[redacted]

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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 171

Geology and Ore Deposits of Copper Mountain, British Columbia

BY
V. Dolmage

OTTAWA
J. O. PATENAUDE
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1934

Price, 25 cents No. 2344

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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

MEMOIR 171

Geology and Ore Deposits of Copper Mountain, British Columbia

BY
V. Dolmage

OTTAWA
J. O. PATENAUDE
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1934

Price, 25 cents No. 2344

CONTENTS

Illustrations

Geology and Ore Deposits of Copper Mountain, British Columbia

CHAPTER I

INTRODUCTION

The name Copper Mountain is applied to a gently arched, nearly flat-topped spur between the deep valley (1,800 feet) of Similkameen River to the west and the shallower valley of its largest tributary, Wolf Creek, to the east. The mountain is appropriately named from the large number of copper deposits occurring on its sides and summit, one of which has been developed into an important producer widely known as the "Copper Mountain mine." The present report deals with an area 5 miles long in a north-south direction and 4 miles wide, in which Copper Mountain is centrally situated. The area lies 12 miles south of the town of Princeton which is 150 miles east of Vancouver on the Kettle Valley Railway. The area is intersected by longitude 120° 30′ and latitude 49° 15′ and is, therefore, less than 20 miles north of the International Boundary. Copper Mountain mine and camp are connected with Princeton by a good motor road down the valley of Wolf Creek, and the haulage level of the mine, which emerges on the side of Similkameen Valley 1,000 feet lower than the camp, is connected with the Kettle Valley Railway by a spur following Similkameen Canyon. This spur passes through the town of Allenby, 6 miles south of Princeton, where the concentrator that treats the ores from the mine is situated.

The general region in which Copper Mountain is situated was first examined geologically during the summers of 1859 to 1861 when Hilliar Bauerman, then attached to the Boundary Commission, examined all the region contiguous to the 49th parallel west of the Rocky Mountains. His report was published by the Geological Survey in the Report of Progress 1882-83-84. The district was next examined geologically in 1877 by Dawson,[1] who mapped in a preliminary way a large section of southern British Columbia lying between Okanagan and Harrison Lakes and extending north from the International Boundary to latitude 50°. In 1906 Charles Camsell[2] began geological mapping in this region and continued until 1913. One area that he mapped and reported upon (Pub. No. 986) includes Copper Mountain, but as the map was made principally for the purpose of outlining the Princeton coal basin, the various igneous rocks underlying

[1] Dawson, Geo. M.: Geol. Surv., Canada, Rept. of Prog. 1877-78.
[2] Camsell, Charles: Geol. Surv., Canada, Sum. Repts. 1906, 1907; Pub. No. 986; Sum. Repts. 1908, 1909, 1910; Mem. 2, 1910; Sum. Repts. 1911, 1912, 1913; Mem. 26, 1913; International Geological Congress, Guide Book No. 8, pt. II, and Book No. 9; Sum. Rept. 1919.

Copper Mountain were not differentiated. Cairnes[1] in 1919 commenced work in the general region, which he continued until 1923. In 1922 he visited Copper Mountain and made some notes on the geology, which were given to the present writer. From 1901 to 1906 R. A. Daly[2] was engaged in making a geological reconnaissance along the 49th Parallel and in his report describes the region south of Copper Mountain area.

The mineral deposits of Copper Mountain area have been reported on by many engineers and geologists of whom the following have published reports. J. F. Kemp made a brief study of the mineralization of this district and published in the Transactions of the American Institute of Mining Engineers, volume 31, page 182, an interesting article concerning the origin of certain of the ores. The same subject is discussed by Jules Cathrinet in the Engineering and Mining Journal of January 10, 1905. The annual reports of the Minister of Mines of British Columbia contain informative articles on the ore deposits of this district, by W. Fleet Robertson in 1901, J. D. Galloway in 1913, and P. B. Freeland in 1923, *et seq.*

The area was topographically mapped in 1922 by D. A. Nichols, of the Topographic Division of the Geological Survey, whose excellent map was used by the writer in laying down the geological boundaries in the field. The writer's field examinations were made during the summer of 1923 and July and August, 1926. In 1923 the writer was assisted by G. F. Barnwell, W. V. Smitheringale, and F. Buckle, and in 1926 by P. G. Patterson. The writer wishes to acknowledge the assistance and friendly cooperation of Mr. N. E. Nelson and other officials of the Granby Consolidated Mining, Smelting, and Power Company who own and operate the Copper Mountain mine, and also of the officials of the Consolidated Mining and Smelting Company who own neighbouring deposits known as the "Voigt property." The many kindnesses received from the late Mr. and Mrs. Emil Voigt are also gratefully acknowledged. The writer is indebted to Mr. Nichols, author of the topographic map, for certain suggestions concerning the physiographic history of the region including the mapped area.

The early history of Princeton district is largely a record of the operations of the Hudson's Bay Company in carrying on its fur trade with the Indians. British Columbia in 1852 soon began to attract miners from all parts of the world and in 1858 they began to come in large numbers from California. Many of these came in by way of Columbia and Okanagan Rivers and some found their way to Similkameen Valley. In 1860 gold was found farther up the Similkameen and for a number of years the bars near Friday and Whipsaw Creeks and Tulameen River were worked. In 1884 a trapper named Jameson discovered high-grade copper ore on what is now known as Copper Mountain. He was not interested in it himself, and owing to the Granite Creek excitement of the following season none of those to whom he showed the copper ore was sufficiently interested to stake the ground. Finally, however, in 1892, the deposit was visited by R. A. (Volcanic) Brown, a well-known prospector, who staked the Sunset claim.

[1] Cairnes, C. E.: Geol. Surv., Canada, Sum. Rept. 1920, pt. A; Mem. 139; Sum. Rept. 1922, pt. A; Sum. Rept. 1923, pt. A.
[2] Daly, R. A.: Geol. Surv., Canada, Mem. 38, (1912).

This claim has since proved to be the richest area of the whole district and is the centre of the large operations carried on by the Granby Consolidated Mining, Smelting, and Power Company. During the following three years many claims were staked covering the greater part of Copper Mountain, Kennedy Mountain, and the intervening Similkameen Valley. In 1900 Mr. Brown organized the Sunset Copper Company for the purpose of developing the Sunset claim and about $16,000 was spent in sinking a shaft and doing other underground work. It is interesting now to note that this first underground work has been found by later exploration to have penetrated the richest ore ever found in the district.

In 1889 Emil Voigt established a camp on Wolf Creek and staked several groups of claims, which he continued to hold until his death in 1927 and which constitute what is generally known as the Voigt property.

In 1905 F. Keffer took a lease and bond on the Sunset and some adjoining claims, and formed the South Yale Copper Company, capitalized at $450,000, for the purpose of exploring these deposits. Owing, however, to legal difficulties and also to the fear of having trouble in smelting the somewhat unusual ores, this bond was dropped the following year. This company then bonded the Voigt property in 1911 and an elaborate development campaign, including a large amount of diamond drilling, was carried out. The property, however, was not purchased and in 1912 the company moved back to Copper Mountain. A large amount of exploratory work was first done on the many claims lying north of the Sunset group and known as the Princess Camp. The Sunset and adjoining claims were again taken over, as well as many other neighbouring claims, until the company had in its control an area of 3,193 acres. The British Columbia Copper Company was at this time reorganized and the name changed to Canada Copper Corporation. The new company then began a vigorous development campaign which was carried on until the outbreak of the war in 1914 when all work was immediately stopped. The high price of copper, caused by the war, induced the company to resume work in 1916 on a still larger scale. The mine was developed and equipped to produce 2,000 tons of ore a day; an elaborate camp was built at the mine and a concentrating plant and another camp were erected at Allenby, 6 miles south of the mine. A contract was made with the West Kootenay Power Company to supply the necesssary power for mining and milling purposes, and an agreement entered into with the Kettle Valley Railway to build a branch line connecting the mine and mill with the main line at Princeton. This branch proved to be very difficult and expensive to build, and its construction, as well as that of the power lines to the mine, was greatly hindered by labour strikes. As a result of these difficulties and delays the mill and mine were not ready to commence operations until peace had been declared in 1918. The first trial runs of the mill were unsuccessful and as the price of copper had suddenly dropped to a point, which, it was thought, would make the profitable operation of the mine impossible, the mine and mill were shut down. Up to this time over $4,000,000 had been expended on the enterprise, no copper had been produced, and the hope of operating the mine had dwindled to a mere spark.

The camp then remained dormant until 1923 when the mine and plant came into the possession of the Granby Consolidated Mining, Smelting, and

Power Company. This company spent considerable money in conditioning the mine and remodelling the mill, but before the end of the year the attempt was abandoned. In the winter of 1925-26 the company, now under new management, again set to work to put the enterprise on a basis of profitable production. The concentrator was remodelled for the third time and before the end of 1926 was operating very successfully. This it continued to do until December, 1930. Prior to its closing down it was treating over 2,000 tons of ore a day, producing a concentrate carrying about 30 per cent copper besides small gold and silver values, and making a satisfactory recovery from this rather refractory, low-grade ore.

CHAPTER II

GENERAL CHARACTER OF THE DISTRICT

Copper Mountain mining area is on the boundary between two large and well-defined physiographic provinces of the North American Cordillera—to the north the Interior Plateaux of British Columbia, and to the south the great Cascade Mountain system of Washington, Oregon, and California. Although the Cascades are extremely rugged and high, and the plateau much lower and comparatively flat, the boundary between the two is gradual and poorly defined. As the Cascade Mountain system crosses the International Boundary it divides into three branches, Skagit or Hope Mountains to the west, the Hozameen in the middle, and the Okanagan to the east. The western and middle branches form the southwest boundary of the plateau, but the eastern, the Okanagan Range, projects northward into the plateau for 20 miles or more before merging gradually into it. To the east of this promontory lies Okanagan Valley, and to the west, between it and Hozameen Mountains, is the basin of the upper Similkameen in which Copper Mountain area is somewhat centrally situated. The Interior Plateaux occupy a belt nearly 100 miles wide extending northwesterly through central British Columbia, and are units of the great system of plateaux that extends through the heart of the Cordillera from Mexico to Bering Sea. In southern British Columbia the plateau ranges in elevation from 3,000 to 6,000 feet; it has an undulating, in places hilly, surface which truncates the ancient and steeply folded strata underlying it. In some places the low relief of the plateau is further accentuated by widespread lava flows of recent geological date and in others by the degradational and aggradational effects of the Pleistocene ice-sheet. Into the plateau surface Fraser and other large rivers have cut deep, steep-walled valleys, in places as much as 4,000 feet deep. In an extended view of the plateau these deep valleys are lost and it appears as an undulating plain with rolling hills, shallow depressions, and gently curving skyline. In the vicinity of Princeton, a depression in the plateau forms a well-defined basin which is floored with a series of nearly flat-lying, Tertiary sediments containing one or two workable seams of lignite. From this basin the upland surface rises gradually towards the south from an elevation of less than 3,000 feet to 4,000 feet at Copper Mountain and 6,000 feet in the upper parts of Similkameen basin where it merges into the rugged and highly diversified topography of the Cascades, with glacier-inhabited peaks rising to over 9,000 feet.

The Upper Similkameen basin has greater relief than the adjacent and lower parts of the Interior Plateaux. However, the valleys of the Similkameen and its larger tributaries, such as Pasayten River, Wolf, Friday, and Whipsaw Creeks, are wide, have flaring sides with gentle slopes, and are separated from one another by subdued, rounded spurs of which Copper Mountain is typical. Such characteristics are indicative of fairly mature topography. In the bottoms of these broad, open valleys, however, have been cut deep, narrow, rocky canyons as shown in Plate II, the steep sides of which form a sharp, angular unconformity with the gentle slopes of the main valleys and obviously have been formed during much more recent times.

The drainage of the whole region, as well as that of the small part included in Copper Mountain area, has some striking anomalous features. The principal stream is Similkameen River. It rises in Hozameen Mountains near the International Boundary and, after flowing northeast for 15 miles, unites with a large tributary from the south, the Pasayten, and flows nearly straight north for 20 miles to the town of Princeton, passing en route through the entire length of Copper Mountain area. At Princeton its joins the Tulameen, then takes a sharp bend to the southeast, passes through the Okanagan Range, and joins Okanagan River a few miles south of the 49th Parallel. Above the junction with Pasayten, the Similkameen and its tributaries flow through normal "V"-shaped valleys slightly modified in the upper parts by valley glaciers. Below this junction, to Whipsaw Creek, the river occupies a deep, rocky canyon cut in the bottom of a wide "V"-shaped valley and meandering for part of its course between flat-topped rock terraces 300 feet high, several of which are represented on the accompanying map (No. 2343). From Whipsaw Creek to Hedley Creek the Similkameen passes through the Princeton Basin and has low banks and lower gradient. Below Hedley Creek it flows through a deep, narrow, but decidedly "U"-shaped valley, which cuts through the Okanagan Range to join Okanagan Valley. The flat bottom, steep parallel sides, faceted spurs, and hanging tributary valleys of this lower section of the Similkameen indicate that it was traversed by a glacier believed to have been a distributary tongue of the Pleistocene ice-sheet that occupied the Interior Plateaux of British Columbia.

Wolf Creek is one of the largest tributaries of the Similkameen and drains the larger part of Copper Mountain area. It rises a short distance south of the area and follows a northerly course parallel to the Similkameen, but at an elevation about 1,000 feet higher. Throughout the area it occupies a normal "V"-shaped valley, but just at the northern boundary it plunges through a narrow gorge into Smelter Lake Valley 700 feet below, where, instead of entering the lake and discharging its waters westward into the Similkameen, it passes close by the end of the lake, bends sharply to the east, and joins the Similkameen 9 miles below Princeton.

In the section of the country surrounded on the west, north, and northeast by Similkameen River, there are many east-west trending through valleys (*See* Plate I). The largest of these, Smelter Lake Valley, extends completely across this section of country just north of Copper Mountain area. Three other, much smaller valleys lie within Copper Mountain area and are: (1) Lost Horse Gulch between Similkameen and Wolf Valleys, entering the latter at Voigt's Camp; (2) Victor Lake Valley between Wolf Creek and its large tributary lying immediately east of the area; and (3) Verde Creek Valley intersecting the same divide but lying farther north at the boundary of the area. There are also several through valleys east and north of the map-area.

Smelter Lake Valley is deep and narrow with steep sides rising in places 1,500 feet above the lake. It is 700 feet lower than the upper part of Wolf Creek in the vicinity of Voigt's Camp. At its western end it is 200 feet higher than the Similkameen; at its eastern end it enters the Similkameen at grade. It is occupied in the western part by Smelter Lake and in the eastern part by Wolf Creek, which, in comparison with the size of the valley, is disproportionately small. This valley has been cut largely through Tertiary tuffs and lavas. Its elevation, grade, position, and direction all strongly suggest that it was at one time a part of the large valley of Whipsaw Creek which enters Similkameen River from the west at a point just opposite Smelter Lake.

Lost Horse Gulch is a narrow, winding, steep-sided valley occupied at its western end by a marsh and in the eastern part by the small stream that drains this marsh into Wolf Creek. At its western end it is 1,100 feet higher than Similkameen River, but at its eastern end it enters Wolf Creek only slightly above grade. Victor Lake Valley is broader and shallower. It is occupied by Victor Lake and a chain of marshes that drain northward into Verde Creek. They are, however, separated from a small creek draining into the tributary of Wolf Creek just east of the map-area, by an almost imperceptible divide. The position and direction of this valley suggest its having been a continuation of Lost Horse Valley.

Verde Creek Valley is parallel to Victor Lake Valley and crosses the same divide, but is several hundred feet lower and drains to the east, entering Wolf Creek just north of the boundary of the area. This valley is connected with Wolf Creek by another, small, through valley running in a northeasterly direction from Voigt's Camp. This valley and Verde Valley appear to have at one time conducted the waters of upper Wolf Creek into the above-mentioned valley east of the area.

In the section of Wolf Creek between Voigt's Camp and Verde Creek there are some well-developed river terraces. They are clearly indicated by contours on the accompanying map. They are composed of medium coarse river gravel made up largely of pebbles of the volcanic rocks underlying the region to the southeast. These terraces were apparently formed at the time Wolf Creek flowed through what is now Verde Creek Valley. Somewhat higher than these terraces, at an elevation of about 3,700 feet, and on the eastern side only of the valley near Victor Lake, are other terraces composed of similar material. These appear to have been formed at a time when Wolf Creek was a tributary to a larger stream which flowed through Lost Horse Gulch and Victor Lake Valley.

Well-developed terraces occur also in Similkameen Valley, particularly on the west side below Friday Creek. These, however, are composed of fine white silts similar to those of Fraser, Okanagan, and other valleys of British Columbia. They are in general believed to be of Pleistocene age.

From the above descriptions it is obvious that the drainage of this district has undergone some considerable changes. The abandoned east-west valleys standing at progressively lower levels towards the north and cut into segments by younger northward trending valleys, the convincing evidence of the rejuvenation of the upper Similkameen afforded by the deep, youthful, rocky canyon cut in the bottom of a broad, open valley, the incised meanders, rock terraces, and present steep gradient of this part of the river, point to the general conclusion that an old land surface eroded to a stage of middle maturity and, sloping generally in a northeast direction, has been tilted a considerable amount towards the north.

Evidence of Similkameen Basin having been over-ridden by a continental ice-sheet during Pleistocene time is abundant and unmistakable, but it is equally evident that the region was only very slightly affected by ice erosion. A mantle of drift averaging 6 feet, but in places 20 feet, deep covers most of the district, and glacial grooves and striations are seen on almost all of the rocks exposed on the uplands. Both these features are especially well exposed by the numerous excavations attendant on the mining operations on Copper Mountain. The drift contains an unusually large proportion of greyish or pale yellowish sandy clay whose origin may be readily traced to the poorly consolidated beds of Tertiary sediments occupying Princeton and other basins to the north. On Kennedy Mountain, west of the Similkameen, the scarcity of boulders in the drift is even more pronounced. All the rock exposures on Copper Mountain are rounded, polished, or striated by glacial action. The striations indicate that the ice moved in a direction 18 degrees west of south.

In the valleys, however, no evidence of glaciation was found, either in the form of grooves and striations or of modifications of the normal shapes of the valleys. Although this is in part accounted for by the fact that the canyons have been largely formed since the recession of the glaciers, it is nevertheless in accord with the fact that the region as a whole has been only slightly affected by glacial erosion. This may have been due to a nearly stagnant condition of the ice occupying this basin caused by the damming effect of an upward slope to the south in the direction of the ice flow.

CHAPTER III

GENERAL GEOLOGY

INTRODUCTION

Copper Mountain area lies within an extensive region in which the oldest rocks belong to an assemblage of limestones and other sediments with considerable volcanic materials. These rocks were named by Dawson the Cache Creek series and are believed to be mainly of late Carboniferous age. This series has an estimated thickness of more than 10,000 feet and at one time occupied most of the region, but has since been replaced by intrusives or covered by later formations to such an extent that it is now found only in small, isolated patches. The Cache Creek strata are overlain by volcanics and sediments named by Dawson the Nicola series. These rocks are, in part at least, of Triassic age. It is not definitely known whether or not there is an hiatus between them and the Cache Creek beds; in places the two series appear to be conformable. In neighbouring regions to the west, marine strata of Jurassic and early Cretaceous age occur, but if such rocks were ever present in the districts about Copper Mountain they have since been removed.

Beginning possibly in late Jurassic and extending through Cretaceous into Tertiary time, there occurred a succession of batholithic intrusions of diorite, quartz diorite, and granodiorite. During the same period the older formations were folded. In Tertiary time, possibly in Eocene, Oligocene, or Miocene time, great thicknesses of volcanic rocks were extruded and with them are local bodies of sediments. The latest batholithic bodies appear to be of about the same age as some of these Tertiary volcanics. During the Pleistocene period the region was covered by a thick ice-sheet, but as it lay in a basin-like depression the movement of the ice-sheet as a whole was slight and as a consequence did not cause great erosion except in a few small areas, such as Similkameen Valley below Princeton, where the ice escaped through gaps in the rim of the basin.

Within Copper Mountain area, the oldest rocks consist entirely of volcanic material, chiefly tuffs and breccias. These occupy the greater part of the area and the beds are steeply folded along the northwest-southeast axes. There is no means of determining their age, but owing to their lithological similarity they are tentatively correlated with the Nicola series of Triassic age.

Intruding these are several augite diorite stocks of unknown age. Still younger than these stocks are many pegmatite and other dykes of various ages extending down to late Tertiary. In the extreme north end of the area the older formations are covered by lava flows of Eocene or later age.

Table of Formations

Quaternary	Recent	Alluvium
	Pleistocene	Glacial drift
Tertiary		Enstatite andesite flows, tuffs, breccias; basic dykes
		Andesite dykes
		"Mine dykes": quartz porphyry, felsite porphyry
		Verde Creek granite
		Dykes of monzonite, pegmatite, and syenite pegmatite
		Copper Mountain stock: syenogabbro, syenodiorite, monzonite, orthoclase-albite pegmatite. Voigt and Smelter Lake stocks: syenodiorite
		Dykes and larger, irregular bodies of augite diorite and biotite monzonite
Mesozoic	Triassic (?)	Wolf Creek: basalt, augite porphyrite breccia, andesite tuff

WOLF CREEK FORMATION

The greater part of the map-area is occupied by a thick series of volcanic tuffs, flows, and breccias, which have been named the Wolf Creek formation. As indicated on the map, these volcanic rocks underlie virtually all the area not occupied by two large stocks and a belt of much younger volcanic rocks in the extreme north. The rocks of the Wolf Creek formation have been observed by Camsell[1], Cairnes[2], and others to extend over large areas outside the Copper Mountain map-area. Within the map-area the Wolf Creek formation consists entirely of volcanic material, but in neighbouring districts Camsell and Cairnes have observed in the series true sediments, the presence of which aids in correlating these rocks with those of Dawson's Nicola series of Triassic age.

In the southernmost section of the map-area is an horizon of well-bedded and finely banded, dark brown, fine-grained tuffs closely resembling true sediments. They consist of nearly equal amounts of augite and andesine in small crystal fragments, with smaller amounts of hornblende, magnetite, and partly devitrified glass. Adjacent to these tuffs are a few flows from 2 to 4 feet thick of amygdaloidal basalt well exposed in Similkameen Canyon south of the Copper Mountain stock.

[1] Geol. Surv., Canada, Pub. No. 986.
[2] Geol. Surv., Canada, Sum. Rept. 1923, pt. A.

North of these, occupying a wide belt in the central part of the area and surrounding the Copper Mountain stock, is a thick series of medium to coarse, dark green breccias, that are of great importance because they enclose all the ore-bodies of the district. Where unaltered they are dark green to black and are made up of medium-grained, porphyritic fragments, both rounded and angular, and from 2 to 10 inches in length, enclosed in a matrix, usually somewhat finer grained than, but in many places so similar to, the fragments that the latter can be distinguished only on weathered surfaces. Both fragments and matrix consist mainly of augite and andesine-labradorite with small amounts of hornblende, magnetite, and, in places, biotite. The augite commonly occurs as medium-sized, dark green phenocrysts, giving the rock, and particularly the fragments, a porphyritic appearance. Among these augite porphyrites in the eastern part of the district are a few small bodies of light grey, hornblende porphyrite having glittering black blades of hornblende in a light grey, feldspathic groundmass. These bodies in places appear to intrude the breccias and may be sills rather than flows. North of the wide belt of breccias the series is made up of basaltic flows which have been intensely sheared and are impregnated over large sections with vast quantities of pegmatitic material, mainly orthoclase. This gives them the appearance of trachytes and latites, for which on occasions they have been mistaken in the field.

All the beds of the formation strike northwest and dip at steep angles. In the eastern part the dips are to the northeast, whereas in the southwestern part they are mainly to the southwest and are steeper and more irregular. As in many volcanic series the structure is so irregular and obscure that it cannot be worked out in detail. Along the northeast contact of the Copper Mountain stock the breccias have been subjected to stresses which have induced a pronounced foliation parallel to the bedding and also to the contact. This foliation extends practically the full length of the stock and has a width of several hundred feet. In this same locality and probably by the same stresses the breccias have been intensely fractured, resulting in vast numbers of closely spaced, straight, parallel cracks standing nearly vertically and striking normal to the contact of the stock and to the above-mentioned foliation. The cracks vary from a small fraction of an inch to more than a quarter of an inch in width, but average not more than one-sixteenth. The wider ones have probably been widened by the process of replacement. These fractures and the foliation were of the greatest importance in allowing the solutions that deposited the ore minerals access to the breccias, as the bulk of the ore minerals are found to be in the fractures. In the same zone the breccias have been intensely altered by the heat and hydrothermal solutions emanating from the stock. These phenomena, together with the fracturing, will be more fully described in a later section dealing with the mineralization. The Wolf Creek formation is either overlain by or intruded by all the other formations in the map-area and is, therefore, the oldest. On lithological, structural, and geographic evidence it is doubtfully correlated with Dawson's Nicola series which is of Triassic age.

LOST HORSE INTRUSIVES

In the northern part of the map-area, principally in the vicinity of Lost Horse Gulch and west of it in Similkameen Canyon, the Wolf Creek formation is cut by a number of small, irregular intrusions of light-coloured, equigranular plutonic rocks. They are so irregular in outline and so poorly exposed, that the larger outcrops only were mapped and no attempt was made to extend contact lines through intervening, drift-covered areas, though, no doubt, many of the outcrops form parts of one rock body. There are two distinct types: (1) a very light-coloured, acid, augite diorite; and (2) a pinkish grey, biotite monzonite or syenite.

The acid augite diorite forms part of the large body at the west end of Lost Horse Gulch, and entirely composes all the areas shown on the map west of this to Similkameen Canyon. These acid diorites consist of large amounts of pure white plagioclase and smaller amounts of pale green augite which together give the rock a very light, almost white, colour. A small amount of orthoclase is present and in some outcrops apatite is a very abundant accessory. In places in the vicinity of the ore deposits these dykes are impregnated with small amounts of pyrite and chalcopyrite and the feldspars are extensively altered to sericite. In such places the pale green augite seems to owe its colour to the action of the solutions that deposited the sulphides, but in other places where no sulphides are present the augites have the same pale colour. These rocks, though much lighter in colour, are very similar in composition to the Smelter Lake and Voigt stocks as well as to parts of the Copper Mountain stock.

The biotite monzonite also forms part of the large body at the west end of Lost Horse Gulch and occurs in the region south of the eastern end of this gulch as dykes and masses too small to map. It consists mainly of orthoclase and plagioclase and is characterized by numerous, small, black specks of biotite sprinkled freely among the much larger crystals of feldspar. Augite and chlorite are present in small amounts. Like the augite diorite this rock is in places impregnated with small amounts of pyrite and chalcopyrite.

The age or ages of these intrusives are not known, but they are in places mineralized by solutions that apparently originated in the magmas that formed the Copper Mountain and other stocks, and are, therefore, somewhat older. Their composition, however, is so similar to that of the stocks that they may be closely related to them in time as well as in origin.

COPPER MOUNTAIN STOCK

Besides these smaller intrusions, three stock-like bodies of plutonic rocks intrude the Wolf Creek formation. They are of medium coarse grain and of a general dioritic composition. The largest occupies several square miles in the south-central part of the area and is known as the Copper Mountain stock. It is complex in composition and genetically related to the large copper deposits for which the district is noted. A smaller body of diorite in the northeast corner of the map-area is known as the Voigt stock. In the vicinity of Smelter Lake just north of the map-area but projecting a short distance into it is a third body of similar composition, referred to as the Smelter Lake stock and probably connected at no great depth with the Voigt stock.

The Copper Mountain stock is elliptical in plan having a major axis of about 5 miles, extending in a northwesterly direction, and a minor axis of about 3 miles. Only about two-thirds of the stock comes within the Copper Mountain area, the remainder extending a mile or two beyond the western boundary. Similkameen Canyon cuts through the centre of the stock, clearly exposing the wide range of rocks of which it is composed. The Copper Mountain ore deposits lie against the northeast side of the stock and several other similar, but less important, copper deposits are situated in the western and southern parts of the stock. All are believed to be genetically related to it.

The composition of the stock varies from a syenogabbro at its outer margin to, in a central core nearly a mile in diameter, nearly pure feldspar-orthoclase and albite. There is a marked change in texture from a fine-grained plutonic at the margin to, in the centre, a medium coarse pegmatite having crystals up to 3 inches in length. As a whole the stock consists of varying amounts of orthoclase, microcline, plagioclase, augite, biotite, hornblende, and also apatite, which occurs throughout the stock in large crystals some of which are one-quarter inch long. The mineral composition of the rock varies in the following way: an increase in the amount of potash feldspar from 10 per cent to 60 per cent is accompanied by a decrease in the amount of plagioclase and by a change in its composition from andesine-labradorite to albite, and the amount of augite decreases from 36 per cent to less than 1 per cent. Biotite is irregularly distributed and is the principal iron-bearing mineral in the central pegmatitic core. Hornblende is absent from both the outer and the extreme central parts of the stock, but is present in small amounts in the intermediate portion where it appears to be an alteration product of augite. Quartz is absent from all phases, even the pegmatite. The chemical variation is well shown in the accompanying table.

Chemical Composition of the Various Rocks Composing the Copper Mountain Stock

—	1	2	3	4	5
SiO_2	43·12	50·60	54·40	62·86	61·84
Al_2O_3	18·19	16·15	19·05	20·41	19·35
Fe_2O_3	6·20	5·68	3·55	0·35	1·03
FeO	6·43	2·50	2·86	0·14	0·53
MgO	6·52	5·06	2·56	0·20	0·54
CaO	14·00	8·72	6·96	1·20	1·06
Na_2O	2·49	3·86	3·88	4·87	6·07
K_2O	0·81	4·54	5·34	7·35	7·12
H_2O-	0·10	0·14	0·04	0·04	0·24
H_2O+	0·65	1·36	0·66	0·59	0·76
TiO_2	0·50	0·35	0·30	0·35	0·10
CO_2	0·17	0·10	0·00	1·16	0·92
P_2O_5	1·00	0·58	0·36	0·34	0·17
S	0·05	0·02	0·02	0·05	Trace
MnO	0·12	0·14	0·11	0·01	0·03
F	....	Trace	....	....	....
Cl	....	Trace	....	....	....

No. 1 is at the extreme edge of the stock at the end of the lower road on the west side of Similkameen River.

No. 2 is 1,200 feet from contact and about 1,000 feet east of the crusher.

No. 3 is 100 yards south of pumping station in Similkameen Canyon.

No. 4 is pegmatite 14 inches from contact in Similkameen Canyon, 2,500 feet south of pumping station.

No. 5 is the central part of pegmatitic core 1,500 feet from contact in Similkameen Canyon.

The variations in the mineral compositions of the stock were determined by Rosiwal measurements made on powdered samples from two series of specimens taken at intervals along two radial lines, one extending in a westerly direction following the pipe-line leading from the water tanks to the pumping station, and the other extending southward along Similkameen Canyon. The powders were immersed in a liquid having a refractive index of 1·53 so that the potash and soda feldspars could be unmistakably distinguished from one another.

The variation in mineral composition is gradual in some places and abrupt in others. At the two concentric boundary lines shown on the map, somewhat sudden changes in both composition and texture were marked, so that these boundaries could be mapped with little difficulty. Within each of the three zones marked off by these two concentric boundaries, the variation was found to be too gradual to permit mapping the various phases of which each is composed.

The change in the mineral composition is shown in the following table.

—	1	2	3	4	5	6	7
Plagioclase	57·00	35·50	47·90	52·00	40·00	48·30	29·00
Potash feldspar	9·00	20·40	12·30	33·00	23·00	35·10	60·00
Augite	20·35	35·50	23·80	11·70	28·00	1·00	1·00
Biotite	10·10	1·80	10·50	0·00	4·00	4·00	3·00
Magnetite	3·10	5·00	4·10	2·80	4·00	4·00	0·00
Hornblende	....	....	....	....	....	6·00	....
					Muscovite		4·00
					Serpentine		1·90
					Sulphides		0·10

Specimens 1 to 6 were secured along the pipe-line at the following places: (1) at eastern contact of stock; (2) 2,700 feet from contact and 800 feet from boundary of intermediate zone; (3) at contact of intermediate and outer zone; (4) outer part of intermediate zone; (5) central part of intermediate zone; (6) inner part of intermediate zone. Specimen (7) came from the central part of the pegmatitic core.

The outer zone varies in grain from fine to medium fine, and in composition from a syenogabbro at the margin to an inner zoned syenodiorite. The syenogabbro consists of about 50 per cent plagioclase, much of it zoned and varying from labradorite to andesine, of 10 per cent to 15 per cent orthoclase, 30 per cent to 40 per cent augite, 2 per cent to 11 per cent biotite irregularly distributed; and about 4 per cent magnetite. The syenodiorite consists of 12 per cent to 20 per cent orthoclase, about 50 per cent oligoclase-andesine and oligoclase, 25 per cent augite, 10 per cent to 12 per cent biotite, and 3 per cent to 4 per cent magnetite.

The intermediate zone varies from a medium coarse to a coarse-grained rock with crystals averaging between a quarter and an eighth of an inch in length. The composition ranges from a syenodiorite having 25 per cent orthoclase, 50 per cent oligoclase, and 15 per cent augite to a rock approaching a monzonite and consisting of 35 per cent orthoclase, 55 per cent albite-oligoclase (85 Ab-15 An), and 7 per cent augite, the remainder consisting of biotite, hornblende, and magnetite.

The change from this phase to the central core of pegmatite is sudden, the contact, in places, being knife-edge and strongly suggestive of intrusive relationships. Inside this contact the rock becomes coarser in grain and less grey and more pink in colour; augite disappears; and biotite is present in only minute quantities, the small amounts of iron and magnesia shown in the analyses being confined mainly to a soft, pale green, chloritic mineral thought from its optical properties to be penninite. Nearly 90 per cent of the rock consists of feldspar, and of this plagioclase forms about one-third, the remainder being made up of orthoclase, microcline, and microperthite. Apatite is an abundant accessory occurring in large, glassy crystals. Muscovite and sericite are present as alteration products and chalcopyrite and bornite are freely scattered through the pegmatite. Dykes of pegmatite exactly similar in mineral composition occur at many places in and adjacent to the stock.

Some of the outstanding peculiarities of all the phases of this stock are; the absence of both quartz and feldspathoids, the great number of large apatite crystals, and the association of an abnormal amount of orthoclase with the gabbro and diorite phases. As a whole the rocks are massive, but near the southern contact distinct gneissic structures were observed over a considerable area in Similkameen Canyon and also on the west side of the Similkameen. At the former locality the strike of the foliation is north 75 degrees east and the dip 85 degrees to the south; at the latter the strike is north 85 degrees east and the dip 75 degrees north. The stock has been faulted in many places, though the amount of displacement is small. The long haulage tunnel of the mine, which passes through nearly 3,000 feet of the outer zone of the stock, intersects a large number of small fault zones having a north-south trend. In the vicinity of the ore deposits the stock is cut by a large number of minute, parallel fractures striking northeasterly and along which the feldspars and augite are decidedly bleached. Similar minute fractures were observed in the intermediate zone of the stock near the contact of the pegmatite. Here they are less numerous, strike north 30 degrees to 40 degrees east somewhat parallel to those in the outer zone, and contain a few scattered grains of chalcopyrite and bornite.

The stock with its several components presents a pattern resembling a target of which the pegmatite core is the bull's-eye. The contacts of the whole mass with the surrounding formations and the boundaries of the concentric zones within the mass, are clearly shown by their intersections with the steep walls of Similkameen Canyon and by mine development work, to be nearly perpendicular over a vertical distance of 1,000 feet or more. There is no apparent tendency of the body to increase in diameter with depth, therefore it conforms closely in size and shape to the definition of a stock and may be so classified.

The marked consanguinity of the widely varying components, the completeness of the series of components, their normal arrangement with the basic gabbro at the margin and the copper-bearing pegmatite in the centre, together with associate pegmatite dykes and mineral deposits outside the stock, all point to the conclusion that the stock represents a series of differentiated components from a single magma. The variations in composition and texture within the several components, the gradations between the different parts, excepting the pegmatite core, indicate with considerable clearness that the differentiation took place largely in situ.

The rather sharp contact between the pegmatitic and the adjoining syenitic phase is more suggestive of an intrusive contact than of differentiation, but it is not so interpreted. It seems more probable that, instead of a stock of pegmatite boring with almost mathematical precision into the centre of a cylindrical stock of differentiated gabbro, the sharp contacts are due to the highly fluid state of the pegmatite magma, rich in alkalis and other volatile materials, permitting a certain amount of movement and probably some replacement of the adjoining syenite. The origin and differentiation of this stock are discussed in a later chapter of this report.

The relations of this body to the surrounding Wolf Creek formation are clearly shown to be intrusive. As the injection of the stock took place after the volcanic rocks were steeply folded it must be considerably younger than the Wolf Creek formation. It differs markedly in composition from the Coast Range intrusives which are rich in quartz and hornblende. A large body of similar but undifferentiated gabbro occurs in the region between the valleys of Fraser River and Harrison Lake. This body of basic material was observed by the writer in 1930 but it has not been mapped or studied and its age is not yet known. There is, therefore, no available information by which to fix the age of the Copper Mountain stock except that it intruded the Wolf Creek volcanics after they were steeply folded.

VOIGT AND SMELTER LAKE STOCKS

The Voigt stock occupies about 1½ square miles in the northeast corner of the map-area and extends some distance beyond the area to the east. The Smelter Lake stock occupies about 1 square mile in the western part of Smelter Lake Valley just north of the map-boundary, and only a few hundred square yards of it, in Similkameen Valley, extends into Copper Mountain map-area. Between the two stocks is an area covered by Tertiary lavas of no great thickness, beneath which the stocks probably join.

Unlike the Copper Mountain stock, these are nearly uniform in composition. They consist of dark grey, medium-grained augite diorite or syenodiorite composed essentially of plagioclase, augite, and hornblende, with small, varying amounts of orthoclase and biotite. The accessory minerals are apatite and magnetite. Plagioclase, the most abundant mineral, is usually zoned and ranges in composition from andesine to labradorite. The orthoclase varies in amount from 10 to 20 per cent and is anhedral and interstitial. Augite is almost as abundant as the plagioclase and much more abundant than the hornblende. These stocks also differ from the Copper Mountain stock in the type of their associated mineralization which is characterized by large amounts of hematite, magnetite, and pyrite with no bornite. The pegmatites associated with all three stocks are almost indistinguishable.

Like the Copper Mountain stock, the other two intrude the folded volcanics of the Wolf Creek formation and are, therefore, post-Triassic in age. Their similarity in composition to the Copper Mountain stock suggests a common origin and age. Their homogeneity and their type of associated mineralization suggest that they are slightly younger than the Copper Mountain stock.

PEGMATITE DYKES AND VEINS

Pegmatite dykes and veins are unusually abundant in the Copper Mountain district, particularly in and near the three stocks above mentioned, and as already stated the centre of the Copper Mountain stock is a cylindrical core of pegmatite one mile in diameter. In the ores of the Copper Mountain mine and throughout a wide belt crossing Similkameen Valley north of Copper Mountain stock a vast amount of pegmatitic material, chiefly orthoclase and albite with little quartz, has been injected into the sheared and fractured volcanics of the Wolf Creek formation in the form of small veins and disseminations. In places this pegmatitic feldspar is so abundant that the original character of the intruded rocks has been entirely obliterated and they have taken on the appearance of what has been called injection gneiss.

Virtually all the pegmatite is of a syenitic type made up of orthoclase, albite, oligoclase, biotite, and in some cases small amounts of augite. Quartz was observed in only small amounts and in only a few of the veins. In many of the dykes and veinlets of pegmatite, bornite and chalcopyrite are disseminated in small but conspicuous amounts, apparently as primary constituents, as in the pegmatite core of the Copper Mountain stock. In some of the pegmatite dykes there is considerable, pale, greyish green chlorite probably of the penninite variety. The larger bodies of pegmatite have the coarse, irregular texture characteristic of pegmatites in general. One small body of pegmatite exposed in the railway cut about a mile north of the bunkers is composed of an outer zone of long, narrow, orthoclase crystals, some a foot in length, projecting inward normal to the walls, and a central part made up largely of green biotite in large sheets standing normal to the orthoclase crystals.

Many of the pegmatite dykes cut the Voigt stock and the outer parts of the Copper Mountain stock and are, therefore, younger. However, their proximity to the stocks and their closely related mineral composition are sufficient proof of their common origin.

VERDE CREEK GRANITE

Occupying a small area in the vicinity of Verde Creek in the extreme northeast corner of the map-area, but extending a considerable distance to the north and east, is a body of reddish granite. About a mile east of the area this granite forms a steep, high bluff.

The rock consists of about 50 per cent quartz, 20 per cent orthoclase, 15 per cent plagioclase (oligoclase-andesine), and 15 per cent green biotite, hornblende, magnetite, and a few small crystals of apatite. The large amount of quartz sharply distinguishes this rock from all the others of the district. It cuts the Voigt stock and the Wolf Creek volcanics. Lithologically it is like Camsell's[1] Otter granite held by him to be of post-Oligocene age.

"MINE" DYKES

A conspicuous feature of the geology is the large number of white or creamy white granophyre and felsite porphyry dykes found in the eastern half of the map-area. They appear, as represented on the map, to be

[1] Camsell, Charles: Geol. Surv., Canada, Mem. 26, p. 99.

most plentiful in Copper Mountain and Voigt Mine Camps, though this may be partly due to the large amount of surface stripping which has been done in these areas in search of copper ores. Besides those shown on the map there are many too small to be represented and probably many more that are concealed beneath the mantle of glacial drift. They vary from less than a foot to 150 feet in width and some have been traced for distances of over a mile. They trend north and south and dip vertically. They have a peculiar habit of splitting and coalescing again, thus enclosing large, lens-shaped masses of the intruded rock. In the Copper Mountain mine they are particularly abundant and have added considerably to the cost of mining, as it has been found impossible to leave them in place while extracting the ore. They are known locally as the " Mine " dykes.

All these dykes are very much alike in appearance, due to a marked uniformity in composition and texture. They are white or light cream, have a fine to dense grain, and contain a very small, almost negligible, amount of dark-coloured minerals. Two main types are distinguished by the presence of quartz in one and its absence from the other, but the types are closely associated, in some cases form different parts of the same dyke. The quartz-bearing variety is a quartz porphyry or granophyre, consisting of minute quartz phenocrysts in a dense white groundmass. Under the microscope the groundmass is seen to consist of a fine, felted mass of quartz and oligoclase often in micrographic intergrowth. No ferromagnesian minerals could be seen, except a few shreds of chlorite commonly associated with a few small grains of magnetite, and both appear to have been formed from the alteration of some other iron-bearing mineral. The other type is a felsite or felsite porphyry consisting of a dense, creamy groundmass holding a few scattered phenocrysts of oligoclase. The dense groundmass is made up of acid plagioclase and a small amount of quartz. Micrographic and microspherulitic intergrowths are common. Small amounts of chlorite and a greenish biotite are present and in some dykes a few crystals of pyrite. One dyke, about 14 feet wide, situated south of the Copper Mountain mine, contains abundant phenocrysts of hematite usually in the form of small rosettes, some of which are one-eighth of an inch in diameter. These are plentifully and evenly distributed throughout the rock which might with some propriety be called a hematite porphyry.

These dykes cut the Wolf Creek formation and the Copper Mountain and Voigt stocks and the ore deposits and pegmatite veins associated therewith, but are themselves entirely unmineralized. They are cut by the andesite dykes described later; their relation to the Tertiary volcanics is not known. They were injected much later than the stocks. In composition they are not closely related to them, being much richer in quartz and poorer in potash feldspars and it seems unlikely, though not impossible, that they were produced from the same magmas by any process of differentiation. Much less do they resemble the andesites of the Tertiary volcanics. They are unlike the Verde Creek granite in texture, composition, and general appearance. Their much finer texture and prevalent spherulitic structure suggest that they solidified near the present surface and are, therefore, younger than the Verde Creek granite.

ANDESITE DYKES

At many places in the Voigt and Copper Mountain Camps, small andesite dykes, 1 to 6 feet in width, were found which trend usually in a direction at right angles to and cut across the "Mine" dykes. They are fresh, fine-grained, in many cases highly amygdaloidal, greenish grey andesites consisting mainly of augite and acid plagioclase. The amygdules are very small and usually filled with calcite. They are younger than the "Mine" dykes and may be related in origin to the Tertiary volcanics, but nothing very definite is known regarding their age.

TERTIARY LAVAS

About 1½ square miles of the extreme northern part of the map-area is occupied by a series of volcanic rocks which extend over wide areas in and about the Princeton basin. Only that part of the series extending into the map-area was examined and the following descriptions refer to this part only. It consists mainly of very finely grained, amygdaloidal flows, but in the vicinity of Wolf Creek there are also some coarse, brownish red tuffs and breccias. The lavas consist almost entirely of nearly equal amounts of andesine-labradorite and enstatite, a fair amount of magnetite, and a little augite and quartz. The enstatite is in the form of short, rod-like crystals a few millimetres in length. They are nearly colourless but show a faint pleochroism, are optically positive, and have indices of refraction between 1·65 and 1·68, all of which indicates that the enstatite is nearly, if not quite, devoid of iron. The plagioclase occurs as minute laths often in parallel arrangement due to flow movements. The amount of quartz is extremely small and the rock, therefore, more closely resembles an enstatite andesite than a dacite.

The tuffs form the reddish bluffs on the west side of Wolf Creek Canyon and extend also down into the canyon. They have a dull reddish matrix of feldspar, augite, and large amounts of volcanic glass and iron oxide. Enclosed in this matrix are large quantities of lapilli and bombs some of which are as much as 8 inches in diameter, usually porphyritic and having a composition similar to that of the matrix. In addition there are many fragments of foreign sedimentary, volcanic, and plutonic rocks, many of which can be correlated with the other formations of the district.

There are also associated with these volcanic rocks many basic dykes which cut all the other formations of the district. One of these, a conglomerate dyke about 8 inches in width, can be traced across Similkameen Valley near the northern boundary of the area. The matrix is an extremely fine-grained, glassy porphyry of basaltic composition. The pebbles are well rounded, are from 2 to 4 inches in length, and consist of the various types of fresh and altered rocks of the neighbourhood. Many partly filled cavities occur in the dyke; these are lined with red and brown bands of agate.

This series of volcanic rocks overlies the Wolf Creek volcanics unconformably and beyond the limits of the area rests conformably on sediments said to be of Oligocene age.

CHAPTER IV

ECONOMIC GEOLOGY

GENERAL REMARKS

Copper Mountain map-area is noted for its copper deposits, particularly those of the Copper Mountain mine which until recently was producing 2,500 tons of ore a day. There are numerous other copper deposits scattered over the northern part of the area on both sides of Similkameen River and some 275 claims have been staked in or adjacent to the area. Some of these deposits are large but low grade, others are high grade but small; all are of irregular form and indefinite limits and none but those of the Copper Mountain mine has been developed to the productive stage. A great deal of shallow development work has been done on all the showings and several fair-sized blocks of ore, scattered from Voigt's Camp to the west side of the Similkameen, have been located, amounting in all to several million tons exclusive of Copper Mountain mine. Much of this development work, however, consists of diamond drilling which was done without sufficient knowledge of the geological structures that determined the distribution of the copper minerals and the results, therefore, are inconclusive and probably in some respects misleading. All the ore thus proved, including that of the Copper Mountain mine, lay within a few hundred feet of the surface and the general conclusion was drawn from the drilling results that the ores would be limited to very shallow depth. More recent underground work in the Copper Mountain mine has proved the incorrectness of this conclusion by the discovery of valuable ore-bodies far below the limits of mineralization determined from drilling results. The geological information indicates probabilities of the ore extending to still greater depths and it is reasonable to hope that large quantities of ore will yet be discovered as mining progresses and when geological and geophysical methods are employed in exploration work.

The only other metals of commercial value known to occur in the district are gold and silver, both of which are present in small but important amounts in all the copper ores. The Copper Mountain mine produced at the rate of about 4,000 ounces of gold and 121,000 ounces of silver annually. As previously mentioned, considerable placer gold was produced many years ago from the gravels of Similkameen River near the mouths of Friday and Whipsaw Creeks.

Feldspar occurs in the district in immense quantities in the many pegmatite dykes, and particularly in the core of the Copper Mountain stock where many millions of tons of pegmatite are exposed in the canyon of Similkameen River. Owing to this deposit's convenient location on the Copper Mountain spur of Kettle Valley Railway and to the immense quantities of easily mined pegmatite, it was hoped that the deposit might eventually become the source of large quantities of commercial feldspar, but on investigation the feldspar was found not to be of marketable quality. Analyses 5 and 6 on page 13 represent the chemical nature, and the microscopic analysis (7) on page 14 the approximate mineral composition of the pegmatite. According to the specifications given by Arthur S. Watts in "The Marketing of Metals and Minerals,"[1] the feldspar is almost up to grade with respect to the content of the alkalis, is very little too high in lime and magnesia, and desirably low in free silica, but, according to tests made by Mr. Hugh Spence of the Mines Branch, Department of Mines, Ottawa, it is badly off colour when burned, probably because of the presence of too much iron. Nevertheless, careful search might discover large sections of this stock which would come up to, or nearly to, present commercial requirements. The immense size of the deposit, a mile in diameter and probably several thousand feet in depth, its convenient location on a railway, and only 150 miles from a seaport, would enable it to be operated on a large scale and at a low cost should a market ever be found for material of this grade, or should sections of it be found that would measure up to present standards of the industry. It is possible, also, that some of the "Mine" dykes with their nearly pure feldspathic compositions and dead white colour might be used for similar purposes.

On the basis of mineral composition, genetic association, and geographic position, the copper deposits of the district fall into three well-defined groups, namely: (1) bornite deposits associated in position and origin with the Copper Mountain stock; (2) chalcopyrite-hematite deposits related to and situated in the Voigt stock; (3) chalcopyrite-pyrite deposits occupying a wide belt extending from the west side of Voigt's Camp across Similkameen Valley beyond the limits of the map-area, and of doubtful affiliations.

The most important of the three is the bornite group which includes the deposits of the Copper Mountain mine as well as several less important deposits at various places in or adjacent to the Copper Mountain stock. The ores consist of bornite and chalcopyrite with small amounts of magnetite and pyrite, and large amounts of orthoclase, albite, augite, biotite, epidote, and zoisite, as gangue minerals and alteration products, deposited during the same general period and by the same solutions. These minerals occur in the gabbro of the stock, in pegmatite veins, in the central core of the stock, and most abundantly in the fractured volcanic breccias of the Wolf Creek formations adjacent to the stock. The chalcopyrite-hematite deposits are less important in size and grade. They consist of hematite, pyrite, magnetite, and chalcopyrite with small amounts of quartz and calcite, in veins that cut the Voigt stock near its margins. The chalcopyrite-pyrite deposits are numerous and spread over a large area extending across the northern part of the map-area and beyond to the west on Kennedy Mountain. They contain large amounts of pyrite with a little chalcopyrite, both of which form disseminations in altered country rock, principally Wolf Creek volcanics and Lost Horse intrusives. Though it is not definitely proved, these deposits are believed to be related in origin to the chalcopyrite-hematite deposits. Each of these groups of deposits will be described separately. The bornite deposits, owing to their greater importance and greater complexity, will be described last.

[1] Spur and Wormser: McGraw Hill Book Co., New York, 1925, pp. 300.

CHALCOPYRITE-HEMATITE DEPOSITS

There are two principal deposits of this class both situated east of Wolf Creek and a few hundred yards north of Voigt's cabins, on the Automatic fraction, Frisco, and Number 14 claims. The ores of these deposits are so similar in composition and appearance that they are indistinguishable, and so characteristic that they could not be mistaken for any other ores in the district. A large quantity of this ore lies on the dump of the tunnel of Number 18 just west of Voigt's Camp on the south side of Lost Horse Gulch. However, it differs so markedly from other ore on the dump and from any ore seen in the tunnel that it is evident it was transported from the tunnel on the Automatic Fractions claim.

These chalcopyrite-hematite deposits occur as replacement veins in the Voigt stock near its western contact. They are comparatively straight, and strike in an east-west direction nearly at right angles to the contact; they dip vertically, and the veins of both claims are in line with one another. It is probable that the veins on both claims belong to one system of fissuring and it is possible that they are continuous from one deposit to the other. The widths of the veins vary from 2 feet to 14 feet with an average greater than 7 feet. The contacts with the country rock are well defined but not sharp and have the minor irregularities characteristic of replacement veins in general.

The minerals of which the veins are composed are listed in order of their relative abundance: hematite, pyrite, orthoclase, albite-oligoclase, quartz, calcite, magnetite, chalcopyrite, chlorite, epidote, sericite.

The hematite constitutes over 50 per cent of the veins and occurs both massive and as well-developed crystals of specularite. The crystals replace orthoclase and albite-oligoclase gangue mineral as well as the original feldspars and pyroxene of the country rock.

The pyrite occurs as scattered crystals in the hematite and in the surrounding country rock, and in places it seems to have replaced blades of hematite as if of a slightly later origin.

The orthoclase occurs as crystals sparsely scattered throughout the veins and more abundantly disseminated in the wall-rocks, to which it has imparted a characteristically pink colour for a width of several inches on either side of each vein. Orthoclase also forms the principal, and in many cases the only, mineral of numerous pegmatite veinlets a few millimetres in width, which occur in vast numbers in and adjoining the veins. Along these pegmatite veinlets the country rock is coloured pink, in the same way as the rock adjoining the veins, by the disseminations of small orthoclase crystals.

Albite-oligoclase accompanies the orthoclase in the veins and in the pegmatite veinlets, but is less abundant.

Quartz is much less plentiful than the feldspars and is present in the hematite as well as in the pegmatite veins.

Calcite in small amounts but in rather large crystals occurs in the hematite veins. It was deposited much later than any of the other minerals. Neither siderite nor ankerite was observed.

Magnetite is very abundant in some of these deposits, for example on the Falum deposit, whereas in others like the Frisco it is very scarce. It seems to be of the same age and origin as the hematite.

Chalcopyrite occurs as blebs in the pyrite crystals and as small, irregular masses between the hematite and pyrite crystals. It was not observed in any part of the veins where pyrite was not abundant.

Chlorite was observed only in small veinlets cutting the original feldspars of the country rock.

Epidote is abundant in certain parts of the wall-rock and is particularly conspicuous along the margins of small veins of specularite branching from the main veins.

Sericite occurs as an alteration product in the feldspars of both the country rock and the veins, but is much less abundant than in most replacement veins of this general type.

The order in which the various metallic and gangue minerals were deposited is difficult to determine, but it is certain that the hematite, pyrite, magnetite, feldspars, and quartz are earlier than the chalcopyrite and that the calcite was the latest. The presence of specularite, magnetite, and the feldspars is evidence of the high temperature at which the deposits were formed. The close proximity of the ores to the contacts of the Voigt stock and the absence from the vicinity of any other intrusive capable of producing such deposits, together with what is known in general regarding the origin of such deposits, strongly suggest that these hematite-pyrite deposits were deposited from solutions originating in the Voigt stock. The confinement of the ores to pronounced fractures in the stock shows that they were formed after it was solidified.

CHALCOPYRITE-PYRITE DEPOSITS

These deposits consist of erratic disseminations of the two sulphides in various members of the Wolf Creek formation and the Lost Horse intrusives. They are scattered over the northern part of the area from Voigt's Camp west across the Similkameen and beyond to Kennedy Mountain. The more important of these deposits are those found on the Annie L, Princess Maude, Silver Dollar, Ada B, Triangle fraction, Duke of York, and Red Buck claims, all of which contain fair amounts of low-grade copper ore.

The deposits occur in various members of the Wolf Creek formation and in the Lost Horse intrusives, generally near the margins of the latter. The chalcopyrite-pyrite disseminations are indefinite and extremely irregular in shape. They seem to be elongated, generally in an east-west direction, but it was not found possible to relate the deposits to any well-defined structural feature. On the Annie L and adjoining claims the mineralized volcanics and intrusives have been fractured and intruded by basaltic dykes which are frequently crowded with included fragments of the mineralized rocks. On the Number 18 claim of Voigt's Camp the ores are in black, fragmental tuff; on the Triangle fraction, Duke of York, and Red Buck they are in pink latite or monzonite. The composition and appearance of the ore vary with the nature of the rocks in which the sulphides are disseminated. The minerals introduced by the ore solutions, named in order of abundance, are sericite, pyrite, feldspars, epidote, zoisite, chalcopyrite, magnetite, actinolite, augite, calcite, leucoxene, scapolite, and garnet. None of these minerals is abundant and usually the original character of the host rocks can be easily recognized. Owing to the presence of feldspars and augite, both as original constituents of the rocks and as later products of metasomatism, it is difficult to estimate the extent of the alteration. The scapolite is present in only minute quantities and its identification is somewhat doubtful. Garnet is still more rare, having been observed in only two thin sections. Epidote occurs as minute veinlets and as small clusters surrounding pyrite crystals. Augite is present both as disseminated grains and in minute veinlets.

These ores appear in general to have been formed by high-temperature solutions acting on various types of igneous rocks and following only poorly defined and partly developed structural weaknesses. Their close association with the contacts of the Lost Horse intrusives seems to indicate that the solutions originated in these magmas and that the deposits are really contact metamorphic deposits. The low metallic content and its erratic and indefinite distribution will tend to make the mining of the ores difficult and expensive.

BORNITE DEPOSITS

The bornite deposits are all definitely associated in position and origin with the Copper Mountain stock. The bulk of these ores form several contiguous ore-bodies which constitute the Copper Mountain mine and are situated in the fragmental volcanics of the Wolf Creek formation adjacent to the northeast sector of the somewhat circular contact of the stock. Other, similar ores, however, occur within the gabbro phase of the stock and still others like those on Friday Creek occur in pegmatite dykes; and a considerable amount of copper, though not sufficiently concentrated to form ore, is present in the pegmatitic core of the stock. Though all three types of ore are very similar in composition and origin their respective modes of occurrence are so different that it will make for greater clearness and simplicity to describe each separately and in the reverse order of their importance.

GABBRO DEPOSITS

Those deposits occurring in the gabbro phase of the stock were observed at two widely separated places, one on the Johnston claim on the south side of the stock and the other on the Hamilton-Fraser group of claims west of the Similkameen and near the western side of the stock. At both places the gabbro has a marked gneissic structure with which the copper minerals are associated. On the Johnston claim the gneissic foliation strikes north 75 degrees east and dips south 85 degrees, whereas on the western contact the foliation strikes north 85 degrees east and dips 75 degrees north. Owing to scarcity of outcrops the extent of the areas of gneissic gabbro could not be determined, but they are probably both much larger than the parts exposed, and it is equally probable that the mineralization is also more extensive. On the Johnston claim a few small pits and a shallow shaft have been opened and on the Hamilton-Fraser group three small tunnels have been driven and two shafts sunk.

The ores on these properties consist of fresh-looking, slightly gneissic gabbro containing in the foliation planes disseminated grains of bornite, chalcopyrite, chalcocite, and covellite. A small amount of malachite is found in places encrusted on the gabbro. A few microscopic blebs of galena and two particles of native silver were observed in a polished section of ore from the Hamilton-Fraser claims. The bornite and some of the chalcopyrite are primary, whereas the chalcocite, covellite, malachite, and some of the chalcopyrite occur as veinlets cutting the bornite or surrounding it, and are found only in ore within 10 or 12 feet of the surface. They are undoubtedly secondary in origin. Considerable magnetite is present as disseminated grains, but it is not easy to determine how much, if any, of this was deposited by the ore solutions. Very little gangue mineral accompanies these ores and the original minerals of the gabbro are remarkably fresh. However, a considerable amount of biotite, and some orthoclase and plagioclase in an unusually fresh state, were probably deposited with or slightly earlier than the metallic minerals, and by the same solutions.

PEGMATITE DEPOSITS

The pegmatite ores consist of mineralized pegmatite dykes or copper-pegmatite veins cutting the outer portion of the stock in the vicinity of Friday Creek. These ores differ from those of the Copper Mountain mine only in that they occur in pegmatite dykes of normal size, composition, and mode of occurrence and that the dykes occur within the stock near its margin, whereas the other ores occur in volcanic breccias accompanied by large quantities of pegmatitic material as gangue minerals. The Friday Creek pegmatites vary in width from $\frac{1}{8}$ inch to 3 feet. They are extremely irregular in size, shape, and attitude, all of which make it difficult to outline workable ore-bodies.

The pegmatites consist of orthoclase, plagioclase, biotite, and sphene, among which are grains and blebs of bornite, chalcopyrite, and chalcocite. The orthoclase and the plagioclase are exceptionally clear and transparent. The bornite is slightly more abundant than the chalcopyrite and both are primary. Chalcocite, though still less abundant, is fairly plentiful. Some of it has a decidedly blue colour and is secondary after bornite and chalcopyrite, but much of it is greyer in colour and has every appearance of having been deposited at the same time and in the same way as the bornite.

In the pegmatite pipe which forms the core of the stock, small grains of chalcopyrite and bornite are widely but sparsely scattered. These sulphides are not associated with any fractures or shears in the pegmatite, but are peppered through the feldspar and biotite crystals of which the pegmatite is composed. Though there is not nearly sufficient copper to form ore, the occurrence is of particular interest as evidence bearing on the origin of the Copper Mountain ores. No pyrite accompanies the copper minerals, a phenomenon so unusual and significant as to be worthy of note, and the absence of quartz is also worthy of mention. Chalcopyrite in minute grains is present in many narrow, tight, straight fractures which radiate from the contact of the pegmatite out into the adjacent portions of the stock. The wall-rocks for half an inch on either side of these minute fractures have been slightly bleached by the solutions that deposited the chalcopyrite. This occurrence of chalcopyrite also free from pyrite and quartz is most unusual.

CONTACT DEPOSITS

The ore-bodies of the Copper Mountain mine are the largest and richest of the district and have been mined extensively. They occur mainly in fragmental volcanic rocks adjacent to the stock, but also to a less extent in the gabbro of the stock near its margin. The volcanic rocks have been intensely metamorphosed, fractured, and sheared before being mineralized. Although the original nature of the volcanic members at this place has been greatly obscured by later changes, enough of their original character remains to correlate them with unaltered fragmental rocks occurring in contiguous areas. The fragments vary in size from less than an inch to more than a foot, and in outline from sharply angular to nearly round. The matrix consists of crystal fragments and varies in grain from medium fine to dense. Both fragments and matrix consist essentially of nearly equal amounts of augite and andesine-labradorite with minor quantities of hornblende, magnetite, and biotite. They have, therefore, a composition very similar to that of the gabbro, but they differ considerably in appearance because of their fragmental nature, their greater content of augite giving them a darker colour, and their pronounced porphyritic appearance which is due to plentiful augite phenocrysts in many of the fragments.

In the general region of the ore deposits which extend along the contact from the Copper Reef to Oriole claims, a distance of 2½ miles, the fragmental rocks have been dynamically and hydrothermally metamorphosed to a marked degree. The first change that appears to have been induced was a very marked schistose or gneissic foliation. The matrix, and to a less extent the fragments, show an almost microscopically fine-banded arrangement of the mineral constituents. The attitude of the foliation follows closely the gently curving but perpendicular contact of the stock. On the Helen H. Gardner claim the average strike is about northwest, whereas on the Princess May claim it is nearly due east.

Accompanying this schistose structure is a very well-defined set of straight, narrow, parallel fractures, striking nearly at right angles to the schistosity and to the contact of the stock. On the Oriole claims these fractures strike north 75 degrees east, on the Sunset mainly north 32 to 60 degrees east, and on the Princess May north 10 to 12 degrees east. The dips are invariably to the northwest and west and generally quite steep. A few exceptional dips of less than 60 degrees were noted, but the great majority are between 65 and 75 degrees. As these fractures played the leading role in conducting the ore-bearing solutions, the various ore-bodies show a tendency to parallel them. These fractures contain the bulk of the ore minerals and are, therefore, referred to as the ore fractures. Some of their characteristics are their straightness, parallelism, and narrowness. Their width varies from a fraction of a millimetre to a centimetre or, as in a few cases, to several centimetres, and averages not more than a few millimetres. The wider ones have no doubt been somewhat enlarged by replacement. In length they vary greatly, some having been traced in underground workings for 20 feet. The spacing of the ore fractures varies from place to place and bears a direct relation to the tenor of the ore. In places the fractures are, on an average, about 2 inches apart, and this is typical of ore running about 2 per cent copper. In other places the fractures are much more closely spaced and the grade of the ore rises to over 3 per cent and in places 4 per cent. Plate III shows a polished surface of an intensely fractured and highly mineralized piece of ore. It also shows the extreme narrowness of the ore-bearing fractures. In other places the rocks were apparently not so brittle and are fractured to only a slight degree, carrying, therefore, little or no copper. In general the more massive beds with few fragments were the least fractured and are almost barren of ore.

Interbedded with the fragmental rocks are several beds or sills of nonfragmental rock situated several hundred feet northeast of, and following, a zigzag course roughly parallel to the contact of the stock. They are light grey, augite-feldspar rocks with a rather fine crystalline texture. In composition, texture, mode of occurrence, and general appearance they resemble the Lost Horse intrusives, but they also resemble the outer phases of the Copper Mountain stock. They have not been schisted or fractured like the fragmentals between them and the stock. They are considerably altered to sericite and may contain some augite of hydrothermal origin, but are entirely unmetallized and mark the northeastern limits of the Copper Mountain ore-bodies. Beyond these nonfragmental rocks there is a widespread but sparse mineralization and no ore of the bornite type. The concentration of the ores between these nonfragmental rocks and the Copper Mountain stock may have been caused by the massive beds forming a dam against the migrating ore solutions; or they may have by their greater rigidity accentuated the shearing and fracturing in the less competent rocks between them and the rigid mass of the stock.

During this dynamic metamorphosis, and to some extent preceding it, a very intense biotitation of matrix, and to a less extent of the fragments, took place over a zone extending outward from the contact for from 200 to 300 feet, the limits being both irregular and indistinct. Within this zone the intensity of the alteration varies widely, but on the whole is very great, and over much of it the alteration to biotite is nearly complete. In these beds the outlines of the original fragments can be only dimly distinguished by slight variations in the size and orientation of the biotite crystals. In the beds which are most completely biotitized, the texture is coarser than in those that are only partly altered. In the latter the alteration is more marked in the matrix which is frequently converted to an extremely dense, brownish black material closely resembling in appearance flint or black chert, but readily distinguishable from it by being easily scratched. Under powerful magnification biotitation may be observed in different stages of development. In slightly altered rocks a few minute scales of brown biotite, almost submicroscopic in size, may be seen on the cleavage planes of the feldspars and augites and in the intergranular planes. In more highly altered and, therefore, browner rocks, the biotite scales occur in the same way but in greater numbers. In still more altered rocks the feldspars and augites are clouded with biotite crystallites; and in the final stage of the alteration the original minerals are completely obscured.

A second type of alteration was developed, principally outside the zone of biotitation but overlapping it to some extent. It was characterized by the introduction of great quantities of pyroxene. In certain parts of the fragmental rock, minute crystallites of pale green pyroxene, probably augite, were introduced in vast numbers. These are disseminated through the feldspars in a manner similar to that of the biotite crystallites. Their presence gives the matrix of the breccias a pale greyish green, cherty appearance which is characteristic of much of the ore. The pyroxene is accompanied by much smaller quantities of plagioclase, epidote, and zoisite. The alteration continued to take place after the biotitation was complete and the biotitized rocks were fractured. Along the margins of the fractured biotitized rock are bleached zones caused by the introduction of the above-mentioned minerals. Still later than this, quantities of pegmatitic and ore minerals were introduced along the ore fractures.

The pegmatite minerals are biotite, orthoclase, and albite with, in places, much smaller quantities of quartz and epidote. The metallic minerals are principally bornite, chalcopyrite, chalcocite, and magnetite. Some of the wider veins contain continuous masses of pegmatite and in every way resemble pegmatite veins or dykelets. Other veins, however, contain only scattered crystals of the various minerals and testify to the metasomatic nature of their deposition.

The composition of the ores is somewhat unusual and differs markedly from the other copper ores of British Columbia. The more outstanding peculiarities are the large proportion of bornite, the almost entire absence of pyrite and pyrrhotite, the large amount of syenitic pegmatite, and the absence of quartz. The presence of pyroxene both as a primary constituent of the gabbro and the basaltic breccias and as an abundant metamorphic and gangue mineral, and likewise the presence of orthoclase in the syenograbbro, in the pegmatite veins, and in the ore as a gangue, increase the difficulty in working out the history of the formation of the ore deposits.

The minerals so far identified are:

Metallic	Gangue
Bornite	Augite
Chalcopyrite	Orthoclase
Pyrite	Albite
Magnetite	Oligoclase
Chalcocite	Biotite
Covellite	Epidote
Malachite	Zoisite
Azurite	Sericite
Hematite	Quartz
Galena	Scapolite
Zinc blende	Apatite
	Garnet
	Piedmontite

Bornite, though not the most abundant mineral, is, on account of its high copper content, the most important mineral of the Copper Mountain ore. It is generally found that where bornite is absent the copper content fails to reach the limit of commercial grade. It is, however, fairly abundant in all the ores associated with the Copper Mountain stock and in the pegmatite ores usually more abundant than the chalcopyrite. It occurs in solid masses in the ore veinlets and is abundant as disseminated particles and thin fibres in the foliation planes of the schistose fragmental rocks, often several inches or a foot from the ore fractures. Its relations to the feldspars, augite and biotite, which accompany it, indicate that it was deposited either simultaneously or slightly later. It appears to have been deposited simultaneously with most of the chalcopyrite. A small amount of chalcopyrite is undoubtedly much later than the bornite and is of supergene origin. Bornite is equally abundant in all parts and on all the levels of the mine and is undoubtedly of supergene origin.

Chalcopyrite is the most abundant metallic mineral in all these ores except those that occur in pegmatite dykes. It is present in minute amounts also in the pegmatite core of the stock and in the numerous small veinlets that radiate from the pegmatite into the adjoining parts of the stock. Though some of it was deposited later than the bornite, much was deposited earlier than, or simultaneously with, the bornite and is no doubt of hypergene origin. Nevertheless, in some of the oxidized ores chalcopyrite can be seen in considerable quantities bordering veins of malachite and calcite which cut the bornite or follow its margins. This chalcopyrite is undoubtedly of supergene origin.

Pyrite is present in uncommonly small amounts. It is seldom visible to the naked eye and even in microscopic sections only minute quantities can be detected. In microscopic examinations made of concentrates and tailings from the Copper Mountain mine, pyrite was observed only occasionally and in exceedingly small amounts. Estimates made by the Rosiwal method on polished sections from these tailings and concentrates showed that pyrite forms only a small part of 1 per cent of the sulphides in the ore. In a few pegmatite veins containing much epidote, easily visible amounts of pyrite associated with calcite were observed, but these veins contained no copper minerals. Few, if any, copper-sulphide ores in the world contain such small amounts of this very common mineral.

Magnetite is present in all the ores associated with the Copper Mountain stock in amounts which, though comparatively small, exceed those of the pyrite. It is less abundant in the ores contained in pegmatite dykes than in those contained in the breccias or in the gabbro of the stock. It was observed in fairly large amounts in the tailings, and in much smaller amounts in the concentrates from the Copper Mountain mill. No doubt much of the magnetite is an original constituent of the gabbro and breccias, but it is equally certain that much of it is of hydrothermal origin. This is proved by the presence of considerable amounts of magnetite in the ore fractures in certain parts of the mine, sometimes to the exclusion of all other minerals. Such magnetite veinlets are not plentiful but were noted particularly in a section of No. 2 tunnel about midway between the Sunset and Helen H. Gardner ore-bodies. There can be no doubt of the hydrothermal origin of this magnetite.

Chalcocite is present in only small amounts, but is most abundant in the ores within 10 feet of the surface where it is associated with both bornite and chalcopyrite ores. In this superficial zone malachite, covellite, and azurite are also present, clearly indicating the action of surface oxidizing waters. Undoubtedly much of the chalcocite of this zone is of supergene origin, but below this zone and extending down to the lowest level of the mine far below any indications of the actions of surface waters, small amounts of chalcocite are found in the bornite and are regarded by the writer as being of hypergene origin. Nowhere is chalcocite sufficiently plentiful to materially affect the copper values.

Covellite in very small amounts is found in the shallow oxidized zone in the form of veinlets cutting the bornite. It was not observed in the deeper portions of the mine and is certainly of supergene origin.

Malachite and *azurite* are confined to a shallow zone near the surface and are economically unimportant. For a time certain small losses in the tailings were attributed to the presence of malachite and azurite or other oxidized copper minerals, but microscopic investigations made by the writer failed to detect appreciable amounts of these minerals in samples of the tailings.

Hematite in small crystals was observed in ore-bearing pegmatite veinlets on the Sunset claim. It was deposited earlier than the bornite and apparently earlier than the orthoclase also. It also occurs closely associated with magnetite crystals scattered through the rock cut by the ore veinlets. This hematite appears to be of magmatic origin, and it is possible that the hematite crystals in the pegmatite ore veinlets are residuals of crystals of primary origin which have resisted replacement by the pegmatitic and ore minerals.

Galena is present in extremely small quantities and was seen only as microscopic grains in the bornite ores, more particularly in the gabbro ores of the Hamilton-Fraser claims. This mineral is present in small quantities in all the copper ores of British Columbia, but in none is it in such small amounts as in the Copper Mountain ores.

Zinc blende was observed in quantities equally as small as those of galena.

Gold occurs in the ores in small but economically important amounts, averaging about 0·01 ounce a ton. The manner in which it occurs is not fully known, though in one polished specimen from the Helen H. Gardner claim some small specks of a bright metallic mineral were observed and were thought to be electrum. It is unlikely, however, that all or even a large part of the gold occurs in this form.

Silver is present in the ores to the extent of about 0·24 ounce a ton. Very small amounts of native silver, electrum, and galena have been observed in polished sections of the ore from different localities, but no other silver-bearing minerals have been identified and those observed seem not to be sufficient to account for all the silver present. This condition with respect to silver obtains in the other large copper deposits of British Columbia, and it is probable that, as in the case of the gold, silver occurs in some invisible form, probably solid solution in one or more of the other metallic minerals.

Augite is probably the most abundant of the gangue or non-metallic minerals in those ores not directly associated with pegmatite dykes. As it is a very abundant primary constituent of both the stock and the volcanic breccias it is difficult to estimate the amount due to hydrothermal activities. However, much of the augite deposited in this latter way may be distinguished by its paler colour and its occurrence in much smaller crystals than the augite of magmatic origin. In places it is very abundant. Much of the ore of the Copper Mountain mine occurs in volcanic breccia the matrix of which has been converted to a pale, greyish green, chert-like material consisting largely of minute crystallites of this pale green augite. Very definite veins of augite cutting feldspars and other minerals of the breccias are not uncommon, and are in many cases bordered by parallel bleached zones up to a quarter of an inch in width that owe their lighter colour to the introduction of large numbers of the pale green augite crystallites.

Orthoclase is very abundant in all these ores. It is a primary constituent of the syenogabbro which in places is mineralized sufficiently to constitute ore. It is the predominant mineral of the ore-bearing pegmatite dykes and also of the pegmatite veinlets that occur in such vast numbers in the principal ore-bodies of the district. It has a pale pinkish colour and in the pegmatite veins and dykes is usually in well-formed crystals. It frequently is found as small, isolated crystals disseminated in the rocks bordering the veinlets, and this mode of occurrence is taken as evidence that much of the orthoclase was precipitated from hydrothermal solutions, in the same manner as the ore minerals.

In many places large crystals of orthoclase were observed, parts of which are clouded by alteration products such as sericite, whereas other parts are perfectly clear and fresh, both parts extinguishing simultaneously. The appearance of these partly fresh and partly altered crystals suggests that the clear portions were in some way purified by the migrating ore solutions. A more probable explanation, however, is that the clear parts were built on to the altered parts in perfect orientation by the ore solutions operating according to a combination of the laws of crystal growth and metasomatic replacement.

Albite is abundant in all the pegmatite veins and dykes and is present also in many of the small ore veinlets which contain no other pegmatite minerals. In such veinlets it is associated with epidote, zoisite, augite, occasionally a little quartz, and the metallic minerals. It often occurs as glassy-clear, well-formed crystals projecting from the sides of the veinlets into solid masses of bornite and chalcopyrite.

Oligoclase is fairly abundant in the ore veinlets, occurring in the same manner as the albite and evidently deposited in the same way by ore solutions. It occurs as glassy-clear, euhedral crystals twinned in the usual way, and was distinguished from the albite only with considerable difficulty.

Biotite is extremely abundant in all the ores. It is a primary constituent of the rock, a very abundant contact metamorphic mineral of early origin, and an equally abundant pegmatitic mineral. Certain sections of the volcanic breccias have been almost completely biotitized by contact metamorphic agencies prior to the deposition of the ore minerals. In the pegmatite it is usually later in origin than the feldspars and often segregated in the centres of the dykes.

Epidote is widespread and fairly abundant both in the ores which occur in the breccias and in those in the pegmatite dykes. In some of the pegmatite veins it was found closely intergrown with the orthoclase in a manner resembling graphic intergrowths and strongly suggesting simultaneous deposition. It occurs as perfectly transparent green crystals and is evidently of the variety pistacite. In one or two thin sections of specimens from the Sunset and Vancouver claims small amounts of a mineral closely related to epidote but different in colour were observed and determined optically to be piedmontite.

Zoisite is abundant in the ore veinlets in well-formed crystals closely associated with pistacite and albite.

Sericite is plentiful in the original feldspars of the gabbro and of the volcanic breccias. It is present also in the orthoclase of the pegmatite dykes, but is almost entirely absent from the orthoclase and plagioclase crystals that were deposited metasomatically by the ore solutions. The sericite in the original feldspars is probably much older than the ores.

Calcite in the form of minute veinlets is present in much of the Copper Mountain ore. The veinlets cut all the other minerals including the sulphides; the calcite is the last mineral to have been formed in these deposits.

Chlorite, probably of the species penninite, is abundant in the pegmatite dykes and in the pegmatite core of the stock. It appears to be secondary after some other mineral which it has completely replaced. Chlorite of a slightly different appearance was observed microscopically in some of the ores and replaces feldspars and augite.

Quartz is conspicuously absent from all the rocks, and almost all of the ores. It was, however, observed in microscopic quantities in a few ore specimens and occurred as a gangue mineral along with the feldspars, etc. In no other metallic deposit known to the writer is this common mineral nearly as scarce as in the Copper Mountain deposit.

Scapolite. In the metamorphosed breccias adjacent to the ore veinlets an indistinct fibrous mineral occurs in small amounts and was observed in most of the thin sections made from specimens of the ores. This mineral is so closely intergrown with the feldspars and other minerals that it could not be definitely determined, but such optical properties as could be measured seemed to resemble those of scapolite more closely than those of any other mineral. It was nowhere observed in hand specimen.

Apatite in fairly large, clear crystals was observed in some of the ores, closely associated with the feldspars and other pegmatitic gangue minerals. As the mineral is present in similar form in the various phases of the stock and particularly those that approach the pegmatite, as well as in the pegmatites themselves, it is reasonable to assume that apatite found in the ores was deposited with the pegmatitic gangue.

Garnet. In a few ore veinlets in the metamorphosed breccias of the mine, microscopic grains of an isotropic, high-refracting mineral were observed and thought to be some variety of garnet. They contain many small quartz inclusions.

Paragenesis. The order in which the above minerals were deposited cannot be definitely determined from an examination of the ores and deposits, but certain groups of minerals can be recognized as having been deposited earlier than other groups. Some obscurity is caused by the presence of some of the minerals in two or more of the above groups. Undoubtedly the first minerals to be deposited by emanations from the stock magma were biotite and augite in the form of minute crystallites more or less replacing the original minerals of the volcanic rocks. The manner in which the augite and biotite are distributed through the rock, as described above, is evidence of the extreme smallness of the openings through which the depositing fluids moved. The biotite is confined mainly to a zone near the contact, whereas the augite is not only distributed abundantly through this zone but is even more abundant outside of it where it imparts to the volcanic breccias a pale greyish green, chert-like appearance. Most of this augite was deposited simultaneously with the biotite, but there is clear evidence that the solutions of this early metamorphic period continued to deposit augite after the deposition of biotite had ceased. Closely associated with the biotite and augite are considerable quantities of chalcopyrite and bornite evenly disseminated as minute grains among the other minerals, and remote from later fractures which are filled with the same sulphides. There is no evidence, microscopic or otherwise, of the relative ages of the sulphides and metamorphic minerals, but from evidence obtained from other contact metamorphic deposits it is thought probable that some of the disseminated sulphides may have been deposited along with the biotite and augite. There is, however, no doubt that much of the bornite and chalcopyrite is of a later period. It is probable that some feldspars were deposited during this period, but it is difficult to distinguish them from the constituent feldspars of the rocks. To what extent the breccias were fractured prior to the biotitation is not known definitely, but much fracturing certainly occurred at a later stage. It is probable from the manner in which the metamorphism is localized that the breccias were to some extent fractured prior to the introduction of the biotite and augite of this earlier period. The bulk of the ore fractures, however, were formed later than the contact metamorphism, and shortly after this fracturing the pegmatite and ore minerals were introduced. The pegmatite minerals, including orthoclase, albite, augite, epidote, biotite, and garnet, in general preceded the ore minerals that may be seen veining them, but there is clear evidence of the simultaneous deposition of both sulphides and feldspars in and adjoining the ore veinlets. Chalcopyrite, bornite, and the primary chalcocite were deposited at the same time. In many of the pegmatite veins there is considerable chlorite which appears to have resulted from the alteration of some earlier ferromagnesian mineral, but the alteration is so complete that it has entirely obliterated the replaced mineral. Accompanying this chlorite and apparently formed by the same solutions are considerable amounts of sericite and talc which replace the adjacent feldspars. It must be remembered, however, that all of these periods of mineralization, as well as that of fracturing, were of long duration and that there was much overlapping. Later than all of the above minerals are many minute veins of calcite. The last group of minerals to be formed in the deposit is the so-called supergene group including malachite, azurite, dendrite, kaolin, covellite, and chalcocite. As previously mentioned, all of these are confined to a superficial zone not more than 15 or 20 feet in depth.

It is, therefore, evident that there were four periods of mineral deposition: (1) the contact-metamorphic period, characterized by deposition of biotite and augite with probably some feldspar and metallic sulphides; (2) the pegmatite-ore period during which most of the pegmatite and the ore minerals were deposited; (3) the sericite-chlorite period closely following period number 2; and (4) the much later period of surface alteration.

GENESIS OF COPPER MOUNTAIN ORE

The theory that many of the common types of metallic ores are derived from the magmas of certain types of igneous rocks has been so well established and become so generally accepted that it may now be regarded as a fact. Many examples may be cited of ores whose genetic relations with nearby igneous intrusions are established beyond doubt. So strong is the belief in this theory that it is now common, in the case of ores occurring in regions of no known igneous intrusions, to assume that the latter must exist somewhere beneath the surface and at no great depth. The copper ores in question are typical of the class that is genetically associated with igneous intrusions and this fact, together with their close proximity to the Copper Mountain stock, would ordinarily be regarded as sufficient evidence of their community of origin. However, in the case of the Copper Mountain ores, there is much additional evidence, chemical and mineralogical, which proves the consanguinity of the ores, pegmatite, and stock. As examples of this additional evidence there is: (1) the mineral similarities including the absence of quartz, between the ores, pegmatites, and various phases of the stock; and (2) the vast amount of pegmatite in the ores and of copper in the pegmatite core and dykes. There can, therefore, be little if any doubt as to the source of the elements composing the ore, but as to the manner and time of their separation from the parent magma and their transportation to their final resting place much explanation is yet wanting. These problems along with other theoretical considerations are discussed in a later section of the report.

CHAPTER V

DESCRIPTION OF PROPERTIES

In this chapter will be found descriptions of all the more important properties, particular attention being paid to ownership, development work, and commercial possibilities. The geology is only briefly described as it has been fully discussed under "Economic Geology." The properties are grouped according to the types of ore of which each is composed.

PYRITIC DEPOSITS

DUKE OF YORK

One of the most important deposits of the chalcopyrite-pyrite class occurs on the Duke of York claim on the Copper Mountain-Allenby Railway about 1½ miles south of the northern boundary of the map-area. This claim is part of the Voigt Estate and, therefore, belongs now to the Consolidated Mining and Smelting Company. The deposit extends from below the level of the railway up the steep sides of the valley to the 3,300-foot contour. The sulphides are disseminated through the Wolf Creek formation which at the above contour becomes covered by the flat-lying beds of Tertiary volcanics. In the vicinity of the ore the Wolf Creek beds consist mainly of latite which contains a large number of pegmatite veinlets. They are also intruded by irregular masses of Lost Horse intrusives and the gently dipping contact of the Smelter Lake stock lies only 1,500 feet to the north. The numerous pegmatite masses and veinlets are irregular in form and have poorly defined boundaries. The pegmatitic material consists largely of pink feldspar with a fair amount of quartz and no biotite, thus differing from the pegmatite of the Copper Mountain stock. The ore consists of blebs of chalcopyrite and crystals of pyrite disseminated through the latite and usually but not always closely associated with the pegmatite. The sulphides also occur in small veinlets. These assume many different attitudes but conform mainly to three directions, namely: north 30 degrees east, dipping 90 degrees; north 80 degrees east, dipping vertically; and north 80 degrees west, dipping 40 degrees north.

There are two segregations of the ore minerals, the larger situated close to the railway and the smaller at the upper limits of the claim just under the Tertiary volcanics. The former has been exposed by a trench 300 feet long parallel to the railway, and by a tunnel driven in an easterly direction for 270 feet. These openings are in rock extensively replaced by pegmatite of a bright pinkish colour in which the sulphides are disseminated. Neither opening exposes the limits of mineralization, but each ends in ore as good as the average. The size and shape of the ore-body are, therefore, unknown, but the grade is shown by sampling to be low. A sample taken the full length of the trench contained 0·37 per cent copper, and samples taken along the length of the tunnel averaged less than 1 per cent.

The ore of the upper showing contains less pyrite and more chalcopyrite, with small amounts of chalcocite and covellite which are more than probably of supergene origin. A specimen of the ore assayed 1·75 per cent copper. Although this ore is to some extent secondarily enriched this may have taken place before the Tertiary lavas covered the ore and it is possible that a considerable amount of this higher grade material extends beneath the lavas. This possibility could be easily tested by an adit driven under the lavas. It is not considered probable, however, that commercially important bodies of this ore will be found.

RED BUCK

The best ore of the pyrite-chalcopyrite type was seen on the Red Buck and adjoining claims situated on the western side of Similkameen Valley directly across from the Duke of York. The Red Buck and Bornite claims belong to T. C. Riveley of Vancouver, who owns an interest in some of the adjoining claims as well. At this point the side of the valley is very steep, the western boundary of the Red Buck claim being 500 feet higher than the eastern boundary which is only 100 feet above the river. The deposits occur in latite and andesite of the Wolf Creek formation where it is extensively impregnated with pegmatite and intruded by irregular masses of Lost Horse intrusives. The pegmatite consists of orthoclase, albite, and quartz, thus closely resembling that on the Duke of York. The pegmatite veins generally trend in a northwesterly direction following the general strike of the Wolf Creek formation. The ore-bodies are very irregular in form and indistinct as to limits, but tend roughly to follow the strike of the pegmatite. The ore consists of irregular disseminations of chalcopyrite and pyrite with much feldspar and other pegmatitic material distributed through andesite and latite over a large section of the Red Buck and adjoining claims. The deposits have not been sufficiently exposed and their limits are too indefinite to enable them to be accurately delineated.

The development work consists of two tunnels and several drill holes. The lower, which is also the longer, of the two tunnels is on the northern boundary of the Red Buck claim adjacent to the Mogul fraction. It extends in a direction a few degrees south of west for 100 feet exposing ore for 90 feet. The first 50 feet exposes ore averaging 3 per cent copper and the first 25 feet of ore averages 4·02 per cent copper. A shipment of 30 tons of this ore made in 1915 yielded: gold, 0·08 ounce a ton; silver, 0·9 ounce a ton; and copper, 6·63 per cent. The sulphur content was 62 per cent; silica 42·8 per cent; iron 10 per cent; and lime 5·1 per cent. The other tunnel and the drill holes revealed the existence of small patches of lower grade material, but are not situated on the strike of the above-mentioned rich shoot. Further prospecting along the apparent strike of the rich ore-body might discover a continuation of it or other similar ore-bodies.

CLAIMS ON KENNEDY MOUNTAIN

Above the Red Buck and lying farther west, on the summit of Kennedy Mountain, are several claims including the Magnetic, La Reine, Ingersoll Belle, Tempest fraction, and others on which considerable work has been done. Like the other deposits of this class these consist of sporadic disseminations of pyrite and chalcopyrite associated with large amounts of pegmatite in andesite. Several tunnels have been driven and much trenching done, but no commercial ore has been discovered. Most of the work was done before the war.

NUMBER 15 FRACTION

This claim is part of the Voigt Estate and is situated immediately east of the Duke of York and considerably higher. The northern part of the claim is covered by Tertiary lavas and the southern part by andesite and basalt of the Wolf Creek formation. On this claim only one mineralized area occurs and it consists of a sparse dissemination of pyrite and chalcopyrite. An adit 40 feet in length was driven on this mineralized area exposing mineralized andesite throughout its length. At several places samples containing as much as 2 per cent copper may be taken, but an average sample taken over the full length of the tunnel assayed only 0·32 per cent copper.

NUMBER 18

This claim, also part of the Voigt property, is on the south side of Lost Horse Gulch just west of Voigt's Camp. On this claim are two tunnels having a combined length of 500 feet and many long trenches. The rocks in the trenches and tunnels consist of andesite and basalt breccias cut by large felsite and smaller andesite dykes. Pegmatite veins are common, but not nearly so abundant as in other deposits of the district. At many places in the tunnels the breccias are impregnated with pyrite and chalcopyrite. Associated with the sulphides are orthoclase, epidote, zoisite, and sericite. The areas thus mineralized are small and irregular with poorly defined limits. The richest areas—and these are small—do not carry more than 1 per cent of copper so that there is no material on this claim that could be profitably mined.

NELSON FRACTION

This claim, at one time part of the Voigt Estate, has reverted to the Crown for non-payment of taxes. It lies north of Lost Horse Gulch opposite the Number 18. A considerable amount of work has been done on this property, including three small tunnels and many trenches. The rock exposed by these excavations is chiefly latite cut by small, irregular areas of augite diorite of the Lost Horse formation. The latite is impregnated with pyrite and chalcopyrite. The most highly mineralized areas appeared to be in a tunnel 110 feet long, situated 600 feet west of Wolf Creek. A sample taken along the south wall for 75 feet from the face contained 0·28 per cent copper and a picked specimen of the ore assayed 1·97 per cent copper and 40 cents a ton in gold. The small copper content and its sporadic distribution discourage the hope of finding commercial ore-bodies on this claim.

NUMBER 18 FRACTION

This claim adjoins the Nelson fraction on the west. A large amount of trenching and some tunnelling have been done. The geological conditions are similar to those above described and the mineralization and values are of the same order.

OLYMPIA CLAIM

This claim, situated immediately south of Voigt's cabins and east of the Number 18 claim, belongs to J. Wright and others of Spokane. The only rock to be seen on the claim is that exposed in two long trenches situated 500 feet west of Wolf Creek and 300 feet south of the old road. The rocks exposed in the trenches consist of hornblende andesite breccia containing chalcopyrite and pyrite in a few small places and in amounts too small to constitute commercial ore. A small shaft sunk on the claim near the trenches was full of water at the time of examination, but among the material excavated was found a small amount of quartz-magnetite ore containing considerable chalcopyrite and pyrite. Some of the specimens of this ore would obviously carry 2 per cent or more of copper, but the extent of such material on the property cannot be determined from existing work nor does it seem likely to be of commercial importance. Other small workings on this and the adjoining claims to the south expose similar geological conditions but no important ore-bodies.

ANNIE L

This claim, together with the Princess Maud, Ada B, and Silver Dollar lying to the west, contains several important copper occurrences, apparently on the same zone and on which a large amount of tunnelling, trenching, and diamond drilling has been done. As most of the underground workings are undrained and cannot be examined, it is not possible to fully appraise these properties. All of the deposits occur in breccias of the Wolf Creek formation, which have been intruded by tongues and irregular masses of acid augite diorite. Along the margins of these masses the breccias are bleached and extensively replaced by small, reddish pegmatite veinlets with which the ore minerals are intimately associated. Several, large, white, felsite dykes occur in the vicinity but are unquestionably younger than the ore and pegmatite.

The Annie L claim, owned by Henry C. Major of New Westminster, is on the old road leading from Voigt's to Copper Mountain Camp and about half-way between the two camps. On this claim at the southwest boundary and close to the road a shaft was sunk and from the bottom of it over 300 feet of drifting and crosscutting done. Besides these workings there are a number of trenches, some diamond drill holes, and another small shaft. The shafts are not accessible and the only available information is that obtainable from the dumps and the trenches.

The geology consists of andesite breccias cut by several irregular bodies of augite diorite, by felsite dykes, and by numerous red pegmatite veins with which the metallic sulphides pyrite and chalcopyrite are intimately associated. In the vicinity of the shaft the copper values are not high, but a fair amount of ore ranging from 1 to 2 per cent copper has been proved by the shaft workings supplemented by diamond drilling. The information available does not permit of a tonnage estimate being made, but is sufficient to indicate that the proved ore would be measured in thousands or tens of thousands of tons. The shape of the ore-body, or bodies, is irregular and the limits are indefinite.

ADA B AND PRINCESS MAUD

These claims adjoin the Annie L on the northwest and southwest, respectively. The Princess Maud lies immediately north of the Vancouver claim, one of the main group embracing the Copper Mountain mine. Both the Ada B and Princess Maud belong to the Granby Consolidated Mining, Smelting, and Power Company. The ore zone appears to be continuous across both claims and to extend west on to the Silver Dollar and east on to the Annie L. This area is heavily drift covered and rock exposures are confined mainly to the small, scattered trenches and open-cuts, in consequence of which detailed geological mapping is impossible.

The rocks exposed in the locality include mainly breccias of the Wolf Creek formation cut by irregular bodies of augite diorite, by several felsite and quartz porphyry dykes, and by numerous, small, pegmatite veins with which the chalcopyrite and pyrite are associated. Besides the above rocks and minerals, which are common to all the deposits of the vicinity, there is on these claims a black diabase enclosing fragments of pegmatite containing pyrite and chalcopyrite.

On the Ada B the workings are segregated along the eastern side of the claim close to the boundary of the Princess Maud and consist of about fifty trenches, nineteen drill holes, a 200-foot tunnel, and a shaft connecting with about 200 feet of underground drifts on one level. All of the drill holes cut mineralized rock and all but three cut ore containing 1·3 to 2·9 per cent copper. Ore of this grade occurs also in many of the trenches. Several thousand tons of it have been proved.

Between the Ada B and the Princess Maud ore-bodies, a long drill hole shows a barren space of about 340 feet. The workings on the Princess Maud consist of nineteen drill holes and a large number of trenches. These indicate a body of ore of several thousand tons ranging from 1·5 to 3 per cent copper. The grade is somewhat higher than that of the Ada B orebody.

THE SILVER DOLLAR

The Silver Dollar claim, owned by the J. Gellatly Estate, Princeton, lies just west of the Ada B. A large amount of development work has been done on the southern part of this claim. The work includes fifty or more trenches, an adit 460 feet long, five shafts one of which is connected with 210 feet of drifts, and a considerable amount of diamond drilling. The shafts and accompanying underground workings being inaccessible at the time of examination, attention was confined to the trenches, the tunnel, and the material excavated from the shafts.

The rocks found in the trenches in the western part of the claims consist mainly of volcanic breccias of the Wolf Creek formation. In some places these are black and unaffected by hydrothermal solutions, but in other places they are cut by small bodies of light grey acid diorite in the vicinity of which the fragmental rocks are changed from a black to a greyish white colour and impregnated with pyrite and small amounts of pyrrhotite and chalcopyrite.

The tunnel shafts, diamond drill holes, and the majority of the trenches are clustered together into a small space in the extreme southeast corner of the claim where the mineralization is most marked. The volcanic breccias of the Wolf Creek formation are coarser grained in this locality than on the Red Eagle and other adjoining claims, and are cut by small masses of a medium fine-grained, black, plutonic rock having the composition of a gabbro. This gabbro was not exposed on the surface but constituted a large proportion of the dump at the most northerly shaft. In some places the gabbro and the breccias are cut by numerous small veinlets of pegmatitic material, along the margins of which the rock is usually impregnated with disseminated particles of pink orthoclase. In other places the breccia and gabbro are cut by numerous, minute veinlets of pyrite in the vicinity of which the gabbro is bleached to a light grey colour. Small veinlets of quartz, scarcely visible to the naked eye, are also present and over large areas are impregnated with considerable magnetite, pyrite with smaller amounts of chalcopyrite, and in one specimen a few particles of bornite.

Where the bleaching is most intense the ferromagnesian minerals are completely replaced by serpentine and the feldspars are noticeably sericitized. In some of the trenches sections of white felsite dykes were observed.

The best ore appears to be associated with the pink feldspar veins. A considerable amount of copper ore, similar in composition and grade to that on the Ada B and Princess Maud, has been blocked out in the southeast corner of this claim.

RED EAGLE

Immediately north of the Silver Dollar and Ada B is the Red Eagle claim owned by A. E. Thomas of Princeton. A considerable amount of trenching has been done along the eastern, western, and northern sides of this claim; and in the northwestern part a shaft has been sunk to about 50 feet and a drift extended from the bottom of the shaft for 160 feet in a northeasterly direction. The drift and shaft were inaccessible at the time of examination, so that attention was of necessity confined to trenches and to materials extracted from the shaft and underground workings. This consisted mainly of white, altered fragmental breccia containing disseminated crystals of pyrite, and in places particles of pyrrhotite. A small amount of the acid diorite of the Lost Horse formation was also found on this dump and the same rock was exposed in some trenches a short distance north of the shaft. The rocks seen in the trenches on this claim are the same as those found on the adjoining claims, with probably a larger amount of black, unaltered, volcanic breccia. Although pyrite was seen in many of the trenches very little chalcopyrite and no other copper-bearing minerals were seen.

TRIANGLE FRACTION AND COPPER KING CLAIM

The Triangle fraction, Copper King, and several adjoining claims belong to C. E. Thomas and others of Princeton. The group is on the rim of Similkameen Valley, just west of the road, and 1,500 to 3,000 feet north of Copper Mountain post office. The development work consists of a 250-foot adit on the Triangle fraction and several trenches on the Copper King. The rocks exposed by these openings consist of fragmental breccias of the Wolf Creek formation which have been intruded by the acid diorite of the Lost Horse intrusives, as well as by several black diabase dykes which are very fresh and probably related in origin to the black dykes of the mine. Tongues or apophyses of acid diorite were observed near the portal and at the face of the tunnel and in the trenches on the Copper King claim. As is invariably the case, the breccias along the diorite contacts are bleached to a light grey colour, and in this locality impregnated with pyrite and in a few localities with chalcopyrite. Throughout the length of the tunnel the rocks consist of bleached and mineralized breccias and in a few places sufficient chalcopyrite is present to form good ore. One section in the tunnel, 15 feet long and beginning at 120 feet from the portal, contains copper ore averaging 3·5 per cent copper with from $2 to $3 to the ton in gold. Another section of 20 feet beginning at 215 feet from the portal carries 1·3 per cent copper. To the northeast 50 and 70 feet, respectively, are two cuts on the Copper King claim that expose the same rocks and a weak mineralization.

PRINCESS MAY

This claim is one of the main group constituting the Copper Mountain mine and is situated just south of the Triangle fraction and down the hill from, and a little north of, the Copper Mountain post office. It is unusual in having two ore-bodies of different types, one of the bornite-chalcopyrite type situated in the southern part of the claim adjacent to the Copper Mountain stock, and the other of the chalcopyrite-pyrite type situated 500 feet to the north of the first and in close proximity to a body of acid diorite. The types of ore merge into one another, the mineralization being continuous between the two ore-bodies. The northern is a typical pyritic ore-body of considerable size and value. It has been thoroughly tested by drilling, trenching, and a long adit passing directly through the ore. These openings expose an ore-body approximately 200 feet wide, of undefined length and depth, and averaging about 1·5 per cent copper with small gold values.

The southern or bornite ore-body lies close to the contact of the stock and has all the characteristics of ore of this type. It is well developed by trenching and drilling and though not so large as the north ore-body it is much higher grade and has an excellent chance of persisting both laterally and vertically.

CHALCOPYRITE-HEMATITE DEPOSITS

These deposits are clustered along the contacts of the Smelter Lake and Voigt intrusives, more particularly the latter. As a group they are not so promising as the other groups, though there are two ore-bodies on the Frisco and Number 14 claims, respectively, that may be of commercial importance.

AUTOMATIC FRACTION AND FRISCO CLAIMS

These claims are part of the Voigt property. The Automatic fraction claim extends across Wolf Creek Valley just north of and including part of the Voigt Camp. The Frisco lies east of the Automatic fraction and the Number 14 east of the Frisco. A pronounced mineral zone extends from the Automatic fraction across the Frisco onto the Number 14. This zone is developed by a tunnel, Automatic Number 1, starting on the Automatic fraction claim but crossing the boundary line onto the Frisco at a distance of only a few feet from the portal. On the Automatic fraction there are two other short tunnels, Number 2 about 500 feet north of Number 1, and Number 3 across Wolf Creek and still farther north. The rocks underlying this claim consist of latite and andesite breccias in the west and of the gabbro of Voigt's stock in the east, the contact as near as can be determined lying along Wolf Creek. Tunnels Numbers 1 and 2 are in the gabbro. Number 3 on the west side of the creek is in latite. Both rocks are cut by large white felsite and quartz porphyry dykes.

Number 3 tunnel is 114 feet long and runs in a westerly direction. The rock in this tunnel and adjacent to it is sparsely mineralized with magnetite, pyrite, and chalcopyrite. The first 70 feet are most highly mineralized, but even here it is difficult to obtain a sample carrying more than 1 per cent copper.

Number 2 tunnel is about 100 feet long and cuts massive gabbro. A pronounced slip crosses the tunnel at a small angle about half-way between portal and face. Mineralization consisting of magnetite, pyrite, chalcopyrite, and red feldspar occurs throughout the length of the tunnel, but is most marked in the vicinity of the slip. Even here, however, it is doubtful if the copper content reached 1 per cent.

Number 1 tunnel is 342 feet long, mainly on the Frisco claim. There are two short crosscuts to the north at 40 and 70 feet, respectively, from the portal. The tunnel is entirely in syenogabbro except for two large quartz porphyry dykes, a felsite dyke, and two andesite dykes, all of which cross the tunnel nearly at right angles. Throughout the length of the tunnel, as well as the crosscuts, the gabbro is intensely impregnated with hematite, magnetite, pyrite, and chalcopyrite with orthoclase, augite, epidote, and calcite as gangue minerals. The intensity of the mineralization is fairly uniform throughout the length, but the average copper content is below 1 per cent and the gold values less than 50 cents. This same mineralized shear is intersected by a diamond drill hole which extends 200 feet below the tunnel and which encountered about 50 feet of ore of the same character but slightly better grade.

This mineralized zone has been traced for nearly 1,000 feet across the Frisco claim by a series of trenches which expose the same rocks and mineralization. Here also the average copper content is low, probably less than 1 per cent.

NUMBER 14

This claim, also part of the Voigt property, lies immediately east of the Frisco. On the western corner of Number 14 an ore-body similar in age to that on the Frisco has been developed by trenches, drill holes, a shaft, and 200 feet of underground drifts. The trenches show a mineralized zone 100 feet wide and several hundred feet long. The grade is higher than on the Frisco and a 30 to 50-foot band in the central part of the zone carries values up to 6 per cent copper and $10 to the ton in gold, with an average of over 3 per cent copper and $4 to the ton in gold. This ore is developed to a depth of 60 feet by the shaft and is cut by diamond drill holes to a depth of 275 feet, but here the values are considerably lower. This is the best body of ore on the Voigt property and gives some promise of developing into a body of sufficient size to warrant mining operations.

FALUM CLAIM

The Falum is 5,000 feet east of the Number 14 shaft. The work on the claim consists of several small trenches and a shaft. The workings are in gabbro of the Voigt stock and show a considerable amount of mineralization consisting of magnetite, hematite, pyrite, chalcopyrite, and a minute amount of bornite associated with albite, hornblende, and epidote. The ore in the trenches appears to be very low grade, but the material from the shaft was of better grade. A picked specimen assayed 2·94 per cent copper and 0·08 ounce of gold a ton.

AZURITE CLAIM

The Azurite and Copper Glance claims are about one mile southeast of Voigt's Camp, near the eastern boundary of the map-area, and belong to John R. McRae *et al* of Windsor, Ontario. The workings consist of a shaft, two tunnels, and a few open-cuts. The shaft was not accessible at the time of examination. The workings are on the contact of Voigt's stock with the volcanic breccias of the Wolf Creek formation and not far from a large quartz porphyry dyke. The volcanic rocks at this locality consist of medium-grained basalt and basalt breccias, containing much hornblende. The basalt is cut by small veins of epidote, and contains pyrite and chalcopyrite as fine particles distributed through the rock. At the surface considerable oxidation of the chalcopyrite has taken place with the production of a considerable amount of azurite. The copper content of the rock is, however, low; the material examined appeared to contain less than 1 per cent.

R. S. CLAIM

This claim is situated immediately east of Voigt's Camp and just south of the Frisco claim. The workings consist of a tunnel 100 feet in length, a small shaft connecting the tunnel with the surface, and several trenches. These workings are largely in gabbro of Voigt's stock, but also in a large amount of altered andesite and latite of the Wolf Creek formation. In this locality the contact of Voigt's stock dips to the west and it is probable that these workings are near to and just under the contact. A large quartz porphyry dyke striking in a northerly direction is exposed at the portal of the tunnel. The mineralization consists of pyrite, magnetite, and chalcopyrite, but no commercial ore was observed.

JUNE BUG AND ONE STRIKE FRACTION

These claims are north of Lost Horse Gulch about midway between Wolf Creek and Similkameen Valleys and not far from the northern boundary of the map. The June Bug belongs to Mrs. B. M. Snowden. On this claim a number of trenches and a shallow shaft expose a small body of mineralized latite. The mineralization consists of a large proportion of magnetite with less pyrite and chalcopyrite. The magnetite occurs as clean-cut veinlets a small fraction of an inch in width, whereas the sulphides are disseminated through the rock. The copper content is less than 1 per cent.

This zone of mineralization has been traced onto the One Strike fraction claim where several trenches have been dug and a small shaft sunk. A specimen taken from the dump of the shaft assayed 1·5 per cent copper, but the material exposed in the trenches obviously contained much less.

BORNITE ORES

A well-defined group of ore deposits of the district, characterized by the presence of much bornite and chalcopyrite and the almost entire absence of pyrite and hematite, are clustered about the Copper Mountain stock and include the ore-bodies of Copper Mountain mine. All the deposits except the Friday Creek deposit are near the margin of the stock, some inside, some outside, and some projecting across the contact. The Friday Creek deposit occurs in pegmatite dykes situated well within the stock towards the southwest side. A considerable portion of the contact of the stock is concealed beneath thick deposits of glacial drift. Of that part of the contact that is exposed some sections are barren, but the greater part is mineralized, some of it very extensively, so that the unexplored parts would seem to warrant systematic prospecting.

The most important of the bornite deposits are those that constitute the Copper Mountain mine and extend along the northeastern side of the stock from the Helen H. Gardner claim down to the Princess May. These will be described in detail later. The other deposits will be described in the order in which they occur along the contact in a clockwise direction from the Oriole.

ORIOLE

This claim is owned by Mrs. Bertha M. Snowden *et al* of 416 "K" Street, Eureka, California. It is southeast of the Helen H. Gardner from which it is separated by the Mabel fraction. The contact of the Copper Mountain stock crosses the Oriole from the northwest to the southeast corner and along it considerable ore is exposed by diamond drill holes and other workings. Several large quartz porphyry and granophyre dykes cross the claim in a north-south direction and cut across the contact of the stock. The workings consist of a large number of trenches, a shaft, and six diamond drill holes. The trenches are located along the margin of the stock, and the diamond drill holes—of which one is vertical and five are inclined radially—were all drilled from one set-up situated 80 feet east of the contact.

The contact of the stock, after entering the claim near the northwest corner, follows a straight course for 500 feet in a direction a few degrees south of east to where it bends sharply to a direction 25 degrees east of south and follows that for 500 feet, beyond which it again bends to a nearly easterly direction. To the north and east of the contact lie the volcanic breccias and conglomerates of the Wolf Creek formation. In this locality these rocks are light grey and consist of rounded fragments 1 inch to 6 inches in length enclosed in a densely fine matrix having the appearance of chert. There is in places a fairly distinct schistosity striking north 80 degrees west and dipping 80 degrees to the northeast. The breccias have been impregnated by vast numbers of minute crystals of augite, zoisite, and biotite and in places by smaller quantities of pyrite, magnetite, bornite, and chalcopyrite, and have been cut by numerous small veinlets containing the same minerals.

That part of the stock exposed on this claim consists of a medium fine to medium coarse-grained syenogabbro, in some places fresh but in others considerably altered. Both the gabbro and the breccias are sliced by fractures striking north 55 degrees to 85 degrees east, in which, and along the margins of which, are deposited pyrite, magnetite, bornite, chalcopyrite, epidote, zoisite, orthoclase, biotite, and occasionally a little quartz. Besides this set of parallel fractures are many others striking in a number of different directions, all carrying the same set of minerals. Considerable amounts of chalcopyrite and bornite are usually present in the pegmatite veins in the form of disseminated grains. The margins of some pegmatite veins are very sharply defined and the adjoining rocks unaltered, but the boundaries of many are indistinct and the adjoining rock is bleached to a light pinkish white colour. The results of oxidation were observed in all the trenches. It has converted the pyrite to limonite and probably leached some of the copper.

Copper is present in most of the trenches in both the gabbro and the breccia, but only in a few does the copper content exceed 1 per cent. Diamond drilling is reported to have proved a body of ore containing over 1·65 per cent of copper. This tends to support the belief that some of the copper has been leached from the trenches.

HUMBOLT

This claim belongs to W. A. Cooper *et al* of Longview, Washington, and is situated southwest of the Oriole and entirely within the Copper Mountain stock. The only other rocks exposed on the claim are five white "Mine" dykes in the extreme eastern part. A line of trenches extends for 600 feet parallel to, and 100 feet south of, the northern boundary of the claim. There are also one shaft and several diamond drill holes. None of the material exposed in these workings appears to contain sufficient copper to be classed as ore except that in the shaft. This shaft is on the eastern boundary of the claim not more than 25 feet from the contact of the stock and only 200 feet from the diamond drill set-up on the Oriole claim. Here a fair amount of chalcopyrite and some bornite are present and in the vertical diamond drill hole considerable ore is reported to have been discovered. It is probable that the contact of the stock dips slightly to the west and that the vertical hole has passed out of the stock into the adjoining breccias in which ore is more likely to be found.

TIN CUP

The Tin Cup claim, which is owned by D. M. French *et al*, represented by T. Day of Princeton, lies immediately north of the Oriole. This claim is entirely outside the stock and occupied by the Wolf Creek breccias. The southwest corner, however, is only about 300 feet from the contact and in this part there is evidence of considerable mineralization. A number of trenches have been dug and a shaft sunk. A considerable amount of pyrite and chalcopyrite is present in some of the trenches and on the dump at the shaft, but no important ore-body has yet been discovered.

NUMBER 27 AND EDWARD FRACTIONS

These belong to Frieda E. Baker, 826 North West Bank Building, Portland, Oregon, and are east of the Oriole. Though not exposed on these claims the contact of the stock evidently cuts across the southern part of the Edward fraction and western part of the Number 27 fraction. No workings were seen on these claims and the surface is deeply drift covered. It is probable, however, that the rocks in the vicinity of the contact are mineralized and possibly sufficiently so to form ore. This section warrants some electrical prospecting.

I.X.L AND RIFLE

The I.X.L. claim, belonging to C. E. Thomas, of Princeton, and the Rifle claim, belonging to W. H. Thomas, of Princeton, are both situated south of the Number 27 fraction and like it are crossed by the contact of the Copper Mountain stock. No work has been done on these claims, but the Wolf Creek breccias are exposed in natural outcrops not far from where the contact is believed to be. A very small amount of mineralization is here present.

KING SOLOMON AND SPIDER FRACTION

These claims lie to the south of the Oriole and belong to Mrs. B. M. Snowden, 416 " K " Street, Eureka, California. Both claims lie well within the Copper Mountain stock though not far from the contact. In two places on the King Solomon the gabbro was cut by quartz porphyry " Mine " dykes and at two other places by dark green, fresh basalt dykes. A few trenches have been dug on the Spider fraction near its south boundary. On the King Solomon near its northern boundary a great many trenches have been dug, a tunnel driven in 190 feet, two shafts sunk, and some diamond drilling done. The tunnel and shafts were, at the time of examination, inaccessible. In a number of the trenches the gabbro was found to be fractured in the usual way, to be impregnated with chalcopyrite, bornite, and magnetite, and to be cut by small veins of pegmatite and epidote. In a few places the copper content appeared to approach that of commercial ore, but over the greater part of the workings it is certainly below 1 per cent. The results of the diamond drilling are not known to the writer. It is possible that here also the gabbro dips to the west or southwest slightly, and that better ore may be found at depth. Further drilling to test this possibility seems warranted.

JENNIE SILKMAN

This is an " L "-shaped fraction between the King Solomon, Rifle, and I.X.L., and is owned by L. G. Barron. On this claim the contact of the stock forms a small bay partly surrounding a small body of breccia. Twelve trenches have been dug, and a shaft sunk to a considerable depth. In the trenches and on the dump from the shaft the breccia and the gabbro were found to be fractured and impregnated with biotite, augite, and later feldspars. The fractures and adjoining rock contain chalcopyrite, small amounts of bornite, and pegmatite. No samples were taken from this property, but some of the specimens examined microscopically were estimated to contain about 2 per cent copper. This is a promising claim on which further prospecting is warranted.

FIRST CHANCE NUMBER 1

The contact of the stock passes close to the northeast corner of the First Chance Number 1 claim, which is owned by the Granby Consolidated Mining, Smelting, and Power Company. This section of the contact has not been prospected.

SOME OTHER CLAIMS

Beyond the First Chance Number 1 the contact is deeply buried for a considerable distance, but from the nearest known exposure it evidently runs in a southwest course along Wolf Creek for about one mile before bending to the west to traverse the Lemon No. 2, Good Cheer, Lemon No. 9, Skagit No. 3 fraction, Marquis of Lorne, Snake No. 1 fraction, Motherlode, Periscope fraction, and St. Louis fraction. The unexposed part of the contact along Wolf Creek is not staked. Of the above-mentioned claims all but the Marquis of Lorne, which has reverted to the Crown, belong to the Granby Consolidated Mining, Smelting, and Power Company. These claims are held for their timber and have not been prospected. The contact is exposed on them for short intervals, but no pronounced shearing and no indication of copper mineralization were observed.

JOHNSTON

This claim belongs to the Charles Willarson Estate *et al* of Princeton. It is on the road leading from Copper Mountain to Combination Camp, about 2 miles south of the former and on the south contact of the stock. At this point the contact forms a bay similar to that on the Jennie Silkman claim and includes a body of Wolf Creek breccias. Just north of this bay and almost on the northern limit of the claim, a small shaft has been sunk in the gabbro. The rock here is distinctly gneissic and cut by numerous, small, pegmatite veins, many of which contain a liberal sprinkling of chalcopyrite, bornite, and magnetite. A picked specimen from the dump contained 1·7 per cent copper. Further prospecting along this part of the contact is warranted.

FRIDAY CREEK DEPOSITS

From the Johnston claim the contact of the stock follows a westerly course across the deep valley of the Similkameen and beyond the limits of the map-area. It is exposed in the canyon and in a few small outcrops on the east side of the valley, but there is no evidence of mineralization. Beyond the western limits of the map-area the contact has not been traced and is deeply buried beneath silts and glacial drift. It re-enters the map-area from the west $1\frac{1}{2}$ miles south of the northern boundary.

On Friday Creek at the very edge of the sheet there are some bornite deposits in pegmatite dykes. These deposits are included in the Gladstone, Beckmeyer, and Muldoon claims, but are referred to as the Friday Creek deposits. They have been held for some time under the regulations of the Mineral Act of British Columbia by Mr. Vale *et al.* Four tunnels have been driven on the south side of Friday Creek and a number of open-cuts made on both sides. The workings are all in gabbro which in this locality is more than ordinarily rich in biotite, but in all other respects similar to the marginal phases of the Copper Mountain stock. The pegmatites though plentiful are not large, varying from a fraction of an inch to 4 feet in width. They consist mainly of orthoclase, albite, and biotite with sphene as an abundant accessory. The orthoclase occurs in small grains and is exceedingly fresh, contrasting in this respect with most of the orthoclase on Copper Mountain. Sprinkled through all the pegmatites, even the very smallest, are numerous grains of bornite, chalcocite, and chalcopyrite. Some of the pegmatite veins are less than one-eighth of an inch in width and contain all the above minerals. The adjoining rock is not altered and is free from any of the above minerals. There is a little malachite in the fractures of the rock which suggests that the chalcocite, or at least some of it, is of supergene origin. However, no direct microscopic evidence of this was obtained. The values being confined to the pegmatite veins and these being small, irregular, and scattered, the possibility of finding a commercial ore-body in this locality does not appear to be very great. However, if these pegmatite veins or dykes were traced along their strike to the stock contact important bodies of ore might be found.

HAMILTON, FRASER, AND FRASER FRACTION

The northern contact of the Copper Mountain stock enters the map-area from the west just north of the Hamilton, Fraser, and Fraser fraction claims, all of which belong to John McKay *et al* of Oshkosh, Wisconsin. On or near the Hamilton and Fraser fraction three shafts have been sunk, and down in the canyon of Similkameen River two tunnels have been driven on the Fraser claim and one immediately below it on the Copper Cliff claim. This lowest tunnel, however, extends for some distance into the Fraser claim.

All of the workings are well within the stock, the shafts being 1,300, 1,850, and 2,050 feet, respectively, south of its contact; the tunnels are all within 500 feet of the main contact but within 100 feet of an inclusion of Wolf Creek breccias. All workings are in gabbro which is normal in every respect except for a slight excess of biotite and the presence of a considerable amount of bornite and chalcopyrite. The gabbro is cut by a few small veinlets of orthoclase, along some of which it is slightly impregnated with small crystals of magnetite. The only other rock of the vicinity is a 6-foot dyke, near the face of the upper tunnel, which consists of pink, micaceous monzonite having abundant magnetite. Scattered irregularly through the gabbro are small areas in which bornite, chalcopyrite, and chalcocite are disseminated or spread out in thin films along minute fractures. In some of these areas pegmatitic material is present, but in others the gabbro is fresh and normal. Samples taken in the tunnel failed to reveal any ore of workable grade, though specimens were found on the dumps which, judged by the large amount of bornite visible, would carry more than 2 per cent copper. The section of the stock contact nearest these occurrences is especially worthy of intense prospecting.

COPPER CLIFF AND COPPER REEF CLAIMS

From the Fraser claim the northern contact of the stock crosses the river on the Copper Cliff claim, owned by J. J. Malone of Princeton, and passes onto the Copper Reef claim owned by C. E. Thomas *et al* of Princeton. No showings were observed on the Copper Cliff claim except at the above-mentioned tunnel, the portal of which is situated immediately below the line dividing this claim from the Fraser. Though the contact extends from one side to the other of the Copper Reef claim and over a vertical range of nearly 800 feet, no exposures occur except in the extreme easterly part of the claim adjoining the Princess May.

There a large number of trenches have been dug, a shaft sunk, and four or five diamond drill holes bored.

All of these workings are in the Wolf Creek formation, but within 600 feet of the contact of the stock. The Wolf Creek rocks at this point consist of coarse breccias having rounded and angular fragments up to 3 inches in length. They consist mainly of hornblende diorite and coarse, syenitic pegmatite and are enclosed in a medium coarse-grained, greenish, andesitic matrix. A zone about 100 feet wide following the contact of the stock has a pronounced schistose structure striking north 80 degrees west and dipping south 70 degrees. Besides being schistose this zone is intensely fractured, the principal fractures being at right angles to the schistose foliation. The rocks of this zone are intensely altered to a light grey, densely fine, cherty-like mass and in places contain much bornite and chalcopyrite. Copper is present in all of the workings and two ore-bodies of fair grade have been outlined in this part of the claim.

PRINCESS MAY

From the Copper Reef the contact passes to the Princess May claim, one of a large group owned by the Granby Consolidated Mining, Smelting, and Power Company and extending southeast along the contact of the stock to the Mabel fraction and containing the large ore-bodies of the Copper Mountain mine. The ore-bodies on the Princess May are, however, separated by a considerable distance from those of the Copper Mountain mine and for this reason, as well as because they differ somewhat in character, they will be described separately.

The workings on this claim consist of several hundred trenches, thirty or forty diamond drill holes, several shafts, and a system of tunnels and crosscuts totalling nearly 800 feet in length. The underground workings were not accessible at the time of the writer's visits to the district.

The workings on the Princess May, as on the Copper Reef, are outside the Copper Mountain stock. They extend from near the contact to a point 700 feet from it. Some copper is present in almost all of the trenches, but so far as the surface is concerned commercial ore is confined to two separate areas, one adjacent to the contact and another 400 to 600 feet to the northeast. The whole of this claim except the part occupied by the stock is underlain by the rocks of the Wolf Creek formation. Adjacent to the contact are breccias with rounded and angular fragments of coarse augite diorite porphyrite, 2 inches in maximum length. Farther away are non-fragmental bands of fine-grained augite diorite beyond which are more breccias.

Adjacent to the stock the breccias are foliated to a slight degree parallel to the contact and fractured or sliced in a direction perpendicular to it. In places the breccias have been extensively impregnated with biotite and later than this have been altered by hydrothermal solutions which, by the introduction of much augite, epidote, zoisite, and feldspar, have changed them to a dull greyish colour and exceedingly dense texture. Chalcopyrite, bornite, and a small amount of pyrite and magnetite were also introduced.

In the outer zone of mineralization the breccias are not biotitized and the type of mineralization differs markedly from that of the inner zone by the presence of much pyrite and chalcopyrite and the entire absence of bornite. The mineralization of this outer zone is typical of the pyrite-chalcopyrite ores and is situated close to a body of Lost Horse intrusives. It is, therefore, considered to belong to that type and period of metallization.

COPPER MOUNTAIN MINE

The mine as at present developed furnished ore from the Helen H. Gardner, Sunset, Sunrise, Vancouver, and Copper Farm mineral claims. The ore zone, however, extends beyond these claims northwest to the Princess May and Copper Reef claims and southeast to the Rifle claim. Two main ore-bodies and several smaller ones have been opened up. The mine was originally laid out to top these ore-bodies at two levels only, an upper one at elevation 4,073, now known as Number 1, and a main haulage level at elevation 3,945 feet, now Number 2 level. When it was decided to build the railway up Similkameen Canyon, a haulage tunnel 2,700 feet in length was constructed at an elevation of 3,185 feet, 800 feet below Number 2 level and at a sufficient distance above the railway to permit of the construction of a crushing plant and ore bunkers. This tunnel was connected with Number 2 level by a vertical shaft and a zigzag ore pass situated a few hundred feet from the portal of Number 2 level. Since the commencement of operations by its present owners in 1926 three levels have been developed between Number 2 and the haulage level, now known as Number 6. These intermediate levels, named 3, 4, and 5, are approximately 200 feet apart and have been extended through all the ore-bodies. Number 6 level also has been extended into each of the ore-bodies and considerable stoping has been done above this level. The main shaft has been sunk 400 feet lower than Number 6, and two levels, Numbers 7 and 8, have been started but have not yet reached the ore which has been proved to this depth by diamond drilling.

The two main ore-bodies are known as the Sunset and the Contact, the latter throughout its entire length closely following the contact of the Copper Mountain stock. The Sunset ore-body has decreased in size with depth, whereas the Contact ore-body has increased in length from 400 feet as exposed on the surface on the Helen H. Gardner claim to 2,570 feet on level 6. The limits of the ore-bodies do not mark the limits of mineralization, but merely of commercial grade ore. The mineralization is almost universal throughout the mine workings except where they are inside the stock. The concentrations are due entirely to an accentuation in these sections of fracturing. The less fractured rock, at least in some places, appears to be of coarser texture and to consist mainly of biotite and black augite phenocrysts, which are the original augites of the volcanic breccias. It seems that the coarse biotite rendered the rock more pliable and less brittle than the densely fine rocks which are usually intensely fractured.

The mining is done from stopes and from several large glory-holes from which much of the ore above Number 1 level and some from above Number 2 has already been removed. The ore is drawn from stopes and ore pockets on the sixth level and delivered from there to the crusher.

CHAPTER VI

THEORETICAL CONSIDERATIONS

The Copper Mountain stock, with its several rock types, its pegmatites, metamorphic minerals, and copper ores, together with the Lost Horse intrusives and Voigt stock with their respective pegmatites and ores, constitute a series of related products of igneous activity more numerous and complete than is commonly found in one such limited area, and seem to illustrate more than ordinarily well the now generally accepted theories of petrogenesis and ore genesis. According to these theories groups of related igneous rocks and ores such as the above may be evolved from a single magma by certain physiochemical processes related to the slow cooling and crystallization of the magma and generally referred to as magmatic differentiation. It is proposed in this section to review in the light of these theories some of the facts already recorded in the descriptions of these rocks and ores and to suggest an explanation of how they may have been evolved from a single magma. The discussion is confined to the above-named rocks and ores and no attempt is made to establish a relationship between them and the much younger felsite dykes or the much older Wolf Creek volcanics, though some distant relationship may possibly exist. It is assumed that the reader is familiar with, and in more or less general agreement with, the principles of magmatic differentiation as enunciated by the leading petrographers and economic geologists.

The community of origin of the rocks in question with their attendant pegmatites and ores is suggested by their segregation in one small area situated in a general region characterized by rocks of distinctly different types, namely, quartz diorites and granodiorite. Consanguinity is suggested by common traits in composition; for example, all the rocks are feldspar-augite rocks with little or no quartz and unusual amounts of orthoclase and apatite; the pegmatites and ores also are virtually devoid of quartz and rich in orthoclase. The series ranging from syenogabbro through syenodiorite, and syenite to a syenitic pegmatite is complete. The close correspondence in composition between the various phases of the Copper Mountain stock and the separate homogeneous intrusions is also evidence of consanguinity. The concentric arrangement of the various phases of the Copper Mountain stock in a continuous series of decreasing basicity from margin to core and the gradational character of the contacts between the several phases are the strongest possible evidence of magmatic differentiation. Considering all this evidence and in view of the firmness with which the principles of magmatic differentiation have been established, it is hardly to be doubted but that the rocks and ores of Copper Mountain were evolved from a single magma.

Granting this, it becomes appropriate to consider what was the nature of the primary magma, how and where it became divided into its various components, and how some of these were subdivided into their separate phases.

The nature of the primary magma prior to its solidification and differentiation can only be surmised from those of its satellites that happen to be exposed and from the various products of metamorphism and metasomatism. Some conception of its composition may be had by imagining a magmatic solution of all the elements present in the various rocks, pegmatites, and ores. This picture, however, would not be complete, since the series of products is incomplete. It seems probable that the Voigt stock was injected from the main magma chamber before any important amount of differentiation had taken place, and, therefore, this stock with its only very limited amount of differentiation indicates fairly closely the general character of the primary magma. The preponderance of syenogabbro in the area and the fact of its being the most basic member of the series also indicate that the original magma had a composition that would crystallize into a syenogabbro. The somewhat unusual amount of orthoclase in all the rocks, pegmatites, and ores, together with the conspicuous absence of quartz from all three, would seem to indicate a primary magma more than ordinarily rich in potash. The large amount of pegmatite and ore, together with the extensive evidence of metasomatism, seems to indicate a magma rather more than ordinarily rich in volatile materials, particularly water.

The parent magma is believed to have been divided into its several components by the processes of magmatic differentiation. These processes, however, are not completely understood and there is some difference of opinion as to the relative importance of some of the reactions involved. It is generally agreed that the crystallization of the magma under conditions of slow cooling, aided to some extent by the settling out of some of the earlier formed crystals, is the controlling process of differentiation. The first crystals to form in a slowly cooling magma are those composed of the least volatile components, such as iron oxide, lime, alumina, and magnesia. This causes a reduction of these components in the still molten magma and a consequent increase in the proportion of the more volatile and mobile components. As crystallization proceeds the liquid component becomes increasingly rich in volatile constituents and the end product is a thin, mobile fluid consisting largely of an aqueous solution containing the more volatile and soluble ingredients of the original magma. It was considered by petrographers that these residual fluids were represented mainly by pegmatite, but now a still further stage in the evolution of a magma is recognized, particularly by students of ore deposition, which results in solutions still more watery than those forming pegmatites and which form those common types of ore deposits characteristically associated with igneous activity.

Because of their separate positions the Voigt and Smelter Lake stocks, the various members of the Lost Horse intrusives, as well as many scattered pegmatite dykes and masses, are thought to have been evolved from the parent magma by differentiation taking place in the main magma chamber, and to have been injected into their present positions at different times and during different stages in the differentiations of the magma. The various phases of the Copper Mountain stock appear to have a different mode of origin. Their systematic arrangement in concentric tubes within the stock in a regular series of decreasing basicity from margin to core is suggestive of differentiation in place. The gradational contacts between successive phases are further and stronger evidence of differentiation in place. The rather sharp contact between the pegmatite core and the adjoining phase is, however, suggestive of the pegmatites having been injected, but its large size, its central position in the stock, and the absence of any appreciable amount of fracturing of the outer shell of the stock seem to preclude any possibility of the pegmatite core having been injected. It is possible, however, that there may have been some upward or downward movement of the pegmatitic magma after the outer shells of the stock were solidified. Moreover, the pegmatite core lacks some of the characteristics of pegmatites in general and those of this area in particular; notably, coarseness and irregularity of texture, irregularity of shape, and a tendency for the marginal feldspar crystals to arrange themselves perpendicularly to the enclosing walls of the pegmatite body.

The explanation here offered of the fact that the Copper Mountain stock differentiated into a complete series of different rock types, whereas its related stocks did not, is as follows. The Copper Mountain stock is considered to be a cupola, i.e. so situated at the apex of a gable-shaped or inverted funnel-shaped projection of the magmatic chamber as to collect a large proportion of the volatile components rising in the main magma as it slowly crystallized. This high proportion of volatile constituents would aid differentiation by maintaining a high fluidity and lowering the freezing temperature of the magma, thus greatly facilitating crystal growth and sinking.

One of the best known phenomena of igneous intrusions is their power to change or metamorphose the rocks adjacent to their contacts. This so-called contact metamorphism has been described in detail by many authors and there is now a general agreement among all observers regarding the nature of the processes that produce these changes. Undoubtedly some of the changes are effected mainly by the heat of the advancing magma assisted by moisture inherent in the adjacent rocks, but the more widespread and pronounced changes are now believed by the leading petrographers to be produced by the escape from the magma of quantities of its more volatile components, principally water carrying in solution silica, alumina, iron, sulphur, copper, etc. This latter effect has been named by Barrell[1] contact metasomatism in distinction from the former contact metamorphism. Both Harker[2] and Barrell believe that these volatile fluids escape at different periods during the cooling and crystallization of the magma. It is also well known that metamorphism is not by any means universal along igneous contacts but is definitely confined to certain types of rocks or to certain zones in other types. Sediments of various kinds, particularly limestone, appear to be most susceptible to metamorphism; in igneous rocks it is best developed in porous tuffs or granitic rocks, but it occurs in sheared and fracture zones in rocks of any type. All of the above characteristics of contact metamorphism and the theories explaining them apply to conditions observed at Copper Mountain. Here the most

1 Barrell, J.: Prof. Paper No. 57, U.S. Geol. Survey, 1907.
2 Harker, Alfred: "The Natural History of Igneous Rocks", 1909.

pronounced alterations of the invaded rocks are to be found in the sheared and fractured zone in the volcanic rocks where it is traversed by the Copper Mountain stock.

Several periods of contact metasomatism can be distinguished: first, one in which were produced vast amounts of biotite, augite, and perhaps some plagioclase and a small amount of copper-iron sulphide; second, a period during which epidote, zoisite, scapolite, and andesine were deposited; and third, a period characterized by the introduction of large amounts of orthoclase, albite, green biotite, and iron and copper-iron sulphides. The action of the first period was confined almost entirely to the sheared and fractured zone adjacent to the northeast side of the Copper Mountain stock. This biotite-augite alteration is not present at any other part of the contacts of this or of the other intrusives and does not penetrate the Copper Mountain stock, but stops sharply against syenogabbro which is either unaltered or has been affected only by later periods of metamorphism.

The biotite-augite alteration involves the transfer from the magma to the altered rocks of large quantities of water, together with lesser amounts of the principal non-volatile, rock-forming elements such as silica, iron oxide, alumina, magnesia, and lime. The localization of this material entirely in a sheared and fractured zone suggests that its transfer from the magma depended largely on its finding a somewhat porous section in the walls of the magma chamber through which to escape. The manner in which the biotite leaves are distributed on the cleavage planes of the feldspars and on intergranular faces is proof of the extreme smallness of the openings through which the fluids were able to move. This is at the same time proof of the imperviousness of the unsheared members of the Wolf Creek volcanic series. The fact that these intensely altered rocks butt against nearly fresh syenogabbro would seem to indicate that the transfer from the magma took place prior to solidification. The fact that the bulk of the materials transferred consist of the most common and abundant rock-forming elements indicates that the separation took place before the more volatile and more rare components had been concentrated in the magma by differentiation and, therefore, while the temperature of the magma as well as of the escaping fluids was still high, probably above the critical temperature of the latter. The vapour tension of the volatile components of a normal magma, as shown by Paul Neggli and others, is not high during the first stages of crystallization, but rises gradually to a maximum when the bulk of the non-volatile materials have entered into plagioclase and other anhydrous minerals. It is, however, probable, as pointed out previously, that the magma under discussion was abnormally rich in water and other volatiles and that, therefore, it had a higher-than-normal vapour tension, but, notwithstanding this, it is possible that the transfer of the volatile materials at this stage was induced more by certain other extraneous forces than by its own partial pressure. These extraneous forces are selective adsorption, or absorption, or other forces related to surface tension phenomena.

It seems probable that on the walls of a magmatic chamber fractures or pores might exist that would be too small to permit a viscous magma to rush in and form dykelets or apophyses, but which would not only admit but might even absorb the more highly attenuated volatile components. From this it appears probable that a part at least of the volatile component of a magma may be separated from it prior to, and independent of, its crystallization, and, if so, should be regarded as one of the early if not the first steps in the process of differentiation.

Whether or not these early emanations from a magma carry with them and deposit metallic minerals is an important question, unfortunately the area here described throws little or no light on this problem. There are, however, in the biotitized volcanics extremely fine particles of chalcopyrite and bornite which appear to have been deposited simultaneously with the biotite. Certain contact metamorphic deposits situated above nearly flat, intrusive contacts and butting downward against unmineralized and unaltered granitic rock, such as for example, the Marble Bay mine on Texada Island,[1] present strong evidence in support of the view that contact metamorphic deposits are formed prior to the solidification and, therefore, the differentiation of the magma. Still other deposits situated in the lower extremities of roof pendants or inclusions and butting downward against unaltered and unfractured granitic rock, also afford evidence in support of this view.

The epidote-zoisite andesine stage of contact metasomatism is of no economic importance, but is clearly evidenced by veins of these minerals cutting and bleaching biotitized rocks.

The third is the most important stage as it is responsible for most of the ore deposition. The materials of this stage are much later than the biotitation, as evidenced by their forming veinlets in the biotitized rock. The presence in the emanations of this stage of large quantities of soda, potash, sulphur, and copper, along with lesser amounts of the other principal components, silica, alumina, lime, and magnesia, is evidence that the more volatile and the least abundant components had become more highly concentrated by the advancing stages of differentiation. The lateness of this phase of metasomatism is evidenced further by the fact that it has affected a fairly wide zone within the contacts of the various intrusives as well as without. Since at this stage in the crystallization of a magma the vapour tension of the volatile constituents is high, it is possible that they were forced through the surrounding rocks by their own pressures.

The significant fact that the ores of each separate intrusion are different from those of the others is an indication that the ores represent differentiation products developed by and deposited near the contact of each intrusive and were not formed by fluids coming from the main magma chamber. If, as seems likely, the main body of magma passed through the same series of differentiation as the Copper Mountain stock, it is a reasonable conclusion that ores, not yet exposed, were formed near its contact also.

There is recognized in the life history of all normal magmas a period of mineral deposition called by Neggli and others the hydrothermal stage.

---

[1] This deposit continued down to the flat surface of an underlying body of granodiorite which was found to be mineralized only slightly and to a depth of only a few feet.

It is later than the pegmatitic or pneumatolytic and during it the bulk of the ores are deposited, usually accompanied by large quantities of quartz and other gangue minerals such as siderite, calcite, etc. In Copper Mountain area this hydrothermal stage is inconspicuous because of the absence of quartz from the region and also because in this case the so-called gangue minerals consist of orthoclase and albite, which are also the principal pegmatite minerals. The hydrothermal stage is, however, believed to be represented by much bornite, chalcopyrite, and pyrite, which are clearly later in origin than the orthoclase and biotite of the pegmatite, and by still later veinlets of calcite, and is believed to have followed without any break the true pegmatitic stage. Most of the orthoclase, albite, and quartz that accompany the ores of Voigt and Lost Horse intrusives are believed to have been formed by hydrothermal rather than by pegmatitic or pneumatolytic action.

The above theoretical considerations may be all summed up in the following historical outline of the injection and differentiation of the Copper Mountain magma, as visualized by the writer.

Long after the Wolf Creek volcanics had been extruded, steeply folded, and, in places, sheared, they were intruded by a basic magma of syenogabbro composition. The main body of this magma has not yet been reached by erosion and is not, therefore, exposed to view. Its presence at some considerable, but unknown, depth beneath the surface is inferred from the exposures of its satellites or appendices. Soon after or at the same time that the main body of magma arrived at its final resting place the Voigt and Copper Mountain stocks were injected into their respective positions. The Copper Mountain stock is believed to be situated at the apex of a gable-like or inverted-funnel-shaped upward projection of the top of the main magma chamber, thus forming a cupola in which were accumulated volatile components rising in the magma as it slowly crystallized.

After reaching its final position the main body of magma began to cool slowly and to crystallize. The first minerals formed were augite and labradorite which extracted from the magma principally non-volatile components, thus concentrating the volatile component in the remaining magma. At a fairly early stage in the process the Lost Horse diorite was injected into its present position and represents the composition of the magma at this stage. Still later, when crystallization and differentiation had proceeded to a more advanced stage, the mica syenite of the Lost Horse intrusives was injected into its present position, representing the composition of the magma at this later stage. Still later the various bodies of pegmatite were formed representing the pegmatitic stage of the differentiation. After this it is probable that there ensued a period of hydrothermal mineralization along the contacts of the main magma chamber, but, as these are not exposed, this phase of activity is hypothetical.

Paralleling this series of changes in the main magma chamber there occurred in the Copper Mountain stock a similar series; but in the latter case the whole series of products is exposed to view and there are present two phases not evident in the case of the main magma chamber. These are the contact metamorphism and contact mineralization which occur on the northeast contact of the stock. Another difference is the presence of a considerable amount of copper in the pegmatite core of the stock and its entire absence from the pegmatites outside of the stock.

The sequence of events that mark the history of the Copper Mountain stock after its arrival into its present position are as follows. Immediately after reaching its resting place a large amount of its volatile constituents escaped into the shear zone and formed the immense quantities of biotite and augite, together with some plagioclase, and probably small amounts of sulphur and copper. Crystallization began along the margins of the stock where labradorite and augite crystals formed in abundance, fixing in their crystals much alumina, iron oxide, silica, lime, and magnesia. These elements being subtracted from the magma enriched it in the volatile components such as water, sulphur, and the alkalis. The magma, still quite viscous, resisted diffusion and retarded the growth of large crystals and the sinking of the heavy augite crystals. As these crystals continued to form, the residual magma became richer in the alkalis and other volatiles and, therefore, became less viscous. This enabled the formation of more acid plagioclase, of more orthoclase, and the reduced viscosity permitted the growth of larger crystals resulting in the intermediate type of rock characteristic of an inner zone in the stock. Throughout the stock, excepting the pegmatite core, the orthoclase very evidently was much later in crystallizing than the other minerals. It is always interstitial and anhedral and has the appearance of a congealed medium in which the euhedral plagioclase and augite crystals were suspended. The final stage was the consolidation of the pegmatite core which had become so fluid that it could support no augite crystals. The small amount of copper in this core represents a residual concentration of this element along with its associated sulphur from the original stock magma. Some time or times during the consolidation of the stock, solutions escaped into the porous shear zone and deposited quantities of orthoclase, albite, green biotite, with much bornite, thus forming the rich copper deposits of this locality. The stage at which these solutions escaped is not known, but it must have been long enough after the first solutions had escaped to permit of the later fluids becoming enriched in the alkalis as well as in the rarer elements copper and sulphur.

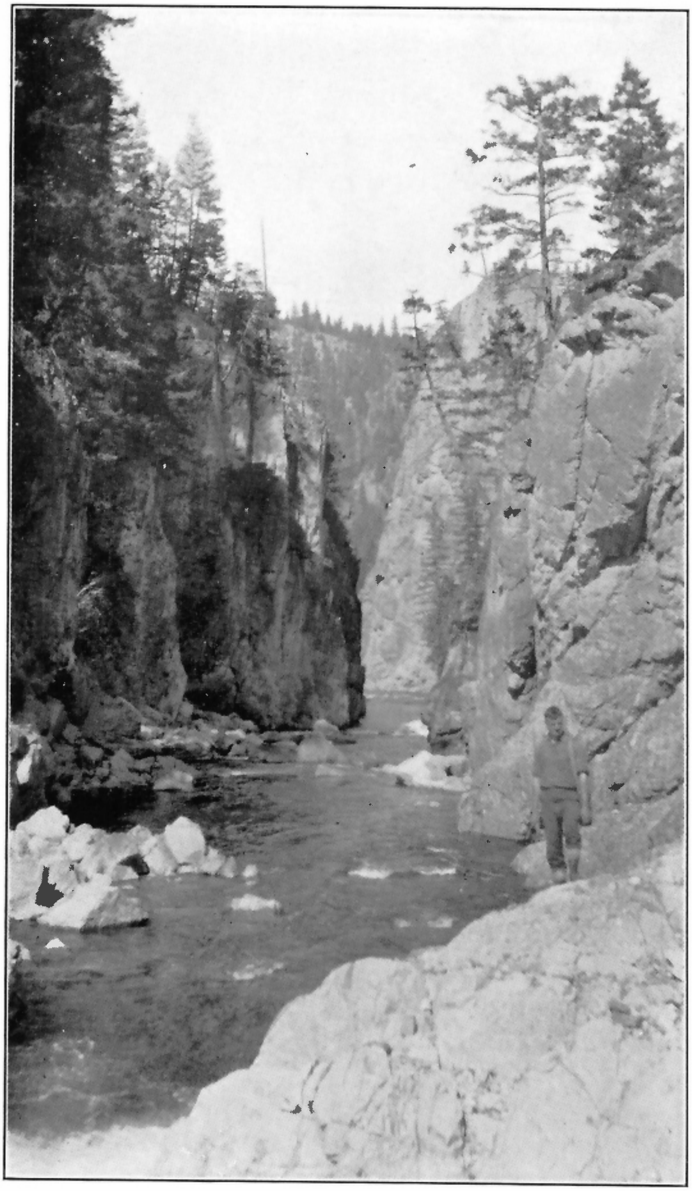
During the long period of crystallization it is possible that at one or two intervals the column of magma may have, for some unknown cause, moved up or down in the stock forming the two rather abrupt transitions represented as contacts on the map. These movements are suggested by curved orientations of the plagioclase crystals near these contacts, but the movements are not considered to have been great enough to alter the general conception that the stock as a whole was differentiated in situ. It is thought probable that this magma throughout its evolution was being continually enriched by more volatile ingredients rising into it from the main magma chamber. This assisted in its differentiation by maintaining a high temperature and high fluidity.

The other intrusives solidified much more quickly and without much differentiation, but not without expelling into their already frozen margins and the surrounding rocks quantities of fluid which deposited pyrite, chalcopyrite, orthoclase, albite, epidote, zoisite, scapolite, and sericite and, in the case of the Voigt stock, much hematite and magnetite. These fluids were apparently not expelled immediately on the arrival of the magmas into their respective positions, probably owing to the lack of a porous rock to absorb the fluids which at that stage would not have high vapour pressures. Their expulsion occurred at a later period when they had developed a high pressure, had become enriched in the more volatile and rarer ingredients of the magma, and when sufficient cooling had taken place to provide fractures for their escape.

PLATE I

Copper Mountain and divide between Similkameen and Wolf Creek Valleys showing "through" valley Lost Horse Gulch, and Smelter Lake Valley. (Page 6.)

Plate II



Recent canyon cut in bottom of Simalkameen Valley just below Copper Mountain. (Page 6.)

Negative No. 59391

PLATE III

Polished section of Copper Mountain ore showing intensity and fineness of fracturing; $\frac{2}{3}$ natural size.
(Page 27.)

Negative No. 67249

INDEX