralized the fissures themselves but impregnated the veins of the "A" type near their intersections with the group of sulphides above mentioned. A sufficient number of these intersections was seen to establish the fact that definite shoots of ore of fair size may be found at these points.

Continuation of Values with Increasing Depth. The coarse nuggety gold of the gravels has only to an exceedingly limited extent been encountered in the veins. There is a popular conception among the placer miners, and even among those interested in the lode deposits, that this is because erosion has removed the upper primarily rich parts of the lodes in that only the roots remain. This hypothesis, though containing an element of truth, is founded on a misconception, as will appear from a subsequent section.

A diagnosis of the mineralogy and structure of the veins proves that there is no apparent reason for any rapid change in the character of the primary minerals or in their gold content within minable depths. The presence of scheelite and minor amounts of pyrrhotite and tourmaline in the veins of the "B" type strongly suggests that the solutions which deposited the minerals were of intermediate to high temperature, and there is no indication of near-surface conditions of depcsition. The solutions certainly owe their origin to deep-seated intrusive rocks, evidence of whose existence is given by the occurrence of numerous quartz-porphyry and aplite dykes and sills. The veins are found to be genetically associated with these minor intrusions.

The misconception mentioned above is due to the failure to differentiate between the primary or original gold content of the veins as present in the sulphides, and the free visible gold of the upper parts of the veins, which is a secondary enrichment due to the oxidation of the sulphides.

Relationship of the Free Crystal Gold of the Upper Parts of the Quartz Veins to the Auriferous Sulphides at Depth and to the Gold of the Placers. Fine to coarse-grained crystalline gold, frequently in the form of definite single crystals, groups of crystals, wires and plates, has been recovered by washing the upper oxidized parts of many of the quartz veins. Two masses of this type of gold, said to have been worth $120 and $80, were obtained from the veins of Burns mountain about the year 1880. Today the chief method of locating auriferous lodes is by panning the disintegrated and decomposed country rock and vein matter. In many cases the amount of gold so obtained is very small and is in the form of exceedingly fine colours. In other cases, very encouraging amounts of coarse, ragged gold, associated with small grains of quartz, are recovered in the pan.

Several times during the past season the writer had occasion to visit the Rainbow prospect on the east slope of Cow mountain, where Mr. A. W. Sanders was opening up a prospect. This prospect consists of the intersection of a few shattered and disintegrated quartz stringers in decomposed and broken schistose quartzite. There are two small open-cuts on the property, and from these several panfuls of broken and rotten rock were taken in the presence of the writer. The material was rapidly and roughly panned without being crushed. The gold in two pans was weighed and found to have a value of $1.57. Other pans were estimated to contain upwards of $2 each.

From the vein material below the zone of oxidation, where it has been encountered in the old shafts and in one new one on the Warspite claim, no such free gold was recovered. The reason is, doubtless, that the sparsely disseminated gold which was originally present in the iron sulphides of the unaltered vein material was released by the oxidation of the sulphides and appeared as free gold in the upper disintegrated parts of the veins. By an alternating process of solution and re-deposition, the gold grew into fairly large-sized grains, crystals, wires and plates, whereas the pyrite and other iron sulphides were partly changed into iron and arsenic oxides and partly carried away in solution. Accumulations of gold of this character in the upper parts of the veins supplied the material for the Tertiary placers.

GEOLOGICAL EXPLORATIONS IN YALE AND SIMILKAMEEN MINING DIVISIONS, SOUTHWESTERN BRITISH COLUMBIA

By C. E. Cairnes

CONTENTS

Illustrations

INTRODUCTION

The field season of 1922 was spent by the writer in a geological reconnaissance of sections of southwestern British Columbia in the Yale and Similkameen mining divisions (Figure 8). The work was done to obtain a general idea of the trend and relation of the geological formations between areas which had already been studied in more or less detail, and at the same time, to ascertain the economic possibilities of these intermediate areas. In the field work able assistance was rendered by Carl Tolman and J. S. Godard.

In Figure 8 those areas which had been previously mapped are differentiated from those which were explored in 1922. The latter are three in number. The most northerly, "A", includes a strip along the Kettle Valley railway between Cañon House and Coquihalla station, a distance of nearly 24 miles. It extends eastward from Coquihalla station to include the Independence copper camp at the northern end of Coquihalla map-area. The intermediate section "B" lies chiefly between the Coquihalla and Tulameen map-areas. It includes Summit camp at the heads of Amberty and Sutter creeks, tributaries of Tulameen river. A detailed report is given on the silver-lead deposits at this camp. The most southerly section "C" follows along the trail from Hope to Princeton between Beaver lake at the eastern edge of the Coquihalla map-area and Ninemile creek in the Similkameen map-area. It includes Twentythreemile mining camp and certain mineral claims on Whipsaw creek.

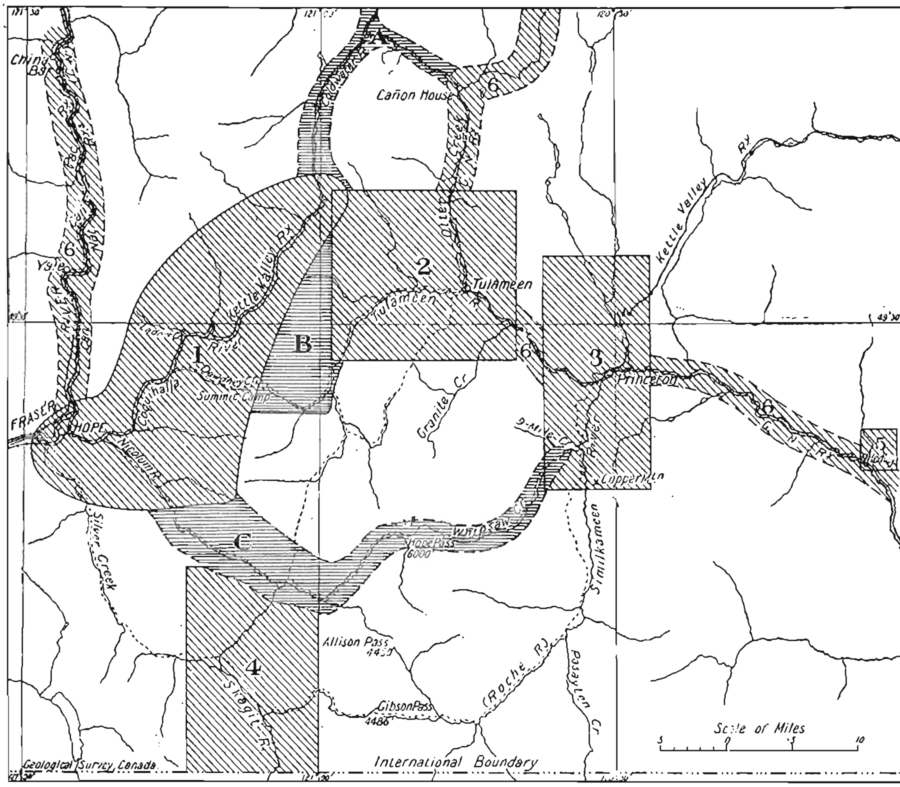

FIGURE 8. Index map of a part of southwestern British Columbia, showing areas A, B, and C (in horizontal shading) dealt with in this report, and other areas previously mapped (in oblique shading) as follows: 1, Coquihalla map-area; 2, Tulameen map-area; 3, Similkameen map-area; 4, Skagit Valley map-area; 5, Hedley map-area; 6, Guide Books 8 and 9, Twelfth International Geological Congress, 1913.

All three sections lie in a physiographic transition zone between Cascade mountains and the Interior Plateau region of British Columbia (Plate II A and II B). In section A the transition from the northern end of Hope mountains, which form a unit in the Skagit range of the Cascade system, into the Plateau belt, is very gradual. Farther south, in section B, there is a more noticeable difference in the topography on either side of the divide between Tulameen and Coquihalla rivers. This divide forms a part of the Hope range. The descent on either side is abrupt, but to the east it fetches out into the lower, more rolling, topography of the plateau, whereas to the west the ruggedness of the Hope range is continued in other units of the Coast mountains. In section C the line of physiographic division falls along the divide between the heads of Skaist river and Whipsaw creek (Plate II A). The hills on either side show no great difference in elevation but there is a marked dissimilarity in relief, the abrupt westerly descent of Skaist river forming a noteworthy contrast to the gentle easterly grade of Whipsaw creek.

The physiographic histories and characteristics of the Coast mountains and Interior Plateau region of British Columbia have been dealt with in previous reports.[1] The regional geology has also been discussed in these reports and will be referred to only where it may throw some light on problems encountered in the particular sections under discussion.

SECTION A: KETTLE VALLEY RAILWAY BETWEEN CAÑON HOUSE AND COQUIHALLA

Section A includes a strip of territory along the Kettle Valley railway between Cañon House on Otter creek and Coquihalla station at the head of Coquihalla river (Figure 9). The geology and physical characteristics of Otter Creek valley on either side of Cañon House are referred to in an earlier report.[2] West of Otter creek and nearly 8 miles from Cañon House is Coldwater river, a stream which drains northward into Nicola river at Merritt. The Coldwater is nearly parallel to Otter creek, but flows in an opposite direction. It heads in Anderson River mountains near the northern end of Coquihalla map-area. North of this area the geology of Coldwater valley has not been studied in recent years except in the vicinity of Merritt, where a basin of Oligocene (Coldwater) sediments contains coal seams of commercial importance. In 1877, however, Dawson traversed this stream and recorded his observations on the geology and general characteristics of the valley.[3] The present section includes only the upper part of the Coldwater between Coquihalla station and the mouth of Brook creek, 1½ miles below Brodie junction, a distance of 15 miles.

General Geology

The geological formations of section A may be tabulated as follows:

Glacial and stream deposits—
Tertiary—
  Porphyritic intrusives, chiefly syenite and diorite
  Oligocene ?—Spence Bridge series
    Porphyritic volcanic rocks including rhyolite, trachyte, andesite, and basalt; tuffs, breccias, and tuffaceous sediments
Cretaceous—
  Granite porphyry
  Eagle granodiorite
Triassic—
  Tulameen series: massive and schistose greenstones; quartzite, slate, limestone.

Triassic (Tulameen Series). The oldest rocks of this section have been correlated with the Tulameen series of the adjacent Coquihalla and Tulameen map-areas. They occur in a belt averaging 3 miles or more in width which extends across Coldwater river in a northerly direction on either side of Juliet station. They are composed dominantly of green schistose rocks of igneous origin, but include some intercalated sediments. The greenstones are certainly in part volcanic, but may include later intrusives. Some of the effusive members are somewhat massive, but in general they are schistose and often greatly deformed. The schists are all greatly

[1]Dawson, G. M., Rept. of Prog., 1877-78.
Camsell, C., Geol. Surv., Can., Mem. 26.
[2]Int. Geol. Cong., Guide Book No. 9, pp. 126-127.
[3]Rept. of Prog., 1877-78, pp. 38 B-40 B; 69 B-70 B.

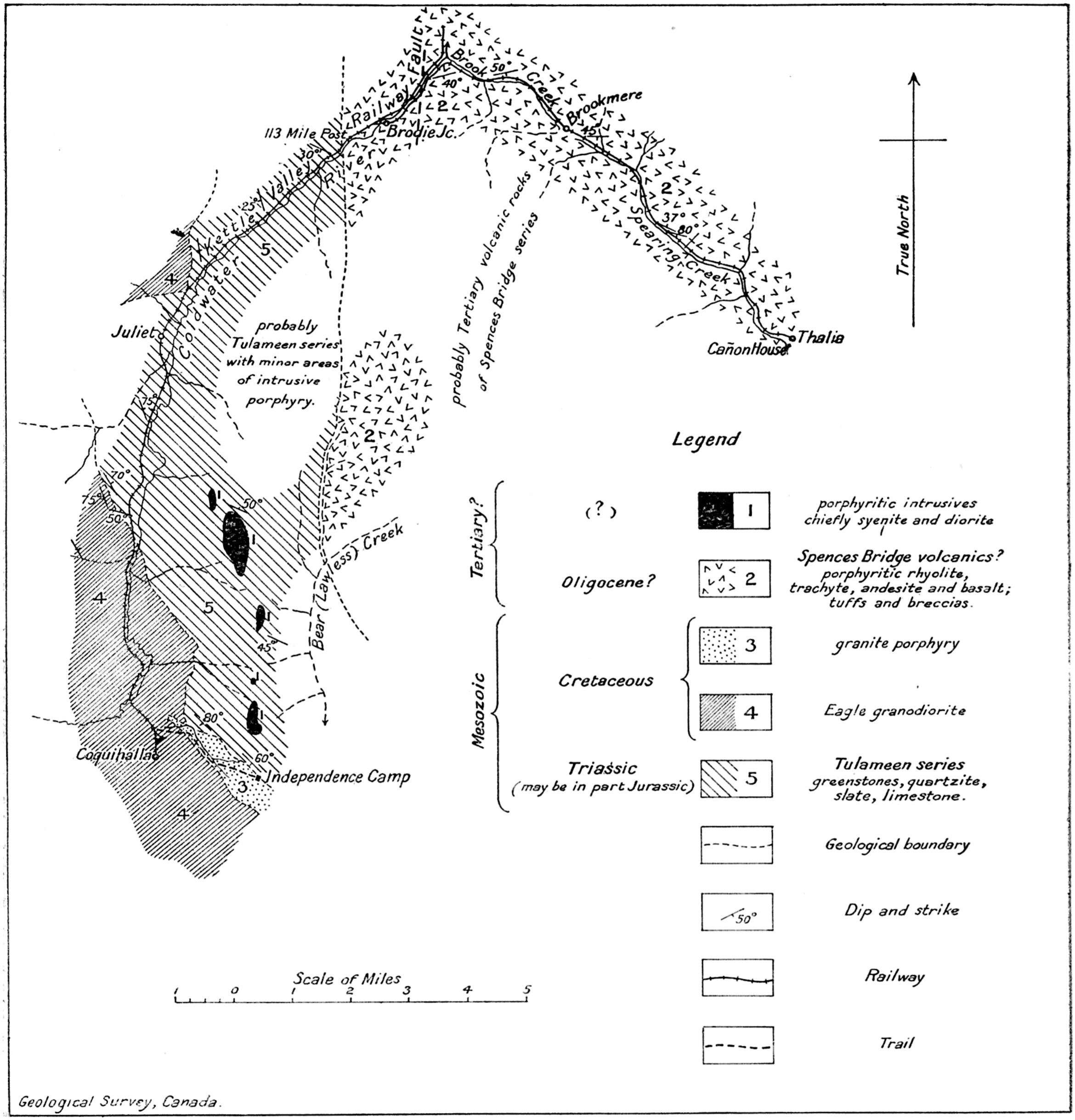

FIGURE 9. Geology along the Kettle Valley railway, between Coquihalla and Thalia (Area A).

58617—*To face p. 90.*

altered and their original composition has been judged principally from that of the more massive greenstones in which decomposition has not proceeded as far. These less altered rocks have the general composition of andesites. Associated with them are members of coarser grain in which crystals of hornblende are specially conspicuous. These are equally deformed with the rest of the series and are probably, therefore, not very different in age. Their contacts with the finer-grained greenstones are in certain instances sharply defined and suggest intrusive relations, whereas at other points there appear to be every gradation from the finer-grained andesites to these coarser-grained hornblende porphyrites. This transition of the two types, combined with an intricate intercalation, rendered it impracticable to map them separately.

The Tulameen series includes a minor proportion of sediments. These are chiefly slaty and limy rocks, but include some quartzites. Their intercalation with the volcanic rocks suggests a submarine accumulation for the entire series.[1] The limy rocks include distinct limestone beds which, however, may be only a few inches in thickness.

The trend of the series varies from a few degrees north of east to nearly north and south. Abrupt changes in attitude occur, and are, in part, the result of faulting. The rocks dip both to the southwest and northeast usually at angles of 50 degrees or less. Along the railway above Juliet the dip is to the northeast, but below this station the beds incline to the southwest suggesting thereby a general synclinal structure in the series. On the ridge north of Independence camp the dips are again predominantly southwesterly and it is probable that an anticlinal axis extends to the northwest across this ridge from a point on the railway near the granodiorite contact.

The main contacts of the Tulameen series are with the Spence Bridge volcanic rocks to the northeast and the Eagle granodiorite to the southwest. The contact with the former crosses the railway less than a mile above Brodie junction. Here, the older schistose members of the Tulameen series are overlain unconformably by younger volcanic rocks, and a number of dykes or sills of feldspar porphyry, much resembling extrusive types of the Spence Bridge series, intersect the Tulameen rocks near the contact. To the southwest the Tulameen rocks are intruded by a batholithic formation, probably of Cretaceous age, which has been correlated with the Eagle granodiorite of the Coquihalla and Tulameen map-areas. Near their contact with this intrusive the Tulameen rocks are cut by a great number of sills whose width, in proportion to that of the intervening belts of older rock, becomes greater and greater as the main body of granodiorite is approached. Within the zone of heat metamorphism induced by the granodiorite the older rocks are impregnated with igneous materials, and partly recrystallized. A very considerable mineralization by iron and copper sulphides was observed in some of the more limy members of the Tulameen series near this granodiorite contact. The Tulameen series is also penetrated by a large dyke of granite porphyry; by a number of bodies of syenite and diorite porphyry; and by many minor intrusives too small to map. The dyke of granite porphyry occurs at the southwestern corner of the section and contains the ore-bodies of the Independence copper mine.

[1]Camsell, Charles, Geol. Surv., Can., Mem. 26, p. 42.

It is intrusive in both Tulameen rocks and granodiorite, but is in turn intersected by many small dykes of the syenite and diorite porphyry group. This group occupies a considerable part of the belt otherwise represented by members of the Tulameen series. A few of the larger porphyry outcrops have been roughly outlined.

The Tulameen series has been placed tentatively in the Triassic, following the discovery by Camsell of plant fossils in certain sedimentary members of the group in Tulameen map-area.[1] No fossils were found in these rocks in the present section, but they are continuously exposed to the west across Coldwater valley into Tulameen area and are consequently grouped with the Tulameen series and accorded the same age classification.

EAGLE GRANODIORITE[2]

This intrusive is a northerly extension of the Eagle granodiorite of both the Coquihalla and Tulameen map-areas. It is a moderately coarse-grained, light grey to pinkish rock showing in the hand-specimen an abundance of glassy quartz, white to pinkish feldspars, and considerable biotite. Hornblende may also be a conspicuous mineral and muscovite is sometimes the predominating mica. The composition is very nearly that of an average granodiorite as given by Daly. Commonly, a distinct foliation is observed running about north 25 degrees west, a direction closely parallel with the longer axis of the body. This granodiorite is very similar to and probably continuous with, the granodiorite exposed on the Hope-Princeton trail at the head of Whipsaw creek and described in the report on section C. It is intrusive in the Tulameen series and in Coquihalla area is apparently intrusive in sediments regarded as Lower Cretaceous. In its general form this body of granodiorite much resembles a huge sill, between 4 and 5 miles wide, extending in a direction a few degrees west of north through Coquihalla and Tulameen map-areas and probably continuous with the granodiorite at the head of Whipsaw creek. South of Hope Summit or north of Coldwater river its extent is unknown. In connexion with this resemblance to a sill it is of interest to observe that both in Coquihalla area and in section C there are more basic types along the western flank of the granodiorite which are regarded as practically of the same age and belonging to the same period of intrusion. They are sufficiently distinct in Coquihalla area to be mapped separately as the Eagle diorite formation.

GRANITE PORPHYRY

A single large dyke of granite porphyry intersects both the Tulameen series and Eagle granodiorite near the extreme southern edge of the section. It is, in turn, intruded by dykes of feldspar porphyry similar lithically to those porphyritic intrusives farther north. The granite porphyry contains the ore-bodies of the Independence copper mine. It extends into both Tulameen and Coquihalla map-areas and is described at length in reports on those areas. A discussion of the ore deposits at Independence camp is also included in these reports.

[1] Geol. Surv., Can., Mem. 26, p. 40.
[2] Camsell, Charles, Geol. Surv., Can., Mem. 26, pp. 76–82.

TERTIARY

Spence Bridge (Volcanic Series?)

A series of volcanic flows and fragmental types is exposed along Kettle Valley railway between Cañon House and Brodie junction. From a study of their structure and lithology these rocks have been correlated, provisionally, with the Spence Bridge group which is exposed along Thompson river on either side of Spence Bridge.

Between Cañon House and Brookmere this group includes a preponderance of pyroclastic rocks of intermediate or andesitic composition. These mostly contain a variety of foreign fragments of coarse-grained plutonic and finer-grained rocks of both igneous and clastic origin. The bulk of these tuffs and breccias form massive beds which appear to have accumulated rapidly under water without suffering much reassortment. To a minor degree normal sedimentary detritus is interbedded with the effusive materials, forming thinly-bedded, shaly rocks containing here and there thin seams of coal a fraction of an inch in thickness.

Intercalated with the fragmental beds are flow rocks, commonly porphyritic, in which white or pinkish phenocrysts of orthoclase or acid plagioclase stand out prominently in a fine-grained groundmass varying in colour from black to grey with intermediate shades of red and pink. These porphyritic rocks become more prominent near Brodie junction and are the prevailing rocks exposed on the summits to the northwest of the head of Bear creek. They are there associated with a minor proportion of pyroclastic beds and are intersected by feldspar porphyry dykes probably of the same age as the porphyries that intrude the Tulameen rocks farther to the west.

About a mile below Brodie junction are outcrops of dark green tuffaceous sediments in which a few plant fragments were observed. Under the microscope these rocks have a remarkably fresh appearance. They are composed chiefly of clear, angular feldspar crystals and large lava fragments. Very little quartz is present. Calcite is a variable constituent. These sediments have been likened to those accompanying the coal at the mouth of Coldwater river,[1] near the present town of Merritt.

Neither top nor bottom of this series was exposed within the section examined. The members are folded into a series of anticlines and synclines whose general trend is nearly east-west. Dips of 40 degrees or more are common, and the beds sometimes reach a vertical position. The section is also complicated by faults, and most of the members are traversed by innumerable fracture planes which have been subsequently filled with calcite and chalcedonic quartz. These minerals together with zeolites are also found in the vesicles of the amygdaloidal lavas of the series.

These rocks have been correlated, provisionally, with the Spence Bridge group, which Drysdale[2] referred to the Jura-Cretaceous. Such plant remains as were discovered by the present writer in Coldwater valley were of no determinative value. Structurally the rocks of the typical

[1]Dawson, G. M., Rept. of Prog., 1877-78, p. 39 B.
[2]Geol. Surv., Can., Sum. Rept., 1912, p. 137.

Spence Bridge series and those from the present section appear to have been about equally deformed, and lithically there is a distinct resemblance between the series from these two localities. This resemblance is pronounced in the abundance of distinctly porphyritic flows in the series; in their great variability in composition but predominance of rhyolitic and andesitic types; in the large proportion of highly coloured rocks in which various shades of red are most conspicuous; in the occurrence of vesicular flows in which the amygdules are filled with zeolites, calcite, and chalcedony; in the intercalation of thinly-bedded, shaly sediments with the more massive tuffs of the series; and in the discovery of plant fragments in certain tuffaceous beds from both Thompson and Coldwater valleys.

In spite, however, of this resemblance the writer doubts that the rocks in the present section are pre-Tertiary. The fragmental members are fresher than any rocks of known Mesozoic age he has observed in southwestern British Columbia. In addition, the tuffs contain many fragments of granitic rocks identical in appearance with certain Cretaceous intrusives in the adjoining Coquihalla area. The general trend of deformation of this series, too, running nearly east and west, is at a marked angle to the major axis of deformation of other Mesozoic rocks in this region. Nor is this deformation, on the whole, as great as that in the presumably Cretaceous and Jurassic rocks farther to the south. The deformation is, in fact, not more excessive than that shown by rocks of early or mid-Tertiary age in neighbouring areas, and there is a great resemblance lithically to rocks of Oligocene age in these areas. The series under consideration is, accordingly, assigned tentatively to this period. It is almost certainly not younger, but may be older, and from the many points of resemblance to the Spence Bridge series is correlated provisionally with those rocks.

Syenite and Diorite Porphyries

Numerous porphyritic intrusions, many of which are too small to map, intersect all other formations in section A. A few of the larger ones have been roughly outlined. They are markedly porphyritic, acid plagioclase forming the conspicuous phenocrysts. The groundmass is commonly fine-grained to aphanitic and, as a result, the rocks have that spotted appearance to which the term "bird's-eye porphyry" is commonly applied. In the larger bodies more holocrystalline types also occur, but, even in these, crystals of feldspar usually stand out prominently in a finer-grained groundmass.

The composition of these rocks is variable, but the great proportion of them are characterized by an absence or scarcity of free quartz, by an abundance of acid plagioclase, and by minor proportions of mafic minerals. Orthoclase may be an essential constituent, in which case the rocks approach a syenite in composition. Hornblende and biotite are usually present, the former generally in excess.

These rocks include the youngest consolidated rocks in section A. They definitely intrude the Tulmaeen series, the Eagle granodiorite, and the granite porphyry. Dykes of very similar porphyritic rocks cut the series of volcanic rocks provisionally correlated with the Spence Bridge series. It is not improbable, however, that they may range in age from a period antedating Tertiary time, for there seems to be some relation both in composition and disposition between them and the larger bodies of Createceous intrusives in this and adjoining areas. This relation is probably not as well shown in this section as in section "B" where very similar porphyritic rocks are encountered.

GLACIAL AND STREAM DEPOSITS

Evidences of glaciation are everywhere abundant in this section. The upland surfaces have been smoothed by an ice-sheet which, at one time, covered the entire area. None of the summits appear to have escaped erosion, their maximum elevations not reaching above 6,500 feet, which, in the adjoining Coquihalla map-area, was regarded the approximate upper limit of continental glaciation.

The glacial debris accumulated in the valleys by the action of this ice-sheet, and by subsequent erosion of valley glaciers, was reassorted under water to form a series of terraces, remnants of which still fringe the valleys above the present stream beds. A number of such terrace deposits were observed along the railway between Brookmere and Coquihalla station. They occur at elevations of about 50, 70, and 250 feet above and 20 feet below the track at points within 2 miles west of Brookmere. Railway cuttings through terrace deposits also occur near Coquihalla station and at other points above Juliet. Still others were observed below Brodie junction.

The present streams have cut through these older terrace deposits into the underlying bedrock or have accumulated more recent sand and gravel deposits along their courses.

As far as is known, however, no placer deposits occur within the limits of the section.

SECTION B: HOPE MOUNTAINS BETWEEN COQUIHALLA STATION AND TULAMEEN MOUNTAIN

Section B includes the triangular strip of territory lying between the northeastern edge of Coquihalla map-area and the western boundary of Tulameen area (Figures 8 and 10).

The greater part of this section falls along the eastern slope of the drainage divide between Coquihalla and Tulameen rivers. The divide itself forms the northern end of Hope range and has an average elevation of about 6,000 feet. It includes such prominent peaks as Tulameen and Coquihalla mountains. The streams tributary to Tulameen river have a more gentle gradient than those flowing west into the Coquihalla, and the topography east of the divide grades into the type characteristic of the Interior Plateau region, whereas to the west it forms a part of the rugged Coast mountains.

General Geology

The rock formations of this section may be subdivided as follows:

Glacial and Recent Deposits—
Miocene—
Coquihalla series—consisting of rhyolite and basalt flows; tuffs and breccias
Post-Cretaceous—
Porphyritic intrusives, chiefly syenite and diorite, but including intermediate types
Cretaceous—
Chiefly quartz diorite (may be Tertiary)
Granite porphyry
Eagle granodiorite and diorite
Lower Cretaceous (in part)—
Conglomerate, arkose, shale, slate, tuffs, and breccias (the pyroclastic rocks are probably either late or post Cretaceous)
Jurassic—
Dewdney series (may be Lower Cretaceous) chiefly tuffaceous, fossiliferous rocks
Pyroxenite
Triassic (probably Upper Triassic)—
Tulameen series—greenstones, quartzite, slate, argillite, limestone.

TULAMEEN SERIES

The oldest rocks in this section belong to the Tulameen series. Their exposures in this section are included in part within the limits of Tulameen and Coquihalla map-areas and in part in section A of the present report. They are discussed at some length in the preceding report on section A and will only be briefly referred to here. They are composed chiefly of altered andesitic flows mostly somewhat schistose and referred to, in general, as greenstones. Intercalated with these are normal sediments including quartzites, argillites, slate, and limestone.

The Tulameen rocks are intruded by the pyroxenite, Eagle granodiorite, and granite porphyry. Ore deposits of value have been developed along or near these intrusive contacts and have been described in earlier reports on the Tulameen and Coquihalla map-areas.

PYROXENITE

Only one small area of pyroxenite is included in section B. It falls within Tulameen map-area and is fully discussed in the report on that area.[1]

The pyroxenite is composed chiefly of a pyroxene (diallage) and magnetite with varying but minor proportions of plagioclase and, occasionally, biotite. The pyroxene is commonly partly or completely altered to hornblende, and hornblende schist is the usual product of deformation of the pyroxenite. The latter resembles that occurring in the basin of Whipsaw creek and is referred to in discussing the geology of section C. It is not improbable that these two areas of pyroxenite are parts of a single intrusion and may be continuously exposed between sections B and C.

The age of the pyroxenite has been assigned, provisionally, by Camsell to the Jurassic[2]. The pyroxenite cuts the Tulameen rocks, and is in turn intersected by the Eagle granodiorite. Its relation to the Dewdney series is not definitely shown, for no contacts between the two formations occur.

[1]Geol. Surv., Can., Mem. 26, pp. 59–68.
[2]Geol. Surv., Can., Mem. 26, p. 68.

DEWDNEY SERIES

Rocks of this series occupy the southwestern corner of the section, and are continuous into Coquihalla map-area. They consist in part of thinly bedded, and in part of more massive, tuffaceous rocks striking about north 30 degrees west and dipping generally at high angles to the southwest. With the tuffaceous beds are other more normal sedimentary types, chiefly fine-grained, argillaceous rocks sometimes slightly calcareous. The basal member of the series along its northeastern contact with the Lower Cretaceous rocks is a massive, dark green andesite flow. The structure of these rocks is complicated by faulting on both a large and small scale, and by high dips which frequently vary but little from the perpendicular.

The Dewdney rocks are cut by many intrusive bodies the largest of which have the composition of quartz diorite. The Dewdney series is also intersected by a number of hornblende lamprophyre sills and by other less basic feldspar porphyry dykes.

Nearly all members of the series contain scattered fossils which, from collections made in Coquihalla area, were regarded as either Jurassic or Cretaceous in age, but more probably Jurassic.

Several of the mineral properties at Summit Camp occur in these Dewdney rocks but are not confined to them.

LOWER CRETACEOUS?

Adjoining the Dewdney rocks to the northeast is a series of sedimentary and volcanic rocks which have for lack of more specific data been grouped together. They are in part continuous with Lower Cretaceous sediments from Coquihalla area and form a belt about 4 miles wide, extending in a general north-south direction between the Middle fork of Sutter creek and the divide between Railroad and Kelly creeks. The basal member along the western flank of the series is a coarse conglomerate containing well-rounded cobbles of granitic, volcanic, and sedimentary rocks. The plutonic cobbles are chiefly of massive granite or granodiorite and are very abundant. The sedimentary cobbles are principally of dark cherty rocks, but include occasional fragments of argillite and slate. The volcanic detritus is chiefly from somewhat massive, dark green, andesitic rocks. This conglomerate dips to the east at an angle of 70 degrees, and suggests that these Cretaceous rocks are faulted against the Dewdney series. A similar relation was observed between these rocks farther to the northwest in Coquihalla area.

Another conglomerate bed very similar to the last was observed on the crest of Treasure mountain about a mile farther east. It dips 45 degrees in the opposite direction. The structure between these two conglomerate beds is apparently synclinal, the intermediate strata being composed largely of grey arkose with a smaller proportion of shaly sediments. East of this syncline the rocks dip to the east again, but are, for the most part, poorly exposed. In this direction they are intersected by a number of both large and small feldspar porphyry dykes. On the Railroad-Kelly Creeks divide, the rocks dip again to the west at angles which seldom exceed 30 degrees. The basal bed is a purplish-red volcanic breccia interbedded with grey, feldspathic beds. The peculiarly fresh appearance of these rocks on this divide, their evident unconformable relation with the older granodiorite, their undoubted relation to vulcanism, and their generally low dips differentiate them from the more deformed series of arkoses, shales, and conglomerate on Treasure mountain. These sediments, too, are continuous with the Lower Cretaceous rocks from Coquihalla area, where they were considered to be older than and intruded by the Eagle granodiorite. By reason, however, of absence of fossils and sufficient structural data, no attempt has been made to map them separately. All are included with the Cretaceous rocks of this section.

Some of the more important properties of Summit Camp are located in these Cretaceous rocks on the western slopes of Treasure mountain.

EAGLE GRANODIORITE AND DIORITE

A large part of the section is occupied by an intru ive referred to as the Eagle granodiorite. This intrusive extends in a general northerly direction across both Tulameen and Coquihalla map-areas. How much farther it extends to the north and south is uncertain, but in the latter direction it is, probably, continuous with granodiorite exposed at Hope Summit on the Hope to Princeton trail (section C of this report). Its occurrence as a long and comparatively narrow belt suggests the form of a huge sill rather than a batholith in the generally accepted sense of this term. It is, however, referred to as a batholithic rock by reason of its size and texture rather than its particular shape or mode of origin.

The Eagle granodiorite has been fully described in an earlier report and also referred to more particularly in the preceding discussion of the geology of section A. Briefly, it is a moderately coarse-grained intrusive varying in colour from dark grey to slightly pinkish and possessing the average mineral and chemical composition of a granodiorite. More basic as well as more acid variations do, however, occur. In the present section and on the Coquihalla side of the divide part of the Eagle diorite formation of Coquihalla map-area is included with the Eagle granodiorite. These two batholithic intrusives are regarded as of almost the same age, although the diorite may have been intruded slightly in advance of the larger bulk of granodiorite. The possibility, however, of the more basic formation being a differentiate in place, developed near the base of the huge sill-like body of the granodiorite, has also been suggested in section A of this report. Both Eagle diorite and granodiorite frequently exhibit a strong foliation in the general direction of their longer axes, and, both in the outcrop and under the microscope, show evidence of very considerable deformation.

Near the contact of the Eagle granodiorite with older rocks ore deposits have been discovered. These are valuable chiefly for their copper content. They include the properties at Independence and Laws camps and on Britton mountain, all of which are described in Camsell's report on Tulameen map-area.

QUARTZ DIORITE

Two areas of quartz diorite occur in section B. The larger area near the head of Dewdney creek, and the greater part of the smaller area, are included in Coquihalla map-area. This quartz diorite is so similar lithologically and structurally to the quartz diorite exposed in Skagit valley north of Sumallo river and west of Cañon creek, that it has been correlated with that intrusive and is referred to again in discussing the geology of section C. In Coquihalla area, the position and composition of the quartz diorite bodies with reference to larger batholithic intrusive bodies suggest them to be satellitic stocks. They are dominantly light-coloured rocks containing quartz, plagioclase, hornblende, and biotite as their essential constituents. Some orthoclase is usually present. Hornblende commonly forms comparatively large rectangular crystals, which stand out conspicuously in a finer-grained holocrystalline groundmass.

These rocks intrude members of the Dewdney series as well as Lower Cretaceous sediments. They are, consequently, either late or post Lower Cretaceous in age, but, from their interpretation as satellitic stocks to Cretaceous batholithic rocks, have been regarded as pre-Tertiary. This quartz diorite is considered to be related to the ore deposits at Summit Camp and will be referred to later in this connexion.

PORPHYRITIC INTRUSIVES

Within a mile or so of the Eagle granodiorite contact the sediments included with the Cretaceous rocks are intersected by porphyry dykes which become both larger and more abundant in approaching the granodiorite, and lend some support to the view that they represent a late phase in the intrusion of this granodiorite. They are commonly distinctly porphyritic and, due to the development of large feldspar phenocrysts in a comparatively fine-grained groundmass, are, in a general way, referred to as "bird's-eye porphyries". Less frequently the porphyritic texture is obscured by a more holocrystalline development of the constituent minerals. With few exceptions quartz is not an important constituent. Feldspar, and in particular plagioclase, of acid or intermediate composition, is the most abundant mineral. Hornblende is the more common mafic constituent. Pyroxene is less characteristic of these rocks. Biotite may or may not be present in macroscopic flakes.

These rocks are very similar to those porphyritic intrusives which occur in section A, and may be provisionally correlated with them. In both areas they have a similar mineral composition and as far as their relations with other formations were observed, are apparently of about the same age, although this age cannot be precisely fixed. They are, however, probably pre-Miocene and, perhaps, post-Cretaceous.

COQUIHALLA SERIES

The members of this series are discussed in some detail in the forthcoming report on Coquihalla map-area and will only be briefly referred to here. They are chiefly basalt and rhyolite flows with later tuffs and breccias, the whole intersected by a few basalt dykes. The core of Coquihalla peak is composed of pyroxene gabbro, and marks the site of a volcanic crater that supplied much of the material for the series. This core rock is probably of the same age as the basaltic dykes cutting the other members of the series, and it is possible that much basaltic material was extruded in the late stages of accumulation of this series only to be removed by subsequent erosion.

The series is gently folded and overlies eroded surfaces of the Eagle granodiorite and diorite formation. Fragments of the granodiorite are common in the tuffaceous members of the series.

No sediments were observed intercalated with the volcanic members of this series nor were any indications of deposition under water discovered.

The age of the Coquihalla series has been referred, tentatively, to the Miocene.

GLACIAL AND RECENT DEPOSITS

With the exception of the higher peaks, the entire upland surface of section B has been scored by a regional ice cap which moved over the area in a southwesterly direction. The records of this movement are preserved in striæ, roches moutonnées, and the position of erratics and other glacial debris. A thin mantle of unassorted glacial materials lies over a large part of the section up to an elevation of about 6,500 feet, the approximate upper limit of regional glaciation for this section.

In the period of mountain and valley glaciation succeeding the retreat of the ice cap much material was eroded from the valleys and deposited in the lower stream courses. The reworking of these deposits by the streams resulted in the formation of terrace deposits, remnants of which still fringe the valleys above the present stream beds. Such deposits occur along the Kettle Valley railway on either side of Coquihalla station, but are absent from the greater part of section B because of the steeper stream gradients and the narrow and somewhat precipitous character of the valleys which did not favour either the accumulation or preservation of such terrace deposits. For a similar reason there has been but little accumulation of stream gravels in this section and, partly at least, on this account, no placer deposits of economic importance have been worked within the limits of section B.

Economic Geology

With the exception of the Independence copper mine and the silver-lead deposits at Summit Camp no ore deposits of economic importance have been discovered in section B. The copper deposits at Independence camp have been fully described in reports on both the Tulameen and Coquihalla areas and require no further discussion at present.

SUMMIT MINING CAMP

Summit Camp lies chiefly on the eastern slope of the divide between the headwaters of Amberty and Sutter creeks, tributaries of Tulameen river, and of Dewdney creek, which flows westward into the Coquihalla. A few claims have been staked and some mineral deposits discovered on the summit of the divide. Still others occur on the Dewdney Creek slope, but are not included in Summit Camp.

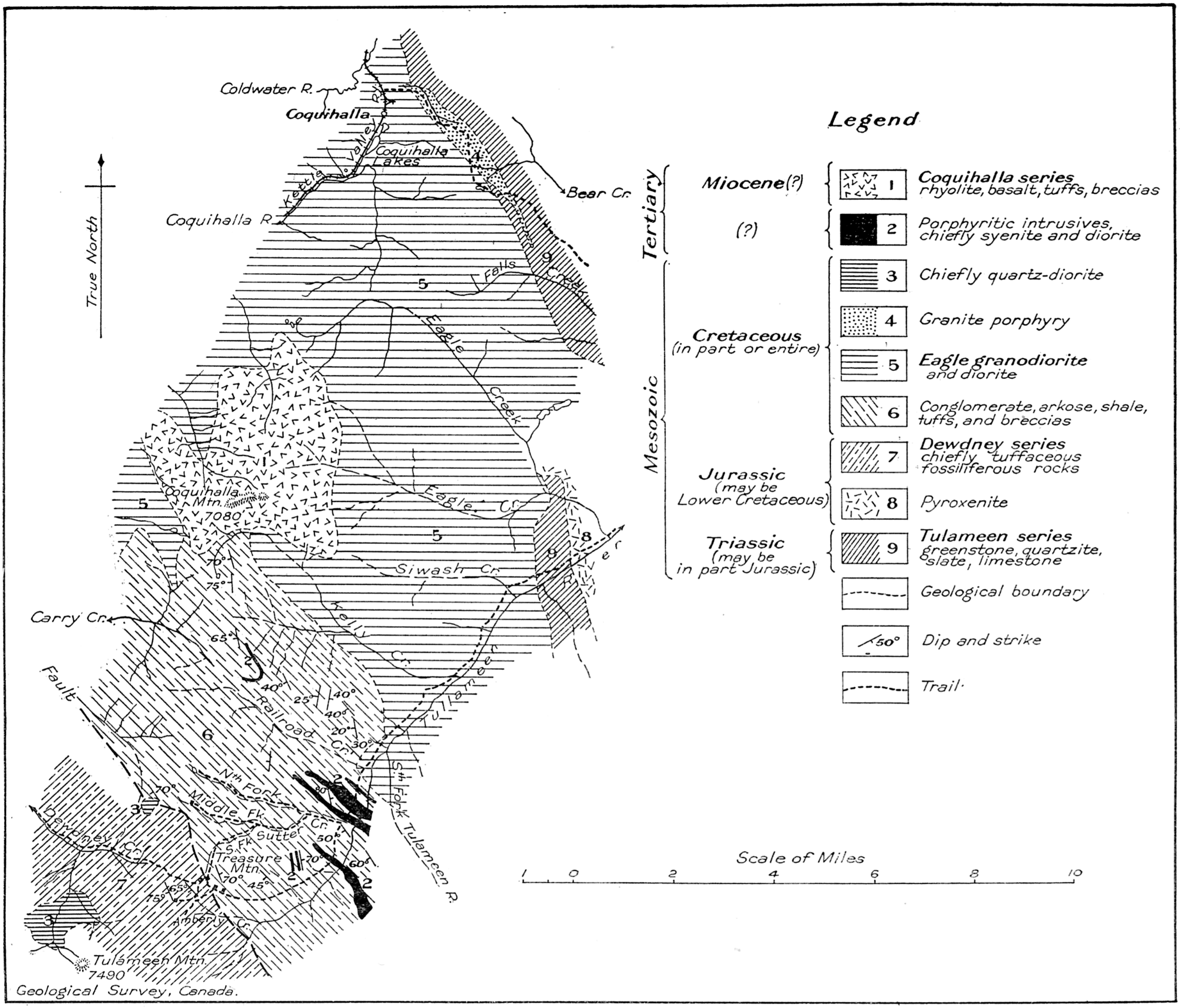

FIGURE 10. Geology of Hope mountains between Coquihalla (Kettle Valley railway) and Tulameen mountain (Area B).

58617—*To face p. 100.*

The camp is traversed by a number of trails, the chief of which leads up Tulameen valley from Tulameen village. This trail follows around the southern shoulder of Treasure mountain and up the divide between Sutter and Amberty creeks to the head of Dewdney creek distant 25 miles from Tulameen. Thence it follows down the valley of Dewdney creek for about 11 miles to Coquihalla river. From there the distance to Hope by the Kettle Valley railway is approximately 15 miles. It is most desirable that the trail down Dewdney creek, which is at present impassable for pack horses, be cleared for transportation, as it would not only be a much shorter route to the railway but would encourage further prospecting on the Coquihalla side of the divide where similar geological conditions and mineral deposits occur. The height of the divide at the head of the Dewdney Creek trail is approximately 5,800 feet. In the first mile the trail descends nearly 1,500 feet and in the next 2 miles about 1,300 feet. From this point to the mouth of Dewdney creek, a distance of 8 miles, the grade is uniform and averages 225 feet to the mile. This section of the trail is still in fair condition.

History and Previous Geological Work

Summit Camp was discovered in 1895 by Fred Sutter, and in the following year he and John Amberty staked the Vigo, Lulu, Sutter, and Skyline claims for people of Terre Haute, Indiana[1]. Although considerable excitement was caused by their discoveries, resulting in the staking of the entire camp, no work of consequence was done until 1910. In this year a partnership of Spokane people began work on the Silver Chief group of claims, located by Andy Jensen, and in the succeeding years development work was done on a number of groups of which the Silver Chief, Indiana, Stevenson, Queen Bess, and Morning Star are the more important.

The camp was visited by Camsell in 1910[2], and in 1913 Galloway made a more detailed examination of the ore deposits[3]. During his work in the adjoining Coquihalla area the present writer had an opportunity to pay the camp a brief visit in 1920 and in the summer of 1922 he made a more detailed investigation. The present report is based chiefly on these examinations and earlier reports, together with the results acquired from a study of the geology in this and adjoining territory.

The geology of the camp has already been included in a general way with that of section B. A study of Figure 10 will show that the properties at Summit Camp occur in two geological formations. The older of these is the Dewdney series. These rocks are commonly thinly bedded, but include an abundance of more massive strata. Exposures are numerous, and measurements of the beds for attitude were taken at a number of points. They strike from 10 to 40 degrees west of north and dip at high angles to the southwest. They are intersected by many dark, coarse-grained hornblende lamprophyre sills and by dykes of more siliceous and feldspathic composition. The younger formation is composed of a series of sediments ranging from coarse conglomerates to calcareous shales. The basal bed is the coarse conglomerate already referred to in discussing the

[1]Jensen, A., Personal communication.
[2]Geol. Surv., Can., Sum. Rept., 1910, pp. 118–119.
[3]Galloway, J. D., Rept. of Minister of Mines, B.C., 1913, pp. 226-232.

general geology of section B. It dips to the northeast at a high angle and appears, consequently, to mark a faulted or unconformable relation with the underlying Dewdney rocks whose adjoining member is a dark green, massive andesite. Above the conglomerate are finer-grained sediments composed principally of massive arkose but including some thinly-bedded shaly rocks. No fossils were found in these rocks, but they are continuous to the northeast into the Coquihalla area where their age was referred to the Lower Cretaceous. These rocks are intersected by a number of porphyry dykes, but none of the hornblende lamprophyre sills so common in the Dewdney series was observed cutting them.

Ore Deposits

The ore-bodies at Summit Camp are fissure-vein deposits of the silver-lead type and are fairly high grade. The lines of fissuring run from northeast and southwest to east and west and, in some instances, are persistent over hundreds and possibly thousands of feet. An apparent continuity in certain cases for a mile or more has not been proved by continuous exposures and its semblance may be due to alignment of a series of shorter fissures. The fissure veins themselves rarely exceed a few inches in width, but replacement of the wall-rock by mineralizing solutions has, under favourable conditions, extended for several feet on either side. The zone of replacement is, however, not often of economic value for more than a few inches on either side of the fissure walls. In certain cases the fissures follow the walls of intrusive dykes and the fracturing, in the case of the younger feldspar porphyry dykes, may have accompanied or even preceded their intrusion. The hornblende-lamprophyre sills of the Dewdney series, however, are involved with the rocks they intrude in this fracturing, and are consequently regarded as older than the ore deposits, and not connected with them in origin.

The principal ore minerals include galena, sphalerite, chalcopyrite, pyrrhotite, and pyrite. Magnetite, arsenopyrite, and tetrahedrite are less frequently observed. The principal gangue mineral is quartz, but calcite, ankerite, and zeolites have been observed. Galena and sphalerite are the prominent minerals in the ore-bearing fissure veins themselves. Pyrite is more common in the zone of replacement on either side of the fissure.

The more important mining properties examined by the writer at Summit Camp are located on the following claims: Blue Bell, Blue Bell Fraction, Sutter, Queen Bess, Summit, Morning Star, Silver Chief, Why-not Fraction, Eureka.

Blue Bell Claim

The showings on this claim lie in well-bedded rocks of the Dewdney series striking north 45 degrees west and dipping 65 degrees southwest. The ore occurs in a fissured zone that stands almost vertically and strikes north 60 degrees east. Along this zone, at an elevation of 5,150 feet, an adit has been driven for 130 feet. A couple of hornblende lamprophyre sills are crossed by the ore vein and appear to bear no special relation to the ore minerals. The fissure vein varies in width from a couple of inches to nearly a foot. A series of small faults were observed which appear to antedate the ore mineralization. The principal ore minerals are sphalerite, galena, arsenopyrite, and limonite. Quartz and calcite are the chief gangue minerals. A polished specimen of the ore, studied under reflected light, showed comparatively large areas of sphalerite intersected by veinlets of pyrite and chalcopyrite. Minute specks of chalcopyrite are abundantly scattered through the zinc blende.

Blue Bell Fraction

Two hundred feet below and to the east of the adit on the Blue Bell claim two fissure veins come together, although their actual point of intersection is not exposed. One of these fissures trends north 60 degrees east and dips at a high angle to the southeast. The other strikes north 85 degrees west and dips 60 degrees south. The latter shows 4 inches of ore consisting chiefly of a mixture of lead and zinc sulphides and pyrrhotite. The other fissure is apparently a continuation of the one on the Blue Bell claim farther up the hill, and a second adit has been driven 100 feet below the portal of the other and for a distance of 100 feet. This adit exposes a vein of ore from 6 to 8 inches wide carrying a large proportion of galena. An open-cut 30 feet above the portal of this adit has exposed the ore over a width of 10 inches and has uncovered a second vein $3\frac{1}{2}$ feet to the south showing 3 inches of ore. There has been much slipping and slickensiding of the wall-rock in these lower workings, but most of it, at least, antedates the ore deposition.

Sutter Claim

Some of the earliest discoveries at Summit Camp were made on this claim. The principal showing has been developed by the old "Indiana tunnel" whose portal stands at an elevation of about 5,100 feet. It has a total length, including its two underground branches, of 300 feet. The ore vein is approximately in line with that on the Blue Bell Fraction and about 1,500 feet to the southwest. The country rock is represented principally by massive bands of tuffaceous rocks, but includes some more thinly bedded strata. These rocks strike north 30 degrees west and have almost vertical dips. They are intersected by a couple of small basic sills, one, 2 feet, and the other, 5 feet, wide. The ore occurs in narrow stringers in a fractured zone running nearly east and west and dipping at high angles to the south. The width of the main stringer or fissure vein along which the adit is driven is variable, but does not average over 4 inches, and appears to be greater near the surface. There are still narrower stringers on either side of the main vein, but the intermediate rock is nearly barren of ore minerals, the principal of which are galena, sphalerite, pyrrhotite, chalcopyrite, and pyrite. A polished specimen of the ore was studied in which these minerals were present. In this specimen pyrrhotite appeared to be the first to have formed and chalcopyrite the last. Sphalerite preceded the galena, and is filled with minute specks and veinlets of the chalcopyrite. A sample obtained by J. D. Galloway over a length of 10 feet along the main ore vein from the face of the tunnel back assayed gold 0·08 ounce; silver 23·8 ounces; lead 3·6 per cent[1].

[1]Rept. of Minister of Mines, B.C., 1913, p. 228.

Queen Bess

The showings on the Queen Bess claim represent some of the later discoveries in this camp and are still in the prospect stage. They occur in well-bedded rocks of the Dewdney series, running north 20 degrees west and dipping 75 degrees southwest, and consist of a series of small stringers nearly parallel and occupying a fracture zone which is from a few inches to several feet wide and cuts nearly east and west across the formation. Assays across 7 feet of this zone were said by the owner to average 8 per cent in lead, and 8 ounces in silver. The solid ore from the narrow stringers has an assay value of between $100 and $150. Considerable replacement of the wall-rock on either side of the stringers was observed. The principal ore mineral is galena, but arsenopyrite is a notable constituent of the entire mineralized zone. The chief gangue minerals are quartz and calcite.

Summit Claim

This claim, as its name implies, lies on the divide between Sutter and Dewdney creeks. The country rock is represented by massive beds of the Dewdney series. The main vein is, apparently, closely in line with that from the Indiana tunnel on the Sutter claim and has been exposed by a couple of open-cuts, in the lower of which a hole has been sunk about 8 feet on the ore vein, which is here from 6 to 8 inches wide. The ore is chiefly galena, and assays about 15 ounces in silver. At 75 feet above this showing is another open-cut, apparently on the same zone of fracturing, and showing a number of very narrow stringers of almost pure galena across a width of 5 or 6 feet of sparsely mineralized rock.

Morning Star

The showings on the Morning Star claim are located near the head of the Middle fork of Sutter creek, in a massive andesite and tuffaceous members of the Dewdney series. At an elevation of 5,200 feet an adit has been run to the south for 60 feet, where it intersects an ore vein running east and west and dipping at 40 degrees to the south. Along this vein, whose width varies up to 3 or 4 inches, a drift has been run west for 80 feet, whence a crosscut to the north 27 feet long cuts a mineralized fracture zone about 5 feet wide. This zone is exposed at the surface by the portal of the main adit and cuts north 60 degrees east across the hillside. The ore occurs as small stringers in this fracture zone and is reported to be exceptionally high grade. Galena is the most important and abundant mineral. Assays of the solid sulphide were stated to run as high as 613 ounces in silver. A small percentage of grey copper, or tetrahedrite, is associated with the lead sulphide, and a little chalcopyrite is also present. Gold values up to $2.50 a ton are reported from this showing. Quartz is the chief gangue mineral.

Treasure Mountain Properties

Silver Chief Claim. The Silver Chief claim lies wholly within the belt of Cretaceous sediments which include conglomerates of varying coarseness, arkoses, and shales. The finer-grained sediments are in part quite calcareous, but no distinct limestone beds were observed.

At an elevation of 5,150 feet an important showing has been developed by the Mary-E tunnel (first known as the Upper Treasure Mountain tunnel). The main adit, driven in a northerly direction, struck the orebody about 60 feet from the portal. The ore follows very nearly the hanging-wall of a feldspar porphyry dyke which strikes about north 50 degrees east and dips 65 degrees southeast. A drift has been run for 152 feet exposing an ore vein varying in width from 2 to 8 inches exclusive of the hanging-wall rock, which from 1 to 4 feet out from the main ore vein is impregnated with ore minerals. Much soft, decomposed material has formed along the walls on either side of the ore vein and has been stained by oxidation of the iron sulphides present. A sample of this decomposed product assayed by the Mines Branch, Ottawa, gave 0·20 ounce silver, 0·10 per cent lead, and 4·00 per cent zinc. The principal ore minerals are galena and sphalerite. The former is coarsely crystalline, and a sample of the pure sulphide assayed gave 242·15 ounces in silver. Both sphalerite and galena tend to occur in pockets along a line of fissuring, and either sulphide may be present almost to the exclusion of the other.

Whynot Fraction and Silver Chief Claim. About 400 feet below the portal of the Mary-E tunnel another adit has been driven for over 700 feet north 25 degrees east, and at 630 feet from the portal meets the same dyke encountered in the upper tunnel. The dyke here strikes north 70 degrees east and dips 65 degrees southeast. It has a width of 24 feet. Ore on both walls of this dyke has been followed by drifts aggregating 300 feet in length and by a raise of 50 feet on the south side of the dyke. On this side a drift 200 feet long was carried to the northeast and at 100 feet from the main adit the raise of 50 feet was made. Between the main adit and this raise the ore vein averaged 6 to 8 inches in width and showed in some places nearly solid galena and in others a large proportion of zinc blende. Beyond the raise the ore seems to pinch out. On the north side of the dyke two short drifts, each about 50 feet in length, were run in both directions from the main adit. Toward the west the ore is close to the hanging-wall of the dyke, but to the east the main ore fissure lies nearly 3 feet from this dyke.

Eureka Claim. A few feet below the main trail and at an elevation of about 4,600 feet an adit has been driven to the northwest for 50 feet, where it encountered a couple of small fissure veins running nearly north and south. These were followed for 230 feet. The ore veins rarely exceed 3 inches in width, but the wall-rock is slightly mineralized for a thickness of 2 to 6 feet. The fissure veins are, in places, composed of nearly solid galena associated with a quartz and yellowish ankerite gangue. Under reflected light and at high magnification the galena from this property showed when etched with hydrogen peroxide, innumerable minute specks of a white mineral that is presumably argentite.[1] Some tetrahedrite was also observed in this specimen. The zinc blende was characteristically filled with fine threads and specks of chalcopyrite. The chalcopyrite also appears to be, for the greater part, later than the galena. A number of perfect quartz crystals through the sphalerite suggests that this gangue mineral was, at least in part, formed before the zinc sulphide was precipitated.

About 100 feet above this adit, and on the upper side of the trail, the outcrops of Cretaceous sediments, chiefly conglomerate at this point, are much decomposed and iron-stained and so leached as to resemble an iron cap beneath which some concentration of mineral sulphides may occur. This mineralization occurs within a few feet of the base of the Cretaceous series; and a porphyry dyke, probably a continuation of the one from the Silver Chief claim, cuts across both these rocks and the adjacent members of the Dewdney series.

General Remarks

The ore deposits at Summit Camp occur at a number of widely separate points and under a variety of geological associations. There is, however, a rather remarkable uniformity in the character of the ore-bodies at the different showings, a uniformity embracing not only their physical but also their mineralogical characteristics. At each porperty the ore occurs in veins rarely over a few inches wide but which may fall within a wider and more sparsely mineralized zone containing other such veins. The entire zone of mineralization constitutes the potential ore-body. It may have a width of several feet, and the whole of it, in at least certain cases, constitutes concentrating ore. On examination, it is found that the mineralized veins are following either lines of fracture or of movement and that, depending upon the character of the rock traversed, there is some replacement of the wall-rock by mineralizing solutions. The most abundant ore minerals are galena and sphalerite. They commonly occur in nearly equal proportions, but either may be present almost to the exclusion of the other. The galena is commonly coarsely crystalline and assays of the pure sulphide run between 150 and 600 ounces in silver. Polished specimens of the galena show that the silver values occur as argentite minutely disseminated through the lead sulphide. No argentite or other silver mineral was observed in the sphalerite. This zinc sulphide is dark, lustrous, and either coarsely crystalline or massive and, underground, is sometimes difficult to distinguish from the lead sulphide. Following these minerals, pyrite is probably the most abundant metallic constituent and with it may be associated the small gold values, usually under a dollar to the ton.

The ore veins extend indifferently across the strike of both Lower Cretaceous and the Dewdney series. They also follow lines of fracturing or faulting involving the basic hornblende lamprophyre sills that intersect the Dewdney rocks, and consequently belong to a later period than these intrusives -a deduction which supports the view that these sills are pre-Lower Cretaceous, for they have nowhere been observed to intersect those

[1]Bastin, E. S., Econ. Geol., vol. XI, No. 7, 1916, p. 691.

sediments assigned to this period. The ore-bearing fissures, however, do not appear to cross the feldspar-porphyry dykes which include the Lower Cretaceous rocks, but may, as in the case of the ore showings on the Silver Chief claim, follow either wall of these dykes. The dykes appear, in certain cases at least, either to follow lines of weakness in the sediments they intrude or to be themselves the immediate cause of the fracturing of the rocks in their vicinity. The ore is regarded as being derived either from the great body of Eagle granodiorite to the east of Treasure mountain or from the smaller bodies of quartz diorite occurring near the main divide at the head of Amberty and Sutter creeks and also near the headwaters of Dewdney creek on the western slope of the divide. The greater abundance of ore veins in the direction of this divide, rather than towards the east, favours this quartz diorite as being the principal source of the ore, a theory strengthened by observation of the very noticeable pyritic mineralization of the older formations almost everywhere in the vicinity of this intrusive.

The order of deposition of the ore and gangue minerals is to some extent variable. The gangue is commonly composed of quartz and calcite, but ankerite and stilbite have been observed. These gangue minerals tend to form along the walls of the fissures, leaving the more central portion to be filled, subsequently, chiefly by the ore minerals, of which the most important are galena and sphalerite. Chalcopyrite is sometimes a conspicuous vein mineral and appears to have been the last sulphide precipitated. Pyrrhotite and pyrite, also, are locally abundant, and not only occur within the fissure deposits but commonly impregnate the wall-rock on either side or may be found disseminated through the rock formation far from any fissure deposit. Both of these iron sulphides precede the galena and chalcopyrite, but in one instance at least the zinc blende was observed to be intersected by veinlets of pyrite. Arsenopyrite is noticeably abundant in certain of the properties, and appears to precede the lead and copper sulphides. Its order with respect to the iron sulphides is less certain. There is, probably, however, much overlapping of all the ore minerals, but the order in which they each begin to precipitate seems to be pyrrhotite, pyrite, sphalerite, arsenopyrite, tetrahedrite, galena, chalcopyrite.

The association of ore and gangue minerals at Summit Camp, and the character of the ore deposits suggest that the solutions from which these minerals were precipitated were of intermediate or in the case of some of the properties possibly of high temperature and that, consequently, the source of these solutions was at no great distance from the ore-bodies. It has been shown that the quartz diorite intrusive bodies near the main divide afford the most likely source for the mineralizing solutions and, in this connexion, it is of interest to note that near these intrusives, and within the zone of contact metamorphism, the older formation is heavily impregnated with pyrite and, to a less extent, pyrrhotite and magnetite, but does not include the other ore minerals so common in the fissure veins at a greater distance from the intrusives.

SECTION C: DEWDNEY TRAIL BETWEEN BEAVER LAKE AND NINEMILE CREEK

Section C connects the Similkameen and Coquihalla map-areas and includes part of the Skagit Valley map-area. It follows the pack trail leading from Princeton to Hope, a distance of about 65 miles, and coincides nearly with the old Dewdney trail built in 1860, by a party of Royal Engineers, between Hope and Osoyoos lake. Parts of the old road-bed constructed for 25 miles from Hope, or to Cañon Creek crossing, still remain, but over other sections rock slides have narrowed it to the width of a trail. This route from Lower Fraser valley into the interior of the province has received recent careful consideration as affording a possible solution for the site of a transprovincial highway. The abrupt descent from Hope Summit down Skaist valley (Plate II A) would, however, render construction over this section difficult and costly, and the elevation of the pass, about 5,850 feet, is such that the abundant snowfall of the late autumn and winter months would, probably, close the road during part of each year. A more practicable route leaves the Dewdney trail at Cedar flats a short distance above the mouth of Cedar creek and about 30 miles from Hope. This route follows up Cedar Creek valley and over Allison pass at an elevation of about 4,400 feet into Similkameen valley and thence northward to connect with the Dewdney trail near the mouth of Ninemile creek.

Little geological work has previously been done on this section. In 1877 Dawson followed the route over Hope Summit in his reconnaissance of a large section of southwestern British Columbia.[1] Camsell[2] made a few observations on the mining properties in Whipsaw Creek district. The Skagit Valley sheet includes a section of the trail on either side of the mouth of Sumallo river. Near the junction of this stream with Skagit river are a number of mining properties collectively referred to as Twentythreemile Camp.

In addition to the ore deposits of Twentythreemile Camp some mineral showings on Whipsaw creek were visited by the writer, and, from the character and relation of the geological formations over a large part of the section, there seems every likelihood that with more careful prospecting other discoveries of importance may be made. Some placer mining was done a number of years ago on Whipsaw and Ninemile creeks, but the productive bars have been worked out and no important discoveries have since been made.

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[1]Geol. Surv., Can., Rept. of Prog., 1877-78.
[2]Geol. Surv., Can., Sum. Rept., 1911, p. 123.

General Geology

The geological formations include representatives of the Carboniferous; of, probably, all periods in the Mesozoic; of the Oligocene and later Tertiary time; and of the Quaternary.

Table of Formations

Quaternary	Glacial and Recent deposits
Post-Oligocene	Porphyritic andesites, trachytes, and basalts; tuffs and breccias
Oligocene	Shales, and sandstones with seams of lignite
Post Lower Cretaceous	Hornblende diorite and diorite porphyry
	Quartz diorite
	Biotite granodiorite
Late or Post Lower Cretaceous	Eagle granodiorite?—foliated in part—may be pre-Cretaceous
Lower Cretaceous	Conglomerate, arkose, shale
Upper Jurassic (may be Lower Cretaceous)	
	Dewdney series; tuffaceous beds; feldspathic sediments; shale and slate
Jurassic	Basic intrusives; diorite, gabbro, pyroxenite
Triassic	Tulameen series?
	Chlorite and hornblende schists; conglomerate, greywacke, limestone
Carboniferous	Cache Creek (Hozameen)
	Andesite flows and pyroclastic rocks both schistose and massive and including later intrusives; chert, argillite, slate, limestone.

CARBONIFEROUS

The Carboniferous rocks occur chiefly in the basin of Sumallo river. They are continuous into Coquihalla area where they were referred to the Pennsylvanian period and correlated both with the Cache Creek rocks of Thompson valley and with the Hozameen series at the International Boundary. They are composed of volcanic and sedimentary rocks. The volcanic members are chiefly dark green andesitic rocks referred to in a general way as greenstones. They consist dominantly of flow types, but include some pyroclastic beds. In part these rocks are massive and of these some, probably, represent later intrusions. A large proportion, however, of these greenstones exhibit some degree of schistosity and, in part, have a very slaty structure. The more deformed members show much alteration to chlorite and, in some cases, to sericite. The sediments include chert, slate, and limestone. The limestone occurs in small proportion compared with either the chert or slate, but is of economic importance in that the ore deposits of the section are commonly associated with it. The siliceous material composing the chert was, probably, derived from a magmatic source associated with the volcanic extrusions, but the slates are composed of normal sedimentary detritus.

Near igneous intrusions these older rocks are all metamorphosed in varying degrees. The limestone suffers the most complete change, and its identity may be completely obscured in the process. The cherty and slaty rocks may also be greatly altered in composition and appearance.

Near the junction of Sumallo and Skagit rivers, and alongside the Dewdney trail, outcrops of a peculiar mottled rock may be seen. This rock was originally a chert interbedded with thin layers of slate or argillite. It has been irregularly bleached by the nearby intrusion of quartz diorite, and recrystallized to form a much coarser-grained rock than that from which it was derived.

These Carboniferous (Cache Creek) rocks have a general trend of north 30 to 40 degrees west; and, north of Sumallo river, dip at an average angle of 50 to 60 degrees to the southwest. South of the river several dips in the reverse direction were observed. The structure, however, includes probably more than one major fold and is complicated by faulting, thrusting, and overturning to the northeast.

The ore deposits of Twentythreemile Camp occur in these rocks and will be referred to more fully in discussing the economic geology of this section.

TRIASSIC

Tulameen Series

Exposures of rocks correlated provisionally with the Tulameen series occur in the belt, averaging 2 miles in width, which crosses Whipsaw creek between 3½ and 6½ miles below Hope Summit. The section of sedimentary rocks exposed on the ridge to the east of Whipsaw creek has also been included in this series. Remnants or inclusions, presumably of the same rocks, were observed at other points in Whipsaw valley. Many are too small to map, and others, replaced largely by batholithic material, are mapped with these intrusives. The series is composed in part of greenstone schists representing greatly altered flow and fragmental volcanic rocks of general andesitic composition, and in part of sedimentary rocks including fine conglomerate, greywacke, argillites, and occasional beds of limestone. The occurrence of the limestone strata between volcanic flows and pyroclastic beds suggests deposition of the whole series beneath the surface of the sea.

The volcanic members of the series are most abundantly represented in the belt previously referred to. They vary in character according to their original constitution and their subsequent metamorphosis. The principal varieties include mica and hornblende schists. The latter are abundantly exposed in the zone of contact metamorphism of the batholithic intrusives and, in certain cases, represent products of complete, or nearly complete, recrystallization. Both varieties of schist may be chloritized or sericitized, depending upon their original mineral composition. Calcite is frequently an important secondary mineral. The fragmental beds as a rule are difficult to separate in the field from the flow types, and even under the microscope alteration has sometimes proceeded so far as to render doubtful the original character of the rock. In general these volcanics are of intermediate or andesitic composition. Hornblende is the predominating mafic mineral, but pyroxene may also be present.

The sedimentary members of the series occur most prominently on the ridge east of Whipsaw creek above the junction of Ninemile creek. Here a number of exposures were observed over a distance of about 2 miles. These outcrops, however, threw but little light on the structure of these beds. Some fine conglomerate was observed in the more southerly outcrops, but the bulk of the rocks are fine-grained greywackes and slates containing a considerable proportion of calcite. No limestone beds were noted. These rocks are probably of the same age as other smaller remnants still remaining in the main valley of Whipsaw creek. Of these an important exposure crosses Whipsaw creek about 7 miles above the mouth of Ninemile creek. It is surrounded by intrusive diorite and has been metamorphosed to a dark grey, massive hornfels. On close examination it shows banding, but the attitude is very irregular. These are probably the rocks in which Dawson[1] found a few poorly preserved fossils doubtfully identified with the Triassic pelecypod *Monotis subcircularis*.

A few limestone beds were observed associated with greenstone schists farther up Whipsaw creek. Near their contact with the belt of granodiorite these beds have been greatly metamorphosed and, in certain localities, mineralized by a variety of metallic sulphides carrying values in copper, silver, and gold.

The general trend of these Triassic rocks, about 20 to 30 degrees west of north, together with their association with basic intrusives on the one side and a large body of granodiorite on the other, tends to correlate them with the Tulameen series of Tulameen area, where similar relations were observed. The Tulameen series has been placed tentatively in the Triassic[2], and the Triassic fossil *Monotis subcircularis* has been discovered in the rocks of Whipsaw valley. In addition there is a very great lithical resemblance between the members in Tulameen area and those in the present section.

UPPER JURASSIC?

Dewdney Series

To the northeast the Cache Creek rocks are in unconformable contact with a series of younger sediments referred tentatively to the Upper Jurassic, but possibly Lower Cretaceous. These have been correlated on lithical and faunal grounds with the Dewdney series from Coquihalla area, and may also include some representatives of the Ladner series in that area. To the south they are continuous with members of the Pasayten series[3] at the International Boundary. With the Pasayten series would also be included the Lower Cretaceous rocks from the present section. The latter, however, seem to the writer to be distinct from the members of the Dewdney series, not only lithically but also in age. The distinction is not as evident in this section as in Coquihalla area where the division was first made and it is quite possible that the series mapped as Dewdney or Upper Jurassic in section C may include members which more detailed study would correlate with the Lower Cretaceous rocks.

[1] Geol. Surv., Can., Rept. of Prog., 1877-78, p. 66 B.
[2] Camsell, C., Geol. Surv., Can., Mem. 26, p. 42.
[3] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 479.

The rocks included with the Dewdney series in section C form a belt about 5 miles wide extending across Skagit and Skaist rivers in a general north 15 degrees west direction above the mouth of Cañon creek. This trend corresponds closely with the average strike of the series. The structure is, apparently, synclinal, complicated by minor folding and by much faulting. A large part of the series is thinly bedded in shades of brown and black and some distinctly slaty strata are included. Massive beds are also abundant and from these in particular and at a number of localities poorly preserved fossils were discovered. The most important collection was made from the southern shoulder of Hopeless mountain (Plate II B), overlooking the valley of Cañon creek. The fossils were regarded as belonging to the same fauna as that obtained from the Dewdney series of Coquihalla area. The similarity in lithology and structure of the rocks from these two fossiliferous localities makes their correlation even more certain.

In a general way the members of the Dewdney series in section C are notable under the microscope for their tuffaceous appearance, a characteristic obtaining even in those members which in the outcrop and hand specimen strongly resemble normal sediments. The coarser rocks are all highly feldspathic. Their constituents under the microscope include plagioclase of intermediate composition, a minor proportion of quartz grains, and abundant fragments of lava, the whole in an almost isotropic ashy groundmass. The proportion of crystal to lithic fragments varies greatly and the groundmass usually constitutes a large proportion of the slide, differing in this respect from the feldspathic greywackes and arkoses of the Lower Cretaceous. Occasional sills of hornblende lamprophyre were observed in this section. They have been referred to in discussing the geology of the Dewdney series in section B and, as noted there, do not appear to cut the Lower Cretaceous rocks. Exposures of slate occur at Skagit bluffs between 2 and 3 miles above the mouth of Cañon creek, and also on the divide west of Skaist river, a short distance above the junction of that stream with Cedar creek. These slates are much softer and more argillaceous than the bulk of finer-grained members of the series. They are sparingly fossiliferous.

LOWER CRETACEOUS

Rocks referable to the Lower Cretaceous form a belt between 4 and 5 miles wide crossing Skaist river in a direction a few degrees west of north about 3 miles above the mouth of Cedar creek.

These rocks comprise conglomerates, arkoses, and shales, but no distinct limestone beds were observed in the series. The conglomerates vary in coarseness and in some the constituent cobbles average as much as 3 or 4 inches in diameter. These are well rounded and include a variety of rock types among which representatives of granitic and dense cherty rocks are most conspicuous. The coarsest and thickest conglomerate belt observed in this series is exposed in rock-cuttings along the trail down Skaist river beginning about half a mile below that point where the trail first crosses the river below Hope Summit. This conglomerate has an estimated thickness of about 700 feet. It strikes north 60 degrees west across the valley and dips to the southwest at 45 degrees. On the line of its strike it is carried up onto the hills on either side of Skaist river. Towards the west the belt rapidly diminishes in width and coarseness, but on the east side of the valley it extends more uniformly, as far, apparently, as the granodiorite contact. Other narrower bands of conglomerate were observed in the series and fine conglomerate beds occur near the contact of these rocks with the Dewdney series.

The bulk of the series is composed of coarse to fine-grained grey arkoses often so massive and crystalline as at first glance to be mistaken easily for plutonic rocks. Very similar types occur in Coquihalla area and are mentioned in section B of the present report. They are composed largely of the detritus of acid plutonic rocks. The constituent grains are very angular. Feldspar is prominent and is noticeably fresh. Quartz is the most abundant mineral and in this respect these rocks differ from the Dewdney series where feldspar and lithic fragments predominate.

The finer-grained types include dark slaty and shaly rocks, which, however, constitute a much smaller proportion of the series than the coarser sediments.

These Cretaceous rocks are in contact to the southwest with members of the Dewdney series and to the northeast with a belt of granodiorite that occupies a wide stretch of the trail on either side of Hope Summit. They are, in addition intersected by an abundance of porphyry dykes and by one large body of diorite porphyry. The general structure of the series is, apparently, monoclinal with an average dip of about 50 degrees to the southwest, and in this direction it might appear as if these rocks dipped under the Dewdney series. Their attitudes, however, where observed near their contacts, did not coincide, and the change in the character of the rocks from the massive conglomerates and arkoses of the Cretaceous to the tuffaceous members of the Dewdney is abrupt. Moreover, in other areas farther to the northwest, the Dewdney series has been shown to underlie the Cretaceous rocks. It is probable, therefore, that the relation between the two series is here a faulted one.

INTRUSIVE ROCKS

Intrusive rocks occupy a large proportion of section C. They range in age from Jurassic or Jura-Cretaceous to Tertiary and in composition from pyroxenite to granite.

Jurassic?

Pyroxenite Diorite Complex. The intrusives included in this group are the oldest in the section. They are exposed at a number of points along and on either side of Whipsaw Creek trail. Pyroxenite is best exposed on the hills on both sides of Whipsaw creek within a mile or so of the large belt of Triassic (Tulameen) rocks. Farther down the valley the intrusives are less basic in appearance and are more nearly allied in composition to diorite. Occasional small outcrops of these intrusives occur higher up Whipsaw valley within the area mapped as Triassic, but are too small to map.

The rocks included in this group have a sheared and in part, a distinctly gneissic appearance. The most abundant type is a dark green hornblende diorite merging in its more basic phases to gabbro. The exposures farthest up Whipsaw creek include a considerable proportion of almost pure pyroxenite which appears, without reasonable doubt, to form a part of the same complex as the diorite. There is a great resemblance between this pyroxenite and that observed in Tulameen area, and although the former was not studied microscopically its general appearance and associations and its occurrence almost in line with the basic rocks from Tulameen area have suggested its correlation with these more northerly exposures.

The age of the pyroxenite in Tulameen area has been regarded as Jurassic. That in Whipsaw valley cuts sediments containing fossils of presumably Triassic age and is, in turn, intersected by a belt of granodiorite whose age has been referred to the Cretaceous, following a tentative correlation with the Eagle granodiorite of Coquihalla area. This pyroxenite, and consequently the basic complex as a whole, is, therefore, placed in the Jurassic, but it may be of late Cretaceous age.

Eagle Granodiorite

Extending across the trail on either side of Hope Summit for a total width of over 5 miles is a crystalline complex with the average composition of granodiorite but including more acid as well as more basic phases. This intrusive is, in part, distinctly foliated. Banding is particularly pronounced near the more easterly contact with Triassic greenstone schists and seems to be due, in some degree, to replacement of these schists by batholithic material which still preserves the laminated structure of the older rock. The general trend of foliation corresponds closely with that of the schistosity in the adjacent greenstones, being north 30 to 50 degrees west, with dips of 35 to 90 degrees southwest. Over a large part of the central part of the granodiorite belt east of Hope Summit this intrusive is more massive, although even in this section foliation is sometimes observed. Between Hope Summit and the contact with Cretaceous rocks on Skaist river this intrusive is more generally gneissic and the composition in part more nearly allied to diorite than granodiorite.

The essential minerals composing the granodiorite include quartz, orthoclase, plagioclase, mica, and hornblende. Glassy quartz is usually conspicuous, but in the more basic phases may be very subordinate to either plagioclase or hornblende. Orthoclase is less abundant than plagioclase and is commonly slightly pink in colour. Plagioclase is the predominant feldspar and ranges in composition from albite-oligoclase to andesine. Biotite is the common mica, but muscovite is more abundant in some sections of the belt and the composition of the rock in such instances more nearly approaches that of a granite than a granodiorite. Hornblende is a variable constituent. Apatite, magnetite, and titanite are common accessory minerals. Secondary minerals include epidote, chlorite, and sericite.

The age of this granodiorite cannot be definitely fixed. No actual contact with the Lower Cretaceous sediments to the southwest was observed, but the general trend of these sediments is at an angle to the line of foliation in the granodiorite, and suggests either an intrusive or faulted relation.

In view of the probable correlation of this granodiorite with the Eagle granodiorite of Tulameen and Coquihalla areas it seems to the writer that the relations observed in Skaist valley are indicative of intrusion. Subsequent faulting, may, however, also have occurred.

Biotite Granodiorite

To the north of Sumallo river and on either side of Eighteenmile creek are two areas of intrusive rocks so similar in lithological and structural characteristics as to admit of correlation. The more westerly body is much the larger and extends into Coquihalla map-area, where it was correlated with the later Cretaceous intrusives and referred to as an acid granodiorite. The principal constituents are abundant glassy quartz, white to pinkish feldspars, and biotite. The proportion of orthoclase in specimens examined microscopically is considerably less than that of plagioclase. The latter is about albite-oligoclase in composition. Some hornblende is usually present, but in smaller proportions than biotite. These intrusives are moderately coarse and massive. They have, however, been crushed and sheared to a certain degree and the constituent minerals show strain under the microscope.

Quartz Diorite

An intrusive body of the general composition of quartz diorite is exposed near the mouth of Sumallo river and extends northerly between this stream and Cañon creek. It is referred to by Camsell[1] and is almost identical lithically and structurally with the quartz diorite at the head of Dewdney creek, described in section B of this report. It is typically a light-coloured massive rock of medium grain in which large rectangular crystals of hornblende are often conspicuous. Its northerly exposures in section C are more basic. Glassy quartz, plagioclase, hornblende, and biotite are the more important constituents. Some orthoclase is present. Magnetite, titanite, chlorite, and calcite constitute the common accessory and secondary minerals.

With this quartz diorite is included another intrusive body exposed on the hills east of the mouth of Sumallo river and south of Skagit river above the mouth of Cañon creek. It has been called a "granophyre" by Camsell[1] who described it as "a fresh, light-coloured rock of medium grain containing quartz, feldspar, biotite, chlorite, and titanite with much secondary calcite". It is regarded by the present writer as of probably the same age and origin as, and very similar in composition to, the quartz diorite body west of Cañon creek.

These intrusives cut both the Carboniferous (Cache Creek) and Dewdney series. The quartz diorite in Coquihalla area intersects sediments regarded as Lower Cretaceous and was assigned tentatively a late or post-Lower Cretaceous or possibly Tertiary age. The intrusives in section C cannot be placed more closely than this.

[1]Geol. Surv., Can., Sum. Rept., 1911, p. 119.

Hornblende Diorite and Diorite Porphyry

Intersecting the Cretaceous sediments on either side of Skaist river are a number of hornblende and feldspar porphyry dykes which, unless closely observed, are easily confused with the sediments themselves. These dykes appear to radiate from a locality to the north of Skaist river where a large body of diorite intrusive forms the body of some of the larger peaks on the divide between Skaist river and Cañon creek. These rocks vary somewhat in colour and texture, but have the general composition of a diorite. Hornblende is usually a conspicuous mineral, occurring in the more porphyritic varieties as comparatively large phenocrysts. Plagioclase is always abundant. It may form even larger and more numerous phenocrysts than the hornblende and usually constitutes the bulk of the groundmass. A little quartz is usually present. Both hornblende and feldspar show some alteration, the former to chlorite, and the latter to sericite and calcite. Calcite is sometimes quite an abundant secondary mineral.

These rocks intersect sediments, presumably of Lower Cretaceous age. Their comparatively fresh appearance and massive structure point to a later period in geological time than that represented by the granodiorite of Hope Summit. No definite intrusive relations, however, were observed near the contact of these two formations and no dykes similar to those intersecting the Cretaceous sediments were found cutting the granodiorite. From such negative evidence it is considered that the diorite and diorite porphyry intrusives may be faulted against the granodiorite. Such faulting would be on a large scale and referable, therefore, to an orogenic activity in late Mesozoic or early Tertiary time. Consequently, these intrusives are, perhaps, of Cretaceous age and are, probably, related to the quartz diorite intrusions already described from farther down Skagit valley.

TERTIARY ROCKS

Oligocene

A very small area of Oligocene sediments occurs at the extreme northwestern end of this section. It is included within the preliminary map and report on Similkameen district[1] and will only be briefly referred to here. In section C these rocks are mainly of thinly-bedded shales containing an abundance of plant remains. Fossil insects, also, have been obtained from this locality.[2]

On palæontological grounds these rocks have been assigned to the Oligocene period and correlated with the Coldwater group of the Nicola River country. Some coal prospects have been located in these rocks on Ninemile creek.[3]

[1]Camsell, C., Geol. Surv., Can., Rept. No. 986, pp. 27-31.
[2]Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877-78, p. 130 B.
[3]Camsell, C., "Preliminary Report on a Part of the Similkameen district, B.C.," Pub. No. 986, p. 30.

Post-Oligocene Volcanic Rocks

Under this heading is grouped a series of extrusive rocks which overlie the Oligocene sediments. They cover a considerable area within the present section and are widely exposed farther to the east and north. They include both pyroclastic and flow types, and many of the dykes cutting both these volcanic rocks and older formations in this general locality belong probably to about the same period of igneous activity.

These volcanic rocks range from rhyolites to basalts with a preponderance of intermediate or andesitic types. The flow rocks are nearly all porphyritic and the majority of them show prominent phenocrysts of more than one mineral, usually feldspar and hornblende, in an otherwise dense groundmass. The pyroclastic types also show embedded crystals caught up in fragments of lava, and suggest that the development of these phenocrysts took place prior to the eruption of the volcanic materials. The flow rocks are commonly vesicular and the amygdules are partly or completely filled with chalcedonic quartz, calcite, or zeolites. Thin sections of these rocks are mostly fresh, and flow structure is often pronounced. Plagioclase commonly shows well-developed zonal structure.

QUATERNARY

Evidences of glaciation are everywhere abundant in section C. In the more mountainous areas glacial striæ pointing southwestward were observed up to heights of about 6,500 feet. Mountain glaciation has been pronounced, and on the northeastern flanks of Seventeenmile hill a small glacier still remains, a tiny remnant of a once great field of ice which swept over the entire area in Pleistocene time. The plateau country was entirely covered by this ice field and its upland topography has consequently been subjected everywhere to ice erosion. Glacial striæ were observed at certain points on Whipsaw creek running approximately parallel to the valley.

Superficial deposits are relatively scarce in the western mountainous part of section C and are chiefly confined to the lower stream valleys where the more gentle gradients permitted their accumulation. Their almost complete absence from the valley of Skagit river was commented upon by Dawson[1] following his reconnaissance work along the Dewdney trail in 1877. On the less rugged plateau country drained by Whipsaw creek, deposits are more widespread and include both unmodified and modified types. The former include patches of boulder clay which are found clinging to the more gently sloping valley walls. The modified deposits include the numerous remnants of terrace deposits formed in the more important valleys by the reassortment under water of glacial debris left, principally, during the retreat of the glacier ice. A number of such terraces were observed in the valley of Whipsaw creek. Their elevations above the mouth of Ninemile creek are given by Dawson[2] as 2,956, 3,078, 3,237, 3,252, and 3,845 feet. The last of these stands 200 feet above the present stream bed.

[1]Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1877–78, p. 48 B.
[2]Geol. Surv., Can., Rept. of Prog., 1877–78, p. 147 B.

Since the deposition of these terrace deposits they have been deeply incised or entirely cut through by the streams. A large part of the original terrace deposits has been carried away and has mingled in the lower reaches of the valley with products of more recent stream erosion.

Both the present stream deposits and older bench gravels have been explored for placer deposits, but no claims are at present being worked within the limits of the section.

Economic Geology

PLACER DEPOSITS

Reference has already been made to the occurrence of placer deposits in the valleys of Whipsaw and Ninemile creeks. It was pointed out that such productive bars as were discovered a number of years ago are worked out and that no recent placer work has been done in these creeks. The occurrence of basic intrusive rocks very similar to, and probably continuous with, some of those from Tulameen area suggests that these may have contributed any platinum values occurring in these stream deposits, but that the more acid intrusives and the patches of either sedimentary or volcanic rocks metamorphosed and mineralized by these intrusives constitute a more likely source of placer gold. The basic intrusives were not observed to include any of the platiniferous peridotite like that occurring in Tulameen area and its absence from section C accounts, probably, for the lack of important platinum deposits there.

LODE DEPOSITS

The lode deposits of this section fall into two groups: (1) contact metamorphic deposits in limestone containing values in gold and copper; and (2) silver-lead deposits. The deposits of the first class are the more numerous. They usually include small stringers of argentiferous galena in very minor proportions to those minerals with which the gold and copper values are associated. These deposits are invariably low grade and depend for their economic importance on their bulk, which is in certain cases large, and on transportation facilities, which, up to the present, have been poor. If a transprovincial highway were built through this section, an impetus would doubtless be given to both prospecting and development work.

The bulk of the properties at Twentythreemile Camp and lower down Skagit river, and the ore deposits on the Marian group of claims on Whipsaw creek, may be included in the first group. The ore occurs in members of both the Carboniferous (Cache Creek) and Triassic (Tulameen) rocks. The limestone beds affected by heat and mineralizing solutions are not as a rule over a few feet thick and in some cases have been entirely recrystallized. The ore minerals include various sulphides of which pyrrhotite is the most generally abundant and characteristic. Others are pyrite, arsenopyrite, galena, sphalerite, and molybdenite. Magnetite also occurs in these deposits. In addition to calcite the gangue includes various lime silicate minerals of which andradite and grossularite, garnets, epidote, tremolite, wollastonite, and diopside, are most common.

The deposits of the second, or silver-lead, class are not as common as the other, and appear, from their geological association and mode of occurrence, to have originated under somewhat lower temperature conditions. They occur as comparatively narrow veins or stringers cutting rocks of both Carboniferous and Triassic age irrespective of the particular composition of the members of these series. Galena is the most abundant and important ore mineral, but sphalerite, chalcopyrite, and pyrrhotite may be associated with the lead sulphide. The Silver Daisy mine at Twentythreemile Camp and the showings on the S. and M. group on Whipsaw creek may be included in this class.

S. and M. and Marian Groups

A brief reference to these properties is given by Camsell in his report on the Whipsaw Creek district.[1] The S. and M. group consists of eight claims on the north side of Whipsaw creek about 4 miles below Hope Summit and mainly east of the tributary stream known as Fortyfivemile creek. The property lies about 45 miles east of Hope and 20 miles west of Princeton. It adjoins the Marian group of five claims lying on Marian mountain between Fortythreemile and Fortyfivemile creeks. A trail has been constructed through these properties a short distance above the main trail down Whipsaw creek. Geologically, these two groups lie on either side of the contact between a belt of greenstone schists and another of intrusive granodiorite correlated provisionally with the Tulameen series and Eagle granodiorite of Tulameen area.

S. and M. Group. The S. and M. group falls almost entirely within the greenstone belt of soft chloritic schists and others less altered. A thin section from one of the latter proved under the microscope to be completely recrystallized and composed principally of clear crystals of plagioclase and quartz of about equal size and arranged in rows parallel with others of greenish hornblende. Included in the slide were some grains of iron sulphide and numerous specks of black carbonaceous material.

Development work on this group includes four short adits, two shafts, and five large open-cuts. A large part of the work has been done on the S. and M. claim near the middle of the group. The ore occurs in a decomposed green chloritic schist which forms a belt from 200 to 250 feet wide running about east and west between walls of more massive hornblende schists. The entire belt is more or less sparingly mineralized with iron and copper sulphides and, according to the owner, has assayed $2.50 in gold. The principal values are, however, regarded as occurring in a number of stringers of ore from a fraction of an inch to 2 or 3 inches wide. These are composed chiefly of galena. A picked sample of the ore assayed by the Mines Branch, Ottawa, gave 151·8 ounces silver, 48·5 per cent lead, and 1·70 per cent zinc. The best assay of a sample of ore selected by the owner gave, per ton, 325 ounces silver, 68 per cent lead, 2 per cent copper, and 60 cents in gold.

[1]Geol. Surv., Can., Sum. Rept., 1911, p. 123.

Although galena is the most important ore mineral on this property, sphalerite is an important or even dominating constituent in some of the showings. Chalcopyrite and pyrite are also present in smaller proportions. Quartz is the chief gangue mineral. Calcite is less common.

Both ore and wall-rock are greatly decomposed by surface waters and as none of the workings have penetrated below the zone of oxidation it is impossible to obtain reliable figures as to values in the primary ores beneath.

Marian Group. The Marian group consists of five claims adjoining the S. and M. group to the west and located along the contact of the granodiorite with greenstone schists and intercalated limestone beds. The latter, from a few inches to several feet thick, form a large part of a zone between 300 and 400 feet wide adjoining the granodiorite contact.

The ore deposits are associated with the limestone beds and are of contact metamorphic origin. A variety of admixed sulphides occur, including pyrrhotite, pyrite, sphalerite, galena, and molybdenite. Magnetite is also conspicuous. The gangue includes calcite and quartz together with an abundance of garnet, epidote, pyroxene, and other lime silicates.

The principal workings are located on the Marian No. 1 claim and include a shaft, large open-cuts, and an adit, in all of which a very similar type of ore is encountered. A composite picked sample from the different showings was obtained by the owner and on assay gave: 30 per cent lead, 2 per cent copper, and $12 gold and 8 ounces silver per ton.

The occurrence of the ore is, as is characteristic of this type of deposit, very irregular. The total zone of mineralization includes a belt 300 to 400 feet wide adjoining the granodiorite. Only in relatively small sections of this, however, is mineralization sufficiently heavy to be of economic importance and even in these the values are low. The zone of mineralization follows the intrusive contact for a mile or more and is confined chiefly to the different limestone beds within this belt. The ore-bodies, even within these beds, are very irregular in outline and variable in mineral composition. At one locality, on the Defiance claim, a ledge of pyrrhotite 50 feet wide was reported to occur.

Twentythreemile Camp

The properties at Twentythreemile Camp were visited by the writer in the summer of 1920,[1] since which time no new properties have been opened up and only a little additional development work has been done on the old. The present report must, therefore, be considered merely a supplement to what has already been written. It contains a few additional observations based chiefly on a more intimate knowledge of the areal geology in the vicinity of the camp.

Prospecting and development work at Twentythreemile Camp has been more or less active since 1910 when, following the ill-advised stampede caused by the reputed discovery of rich gold ore at Steamboat mountain[2], more systematic prospecting of Skagit valley resulted in opening up a number of properties north of the International Boundary, of which those at Twentythreemile have attracted particular attention.

[1]Geol. Surv., Can., Sum. Rept., 1920, pp. 39–41 A.
[2]Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, p. 120.

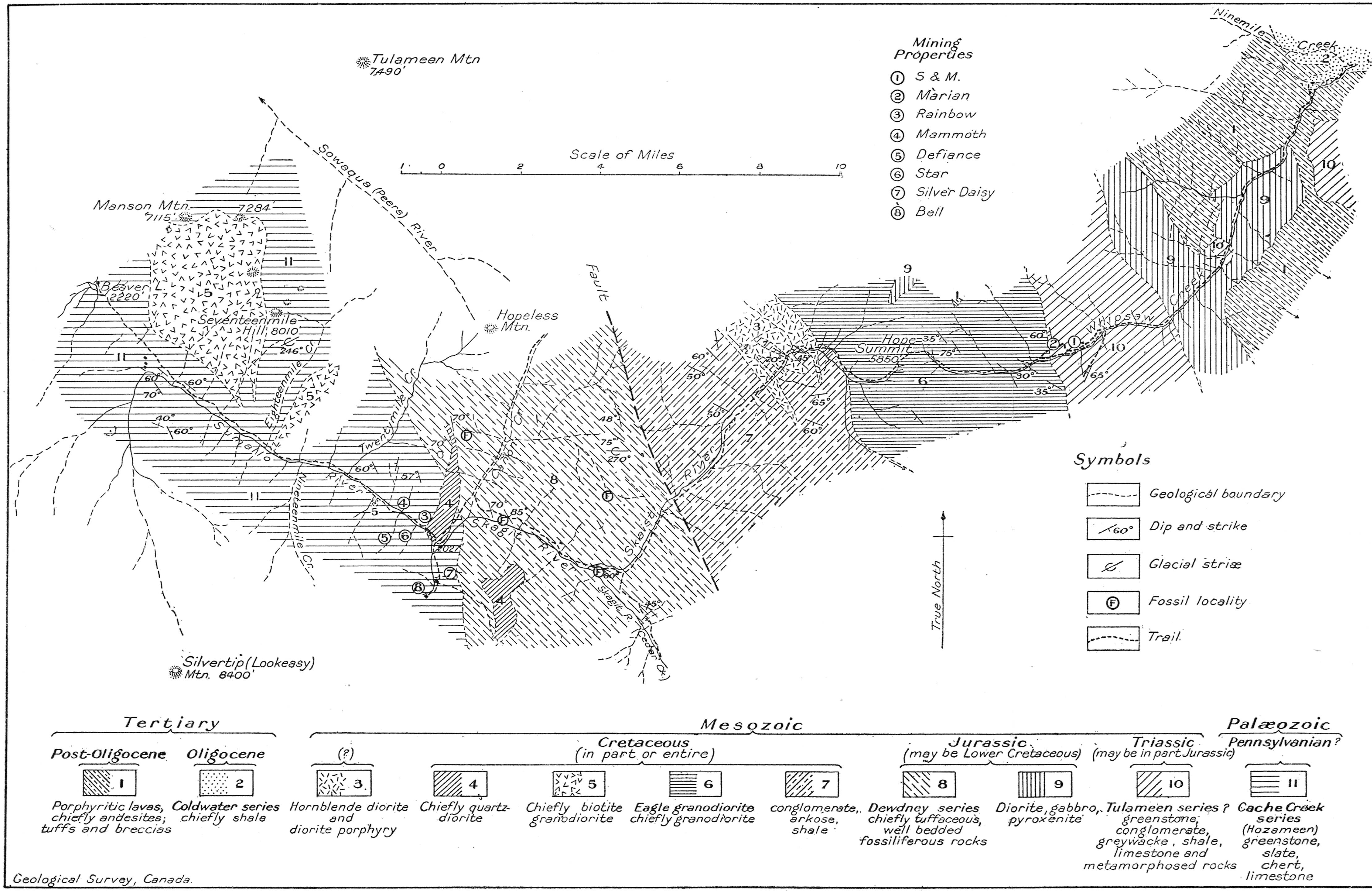


Figure 11. Geology along the Dewdney trail between Beaver lake and Ninemile creek (Area C).

58617—To face p. 120.

An idea of the general geology in the vicinity of the camp may be obtained from the map accompanying this report (Figure 11). All the properties occur in reported rocks of presumably Carboniferous age which have been correlated with the Cache Creek series of Thompson valley and with the Hozameen rocks from the International Boundary. These rocks include great thicknesses of greenstones and sediments. The former are represented chiefly by old schistose volcanic flows of andesitic composition, but include other more massive and more coarsely crystalline members which are probably younger and intrusive in the Carboniferous rocks. The sediments include banded and more massive cherty rocks, slates, thinly banded argillites, and massive limestone beds. The latter are of particular importance in connexion with the ore deposits of the camp. These older rocks are intruded by a couple of comparatively large bodies of quartz diorite and by a number of dykes of varying composition. In addition, there are massive andesite members included with the Carboniferous rocks which are in part intrusive.

As defined in the general discussion of the economic geology of section C, the ore deposits at Twentythreemile Camp fall under two groups: (1) contact metamorphic and high temperature replacement deposits chiefly in limestone, whose principal values are in gold and copper; (2) lead-silver vein deposits.

Under group (1) are included the principal ore deposits on the Mammoth, Bell, Defiance, and, in part, the Rainbow groups of claims. Group (2) would include the Silver Daisy, Star, and, in part, the Rainbow group of claims. A more particular discussion of some of these properties follows.

Mammoth Group. No considerable development work has been done on this property since last reported upon.[1] This showing is chiefly notable for the presence of the lime tungstate, scheelite, associated with lime silicate, carbonate, and sulphide minerals resulting from the metamorphism and mineralization of an original limestone bed about 50 feet thick. Of the lime silicate minerals the most remarkable is anorthite which occurs in coarsely crystalline masses associated with the scheelite and clusters of green crystal aggregates of fibrous actinolite. The ore minerals include an abundance of nickeliferous pyrrhotite and dark ferruginous sphalerite. Pyrolusite and molybdenite are less common constituents.

It was at first thought that the metamorphism and mineralization of the limestone on this property resulted from the intrusion of the body of quartz diorite nearly a mile to the east of the showings on these claims. Although this distance seemed great considering the metamorphism displayed it was believed that a plunging contact of the quartz diorite towards the west would bring it much closer to the ore deposits in a vertical than in an horizontal direction and that the hot solutions arising from this intrusive would be sufficient to effect the metamorphosis now apparent. A more recent study of the geology of this camp has, however, tended to throw some doubt on this hypothesis and favours an alternative view that the more massive hornblende andesite and diorite porphyrite rocks included with the greenstones of the Carboniferous rocks are, in part, intrusive and have effected the metamorphism and mineralization not only in this but in other properties of this camp.

[1] Geol. Surv., Can., Sum. Rept., 1920, p. 40 A.

Bell Group. The Bell group of eight claims has been described in an earlier report, where it was referred to as the Diamond group[1]. Additional development work has been confined to further surface stripping and to the driving of a short adit on the principal showing about 360 feet above the bed of Skagit river.

More recent examinations of this property have, as in the case of the Mammoth group, led the writer to the conclusion that the metamorphism displayed by the several limestone beds has resulted from the intrusion of many dark green andesite dykes which, along the hillside farther to the north, coalesce to form larger, more irregular bodies. On the Bell group a series of such andesite dykes, striking approximately parallel with Skagit valley, are encountered on the way to the summit. Where these come in contact with limestone beds the latter are metamorphosed to more compact garnetiferous lime silicate rocks containing a variety of metallic minerals of which pyrrhotite, arsenopyrite, sphalerite, and chalcopyrite are the most abundant.

About 600 feet above the river a small irregular body of white quartz-porphyry was encountered, but, as far as could be determined, it is post-mineral in age and of no economic importance.

For a more detailed description of the ore deposits on this property the reader is referred to the earlier report[1].

Rainbow Group. The Rainbow group of three claims lies east of the Mammoth group and, like all other properties at this camp, occurs in Carboniferous rocks. These are chiefly banded chert and argillite, with a smaller proportion of greenstones. To the east of this property is the area of quartz diorite which, together with a number of porphyry dykes that are probably off-shoots from the larger intrusive, is regarded as the particular source of the metamorphism and mineralization on this group of claims.

Development work on the Rainbow group consists of a number of open-cuts and a couple of short adits on a series of narrow ore veins and on less regular replacement deposits. The veins are mostly less than half a foot wide, but, occasionally and for short distances, are a foot or more. Although irregular in detail the majority of these veins have a general parallelism, running about north 60 degrees east. They stand almost vertically. On the whole the vein deposits have well-defined walls, but the ore-bodies may occupy a zone of fracturing along which mineralization has occurred, and on either side of which the rocks are impregnated for a variable distance without limiting walls.

It would appear that at no great date preceding the intrusion of quartz diorite and other dyke rocks, the older formation had been subjected to considerable fracturing and deformation, and that the resultant lines of weakness furnished suitable channels for ascending hot solutions genetically related to the intrusives.

A variety of ore minerals are present in these deposits, chief among them being galena, sphalerite, chalcopyrite, pyrite, pyrrhotite, and arsenopyrite. Other minerals include sulphantimonide and sulpharsenide salts of lead and copper, but these are present in very minor proportion. Quartz is the chief gangue mineral. It may be either white, massive, and sugary in texture or may occur in clusters or as individual clear crystals. The

[1]Geol. Surv., Can., Sum. Rept., 1920, p. 39 A.

principal values on this property are in silver, but in certain of the showings copper minerals, chiefly chalcopyrite, are most important. A shipment of $8\frac{3}{4}$ tons of ore sent to Trail smelter in 1914 returned per ton 0·06 ounce gold and 15·7 ounces silver; 0·70 per cent copper, and 2·8 per cent zinc.

HEDLEY AREA

About a week of the field season was spent in Hedley mining area in an examination of the Nickel Plate mine and of several smaller properties nearby. The writer wishes to convey his thanks to Mr. G. P. Jones, General Superintendent, and to Mr. B. W. Knowles, Mine Superintendent, at the Nickel Plate mine, and to other mine officials, prospectors, and property owners of the district for the many courtesies extended to him during his visit.

The Hedley mining area, embracing about 16 square miles near the town of Hedley, and the Nickel Plate mine were reported on in detail by Camsell[1] following his investigations in 1907 and 1908. In this report both the areal and economic geology were fully discussed and to it the reader is referred for the nomenclature and relations of the geological formations and for the discussion of the ore deposits. The following remarks relate chiefly to developments since 1910.

Nickel Plate Mine

The work of the Hedley Gold Mining Company is at present confined to the deposits at the Nickel Plate mine. The underground workings have been extended to the 1,200-foot level in which distance six ore-bodies have been discovered. In all, some $8,000,000 worth of ore averaging about $9.50 a ton has been extracted. The general trend of the ore-bodies with depth is towards the northwest. They follow the limestone beds of the Nickel Plate formation, but obliquely to the dip of these rocks which is, in general, towards the west, so that the inclination, or pitch of the ore-bodies, is somewhat less than that of the enclosing formations. They may occur on either side, but favour the hanging-wall of a series of gabbro-porphyry sills intersecting the older limestone beds. The several ore-bodies underlap each other with depth. They show a peculiar echelon arrangement by which each ore-body, commencing below the lower end of the preceding, plunges farther and farther below the surface. No definite walls limit the width of the ore-bodies, but they grade laterally into material too low in values to be of present economic importance. The factors controlling the echelon arrangement of the ore-bodies are not clearly understood, but its occurrence seems verified by systematic drilling on all sides. The view taken by the management, and the one which seems best to conform to the facts, is that the ore-bodies have formed along a zone of weakness through which ascending mineralizing solutions found a more ready passage than elsewhere. These solutions are regarded as originating with the gabbro-diorite intrusive complex. A gabbro stock of considerable size is believed to be represented by gabbro outcroppings at Climax Bluff, and it is credited with being the centre of distribution of both the mineralizing solutions and the many gabbro porphyry sills which

[1]Camsell, C., Geol. Surv., Can., Mem. 2.

penetrate the surrounding formations. In the Nickel Plate mine the course of these solutions may have been very materially directed by a persistent and nearly vertical gabbro porphyry dyke that cuts across the ore-bodies nearly east and west and may have succeeded in deflecting the bulk of the ore-bearing solutions towards the south and into the zone of weakness now occupied by the ore-bodies. Some of these solutions, however, were apparently able to work their way around the western end of this dyke, for some ore has been discovered to the north of it, although not in such quantity nor as high grade as that occurring to the south of the dyke. To some extent, also, the smaller values in the lower ore-bodies and the more meagre mineralization beyond them, as determined from drilling records, are related to the smaller proportion of gabbro sills to intercalated limestone.

On the assumption that Climax Bluff represents the top of a gabbro stock from which originated the many gabbro porphyry sills intersecting the limestone beds of the Nickel Plate formation, it is to be expected that sills of like character to the west and south of this bluff originated from the same source and should also favour an association with ore deposits similar to those at the Nickel Plate mine. The formations, however, dip west and it is probable that such mineralizing solutions as originated from the vicinity of Climax Bluff would tend to rise along, rather than follow down, the bedding planes or the sill walls. Consequently it might be expected that the bulk of the ore should occur to the east rather than west of Climax Bluff. The gabbro at Climax Bluff, however, forms only a part of the gabbro-diorite complex of this area and most of the diorite itself occurs to the west of Climax Bluff. This is a fact of special economic significance when it is observed that ore deposits related to diorite rather than gabbro do occur on either side of Twentymile creek in rocks not only of the Nickel Plate but of other formations. It justified the writer's belief that important ore deposits related to these diorite intrusives will yet be developed within, as well as at points beyond, the map-area. The ore deposits on the Kingston group of claims described by Camsell[1], as well as those on the Rawhide, Cyclone, and Crackerjack claims and on the Nelson group, appear to owe their mineral content to diorite rather than to gabbro intrusives. A description of some of these properties follows.

Rawhide and Cyclone Claims

The Rawhide and Cyclone claims are situated on the eastern slope of Stemwinder mountain outside, but near the edge of, Hedley map-area and overlooking the valley of Hedley creek.

The principal workings on the Rawhide claim occur in a body of crystalline limestone, a member of the Aberdeen formation. The average strike of these rocks along the slope of the mountain seems to be nearly north and south with moderate to high dips to the west. The limestone forms a very massive bed near the workings, but is apparently only a small remnant of a once more extensive stratum that has been reduced by erosion and cut off, below, by a diorite intrusive. The ore mineralization occurs near contacts with the diorite, and is of a type similar to that encountered elsewhere in Hedley district. At an elevation of about 3,750 feet an adit has been driven for 50 feet along a metamorphosed zone in this limestone.

[1]Camsell, C., Geol. Surv., Can., Mem. 2, pp. 193-202.

Here, heavy mineralization occurs across a width of several feet and marks the position of an ore-body pitching into the hill, or to the west, at from 60 to 70 degrees. The ore-body is, however, irregular in outline and has been subjected to minor faulting near the face of the tunnel.

Arsenopyrite is the most abundant ore mineral near the centre and towards the hanging-wall of the ore-body. Pyrrhotite is also abundant near this wall but nearer the foot-wall chalcopyrite is most conspicuous and is associated with a smaller proportion of zinc blende. Polished specimens of this ore show that the order of deposition of these mineral sulphides begins with sphalerite and passes through pyrrhotite and arsenopyrite to chalcopyrite. Calcite is the chief gangue mineral and is coarsely crystalline. Garnet, epidote, and pyroxene are also characteristically developed in the zone of metamorphism. The surface exposure of this ore deposit is only a few square yards. The depth is a less certain factor, but from the angle of pitch into the hill and the occurrence of coarse intrusive outcrops a few yards above the present workings, it is probably not great.

Gold values are associated with the arsenopyrite, and chalcopyrite is the only important copper mineral. Picked samples containing the latter were said to run as high as 13 per cent copper, and a more general sample taken along 16 feet of the foot-wall averaged $3\frac{1}{2}$ per cent. No assays were made for gold, but it is probable, from a general similarity in the character and location of the ore, that these values will not be very different from those obtained on the adjoining Cyclone group.

The principal showings on the Cyclone group occur on the Cyclone claim about one-half mile south of and 300 feet below those on the Rawhide claim.

An adit 30 feet long has been driven into a dark green, massive lime silicate rock which was originally a limestone bed. A thin section of this rock was seen to be composed chiefly of scapolite, secondary hornblende, and arsenopyrite. The arsenopyrite appeared, in part, to precede the other in order of crystallization, as it was intersected by veinlets of these minerals. The variety of scapolite, as determined from its indices of refraction, proved to be wernerite. Narrow, irregular veins of calcite intersect this rock and both it and the vein materials are impregnated with arsenopyrite. A well-defined system of vertical jointing intersects these rocks in a north 70 degrees east direction. Less altered limestone occurs immediately below, and on either side of the portal of the adit, and is intercalated with fine-grained greenstone of volcanic origin. The general attitude of the whole is approximately north and south with westerly dips at varying angles.

A large body of coarse-grained pyroxene diorite intersects these bedded rocks a few feet west of the adit, and is, probably, responsible for both the metamorphism and mineralization of the limestone.

The ore-body has no definite walls, but has the general lenticular outlines of an ore-shoot pitching into the hill to the southwest and following the limestone bed, which thus forms the enclosing rock. Near the portal of the tunnel mineralization is particularly heavy for a width of about 7 feet. Arsenopyrite is the only ore mineral of importance. It occurs both in massive and in long acicular striated forms. A picked sample of heavily mineralized ore was said to have assayed 7·56 ounces in gold.

Nelson Group

The Nelson group consists of five claims and one fraction located on Independence mountain between the heads of Sixteenmile creek flowing south into Similkameen river 16 miles above Keremeos, and Dry Gulch creek draining to the northeast into Keremeos creek. This property is about 9 miles by wagon road and trail from the Nickel Plate mine. From the west shoulder of Independence mountain to Lookout mountain in Hedley map-area is about north 70 degrees west, and probably under 5 miles in a direct line.

The principal showings lie on the northern slope and near the top of Independence mountain at elevations of from 7,300 to 7,400 feet, on the upper rim of the basin drained by Dry Gulch creek. The rocks here include a variety of members very similar lithically to those classed elsewhere with Carboniferous rocks and correlated with the Cache Creek series. Prominent among them are banded, dark blue cherts with thin partings of argillite or slate. Some conglomerate was also observed, and included with the other sediments are beds of limestone a few feet thick. The limestone is of special significance in connexion with the ore deposits. The series also includes dark green flow and fragmental volcanic rocks together with massive hornblende, andesite members. The latter occur in part as dykes varying in width from a fraction of an inch to several feet and are, probably, related to the coarse diorite intrusive so prominently exposed elsewhere on this mountain. The older rocks are greatly disturbed, but the general trend seems to be about north 55 degrees east with dips of over 40 degrees southeast. Jointing is prominent in a north 45 degrees west direction with a high dip of from 70 to 80 degrees northeast.

A couple of open-cuts and one short adit have exposed three different ore-bodies, each of which has resulted from the metamorphism and mineralization of a narrow stratum of limestone. To a minor extent the adjoining rocks are also metamorphosed and impregnated with ore minerals. The source of the ore is attributed to the great body of diorite of which extensive exposures were observed on the western and southern flank of Independence mountain. This diorite forms probably the bulk of the hill, the older Carboniferous rocks being remnants that have escaped erosion. A specimen of the intrusive examined microscopically was seen to be composed chiefly of hornblende and plagioclase feldspar, the latter about andesine in composition. The specimen also contained a small proportion of interstitial quartz.

The principal ore minerals are arsenopyrite and chalcopyrite, the former carrying from a fraction of an ounce to several ounces of gold to the ton. A polished specimen of high-grade ore showed a great deal of arsenopyrite. No free gold was observed. Several specks of chalcopyrite were disseminated through the gangue, but in particles too small to be seen with the unaided eye. No other sulphide minerals were noted in this specimen. Not much of this high-grade ore has yet been exposed and although the type is similar to that occurring in the Hedley map-area there is comparatively little limestone exposed along this slope of Independence mountain and, consequently, large ore-bodies of the type of those developed by the Hedley Gold Mining Company are not to be expected.

LUCKY FOUR MINING PROPERTY, CHEAM RANGE, B.C.

By C. E. Cairnes

CONTENTS

Illustrations

The Lucky Four mining property is situated in Cheam Range section of New Westminster mining division, B.C., near the summit of the divide between Fraser and Chilliwack rivers. A good pack trail less than 15 miles long leads from the property down the northern slope of Cheam range to Fraser river where, at Jones siding near Laidlaw, it connects with the Canadian National railway 80 miles east of Vancouver. The group of twelve claims and several fractions comprising the Lucky Four property includes about 700 acres extending on either side of the divide to the east of the main peak of Foley mountain. The divide at this point has an elevation of over 6,400 feet and is the site of the most important ore-body. Development work has been conducted at elevations over 400 feet below the divide on the northern slope and over 1,200 feet below on the southern.

TOPOGRAPHY

Cheam mountains are approximately 20 miles long and extend from Chilliwack river north towards the junction of Fraser river and Silver creek near Hope. They are conspicuous for their superior elevations and relief and for their extremely rugged and picturesque topography. About midway along this mountain chain are a number of peaks ranging from 7,500 to 8,000 feet in elevation. The most northerly, called Foley mountain, has a height of 7,550 feet and Stuart mountain to the southwest stands 7,930 feet above sea-level. These peaks have in their upper 1,000 feet or more been unscored by a regional glaciation which rounded off the summits of the divide below a level of 6,500 feet. Their northern and northwestern flanks are, however, the sites for steeply pitching and highly crevassed mountain glaciers. To the northeast of Foley mountain the divide drops within half a mile to an elevation of about 6,500 feet. Near the junction of this crest-line with the steep slope of Foley mountain, and extending on either side of the divide, lies the mineralized belt of the Lucky Four property (Plate III A).

The streams on the northern flank of the divide are tributary to Jones (Wahleach) lake which is drained by Jones (Wahleach) creek into Fraser river. Those on the southern slope are drained by Granite creek into Ford creek, a tributary of Chilliwack river which, in turn, empties into Fraser river near Chilliwack about 23 miles below the mouth of Jones creek.

GEOLOGY

The break in the divide below the peak of Foley mountain is, in addition to being a feature of topographic significance, also one of geological importance, for it marks a position on the contact between a series of stratified rocks and an area of batholithic intrusives (Plate III A). Foley mountain, and probably other peaks to the south, are composed of a series of bedded rocks so similar to that of the Hozameen series[1] of the Skagit River basin that the writer has little hesitation in correlating it with that group. These rocks strike about south 80 degrees east magnetic, which would bring them practically in line with the Hozameen series of the International Boundary, and it is possible that they are continuous between these points. In the vicinity of the Lucky Four property these rocks are black reddish-weathering slates, thinly bedded cherts with shaly partings, and interbedded limestones. One conglomerate bed was also observed, and is of some stratigraphic importance in determining the position of the ore-bodies. These rocks all stand almost vertically or at high angles to the southwest. They are regarded as of Carboniferous age.

The Hozameen rocks have been intruded by a large batholith of massive granodiorite. This intrusive is fresh looking, light grey to slightly pink, and moderately coarse. The principal salic constituents are, in their order of abundance, andesine feldspar with a composition of $Ab_3\ An_2$, quartz, and pink orthoclase. The ferromagnesian minerals include a dark green lustrous hornblende and a smaller proportion of black biotite. Together they constitute between 15 and 25 per cent of the rock. This granodiorite probably forms a part of the Chilliwack batholith tentatively regarded as of Miocene age.[2]

Near the contact with the Hozameen rocks the granodiorite has developed a somewhat gneissic structure and contains, for at least several hundred yards from the contact, innumerable rounded darker ellipsoidal masses mostly less than a foot in length. These may represent inclusions from the Hozameen rocks which have been absorbed by igneous material.

CONTACT METAMORPHISM

Contact metamorphism of the intruded Hozameen rocks provides an interesting example of the effects of batholithic intrusion on a series of stratified rocks of variable composition. It indicates to what distance from the contact these rocks may be noticeably affected, and to what extent certain members are more or less metamorphosed than others of different character. It is also of economic importance in that the deposits of the Lucky Four group owe their origin to contact metamorphic processes.

The batholithic contact on the Lucky Four property closely follows the strike and dip of the Hozameen rocks. Adjoining the intrusive is a belt, 25 feet or more in width, of a highly metamorphosed rock whose original character has been largely masked by recrystallization, but which was probably a fine-grained impure sandstone or greywacke. This has been changed to a moderately coarse mica schist, of somewhat purplish hue because of many small, coloured mica scales. Under the microscope this rock is seen to be composed chiefly of quartz grains which from their lack

[1]Daly, R. A., Geol. Surv., Can., Mem. No. 38, p. 500.
[2]Daly, R. A., Geol. Surv., Can., Mem. No. 38, p. 534.

of strain shadows or any considerable fracturing, their abundance of small inclusions, and their crystalline interlocking texture, are evidently the product of entire recrystallization of the rock, in the course of which the outlines of the original constituent minerals have been lost. Associated with the quartz is a subordinate amount of feldspar, including both alkalic and calcic varieties, of which some of the latter at least are as basic as andesine. The feldspars are mostly beautifully clear, and show both Carlsbad and albite twinning. They are frequently intersected or replaced by thin, colourless shreds of a mica resembling muscovite, but which may in part represent a sericitic alteration product. The most noticeable constituent of the rock and the one, next to the quartz, present in greatest abundance is a biotite occurring in small red scales and shreds that show strong absorption from a pale brown to a deep brownish red. Large granular masses of brown tourmaline are occasionally seen. This rock is best exposed on the south side of the divide near the portal of a tunnel at an elevation of 5,200 feet. Its continuation across the summit is obscured by the edge of a glacier which occupies the northern slope.

Adjoining the mica schist is a mineralized belt about 50 feet wide which contains the ore deposits of the Lucky Four property. It marks the original position of a limestone whose general composition and character were probably not essentially different from those of less metamorphosed limestone strata lying farther from the contact. Its entire width was not studied in any one section. Its contact with the mica schist is exposed on the southern slope of the divide near the tunnel mentioned above. This contact is hidden on the summit of the divide, where, however, the best section, including the most important ore deposit, was obtained.

Contact metamorphism of this limestone belt has resulted in the recrystallization of its original constituents and the introduction of much fresh material. The predominating minerals formed are, in their present order of abundance, pyroxene, garnet, calcite, epidote and zoisite, quartz, amphibole, and feldspar. This order will, however, doubtlessly vary in other sections and at different horizons in each section. Other accessory minerals include apatite, hydrated micas, and talc. Among the metallic minerals chalcopyrite is the only one of present economic importance; but molybdenite, magnetite, pyrrhotite, and pyrite were also observed.

Within this highly metamorphosed belt there appears to be a diminution of certain minerals and an increase of others, according to the distance from the granodiorite intrusive. Nearest the batholith, or adjoining the mica schists, the principal mineral is a beautifully recrystallized calcite, whose large, lustrous cleavage surfaces are penetrated by innumerable red andradite garnets up to one-quarter inch or more in diameter, but mostly much smaller. Thanks are due to Prof. A. H. Phillips who analysed a sample of this garnet and found it to have the following composition:

SiO_2	34·66
Fe_2O_3	27·39
MgO	0·45
MnO	0·36
Al_2O_3	4·49
FeO	1·07
CaO	31·08
TiO_2	0·32
Total	99·82

These garnets are as a rule somewhat distorted, and their faces are slightly striated. The only crystal forms recognized were the tetragonal trisoctahedron and the rhombic dodecahedron. Under the microscope the garnet shows anomalous birefringence and complex zonal growth. It often forms skeleton crystals which are in part intergrown with a green pyroxene and in part replaced by orthoclase feldspar.

Other minerals associated with the calcite and andradite garnet in this section of the metamorphosed belt are a green pyroxene which has partly altered to amphibole, and a black, fibrous, iron-rich zoisite. A few small grains and crystals of apatite were observed and appear to belong to a somewhat later period of crystallization than the pyroxene. Magnetite and pyrrhotite also occur locally in considerable abundance, the oxide both massive and in well-developed octahedrons, and the sulphide without crystal form. Zoisite appears to have been one of the last minerals to form, its fibres penetrating both the metallic and non-metallic constituents. Clear prisms of quartz are often abundant in this zone. They replace calcite and are in turn penetrated by zoisite fibres. Chalcopyrite is common but irregularly distributed and seems to have been introduced even later than the zoisite. Pyrite is an earlier constituent and occurs in very minor proportions as compared with the other minerals.

Farther from the batholith, a different group of minerals predominates. In place of the red andradite there occur massive beds a foot or more thick of a brownish-yellow garnet, whose indices of refraction are about those for grossularite. This garnet is intergrown with a pyroxene identified by its refraction as diopside. The intergrowth is not visible to the naked eye. Between the beds of garnet are others almost equally wide composed of a green pyroxene, masses of black fibrous zoisite, and yellowish-green areas of granular epidote. Molybdenite is distributed through the pyroxene as small, irregular clusters of flakes. It is in this zone that the principal showing of chalcopyrite ore occurs.

Still farther from the granodiorite the metamorphosed belt becomes predominantly pyroxene, which has in part been further altered to a soft talcose rock resembling soapstone. Crushed fragments of the pyroxene show under the microscope as a fibrous and almost colourless mineral with indices of refraction about those for tremolite. A small percentage of calcite is present as an original constituent.

The entire width of the belt just described probably exceeds 50 feet. Its lower contact is with the belt of mica schist; above it lies a moderately coarse conglomerate bed about 40 feet thick containing well-rounded pebbles up to 3 or 4 inches in diameter, some of which are plutonic. Both pebbles and matrix bear the marks of regional deformation and are to some extent affected by heat metamorphism, but in nothing like the same degree as the underlying rocks.

Above the conglomerate the rocks are chiefly banded cherts with argillaceous partings. The cherts are bleached and may be coarser than their unmetamorphosed equivalents.

At about 200 yards from the metamorphosed limestone belt is another limestone bed 10 feet wide which has suffered very little from contact metamorphism. It is still dark coloured, composed almost wholly of calcite with some carbonaceous impurities, and when struck with the hammer gives off a very fetid odour. There has been some recrystallization of the limestone since its deposition, but this alteration may well have been effected by dynamic rather than by heat metamorphism.

ORE DEPOSITS

The ore deposits of the Lucky Four lie in the highly metamorphosed garnetiferous limestone belt already described. Chalcopyrite is the only ore mineral of importance. It occurs sparingly disseminated through the entire width of the belt, and is sufficiently concentrated in at least one locality to provide a deposit of commercial value. This showing lies on the summit of the divide, and is best exposed around the base of a small nub which rises sharply to about 50 feet above the general level of the ridge. Here (Plate III B) the chalcopyrite occurs as a vein mineral between massive beds of yellowish-brown (grossularite) garnet rock and others composed chiefly of epidote, zoisite, and pyroxene. The ore veins pinch and swell in a most irregular fashion, and vary in width from a fraction of an inch to several inches of almost pure chalcopyrite in which are scattered numerous small crystals of garnet. Such a vein is exposed along its strike on the eastern flank of the nub mentioned above, and forms a wall of nearly solid ore several yards long and of unknown thickness. Other veins closely parallel to this one were observed on the southern face of the nub and across the strike of the beds. Some of these may coalesce within the body of the nub, or at greater depth, to form an ore deposit of greater volume. A sample of pure chalcopyrite prepared by the writer and assayed under the direction of Prof. A. H. Phillips was found to contain 23·46 per cent copper. This sulphide in polished sections shows under high magnification numerous minute irregular areas of a darker mineral which is probably zinc blende. No other copper minerals were observed in these sections, but a little bornite was seen in hand specimens of ore from this property. It is probably of secondary origin and not sufficiently abundant to enhance greatly the value of the ore.

The course of the principal ore-body down the northern slope of the divide could not be ascertained because of the precipitous character of the hillside and the occurrence of a glacier overlying the deposit a couple of hundred feet below the summit. Between the top of the ridge and the glacier, the trend of the chalcopyrite veins could be observed by the rich carbonate stains on the surface of the outcrops. The course of the veins beneath the glacier has been partly investigated by drilling, and appears to continue in a fairly regular manner for at least 500 feet below the summit.

On the southern slope of the divide no important ore deposits were observed, but the country rock is locally sufficiently impregnated with chalcopyrite to warrant the expectation that with more careful prospecting some ore will be found.

Genesis of the Ore

The ore deposits are undoubtedly of contact metamorphic origin. Those processes which resulted in the complete metamorphism of the original limestone and its extensive replacement by calcium silicate minerals also provided the solutions from which the chalcopyrite and the less abundant iron sulphides were precipitated. The chalcopyrite appears to have formed in the later stages of metamorphism. Hand specimens and microscopic enlargements of polished surfaces show the copper sulphide replacing the gangue minerals. Calcite has suffered most in this respect; the garnet appears to have offered greatest resistance, as indicated by the presence of innumerable well-preserved crystals in an otherwise solid mass of chalcopyrite. Fractures in the garnet are frequently filled with the chalcopyrite, and the sulphide has also worked its way around the borders of the garnet crystals. There is, too, a distinct tendency for the chalcopyrite to occur as irregular veins between beds of different mineral composition, or to occupy small, irregular cavities left during the earlier replacement of the original limestone by the more compact silicate minerals. The metamorphism was apparently accomplished at high temperatures, involving recrystallization of the original constituents of the limestone belt and the introduction of fresh material from hot magmatic solutions in which, from the occurrence of such minerals as apatite and tourmaline, gaseous activity may have been pronounced.

Development Work

Development work at the Lucky Four has been confined to some tunnelling and open-cut work on the southern slope of the divide and to drill-prospecting on the northern flank.

In spite of the difficulties of the northern slope a diamond drill was set up in two places on the glacier, over 400 and nearly 300 feet respectively below the principal showing on the crest of the divide. From the lower site one hole 576 feet long was driven at an angle of 23 degrees below the horizontal towards and under the summit; from the upper drill site five holes aggregating in all about 850 feet were driven at various angles through the ice and underlying rock towards the same ore deposit on the divide.[1] Although the results of this drilling were regarded as satisfactory, the operation was attended by so many engineering difficulties that it was suspended in favour of an exploration of the southern slope of the divide.

Here an adit about 200 feet long[2] was driven at an elevation of 1,200 feet below the summit of the divide. The rock at the portal of the tunnel is the mica schist which has already been described as lying between the granodiorite and the garnetiferous limestone belt. This tunnel caved in near the portal and neither its direction nor the character of the rock traversed could be determined. The purpose of this adit was to ascertain the position and character of the mineralized ground at this depth below the principal ore-body on the divide.

[1] Report of Minister of Mines of B.C., 1918, p. 285.
[2] Report of Minister of Mines of B.C., 1919, p. 234.

This southern slope affords a very convenient location for future prospecting and development work because of its southern exposure, its comparatively low gradient, and the ease with which the mineralized rocks can be followed and prospected.

GENERAL REMARKS

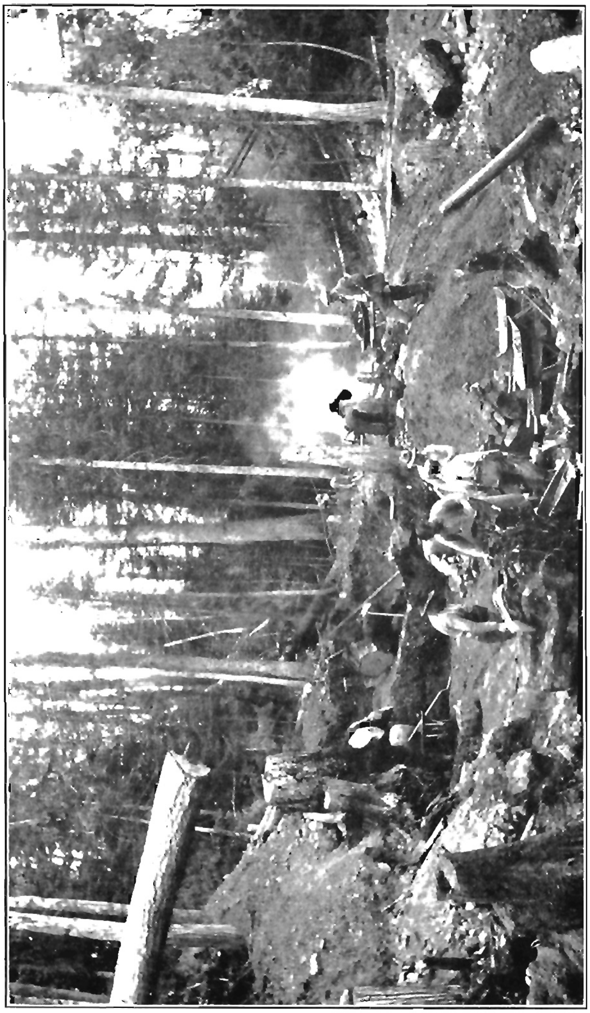
The potential ore ground of the Lucky Four property may be regarded as coincident with the metamorphosed belt in which the abundant development of garnet affords a convenient means of recognition. This belt is regarded as having an average width of probably over 50 feet, and dips in general at high angles to the southwest. It has already been explored at widely separated points and at elevations of over 1,000 feet below the summit of the divide, where the principal ore-body is located. Its persistence in depth and length may be regarded as equivalent to that of any one of a series of strata which here compose the Hozameen series, but its intensity of metamorphism and mineralization will depend largely upon its proximity to the granodiorite intrusive. Other limestone beds have been noted, and it has been observed that less than 300 yards from the batholith they are practically uninfluenced by contact metamorphic processes.

The entire width of the metamorphosed limestone belt is sparingly mineralized by chalcopyrite, but only where this sulphide is concentrated in veins, pockets, or shoots can profitable extraction be made. Sufficient development work has been done to show that there is no regularity in such occurrences, and no specific rules can be set down as to where in this belt they are most likely to occur. The presence of slight mineralization with chalcopyrite is too general to afford any direct clue to the position of ore-bodies. The occurrences of veins or pockets of this sulphide are, however, regarded as of more value in this respect.

Although the Lucky Four is essentially a copper property, a sample obtained by Brewer[1] across the face of an open-cut 20 feet wide on the southern slope of the divide assayed 2 ounces in silver and a trace of gold. A little molybdenite is also locally present.

[1]Report of Minister of Mines of B.C., 1918, p. 286.

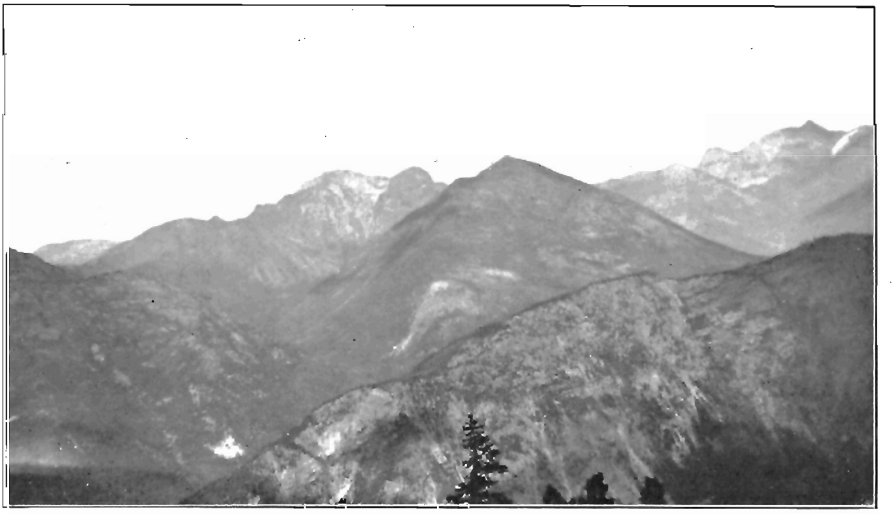
PLATE I



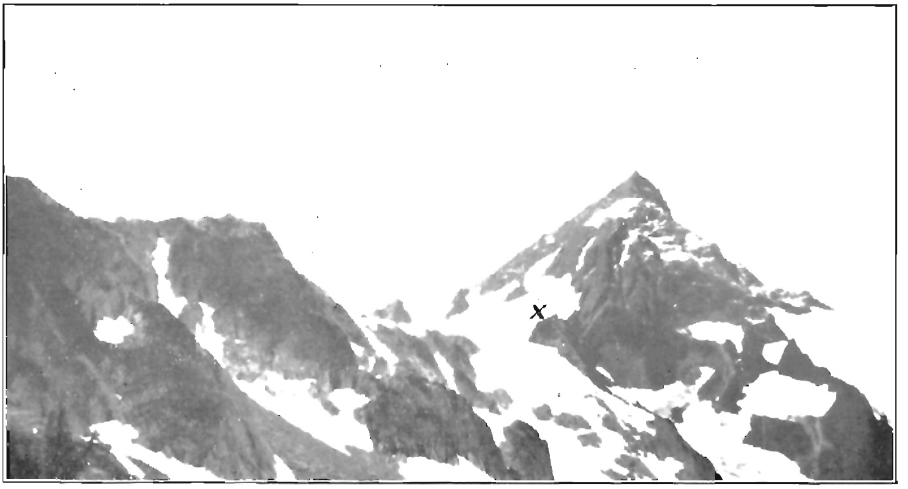
Placer mining on the left bank of discovery draw, Cedar Creek area, Cariboo, B.C. The pay gravels are shown in the open-cut beneath the fallen stump. (Page 76.)

PLATE II

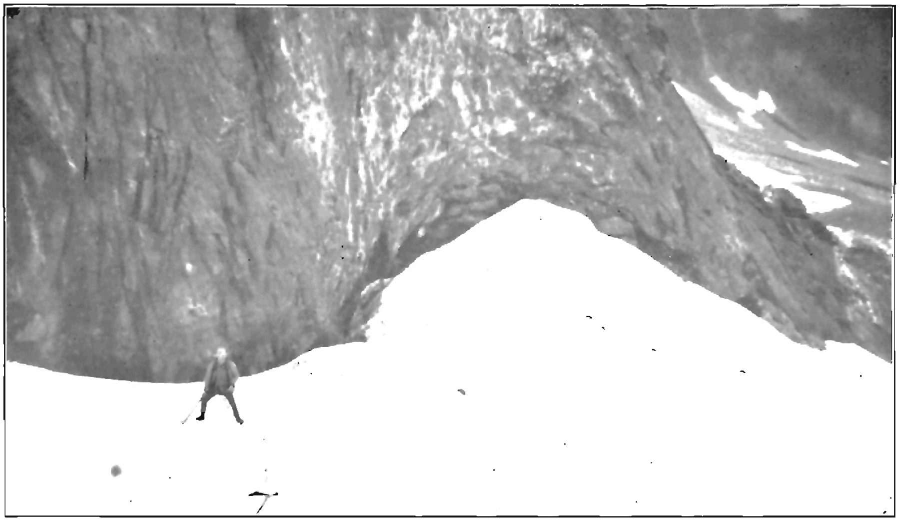
A. Looking east up Skaist valley towards Hope Summit, showing uniformity of summit level along the western border of the Interior Plateau. (Page 89.)



B. Looking north across the valley of Sumallo river and up Twentymile creek towards Hopeless mountain (left centre background), showing Cascade Mountain topography near headwaters of Skagit river. (Page 89.)



A. Looking southwest towards Foley mountain, showing rugged topography in the Cheam range, Cascade mountains. The saddle to the left of the peak marks the position of an intrusive formational contact and also the location of a zone of ore mineralization in which the Lucky Four mining property is situated. (Pages 127, 128.)



B. View of the principal showing on the Lucky Four mining property. This cliff is shown immediately below point "X" in Plate III A. (Page 131.)

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