CANADA
DEPARTMENT OF MINES
HON. LOUIS CODERRE, Minister; A. P. LOW, Deputy Minister

GEOLOGICAL SURVEY
R. W. BROCK, Director.

MEMOIR 19

No. 26, GEOLOGICAL SERIES

Mother Lode and Sunset Mines, Boundary District, B.C.

BY
O. E. LeRoy

OTTAWA
GOVERNMENT PRINTING BUREAU
1913

No. 1166.

Mother Lode mine, 1910.

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THE MOTHER LODE AND SUNSET MINES, BOUNDARY DISTRICT, BRITISH COLUMBIA.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The Boundary district for the last eleven years has been the most important copper producing district in British Columbia and for several years has held the leading position among the copper producing centres of Canada. In the first decade (1900 to 1909) of production in the Boundary the copper content in the ores mined amounted to 247,995,303 pounds, the metal also containing important amounts of gold and silver as by-products.[1] The production in 1910 amounted to 31,354,985 pounds of copper based on smelter returns.

The principal mines which are producing the typical low grade and almost self-fluxing copper ores in the Boundary district are the Knob Hill-Ironsides, Gold Drop, Rawhide, Snowshoe, Monarch, and War Eagle situated at Phoenix; the Oro Denoro and Emma at Summit ; and the Mother Lode at Deadwood near Greenwood (Fig. 1, p. 2). The controlling companies operating the above mines are the Granby Consolidated Mining, Smelting, and Power Company Limited; the Consolidated Mining and Smelting Company of Canada; and the British Columbia Copper Company Limited of New York.

The present report is devoted to a description of the geological relations of the ore deposits of the Mother Lode, Sunset, and adjacent properties at Deadwood, and is an extension of similar work previously carried on at Phoenix in 1908.[2]

[1]Annual Reports of the Minister of Mines for British Columbia 1900 to 1910.

[2]LeRoy, O. E., Geology and Ore Deposits of Phoenix. Geol. Surv., Canada, Memoir No. 21.

FIG. I.

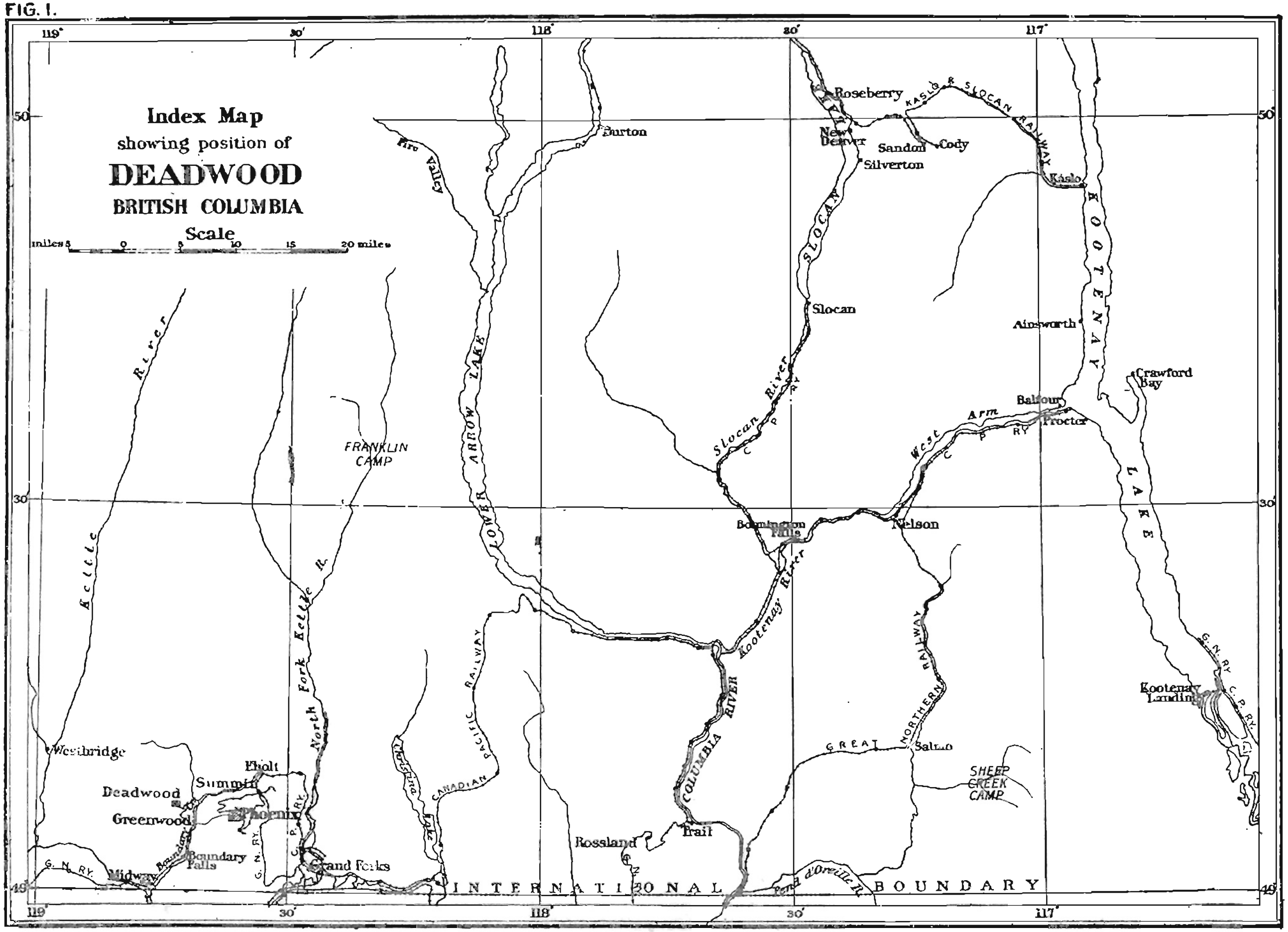
Index Map
showing position of
DEADWOOD
BRITISH COLUMBIA
Scale
miles 5 0 5 10 15 20 miles
119°
30'
118°
117°
50
30
49
Roseberry
KASLO & SLOCAN RAILWAY
New Denver
Sandon
Cody
Silverton
Kaslo
SLOCAN
KOOTENAY
LAKE
Slocan
Ainsworth
Crawford Bay
Balfour
Procter
West Arm
C. P. RY
Slocan River
Burton
Fire Valley
LOWER ARROW LAKE
FRANKLIN CAMP
Kettle River
North Fork Kettle R.
Bonnington Falls
Nelson
Kootenay River
COLUMBIA RIVER
Trail
Rossland
GREAT NORTHERN RAILWAY
Salmo
SHEEP CREEK CAMP
Kootenay Landing
G. N. RY.
C. P. RY.
CANADIAN PACIFIC RAILWAY
Christina Lake
Westbridge
Eholt
Summit
Deadwood
Greenwood
Phoenix
Boundary Falls
Midway
G. N. RY.
Grand Forks
Pend d'Oreille R.
INTERNATIONAL BOUNDARY

FIG. 1.

FIELD WORK AND ACKNOWLEDGMENTS.

The area mapped is about two-thirds of a square mile in extent and includes the Mother Lode, Sunset, Crown Silver, and Marguerite mines (Fig. 3, p. 44). Both topographical and geological work were carried on simultaneously during September, 1910. The topography was in charge of Mr. W. H. Boyd and his assistants. The areal geology was undertaken by Mr. C. W. Drysdale, while the writer devoted his time to the study of the ore deposits and their geological relations. The map is titled the Mother Lode and Sunset mines, named after the two most important mines. It is published on a scale of 400 feet to an inch with a contour interval of 20 feet.

Acknowledgments are due to all the officials of the British Columbia Copper Company, particularly to Mr. J. E. McAllister, Mr. F. Keffer, Mr. E. Hibbert, and Mr. A. Burnett for their courteous co-operation in connexion with the various phases of the work.

SITUATION.

Deadwood camp, with the Mother Lode mine as an arbitrary centre, is about 3½ miles by rail from Greenwood and is about 3,450 feet above sea-level. It is about 12 miles north of the International Boundary and about 6 miles from Phoenix where the other more important mines are situated (Fig. 1, p. 2). Greenwood, 117·3 miles by rail from Nelson, is situated on the southern line of the Canadian Pacific railway, which leaves the main line at Dunmore junction, and which is now being extended to Vancouver through southern British Columbia.

HISTORY.

Gold was first discovered in Boundary creek, and placers were worked as early as 1862. During the interval between 1862 and 1891 little attention was paid to the district and but few claims located. In 1890, the Rossland gold-copper deposits were discovered, and this apparently stimulated prospecting over a wide area in southern British Columbia. During the following year prospecting was actively carried on at Deadwood, Phoenix, and other neighbouring mineralized areas in the district. The prospectors came into the country by way of Marcus in the State of Washington. A pack trail followed the Kettle River valley and connected with the Dewdney trail at Grand Forks; from it branch trails were built into the several camps by the prospectors. In the Deadwood camp the Mother Lode was located on May 23, 1891, by William McCormick and Richard Thompson; the Sunset on June 2 by John East; and the Crown Silver on the same day by William Ingram. These were located under the old law which allowed claims to be 600 feet by 1,500 feet with extra-lateral rights. This act was repealed in 1892 when the present law was established allowing claims 1,500 feet square with vertical side lines. Practically the whole area in the vicinity of the above claims was staked during the subsequent years. In the first few years the same disappointments were experienced by the prospectors at Deadwood as by those at Phoenix. The ores were found to be of a very low grade, though the bodies were apparently of large size. The self-fluxing qualities of the ore were only discovered at a later period when subjected to metallurgical tests.

The history of Deadwood hinges altogether on that of its premier mine, the Mother Lode. It was bonded in June, 1896, to Colonel John Weir of New York, and in 1898 became the property of the British Columbia Copper Company. Extensive developments were planned and carried out, preparations were made for the construction of a smeltery at Anaconda—which adjoins Greenwood to the south—and a spur was built from the Columbia and Western railway at Greenwood to the mine. The latter was completed in 1900 and the first furnace of the smeltery was blown in early in that year. Since then the Company has gradually expanded, both by increasing its holdings of mining properties and by enlarging its smelting and converting plant which is now capable of treating about 2,400 tons of ore per day. The Sunset and Crown silver mines were sold in 1897, and after passing through the hands of several companies, a re-organization was effected in 1909 whereby the holding company, known as the New Dominion Copper Company, passed under the control of the British Columbia Copper Company.

The total production of the mines at Deadwood up to the end of 1910 is probably not less than 2,114,481 tons of ore though exact figures are not available. Of this amount 2,014,481 tons are to be credited to the Mother Lode mine.

PREVIOUS WORK AND BIBLIOGRAPHY

Mr. R. W. Brock of the Geological Survey staff made a reconnaissance survey of a portion of the Boundary district in 1901, and during the following year geologically mapped a belt about 13 miles wide along the International Boundary, extending from Grand Forks west to Midway. Dr. R. A. Daly, geologist to the Boundary Commission, at a later date, geologically examined a 5-mile belt along the International Boundary, the results of which have not yet been published.

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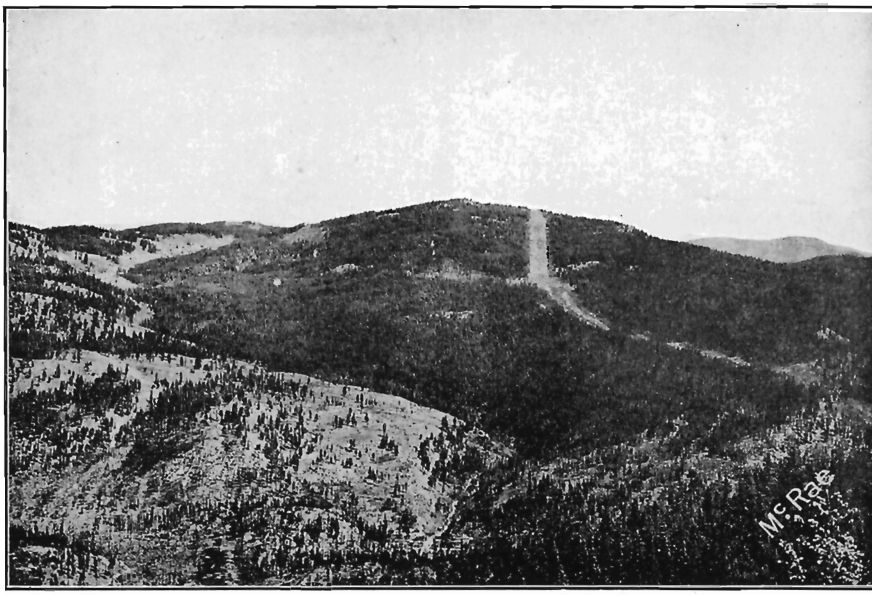
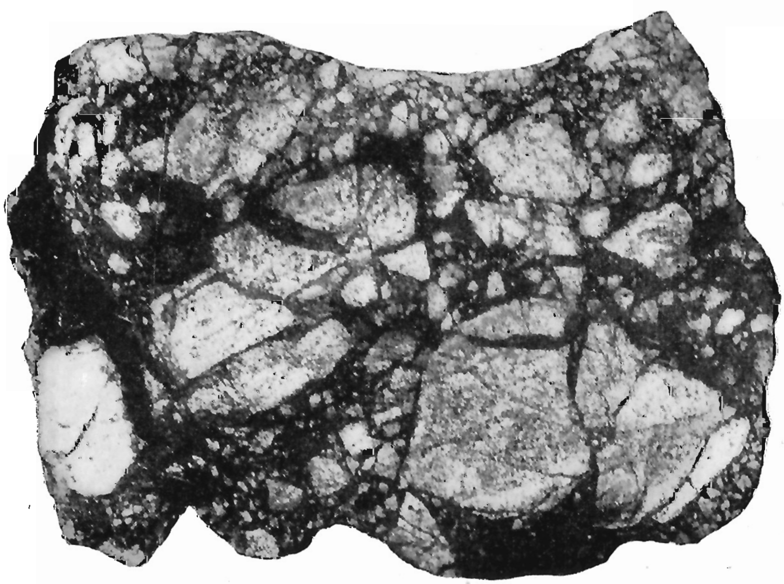


A



B

A. Photograph shows characteristic topography of the Boundary district. Phoenix in the upper right corner, Greenwood lower centre.

B. Brecciated limestone in the mineralized zone being replaced by garnet epidote, etc.

CHAPTER II.

GENERAL CHARACTER OF DISTRICT.

TOPOGRAPHY.

REGIONAL.

The Boundary district of British Columbia as far west as the Kettle river lies within the Columbia system of the North America Cordillera.[1] This system has been divided into a number of groups, bounded, as a rule, by the more important minor valleys. The Midway mountains form the group which includes that portion of the Boundary district lying east and north of the main Kettle river, and west of the North fork of the Kettle (Fig. 1, p. 2). This group is characterized by comparatively low mountains, which, when broadly viewed, appear as rounded ridges and dome-shaped summits, with crests at an average general elevation of 5000 feet above sea-level (Plate II, A). The valley system is well developed; the main or longitudinal valleys are relatively broad and U-shaped with their sides usually flanked by series of terraces which may reach an elevation of 2000 feet above the valley floor. The tributary or transverse valleys are V-shaped and their streams usually flow with steep gradients, often entering the main valley with abrupt change in grade. Plate II A shows the town of Greenwood in the foreground, situated in the U-shaped valley of Boundary creek, into which flows Twin creek occupying the V-shaped valley running up to the Phoenix basin.

The well wooded portions of the district occupy the northern slopes of the ridges. The eastern and western slopes may be either forested, or open and park-like, while the southern slopes are more often open and grassy. The higher ridges and narrower valleys are better watered and are usually densely wooded.

A low precipitation characterizes the district as a whole, and to ensure success in agriculture, irrigation is generally neces-

[1] Daly, R. A.—The Nomenclature of the North America Cordillera between the 47th and 53rd parallels of latitude. The Geographical Journal, vol. 27, 1906, pp. 586-606.

sary on the bottom lands and imperative on the benches or terrace lands. Grains, fruits, and vegetables under proper conditions of tillage give abundant crops, and an ever expanding market for all farm products affords every encouragement for the rapid development of the agricultural resources.

LOCAL.

That portion of Deadwood embraced in the accompanying map, is situated on the southern slope of Deadwood ridge which has a southeast trend and lies between Boundary creek and the Deadwood-Copper Creek valleys. The ridge gradually rises to the northwest and attains a maximum elevation of about 4860 feet above sea-level where it joins the Copper Mountain ridge. The range in elevation in the area comprised by the map is about 700 feet, rising from 3180 feet above sea-level in the south, to a maximum of nearly 3900 feet along the northern border. The subordinate spurs from Deadwood ridge in this area are rather flat topped, and present rounded blunt extremities, or their continuity may be broken by small valleys or depressions which roughly parallel the main ridge. While irregularities of surface give a relatively subdued ruggedness to the hilly portions, the whole is comparatively rolling with a gradual rise to the north. In the southwest, Deadwood creek occupies a rather steep walled valley and is the only permanent stream. The other streamlets are now of the intermittent, wet weather type due largely to the deforestration of their drainage basins. Deadwood drains into Copper creek, which empties into Boundary creek at Anaconda, south of Greenwood.

CLIMATE AND FLORA.

The climate on the whole is an agreeable and healthy one, though for short periods there are extreme ranges both in heat and cold. In summer the days are hot, but are usually succeeded by cool nights. At Midway, 7½ miles to the south, with an altitude about 1600 feet lower than Deadwood, the mean temperatures from 1896 to 1902 were 20·5° F. for January, and

65° for July. The annual mean was 43°. The mean precipitation at Midway for the years between 1894 and 1902 amounted to 12·7 inches per annum. The Deadwood area was originally rather well wooded, pine, tamarack, fir, and spruce being the most important trees. The demand in recent years for wood for mining and building, and the destructive forest fires have reduced the reserves to low limits. Portions of the area are covered with a scrubby second growth, which also has been recently burnt over in part.

CHAPTER III.

GENERAL GEOLOGY.

GENERAL DESCRIPTION OF FORMATIONS.

PALÆOZOIC.

The oldest rocks in the map-area consist of a series of igneous origin. The rocks are mainly tuffs and fine ash rocks, which have been partially or wholly replaced by silica giving a series of cherts, and jasperoids. The term Knob Hill group is retained for this series as the rocks in the main correspond to those similarly grouped at Phoenix. In this area, however, some of the jasperoids have no doubt been formed by replacement of the Brooklyn limestone, but as it was not possible to separate these from similar rocks of the Knob Hill group they have been mapped under the latter. No definite position has been given to the Knob Hill group, but as no stratigraphical break was noted it is possible that it is in the main but little older than the Brooklyn limestone. The succeeding formation is the Brooklyn, being the lower member of the Attwood series. It consists of grey to white non-fossiliferous, crystalline limestones, and has been referred tentatively to the Carboniferous by Daly, from resemblances to similar rocks in the Rossland mountains. The limestone is important because in it are the low grade copper deposits occurring in a mineralized zone of contact metamorphism characterized by the extensive development of lime silicates such as garnet, epidote, and actinolite.

Quartz porphyrite occurring in irregular dykes and small masses cuts the rocks of the Knob Hill group and the Brooklyn formation. The rock is considerably altered and to some extent has shared in the silicification which has affected the formations it intrudes. The time of intrusion is placed provisionally as upper Palæozoic, but may be Mesozoic though earlier than the granodiorite of Jurassic (?) age.

MESOZOIC.

The granodiorite of Jurassic (?) age outcrops at several points and occurs in underground workings, as dykes and masses seemingly connected with a larger mass underlying the whole district. It is wide-spread throughout the district and large areas outcrop in the vicinity of Deadwood (Fig. 2, p. 21). It ranges in composition from granite to monzonite, granodiorite being the prevailing type.

Hornblende porphyrites in a few dykes and small masses also intrude the older rocks. Owing to the few exposures they are not seen cutting the granodiorite, but it is possible that they belong to the Phoenix volcanic group of Daly, which is referred to late Mesozoic. They are so placed here provisionally.

TERTIARY.

The Tertiary is represented by a series of intrusives ranging from olivine basalts to pulaskite porphyry. They occur in dykes and sills, and the order of intrusion, commencing with the oldest, is olivine basalt, augite porphyrite, monzonite porphyry, and pulaskite porphyry. They are referred to the Miocene, and are probably intrusive equivalents of the lavas of the Midway volcanic group, which latter is developed in the immediate vicinity though just beyond the borders of this particular area (Fig. 2, p. 21).

QUATERNARY.

The Cordillera ice sheet covered the whole area, the general direction of movement being S. 18° E. The drift is modified and consists of clays, sands, and gravels with rounded boulders, distributed as a mantle of varying thickness over the greater part of the area.

TABLE OF FORMATIONS.

For purposes of comparison a tabular arrangement of the rock formations at Phoenix and Deadwood is given, following the table of formations for Deadwood.

Quaternary	Glacial and Recent	Modified drift, clays, sands, gravels.
Tertiary	Miocene?	Pulaskite porphyry. (alkali syenite porphyry). Dykes and sills.
		Monzonite porphyry. Dykes and sills.
		Augite porphyrite. Dykes.
		Olivine basalt. Dykes.
Mesozoic		Hornblende porphyrite. Dykes and masses.
	Jurassic?	Granodiorite.
	?	Quartz porphyrite.
Palæozoic	Carboniferous?	Attwood series, Brooklyn formation. Crystalline limestone.
		Knob Hill group. Tuff and ash rock more or less silicified, chert, jasperoid. Small lenses of argillite and limestone. Group in part is silicified limestone of the Brooklyn formation.

COMPARATIVE TABLE OF FORMATIONS.

Period.	Deadwood.	Phoenix.
Miocene	Pulaskite porphyry	Pulaskite porphyry.
	Monzonite porphyry	
	Augite porphyrite	Augite porphyrite.
	Olivine basalt	
		Midway volcanic group (Lavas)
Oligocene		Kettle River formation.
Post-Jurassic	Hornblende porphyrite	
Jurassic	Granodiorite group	Syenite and syenite porphyry.
	Quartz porphyrite	
Carboniferous		Rawhide formation.
	Brooklyn formation	Brooklyn formation.
Pre-Carboniferous	Knob Hill group	Knob Hill group.

DETAILED DESCRIPTION OF FORMATIONS.

PALÆOZOIC.

Knob Hill Group.

INTRODUCTION.

The Knob Hill group consists of cherts, jasperoids, and tuffs, together with small residual masses or lenses of argillite and crystalline limestone. The rocks belonging properly to the group were, in the main, originally tuffs of varying texture usually extremely fine grained. These have been altered wholly or in part to such highly siliceous types as cherts and jasperoids. Part of the jasperoid at least is replaced limestone of the Brooklyn formation, but has been arbitrarily included in the Knob Hill on account of its intimate association with the rocks of that group. Other residual masses of limestone and of argillite may possibly belong to the Brooklyn and Rawhide formations[1] infolded in the tuffs, but any decision to be regarded as final must await more work in other fields where the relations are more clearly shown. In the Phoenix area the jasperoid zone is sharply marked off from that of the cherts, but at Deadwood there is a gradual transition between the two, and in mapping, the boundaries have been somewhat arbitrarily drawn, dividing zones of jasperoid-tuffs from those of chert-tuffs. The age of the group is Palæozoic without any definite position being assigned, though it is probable that no great time interval elapsed between the deposition of the Knob Hill tuffs and the Brooklyn limestones.

DISTRIBUTION AND STRUCTURE.

These jasperoids, cherts, and tuffs probably underlie the whole of the map area. The jasperoids are usually at a higher horizon than the cherts. The rocks are massive, rarely banded, and the several units occur as irregular lens-like masses, overlapping

[1]LeRoy, O. E.—Geology and Ore Deposits of Phoenix. Geol. Surv., Can., 1911, Memoir No. 21.

or dovetailing into one another sharply, or by gradual transitions. They are much jointed and sheared in several directions, the trend varying from N. 3° E. to N. 68° E. with dips ranging from 70° to 90°. It is probable that faulting has been general, with possibly little displacement, but no data regarding the latter question could be gathered on account of the general similarity of the rocks. Locally along zones of shearing small areas of schists have been developed in the chert-tuff zone. Along some of the later fractures which were avenues for the Tertiary igneous intrusives, vertical and horizontal zones of brecciation occur, the fragments in part being cemented by the igneous rock. Finer friction breccias occur in fault planes noted underground.

LITHOLOGY.

Jasperoids.—The jasperoids are grey or greenish grey in colour, and consist of oval, rounded, oblong, and subangular pebble-like individuals of grey or brownish grey chert embedded in a matrix of calcite, quartz, and chlorite. They weather to a light rusty grey colour with the chert individuals standing out in high relief (Plate IIIA) and often simulate in character a conglomerate or breccia. Veinlets of quartz and calcite fill joint and other planes which commonly traverse the rock.

The individuals of chert vary from those of microscopic size up to others an inch or more in diameter, and on the whole the rock is much finer grained than the type occurring at Phoenix. The matrix varies from an almost purely calcareous one, to a dense quartz-chlorite type in which the chert individuals can only be discerned with difficulty. In minute shear zones pyrite and chlorite are usually associated, and the former in crystals and grains is rarely absent from the main body of the rock.

Microscopically the chert individuals are seen to consist of aggregates of microcrystalline or cryptocrystalline quartz up to 13 mm. in diameter, the individual grains having either smooth or interlocking borders. The grains show slight strain shadows, and a development of cataclastic structure in some of the larger ones. The matrix varies depending on the origin of the jasperoid. If it is derived from a tuff the matrix is composed of compact kaolin felts in which lie fragments of feldspar, grains

A

B

A. Limestone in part replaced by silica, represents a transitional type between limestone and jasperoid.

B. Limestone (l), in part replaced by epidote (e) and quartz (q).

3938—p. 14

of quartz, calcite, in small amounts, and ragged plates and fibres of chlorite. If, however, the rock was originally a limestone, the matrix is largely calcite with numerous grains of quartz, and shreds of chlorite. Tremolite, epidote, garnet, magnetite, and chlorite are present in the matrix of some of those types associated with the ore bodies, and are believed to be later metasomatic replacements of part of the calcite matrix, in the zone of contact metamorphism.

The calcite is both clear and turbid, occurring in mosaics of grains or in sponge-like masses enclosing chlorite and tremolite. The tremolite and chlorite usually occur in sheaf-like and radiate clusters, and in minute acicular forms. The former is colourless with a marked parting parallel to the base, and the latter is pale green. The chlorite also fills a few minute shear planes. Pale yellow, turbid epidote and colourless, clear zoisite occur in granular aggregates, or in single grains, either in the calcite or along the contact of quartz veinlets. Pale brown garnet has similar associations, as also have the grains and crystals of magnetite and pyrite.

The jasperoid is traversed by a reticulating system of quartz veinlets with a width up to 0·6 mm. Three or more periods of vein filling exist, each period being separated from the succeeding one by periods of minute faulting (Plate IV B). The fractures and minute fault planes were apparently the channels along which the siliceous solutions travelled during the period of replacement, and many of the veinlets are of tadpole form, and terminate in rounded individuals of chert. In some types the processes of silicification have progressed more uniformly through the rock, and replaced it more extensively, giving gradual transitions between jasperoids and chert in which there are few distinct individuals of the latter.

Cherts.—The cherts are grey, bluish, light greenish, dense grained siliceous rocks generally massive though occasionally banded in various tones of grey. When locally sheared they are cemented into quartz schists. They are finely jointed and fractured, with faulting and slight displacements. The planes are filled with white quartz and occasionally with calcite. They are brittle and have a conchoidal fracture. Near the ore bodies the cherts are dotted with flecks and grains of yellowish green epidote. In the banded types narrow lenses or leaves of pyrite have been deposited parallel to the banding. In appearance they vary from a typical chert to a massive lode quartz or fine grained dense quartzite. They weather from light grey to almost white with rusty patches and streaks due to the decomposition of the pyrite content. In the main they are derived from tuffs though some may have been originally argillites.

Under the microscope they are seen to be composed of grains of microcrystalline quartz from 0·015 to 0·2 mm. in diameter, with smooth or interlocking borders, passing gradually into vague areas of cryptocrystalline quartz which are usually turbid from dark opaque (carbonaceous ?) films surrounding individual grains or aggregates. As in the case of the jasperoids, the cherts are traversed by a similar system of quartz veinlets of three or more generations (Plate IV B). They have a radiating or parallel arrangement, and may swell out into lenses 2·4 wide and 0·7 mm. in length with individual grains up to 0·6 mm. in diameter. Others occur as thread-like lenticular forms, pinching out in both directions along the length of the minute fracture. Calcite in tiny grains is distributed interstitially through the quartz; pyrite is usually present in grains and crystals often surrounded by a narrow rim of limonite; and near the ore bodies, grains and aggregates of turbid epidote are sparingly developed through the rock.

Tuffs.—The tuffs are fine-grained, dense, compact rocks and in colour a dark grey usually with a greenish tinge. They are finely jointed and fractured, the planes being filled with quartz and occasionally calcite. Though generally massive, fine banded types occur in alternating yellowish green and dark green tones. They weather to a rusty grey with a finely spotted surface.

Quartz, chlorite, feldspar, and pyrite are individual minerals which can be distinguished in some of the coarser types. The principal varieties are quartz-chlorite tuff, chlorite tuff, and quartz-feldspar tuff. Microscopically, they consist of fragments or individuals of twinned and untwinned turbid feldspar and grains of clear quartz up to 0·15 mm. in diameter, in a matrix of microcrystalline and cryptocrystalline quartz, shreds of kaolin, felty aggregates of pale green chlorite, vague and turbid areas of calcite and epidote, and grains and crystals of pyrite and magnetite. The thin sections all show additions of secondary silica to a greater or less extent, indicating that the rocks are in the nature of transitional types between tuffs and cherts rather than true unaltered tuffs. Veinlets of quartz similar in character to those described under jasperoids and cherts traverse most of the thin sections examined (Plate IV B).

The jasperoids, cherts, and tuffs, in the vicinity and adjacent to the mineral zone or zone in which lime silicates have been developed, contain epidote, zoisite, garnet, tremolite, actinolite, and magnetite in trifling amounts. These minerals are more abundantly developed where the matrix was originally largely calcite and was, therefore, favourable to replacement by lime-silicates. Veinlets of calcite of a later period fill fractures which cross the quartz veinlets.

The origin of the large quantity of silica necessary to convert the tuffs and associated rocks to jasperoid and cherts, is not quite clear. It may have been derived from some intrusive magma possibly a deep seated body of which the quartz porphyrites are offshoots.

Brooklyn Formation.

INTRODUCTION.

The Brooklyn formation is the lower member of the Attwood series correlated by Daly with the Carboniferous, from its similarity to the rocks of that age occurring in the Rossland mountains. In the map-area the formation consists wholly of crystalline limestone, which, as elsewhere in the district, is apparently devoid of fossils. It has been in part replaced by silica giving rocks of the jasperoid type, and in part replaced by lime silicates in a zone of contact metamorphism, or mineralized zone, which contains the important bodies of low grade copper ore (Plate III A and B.)

DISTRIBUTION AND STRUCTURE.

The main exposure of limestone occurs north of the Mother Lode mine, while a larger area lies to the east of the Marguerite mine, the western border of which appears on the map. Minor outcrops occur at different points as residual masses lying in the jasperoid and the mineralized zones.

The limestone has been associated with the rocks of the Knob Hill group in the various earth movements experienced since their deposition, and the main contacts where they could be seen appear to be faults, the limestone being block faulted down into the tufaceous rocks, the faults in two instances being sharp planes bounding the mineralized zone. A similar fault occurs underground at the north end of the Mother Lode ore body and the plane is followed by a dyke of augite porphyrite. The limestone is massive with the bedding planes obliterated. Irregular jointing causes the rock to break into rough angular fragments. Near the ore bodies the rock is sheared and breaks into flat lens-like fragments coated with a thin film of chlorite.

LITHOLOGY.

The limestone is compact and crystalline throughout and varies from medium to fine grained. The colour varies from grey to pure white, the lighter types often having greenish or bluish casts. The grey limestone in some localities may pass sharply into the white, which on a fine scale gives a mottled appearance to the rock. The white limestone is less compact, and usually has a saccharoidal texture. The rock is traversed by an intricate system of minor planes of weakness now filled by veinlets of white calcite. Pyrite is usually present in minute crystals and grains but generally is in very trifling amount.

Microscopically the rock consists of clear and turbid grains of calcite with smooth and interlocking borders in mosaic arrangement. Evidences of strain are apparent in the uneven extinction and curved planes of twinning and cleavage. Small aggregates of microcrystalline and chalcedonic quartz are of frequent occurrence even in the purest types of rock and are developed interstitially to the calcite individuals, or tend to replace the calcite along cleavage planes. Locally this replacement of calcite by quartz under favourable conditions has continued until the limestone is wholly replaced, thus giving a jasperoid, or a rock having the appearance of a fine quartzite.

In an intermediate stage, the rock, transitional between limestone and jasperoid, consists of oval and rounded, oblong grains of light and dark grey chert embedded in a matrix of light grey crystalline limestone. On the weathered surface the individual grains stand out in high relief and simulate in appearance a fine conglomerate. Further action in some cases causes the grains to anastomose and form irregular areas of solid chert an inch or more in diameter, and in complete replacement a chert is the result in which the original oval forms can only be discerned on a polished surface or microscopically (Plate III A). In places a banding occurs where the jasperoid alternates with limestone, the replacement by silica following more favourable bands in the original rock. This is further accentuated by the jasperoid being of different grain in different bands. Near the ore bodies and along the border of the mineral zone, the limestone shows a spotted replacement by actinolite, garnet, epidote, etc., which have formed in little nests interstitial to the grains of calcite, or along the cleavage planes of that mineral. The mineral zone is composed essentially of lime silicates which have replaced the limestone metasomatically. To prevent needless repetition a description of this zone is omitted here and appears under economic geology.

CHEMICAL COMPOSITION.

Analyses of the grey and white limestones were made by Mr. M. F. Connor of the Mines Branch and appear below.

	I	II	III
Insoluble	0·32	0·60	0·40
Oxides of iron and aluminium	0·10	0·20	0·20
Calcium carbonate	95·86	96·35	97·67
Magnesium carbonate	1·36	1·43	1·40
Undetermined, water, etc.	2·46	1·32	0·33
	100·00	100·00	100·00

I. White crystalline limestone, Marguerite mine.
II. White crystalline limestone, Mother Lode mine, 200 foot level.
III. Grey crystalline limestone, Marguerite mine.

Quartz Porphyrite.

Quartz porphyrite occurs in irregular dykes and small masses intrusive in the cherts and jasperoids of the Knob Hill group, and in the limestone and lime silicate zone of the Brooklyn formation. The porphyrite in the field resembles some types of the chert or tuff, though a close examination reveals its porphyritic texture. The contacts are usually definite in the limestone areas, but much less so in the areas underlain by the tuffs, jasperoids, and cherts. The rock is much jointed and sheared and has been silicified to a certain extent.

Macroscopically the rock consists of dull grey phenocrysts of feldspar, and acicular and lath-like individuals of dark green hornblende, in a dense base composed chiefly of quartz. Under the microscope the feldspar is seen to be very turbid from alteration; it is in part twinned according to the albite law. The hornblende appears to be largely actinolite and is considerably altered to chlorite. The base is a fine aggregate of quartz and turbid feldspar, through which is distributed grains of calcite and grains and crystals of pyrite. Quartz veinlets are common and are similar to those occurring in the rocks of the Knob Hill group (Plate IV B).

The age of these intrusions is not definite. They are post-Brooklyn and pre-Jurassic and have been placed provisionally in the upper Palæozoic.

MESOZOIC.

Igneous Rocks.

INTRODUCTION.

The Boundary district is apparently underlain, and at no great depth, by a batholith of granodiorite and closely associated rocks which outcrop generally throughout the district as bosses, irregular masses, and dykes. The average rock is a light grey biotite-hornblende granodiorite associated with granite porphyries, and quartz diorite porphyries as closely allied types. More basic hornblende gabbro-like rocks passing into pure hornblende rocks also appear to belong to the same period. In several localities the main rock type strongly resembles the Nelson granite, which occurs east, north, and northwest of this district. Many of the smaller masses and bosses are similar in appearance to some phases of the monzonite intrusives in West Kootenay.[1]

The work on these plutonic intrusions has not been sufficiently

[1]Brock, R. W.—Sum. Rep., Geol. Surv., Can., 1902, pp. 100-101A.

detailed to permit a decision being reached in regard to the relations of the several types, whether they are differentiations of one intrusion or whether there were several periods of intrusion originating from one magma basin. No analyses of these rocks have so far been published and none were made of the types occurring in the map-area on account of their not being sufficiently fresh. The age of the batholith is referred tentatively to the Jurassic period.

In the map-area there are small masses and dykes of hornblende porphyrite which are assumed to be Mesozoic. They have not been found in contact with the above intrusives and their relative age has, therefore, not been definitely decided upon. It is possible that they may belong to the Phoenix volcanic group of Daly's classification, in which case they can be referred tentatively to the later Mesozoic.

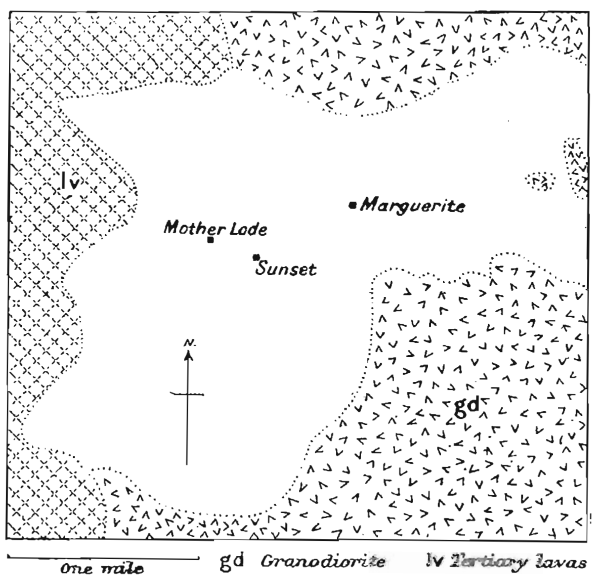


FIG. 2. Map showing distribution of granodiorite in the vicinity of the Mother Lode mine.

GRANODIORITE GROUP.

Distribution.—The rocks of the granodiorite group occur as dykes and small, irregular masses which appear to be more frequent and larger in the lower levels of the mine workings. They are intrusive in all the rocks of the Palæozoic and are cut by the Tertiary irruptives. In places they have been subjected to great alterations which have obscured their boundaries to some extent.

Lithology.—The rocks vary within moderate limits in their mineralogical composition and also in their texture, but they may be broadly classed under granodiorite, monzonite, and quartz diorite. They have all a close similarity in appearance in the field and in hand specimens. The texture ranges from granitoid with medium grain, to porphyritic with microgranitic groundmass. The colour varies from light to dark grey with a greenish tinge from the chlorite content, and the rocks weather to a light rusty grey.

The feldspar phenocrysts are light and dark grey, in some cases pale pink, and vary in size up to 0·3 of an inch in length. Black hornblende, pyrite, and magnetite can also be distinguished in hand specimens. Adjacent to the ore bodies epidote, garnet, and calcite are developed in limited amounts. The rocks as a rule are much jointed, being traversed by several systems, and in some cases are much sheared. The planes are filled with quartz, calcite, and in the vicinity of the ore bodies, by additional epidote, garnet, pyrite, and chalcopyrite. In no case are the rocks sufficiently unaltered for analysis as all the exposures are adjacent to or in the near vicinity of the zones of mineralization and ore deposition.

The rocks consist essentially of feldspar, hornblende, and quartz in phenocrysts or large individuals in a base of the same constituents. Apatite and part of the magnetite are also primary constituents. Chlorite, epidote, carbonates, quartz, limonite, and part of the magnetite are secondary constituents derived from the breaking down of hornblende and feldspar. In the zone of contact metamorphism, garnet, epidote, calcite, chalcopyrite, pyrite, and the remainder of the magnetite are constituents introduced by metasomatic replacement.

The feldspar is both twinned and untwinned and is usually quite turbid from alteration products. In composition, it ranges from orthoclase to acid labradorite. In the porphyritic types, the phenocrysts occur in tabular, lathshaped, and square forms, the average of the larger ones being about 1·5 by 0·5 mm. in size. In the granitoid types the form is usually poor and irregular. The plagioclase is occasionally twinned according to the albite law and a few individuals have the additional Carlsbad twinning. Zonal structure is of rather rare occurrence. The plagioclase phenocrysts are often surrounded by a thin crust of clear untwinned feldspar with a crenulate outer border. Strain shadows with incipient granulation are common. Chlorite and limonite traverse many of the individuals along fracture and cleavage planes. The mineral alters to kaolin, turbid aggregates of epidote, and carbonates with quartz. The hornblende is pale green and yellowish green and occurs in good forms in prismatic and basal sections, an average of the larger individual being 1 by 0·3 mm. in size. It more often is found in irregular individuals with frayed terminals. It is rarely fresh and has either been leached to paler tints or altered to chlorite with a separation of magnetite. Many individuals are completely altered to aggregates of chlorite, epidote, and calcite. The quartz is clear and occurs in rounded individuals up to 0·5 mm. in diameter. Outside of the groundmass it is in trifling amount. Apatite in clear colourless crystals and acicular forms occurs as inclusions in the feldspar and hornblende. Magnetite occurs as primary grains included in the hornblende, as dust-like particles with chlorite resulting from the breaking down of the hornblende, and as an ore mineral introduced at a later period with the lime silicates. It forms rounded grains and crystal aggregates up to 0·6 mm. in diameter. Epidote associated occasionally with zoisite replaces hornblende and feldspar along their cleavage planes in portions of the intrusive adjacent to the mineral zone. Pyrite in grains and streaks apparently replaces the hornblende in part. It also occurs distributed through the groundmass. Many of the grains are surrounded by a rim of limonite. Calcite is usually associated with the epidote but is also found in the groundmass in irregular sponge-like individuals and interstitial grains. In sheared portions of the rock adjacent to the ore bodies, irregular planes are filled with epidote, zoisite, garnet, calcite, magnetite, pyrite, and chalcopyrite.

The groundmass varies in relative amount in the different types. In some types representing border facies it is micrographic in texture and consists essentially of orthoclase, plagioclase, and quartz. The feldspar occurs in tiny laths and grains up to 0·03 mm. in diameter with smooth or interlocking borders, with the quartz interstitially developed. In addition, small individuals of hornblende or its altered equivalent chlorite, in platy and fibrous aggregates, grains of epidote, calcite, magnetite, and pyrite are also present in small and varying amounts.

HORNBLENDE PORPHYRITE.

The hornblende porphyrite occurs in thin dyke-like masses intrusive in the rocks of the Knob Hill group. The rock is dark grey, essentially porphyritic in texture with phenocrysts of grey feldspar and black hornblende up to 0·3 of an inch in length embedded in a dense crystalline groundmass or base. The rock weathers to a light brownish grey colour and has a rough pitted surface. The feldspar is mainly twinned—a few sections showing no twinning—and is basic oligoclase and andesine. It occurs as well formed phenocrysts and tabular forms, the latter showing the re-entrant angles of the albite twinning. It is usually very turbid from alteration products, or epidote and carbonates and numerous minute inclusions of pale green chlorite. Brownish green hornblende as phenocrysts is in greater amount than the feldspar and occurs in rounded idiomorphic forms and irregular individuals up to 2 by 0·5 mm. in size. It occasionally is intergrown with pale brown biotite. Some individuals have completely altered to chlorite and magnetite, with or without epidote and zoisite, others are partly altered and appear with irregular rims of turbid chlorite. The base consists of minute laths and grains of plagioclase, shreds and plates of chlorite, secondary quartz in small aggregates of grains along with a small amount of magnetite and pyrite. Some irregular areas are filled with sheaf-like aggregates of actinolite.

TERTIARY.

Igneous Rocks.

INTRODUCTION.

The early Tertiary (Eocene) was a period of vigorous erosion and the mountain systems resulting from folding and uplifts during the later Mesozoic were reduced from the lofty alpine type to mature forms, the peaks and ridges having a broadly uniform elevation. The district is not regarded as having reached the final stage of a peneplain, but was merely reduced to moderate altitudes.[1]

In Oligocene time the broader valleys wholly or in part became lake basins in which a series of sands, gravels, and clays were deposited, becoming by induration sandstones, conglomerates, and shales. In certain localities vegetation was sufficiently luxurious to cause the formation of lignitic shales with some beds of lignite coal. The formation has been called the Kettle River formation and from the effects of later erosion now appears in isolated or detached areas throughout the district.

The Miocene and possibly the later Oligocene was a period of wide-spread volcanic activity, during which time the district was covered by a series of lava flows aggregating a great thickness. The lavas consist of basalts, andesites, trachytes, and possibly more acid types. The oldest lavas are basalt and the youngest of the series is apparently an alkaline trachyte. They are known as the Midway Volcanic group, and are unconformable to the Kettle River formation. The unconformability indicates only a comparatively short period of erosion. The lavas are cut by their intrusive equivalents, olivine basalt, augite porphyrite, monzonite, and pulaskite porphyry, which occur as dykes, sills, and stocks. The period of lava flows was accompanied with

[1]Brock, R. W., Sum. Rep., Geol. Surv., Can., 1902, pp. 93–94 A. Daly, R. A., "The Accordance of Summit Levels among Alpine Mountains." Jour. of Geol., vol. XIII, pp. 105-125.

and followed by earth movements, which produced warping and faulting, particularly apparent along the contacts of the lavas of the Midway Volcanic group and sediments of the Kettle River formation.

The Midway Volcanic group is probably of the same age as the Volcanic group of Dawson occurring in the Kamloops area, while the Kettle River formation corresponds to the Coldwater group.[1]

In the map-area no lavas are found though they occur in great development immediately to the west (Fig. 2, p. 21). The intrusive equivalents, however, are well represented in dykes or sills of olivine basalt, augite porphyrite, monzonite porphyry, and pulaskite porphyry. In only one instance are they found cutting one another, the case being a sill of monzonite porphyry cut by a dyke of pulaskite porphyry (See general map).

The several types are porphyritic and show well marked selvages or chilled borders an inch or so in width. The dykes are found generally throughout the underground workings, but do not increase in number with depth so quickly here as elsewhere in the Boundary. The augite porphyrite was not noted as outcropping at the surface, but two dykes, however, occur underground, one in the Mother Lode mine, and one in the Crown Silver tunnel. Later movement along the dyke fissures has produced minor faulting with brecciation.

LITHOLOGY.

Olivine Basalt—This rock occurs in only one dyke having a length of 510 feet and a maximum width of 30 feet. It is a dark grey, almost black porphyritic rock in which laths of grey plagioclase feldspar, phenocrysts of black pyroxene, and rounded individuals of yellowish green olivine are embedded in a dense, fine grained base having the appearance of pitchstone. The rock weathers to a rusty grey with a pitted surface due to the removal of pyroxene and olivine individuals. Under the microscope the rock is seen to be comparatively fresh and consists of

[1]Dawson, G. M., "Geological Record of the Rocky Mountain Region in Canada". Bull. Geol. Soc. Am., vol. XII, pp. 80-81.

labradorite, augite, olivine apatite, and magnetite. The labradorite occurs in tabular, lath-shaped, and square individuals up to 3 mm. in length. They have no uniform orientation that would suggest fluidal structure but lie in all directions. Many show the step-like outline indicating incomplete growth. Twinning is by the albite law with occasionally the additional Carlsbad twinning. Many of the individuals have symmetrically arranged inclusions of the groundmass.

The augite is pale yellow or colourless. The large individuals are idiomorphic with sharp or rounded angles, and range in size up to 1·3 by 0·6 mm. Some have irregular borders with embayments indicating corrosion, and a few are twinned polysynthetically. The mineral is fresh with but slight alteration to chlorite along cleavage and fracture planes. It holds as inclusions a few grains of almost completely serpentinized olivine.

The fresh olivine is colourless and occurs in rounded, irregular, and wedge-shaped individuals up to 3 mm. in diameter. The alteration to yellowish green serpentine follows the borders of the individuals and the numerous irregular cracks traversing them, with the fibres and plates of serpentine lying parallel to the cracks which they traverse. Many of the smaller grains are completely altered.

The groundmass is in relatively larger amount than the phenocrysts and consists of irregular individuals and minute laths of plagioclase, grains of augite, fibres and plates of chlorite, and a little magnetite in grains and crystals. Colourless apatite in slender crystals and rounded grains occurs as inclusions in the augite, olivine, and feldspar.

Augite Porphyrite.—This type was only noted in two instances and then as dykes in the underground workings of the Mother Lode and Crown Prince. The dyke in the Mother Lode mine follows for a distance the fault plane or contact between the ore body and the siliceous rocks of the Knob Hill group.

The rock is much decomposed and rather soft from shearing movements subsequent to its intrusion. It is dark grey in colour and consists of phenocrysts of black pyroxene in a finer grained mass of greenish grey feldspar, and minute black plates of biotite. The rock is lamprophyric in its general texture.

Microscopically the feldspar is seen to be both twinned and untwinned, but the alteration has been too great to permit of any satisfactory determination of its composition. The similar rock at Phoenix contained both orthoclase and acid labradorite. Many of the turbid laths contain a large amount of green chlorite which has a certain symmetry in arrangement.

The augite is pale yellow and shows good forms in basal and prismatic sections. The size of the individuals ranges up to 1 mm. in diameter. It is less abundant than the feldspar but occurs in individuals of larger size. It is but slightly altered, chlorite being the secondary product. Biotite occurs in oblong forms and irregular plates of which many are allotriomorphic towards the feldspar. Magnetite in crystals and grains is in considerable amount, and is found in contact with individuals of augite and biotite or as inclusions in them. It also occurs in dust-like grains and aggregates in chlorite. The groundmass consists of laths of plagioclase, biotite, and pale green chlorite, the latter occupying angular interspaces between feldspars and being probably derived from the biotite.

The rock is closely related to the augite porphyrite occurring at Phoenix, but is apparently more basic in character. An analysis of the Phoenix rock by Mr. M. F. Connor of the Mines Branch, is given below. According to the quantitative classification the porphyrite is shoshonose.

SiO_2	55·90
Al_2O_3	15·52
Fe_2O_3	1·22
FeO	5·22
MgO	4·70
CaO	5·79
Na_2O	2·89
K_2O	4·45
H_2O+	1·40
H_2O-	0·60
CO_2	0·14
TiO_2	0·90
P_2O_5	0·46
MnO	0·08
SrO	0·09
	99.36

Monzonite Porphyry.—In hand specimens this rock is grey or greenish grey in colour and of porphyritic texture, with rosettes or irregular clusters of light grey feldspar, in a highly feldspathic trachytic or microgranitic groundmass in which minute laths of glassy feldspar may be discerned. The rock weathers to a pale, rusty brown or dirty dull grey with a pitted surface, due to the removal of many of the phenocrysts of feldspar and the grains of the dark (ferric) constituent. The rock occurs as dykes and sills which present well marked chilled zones along their margins.

Microscopically the rock consists of soda orthoclase and oligoclase (Ab_4 A_7, Ab_3A_7), feldspar, augite, biotite, quartz, calcite, chlorite, apatite, and magnetite. The phenocrysts of soda orthoclase are rounded, oblong, or square, in forms up to 2·75 by 1·5 mm., and are occasionally twinned according to the Carlsbad law. They are very turbid and are usually surrounded by a narrow zone (about 0·1 mm. wide) of clear feldspar in optical continuity with the main individual. The oligoclase occurs in clusters of tabular and lath-like individuals, the average size of which is smaller than those of soda orthoclase (up to $0 \cdot 7 \times 0 \cdot 3$ mm.). They are all twinned according to the albite law and a few have the Carlsbad twinning. They are generally turbid from kaolin and carbonates (calcite?) and are surrounded by narrow zones of clear soda orthoclase. Strain shadows are common in both feldspars.

Pale yellow augite occurs in rounded idiomorphic forms up to 1·5 by 1 mm. in size. The mineral alters readily to chlorite, and the greater part has been altered to aggregates of chlorite and calcite. Apatite and magnetite are in small amount; in some slides the latter occurs in filiform aggregates, the minute threads terminating in small lobes or possibly crystals. In this form it is either included in the feldspar, or forms borders about 0·1 mm. wide around phenocrysts of soda orthoclase, the filaments being arranged with the longer axis at right angles to the margin of the phenocryst.

The groundmass is about three times the volume of the phenocrysts and varies in texture. In some thin sections it consists of a trachytic mass of laths and irregular grains of plagioclase 0·3 by 0·06 mm, a little clear untwinned feldspar, minute oblong forms ($0 \cdot 2 \times 0 \cdot 04$ mm.) and plates of biotite allotriomorphic to the feldspar, and angular grains of clear quartz interstitial to the feldspar, the latter at times in relatively large amount. Chlorite and calcite are also present, the former being due to alteration of biotite. This type passes to one in which there are fewer laths of feldspar and more interlocking irregular grains, the texture becoming coarser and microgranitic. The rock is more basic than the normal pulaskite and probably is closely related to, if not identical with monzonite.

Pulaskite Porphyry.—The pulaskite porphyry (alkaline syenite porphyry or bird's-eye porphyry) is closely related to the above described monzonite porphyry and is probably a slightly more acid phase of the same magma. It is a compact, greyish, porphyritic rock consisting of phenocrysts of light grey feldspar with greenish cast embedded in a dense felsitic or microgranitic groundmass which is highly feldspathic. The feldspars have a tendency to arrange themselves in rosette-like clusters. The weathering of the rock is characteristic, the border becoming a brownish grey, while the phenocrysts become pale brown or pink.

Microscopically the texture of the rock is similar to the monzonite porphyry, and the mineral content is also similar with the exception that nearly all of the phenocrysts are soda orthoclase, the few of plagioclase being acid oligoclase. The volume of the base is much greater than that of the phenocrysts. The biotite which occurs interstitially to the feldspar in the base, is in relatively small amount and for the great part is altered to chlorite. The greater portion of the base consists of soda orthoclase and oligoclase laths. Quartz occurs in very small amount.

The analysis of the pulaskite porphyry occurring at Phoenix, made by Mr. M. F. Connor of the Mines Branch, is given below in column I,[1] and an analysis of the Rossland pulaskite by Dr. Dittrich, Heidelberg, is placed in column II.[2]

The Phoenix rock according to the quantitative classification is monzonose and it is probable that the pulaskite at Deadwood belongs to the same type.

[1]LeRoy, O. E., Geology and Ore Deposits of Phoenix. Memoir No. 21.
[2]Brock, R. W., Sum. Rep., Geol. Surv., Can., 1902, p. 104 A.

	I.	II.
SiO_2	57·32	62·59
Al_2O_3	17·27	17·23
Fe_2O_3	1·62	1·51
FeO	3·94	2·02
MgO	2·68	1·30
CaO	4·24	1·99
Na_2O	4·52	5·50
K_2O	5·96	6·74
H_2O+	0·47	0·30
H_2O-	0·08	......
TiO_2	0·88	0·54
P_2O_5	0·51	0·11
MnO	0·09	tr.
SrO	0·06	......
BaO	0·24	......
	99·88	99·83

QUATERNARY.

During Pleistocene time the Boundary district was wholly covered by the Cordilleran ice sheet, the effects of which are shown in the glaciated peaks and ridges and in the number of erratics, some being blocks of great size. The general direction of movement varied from S. 15° W. to S. 41° E. modified locally by the main topographic features during the closing period of the ice age.[1]

In the map area the local directions of ice movement varied from S. 35° W. to S. 65° W. Weathering has to a great extent obliterated the glacial striae on many of the rock surfaces though the more siliceous rocks and the outcrops of magnetite have retained very distinct markings. Modified drift in the form of clays, sands, and gravels with well rounded boulders occurs as a mantle of varying thickness though usually thin, overlying more than one-half of the area. In the deeper valleys such as that of Deadwood creek, the thickness is much greater and the gravels and sandy clays are rudely stratified. No typical boulder clay was seen.

[1]Brock, R. W., Sum. Rep., Geol. Surv., Can., p. 96 A.

CHAPTER IV.

ECONOMIC GEOLOGY.

DEADWOOD MINERAL ZONE.

INTRODUCTION.

The deposits of low grade copper ore of the Mother Lode and adjacent mines, occur in a mineralized area—termed the Deadwood mineral zone—which is a zone of contact metamorphism in the limestone of the Brooklyn formation, characterized chiefly by the development of lime silicates. The zone consists essentially of actinolite, garnet, epidote, calcite, and quartz, in which the metallic minerals chalcopyrite, pyrite, and magnetite have been deposited in certain favourable areas, so concentrated as to form irregular ore bodies of considerable size. The gangue rock is tough, compact, and usually dark green from the prevalence of actinolite. Where garnet and epidote predominate, the rock is harder, denser, and yellowish green or pale brown in colour. The rock is generally massive, but also occurs roughly banded from alternating layers of the several gangue minerals. It weathers to a reddish brown from the decomposition of the pyrite, with a surface usually deeply pitted from the dissolving out of the numerous small and irregular masses of calcite, leaving garnet, epidote, and quartz standing in relief (Plate III B). The ore bodies originally had a heavy 'iron hat' overlying their outcrop, that of the Mother Lode being a particularly noticeable feature in early prospecting days.

DISTRIBUTION.

The mineralized zone, probably once continuous over a very considerable area, has been separated by erosion into a number of isolated exposures, the major areas being those of the Mother Lode and Sunset, and the minor ones being the St. Lawrence, Great Hopes, and Marguerite.

A

B

A. Glory hole (in part) Mother Lode mine, 1910.
B. Quartz veinlets of three generations traversing a partially silicified tuff (X 40 dia.)
3938—p. 32

The Mother Lode zone is roughly elliptical with a northerly trend. It has a length of 1,250 feet and a maximum width of 1,080 feet. The thickness varies from a foot or so to about 550 feet. The vertical range from the highest point on the outcrop to the lowest point in the underground workings, is not less than 700 feet. The greatest thickness is along the northwest border and thins out towards the southeast (General map-section A-B). The Sunset zone is also of elliptical form on horizontal plan with a northwest trend. It has a length of 550 feet, a maximum width of 330 feet, and a maximum thickness of rather less than 50 feet.

GEOLOGICAL RELATIONS.

The Mother Lode zone lies in an irregular asymmetrical trough, the northwest wall of which is practically vertical and consists of crystalline limestone. The main floor of the zone is composed of the siliceous rocks of the Knob Hill group and granodiorite. The contact between the limestone and Knob Hill rocks is apparently due to block faulting rather than to a sharp folding, possibly a double faulting, one approximately along the strike of the ore body and a second across it as shown by the marked slip or crush zone from the 200 to the 400 levels in the Mother Lode mine. By this faulting the limestone was lowered into the jasperoids, etc., of the Knob Hill group. Small lenses of limestone also appear at a couple of points well within the mineral zone. The zone is cut by later (Tertiary) dykes of augite porphyrite, monzonite, and pulaskite porphyry which are usually very irregular in size, strike, and attitude.

The Sunset zone lies on a floor of the jasperoids, etc., of the Knob Hill group, and is roughly horizontal with possibly a slight tilt to the south. No limestone appears at any point in or along this zone which is blanket-like in nature and shallow. Dykes of pulaskite porphyry are relatively more numerous than in the Mother Lode zone.

The Marguerite zone is not exposed and is probably covered by a portion of the dump at the shaft. It must have a very small surface outcrop and probably stands almost vertical.

The St. Lawrence zone lies along the junction of the Brooklyn formation and the Knob Hill group. It has a length of about 150 feet and an exposed width of 40 feet. The Great Hopes zone is only a small patch, probably not more than a few feet thick at the deepest point, lying on the siliceous rocks of the Knob Hill group.

CHARACTER OF THE ORE BODIES.

The ore bodies are irregular, lens-like masses and vary widely in size and attitude, the latter depending probably on the thickness and attitude of the original limestone. The ore body of the Mother Lode stands almost vertical along the fault face of the limestone block where the vertical thickness of the mineral zone is probably the greatest. The Sunset ore bodies are practically horizontal.

The foot-wall is either limestone or the siliceous rocks of the Knob Hill group, and is practically the commercial as well as the structural foot, though in places a band of barren gangue rock intervenes between the structural foot-wall and the ore body proper. The hanging-wall is usually a commercial one, and the ore either insensibly becomes lower in grade, or the pay ore suddenly terminates along a gouge filled fissure or "slip."

The ore bodies are traversed by a series of fissures, locally termed "slips." These run in all directions and at all attitudes from vertical to horizontal. They vary in length from a few feet to a hundred or more feet, and in width from a fraction of an inch to several inches. The smaller ones pass by gradual transitions into those of almost microscopic dimensions, and the whole form a reticulating system of a very intricate nature and of several ages. Faulting has been general, though usually with small displacements. The system is analogous to that described under jasperoids, and illustrated in Plate IV B.

The fissures, no doubt, have generally been caused by stresses set up during the process whereby the limestone was being replaced by the lime silicates. They are also considered as being a most important factor in ore deposition, forming, as they did, the channels of circulation for ore-bearing solutions, which gradually passed from the trunk channels to the finer series of distributaries, thus permitting an even and wide-spread deposition of their metallic content. Many of the fissures, either wholly or in part, were filled with gouge, and as impervious bands were thus important in guiding and deflecting the general circulation, thereby promoting a better concentration of the ore. In the closing period many of these fissures were filled with calcite and quartz (the last minerals remaining in solution) associated in places with small amounts of chalcopyrite and pyrite. Slight movements along these pre-mineral fissures have taken place subsequent to the formation of the ore bodies, as evidenced by the many slickensided surfaces.

Wedge-shaped masses or ribs of almost barren gangue rock appear in all the ore bodies, and are usually obstacles to economic mining. Depending on their importance and position, they are either stoped or left standing. The ore is so uniform in its low grade character that much admixture of barren gangue would quickly bring it below the shipping grade.

CHARACTER OF THE ORE.

The ore is massive, rarely banded, and consists of chalcopyrite, pyrite, and magnetite, which are finely and uniformly distributed through the gangue minerals along fracture and cleavage planes, and interstitially between individual grains. The gangue minerals are actinolite, garnet (andradite), epidote, tremolite (rare), zoisite (rare), chlorite, calcite, and quartz. The chalcopyrite and pyrite are more closely associated with the quartz and calcite which fill fractures and interstitial spaces in and between the lime silicate minerals.

Occasionally masses of chalcopyrite are found, but these are of relatively rare occurrence. Magnetite also occurs in irregular lens-like masses, both along the border of the main ore bodies and also at various horizons through them. Azurite and malachite were found in the surface zone of oxidation. Arsenopyrite, galena, zinc blende, and pyrrhotite[1] have been noted in very small quantities. The average ore ranges from 1·1 to 1·3 per cent of copper, and the gold and silver values amount to about $1 per ton.

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[1]Brock, R. W., Sum. Report, Geol. Surv., Can., 1902, p. 119A.

The character of the ore differs mineralogically only from that at Phoenix. At Phoenix, epidote and garnet are predominant and actinolite of rare occurrence. The iron oxide generally distributed through the ore at Phoenix is hematite, the magnetite there occurring only in distinct masses.

Mineralogy.

Only the minerals composing the mineralized zone and ore bodies will be considered under this heading. Arsenopyrite, galena, blende, and pyrrhotite referred to in earlier reports[1] of the area, were not noted by the writer.

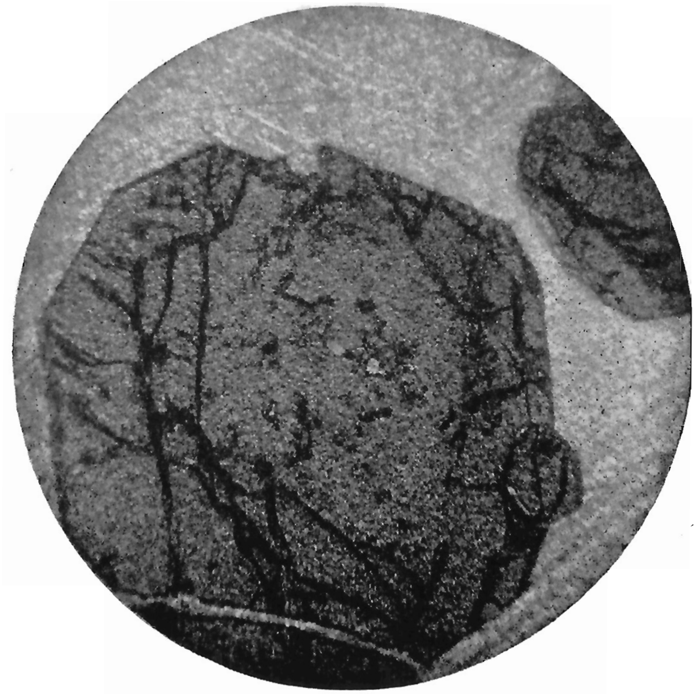
METALLIC MINERALS.

Chalcopyrite (sulphide of copper and iron)—Chalcopyrite is the most important and valuable of the metallic minerals and contains all the copper values, and practically all of the gold and silver as well. It occurs as solitary grains and aggregates up to 2·5 mm. in diameter, as narrow threads and streaks, and as minute elongated lenses up to 12 mm. in length, developed along cleavage, fracture, and shear planes in the gangue minerals (Plate V, B). It is also found associated with the calcite and quartz which fill irregular areas in the actinolite, and actinolite-garnet types of gangue, and usually forms along the contact of the calcite or quartz with the lime silicates. It is usually associated with iron pyrite, which, in part, is contemporaneous with the chalcopyrite. It also surrounds grains and well formed crystals of magnetite, as well as filling minute fractures which traverse the latter mineral. It is also found in larger masses which are relatively pure, but these are of somewhat rare occurrence.

Iron Pyrite (disulphide of iron)—Iron pyrite is closely associated with the chalcopyrite. It often occurs in good crystal forms, the cube and pyritohedron being the more common, and combinations of the cube and octahedron

[1]Brock, R. W., Sum. Report, Geol. Surv., Can., 1902, p. 119A.

Plate V.



A

B

A. Garnet crystals in calcite (40 diameters).

B. Chalcopyrite (black mineral) in actinolite (grey mineral) (40 diameters).

being less so. The crystals vary in size up to a quarter of an inch in diameter. Microscopically they are found disseminated through the gangue minerals in sizes up to 0·1 mm. in diameter. The mineral has a wider range in deposition than the chalcopyrite, part of the pyrite being about the last of the minerals to crystallize.

Magnetite (magnetic oxide of iron) — Magnetite occurs generally distributed, in grains and crystals, both solitary and in aggregates of octahedra, throughout the gangue minerals and favouring the contact between the lime silicates and the calcite or quartz. It also occurs as massive bands alternating with actinolite and garnet and as large irregular lens-like masses of varying size at different horizons in the ore bodies.

It has been formed earlier than the sulphides and is in part slightly later, and in part contemporaneous with the lime silicates. When massive the magnetite forms a dense crystalline aggregate, in which the sulphides are irregularly disseminated, occupying interstitial spaces between the grains, or filling minute zones of shear and brecciation. It is usually traversed by numerous seams of quartz and calcite. Narrow brecciated zones were noted, with the fragments of magnetite cemented with quartz or calcite.

Limonite (hydrous sesquioxide of iron)—Limonite, in brown and reddish tones, results from the decomposition of the sulphides. It often forms a coating on pyrite, and on chalcopyrite with malachite. It occurs generally throughout the ore bodies as thin films along joint and shear planes, and fills microscopic cracks in the garnet (Plate V, A) and cleavage planes in the actinolite.

Malachite (green hydrous carbonate of copper)—Malachite of pale green colour and rather dull lustre occurs as botryoidal incrustations on chalcopyrite. Azurite probably occurs also but was not noted. The oxidized zone has in great part been mined, hence but relatively little of the secondary metallic minerals are now to be seen.

Non-Metallic Minerals.

Actinolite (magnesium-calcium-iron-amphibole)—Actinolite is the best developed and most widely distributed gangue mineral. It varies from pale green to greenish grey and is pleochroic in pale green, almost colourless and yellowish green tones. In places it occurs in columnar masses with fibres several inches in length, which show the eminent cleavage and the characteristic basal parting. It generally occurs in acicular and lath forms with frayed or ragged terminals, arranged either without any particular orientation, or in sheaf-like and radiate clusters forming felty masses which in the aggregate produce a gangue of considerable toughness. At times it appears intergrown with magnetite. The sulphides are deposited in it along the planes of cleavage and parting (Photo B, Plate V) and in minute shear planes. A black variety of hornblende associated with pyrite and calcite occurs in veins filling fissures in the massive actinolite. Along some of the larger shear zones the actinolite has been converted into a substance resembling "mountain leather" consisting of series of interlacing flat thin leaves and fibres, pale grey in colour but lacking the quality of toughness.

Tremolite (lime-magnesia silicate)—Tremolite was only noted microscopically and is of rare occurrence. It is colourless and forms sheaf-like aggregates associated with other gangue minerals.

Garnet (andradite-lime iron silicate)—Garnet occurs both massive and in crystals. A test analysis by M. F. Connor of the Mines Branch, showed distinctly that the variety was andradite. The colour is reddish brown, pale brown, and honey yellow with usually a resinous lustre. The crystals present the rhombic dodecahedron and combinations of it with the tetragonal trisoctahedron, and have formed freely towards or along the borders of the calcite filled areas (Photo A Plate V). Microscopically the massive garnet is pale yellow and occurs in aggregates of rounded polygonal forms traversed by numerous cracks. In all the slides examined it was seen to be quite isotropic. The crystals vary up to 2 mm. in diameter and have developed freely towards the calcite and quartz. The massive garnet has been finely brecciated locally by later movements, and the angular fragments are cemented together by quartz or calcite. In some instances the brecciation has produced a finely comminuted microscopic dust cemented by calcite in which minute grains of ore have been deposited. To a very slight extent the garnet has suffered alteration to chlorite along minute shear or fracture planes.

Epidote (lime-iron-aluminium silicate)—Epidote is present in relatively small amount and is usually found in the mixed gangue of actinolite and garnet. On fresh fracture it is bright green or yellowish green but weathers dull or earthy. Crystals are not common and its usual occurrence is in small granular masses. Where sheared it assumes a finely fibrous aggregate. It replaces the feldspar and femic minerals in the granodiorite, and in certain instances is found replacing limestone in narrow parallel bands alternating with quartz and calcite (Photo B, Plate III).

Zoisite (lime epidote)—Zoisite was only noted microscopically. It is colourless, and occurs in minute crystals and grains associated with epidote.

Chlorite—Chlorite is not abundant. It is pale green, and occurs to a very limited extent as an alteration product of garnet, and to a greater extent from the breaking down of the actinolite along lines of shear.

Calcite (carbonate of calcium.)—Calcite varies from dark grey to pure white, and occurs in irregular areas in the lime silicates, as veinlets traversing them, and as the cement in zones of brecciation. It is usually associated with quartz and also with the sulphide minerals. It has been known to occur in a very pure state, and some excellent crystals of Iceland spar have been found in the Mother Lode mine. At various horizons in the Mother Lode mine the calcite forms the bulk of the gangue to the exclusion of the lime silicates.

Quartz (oxide of silicon)—Quartz is light grey and usually occurs in a manner similar to that described under calcite. It does not, however, form large masses in the gangue but is found as grains and veinlets associated with calcite.

ORIGIN OF THE ORE BODIES.

The copper-gold-silver deposits of the Mother Lode and adjacent mines occcur in a zone of contact metamorphism characterized chiefly in its mineral composition by the abundant development of actinolite, garnet, and epidote. The zone, however, is susceptible of two divisions, one being composed almost entirely of crystalline limestone, the other being made up of lime-silicates chiefly and the ore minerals (See general map). The direct cause of these contact zones is believed to be the intrusion or intrusions of the granodiorite of Jurassic(?) age, which have either invaded limestone formations, or have been intruded sufficiently close to such formations as to profoundly alter them. The granodiorite is also considered as the source of the metallic minerals forming the ore. While the evidence generally through the Boundary district is not absolutely conclusive there is apparently an absence of any other geological factor of sufficient importance to be accounted the prime agent.

In the replacement of the limestone, actinolite, garnet, and epidote were the first to form, and a great part of the magnetite was practically contemporaneous with them. At a slightly later period, the character of the mineralizing vapours or solutions changed somewhat, with the consequent introduction of chalcopyrite and pyrite, which were deposited in fissures, minute cracks, cleavage planes, and interstitial cavities. The final phase of deposition is represented by quartz and calcite which filled all remaining cavities and spaces.

From the prevalence of chalcopyrite, Weed in his genetic classification of ore deposits has referred these to the Cananea type of contact metamorphic deposits.[1]

In the Mother Lode mine the granodiorite forms a part of the east wall of the ore body; it also underlies the ore bearing zones of the Crown Silver, Marguerite, and the Sunset in part. At other points in the Boundary district as well as in this area the granodiorite has been found, locally, to have been replaced by lime silicates, along with ore bearing sulphides. In such

[1] Weed, W. H., Ore Deposits near Igneous Contacts. Trans. Amer. Inst. Min. Eng., Vol. 33, 1903, pp. 715-746.

cases it seems possible, that, with a differential cooling in the batholith, certain portions of the border have solidified in contact with limestone, and both rocks have been subsequently attacked by vapours or solutions from the still fluid portions of the magma, thus producing lime silicates in the rocks on both sides of the contact.

With regard to the origin of the lime silicates there is a considerable diversity of opinion, which may be classified under two schools of thought.[1] On the one hand it is contended that the results are brought about by the metamorphism of impure limestone at, and adjacent to the contact of igneous intrusive rocks, with little or no addition of material from the latter; while the other school advances the view that foreign material from igneous sources was to a greater or less extent introduced, combining with and replacing the limestone, by various species of lime silicates.

From the great diversity of contact deposits it seems probable that one or the other school is correct in certain occurrences, while in other cases a modification of the two would appear to be the more correct hypothesis. In certain instances it has been noted that pure limestone bands only were replaced, while in other cases the reverse has been found true. Besides the character of the replaced rock, the composition of the magma of the intrusive rock is probably an important factor, as well as the size and attitude of the mass.

The residual limestone in the vicinity of the Mother Lode and Marguerite is now wholly crystalline, and is comparatively pure containing but trifling amounts of silica, iron and alumina (see analyses, chapter III, page 19).

If these analyses approximately represent the composition of the original rock, it is, therefore, necessary to assume that the rock has received important additions of ferric iron, alumina, and silica to account for the large volume of lime-iron and lime-iron-alumina silicates and magnetite now present in the contact zone. It also seems probable that the limestone origi-

[1] Barrell, Joseph, Physical Effects of Contact Metamorphism. Amer. Jour. of Science, Vol. 13, 1902, pp. 279-296 and literature referred to in this paper.

Kemp, J. F., Ore Deposits at the Contacts of Intrusive Rocks and Limestones. Econ. Geol., Vol. 2, 1907, pp. 1-13.

Lindgren, W., The Relations of Ore Deposits to Physical Conditions. Econ. Geol. Vol. 2, 1907, pp. 105-127.

nally was rather pure, for the present crystalline types though occurring in large masses over considerable areas, give no indications in their average composition that the rock contained more impurities than at present.

While a definite statement is hardly warranted it seems highly probable that the limestone has been replaced by solutions derived from igneous sources which carried ferric iron, alumina, and silica, attacking and dissolving the limestone and forming lime silicates with a liberation of carbonic acid gas and water.

CHAPTER V.

DETAILED DESCRIPTIONS OF MINES.

THE BRITISH COLUMBIA COPPER COMPANY LIMITED.

INTRODUCTION.

The holdings of the British Columbia Copper Company at Deadwood consist of six claims, namely, the Mother Lode, Primrose, Offspring, Tenbrock, Don Julis, and Sunflower. The Company also controls the Sunset group consisting of the Sunset, Crown Silver, C.O.D., and Florence claims. The former group, of which the Mother Lode is the chief, was bonded for $14,000 in 1896 by Col. J. Weir of New York, who formed the Boundary Mines Company which in 1898 became the British Columbia Copper Company. The Sunset group was sold in 1897 to W. L. Hogg of Montreal. In 1899 the group was known as the Montreal and Boundary Creek Mining Company. The property was taken over in 1900 by the Montreal and Boston Company which purchased the smelter of the Standard Pyritic Smelting Company situated at Boundary Falls. The Dominion Copper Company formed in 1905 assumed control for 4 years, and was then reorganized in 1909 under the name of the New Dominion Copper Company, in which the British Columbia Copper Company has the controlling interest.

The principal mines operated by the British Columbia Copper Company in 1910 were the Mother Lode at Deadwood, the Oro Denoro at Summit, the Jackpot in Wellington camp, and the Rawhide at Phoenix. The Lone Star and Napoleon mines in the State of Washington are also being developed and will shortly add very materially to the general ore production. The ore from the Napoleon and Jackpot supplies the deficiency f sulphur which exists in the normal low grade copper bodies, ypical of the Boundary district.

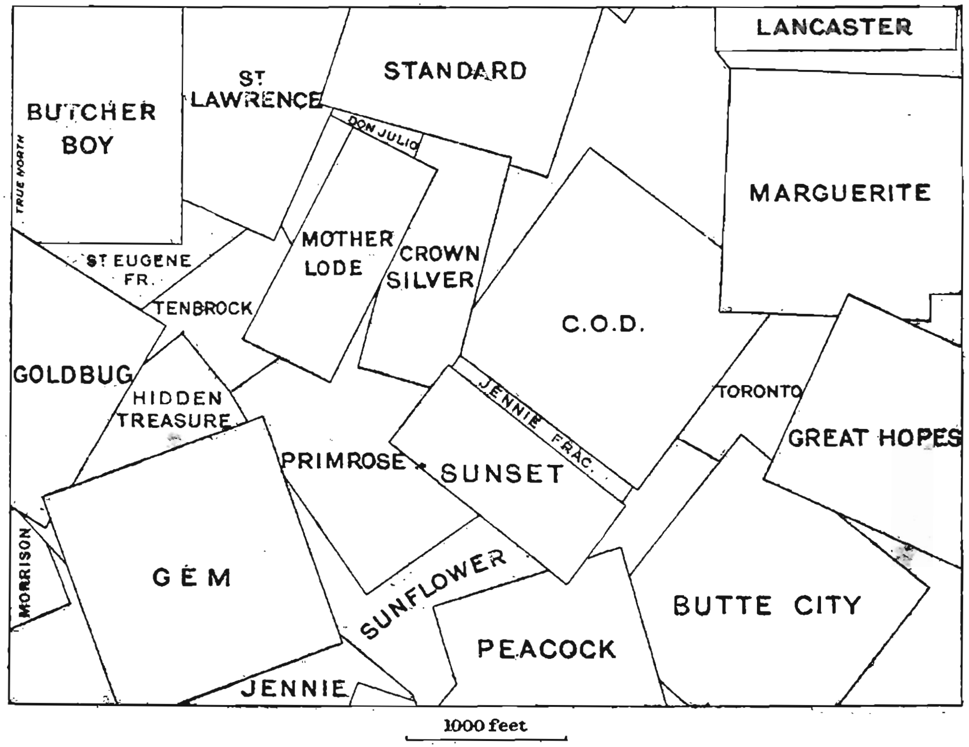


FIG. 3. Claim map. Mother Lode mine and vicinity

The smeltery,[1] of the company is situated at Anaconda and has been enlarged from time to time as necessity demands. The first furnace was blown in on February 18, 1901, and the second one was installed in 1902. At present the smeltery consists of three furnaces which treat from 1800 to 2400 tons per day, with a maximum capacity of 2600 tons. During the early years the matte was shipped direct, but in 1904 a Bessemerizing plant was installed to convert the matte to blister copper. The plant consists of 2 converter stands with 7 horizontal shells and has a capacity of between 40 and 50 tons of matte in 24 hours. The matte, which carries from 45 to 50 per cent of copper, is converted to blister copper about 99·3 per cent pure and carrying the gold and silver values. The blister copper is shipped to New Jersey for complete refinement.

Electric power is used throughout, being derived from the plant at Bonnington Falls on the Kootenay river some 85 miles distant. The coke supply is procured from the International Coal and Coke Company at Coleman, Alberta. About 120 men are usually employed at the smeltery. The smeltery at Boundary Falls owned by the New Dominion Copper Company is no longer used and has been dismantled.

MOTHER LODE MINE.

Location.

The Mother Lode mine is situated on the east side of Deadwood creek at an elevation of 3450 feet above sea-level. It is connected with Greenwood and the smeltery at Anaconda by a spur of the Canadian Pacific railway about 3½ miles long.

Production.

The mine is the second in importance in the Boundary district and ranks next to the Knob Hill-Ironsides mine at Phoenix. The total production of the mine to the end of 1910 amounts to 2,014,481 tons of ore smelted. The recovered values amount

[1]McAllister, J. E. Greenwood Copper Smelting Works, Eng. and Min. Jour., May 20, 1911, pp. 1011-1015.

to 37,648,281 pounds of copper; 93,924·2 ounces of gold; and 336,889·5 ounces of silver. The average value per ton thus amounts to 18·68 pounds of copper, 0·041 ounces of gold, and 0·167 ounces of silver.

Development and Equipment.

The mine is developed by a four compartment shaft to the 500 foot level, with levels at 60, 200, 300, and 400 feet; the 60 and 200 foot levels are also connected with the surface by tunnels. Above the 60 foot level to the highest point on the outcrop, the mine is developed by a series of quarries forming a large "glory hole" (Plate I and general map). The shaft is a vertical 4 compartment one, two compartments of which are used for hoisting ore, one for men, and one manway. Ore pockets have been constructed below each level, and all ore won in the mine is raised in 4-ton skips. Horse haulage is used on the 60 and 200 foot levels, and electric haulage on the 300 and 400. The mine is lighted throughout by electricity. From the upper bins at the shaft pocket head, the ore is dropped to Blake crushers, and after crushing is carried on a belt conveyer to the shipping bins which have a capacity of 2000 tons. These are situated near the terminus of the spur line, and the ore is hauled to the smeltery in 30 to 50 ton cars. Air is furnished by two compressors, one Rand and one Ingersol-Sargent, with an aggregate capacity of 70 drills. Electricity as motive power is used throughout with the exception of the haulage on the 60 and 200 foot levels. About 235 men are employed at the mine.

Methods of Mining.

Parallel drifts are run in the direction of the strike of the ore body, one being at or near the foot-wall, and the series are connected by cross-cuts. Raises with chutes are put up about every 35 feet, commencing in or near ore and connecting with one another at intervals, and also with the level immediately above. The method of stoping is that of the pillar and room. The raises from the several levels were originally driven in spiral forms, but recently the method has been changed to a straight raise. The ground is firm and requires little or no timbering beyond the chutes, while the number of pillars left for supports depend on the local character of the immediate ground with reference to the attitude of the fissures or "slips". The surface ore is still being won from a series of 6 quarries forming the large "glory hole" (Plate I and Plate IV A). The ore is dropped from them to the 60 and 200 foot levels. Diamond drilling has in the past been extensively used to do the initial prospecting and to outline the general dimensions of the ore body.

Geological Relations and Character of the Ore Body.

There is apparently but one ore body, though of irregular form, when examined in detail. In certain sections of the workings where two or more bodies were developed, it was found by later work that they were connected with the main ore body, the separating masses being ribs or irregular wedges of lower grade ore, or almost barren gangue.

Along the outcrop the ore body has a length of about 1,100 feet (see general map). The length, however, diminishes with depth and on the 400 foot level is a little less than 250 feet. The thickness varies from 80 to 160 as maximum, with an average of about 140 feet. The thickness of the ore is modified by the number of lean wedges or ribs which may occur interbanded with it. As an example, a cross section at one point on the 60 foot level gave, starting at the foot-wall, ore 40 feet, waste 40 feet, ore 30, waste 18, ore 32, waste 27, ore 5—a total of 107 feet of ore and 85 feet of lean or barren gangue. The general continuity of the ore body is broken by an upward truncated cone-shaped mass (body) of lean and barren gangue which extends from the base of the mineral zone almost to the 60 foot level. The vertical range from the highest point on the outcrop to the lowest developed portion of the ore body amounts to about 650 feet.

The general strike is N. 30° E., with a curve to the east, at the north end of the ore body. The dip is to the southeast, and varies from 45° to 70°, steepening with depth until the lower half of the ore body is practically vertical (section A-B general map.)

The foot-wall is crystalline limestone and the ore is either in close contact with it, or is separated by a narrow band of the gangue minerals (section A-B, general map).

The contact of ore or gangue with the limestone is usually quite sharp, and the limestone wall often presents an irregular angular or broken surface without a distinct foot-wall fissure. The hanging or east wall is, on the whole, a commercial one and consists of the usual gangue minerals, or partly epidotized and mineralized granodiorite. Along the south boundary, which is marked by a fault from the 200 to 400 foot levels, the ore body is in contact with the rocks of the Knob Hill group.

The system of fissures, of several ages, which traverse the ore body in all directions and at all attitudes, has been an important factor in the distribution of the ore. Along the borders of some the ore is noticeably of slightly higher grade than the average, but gradually fades out into normal ore. Subsequent to its formation, the ore body has been cut by dykes of pulaskite porphyry. They vary from a few inches to over 20 feet in thickness, and are found at all levels from the surface to the 500 foot level. A main dyke on the 200 foot level extends along the length of the ore body and dips into the foot-wall. On account of its low dip it has been a serious obstacle in mining. The ore along the borders of these dykes is of higher grade than the average. This may be a concentration, due to a mineralizing action set up by the intrusion, or the dykes may have followed some of the more important pre-mineral fissures, which have higher grade ore along these walls, as noted above. One dyke of augite porphyrite occurs at the north end of the ore body along the contact between ore and country rock on the levels following a fault fissure. Later movements have crushed and altered it to a great extent. The thickness varies up to 25 feet and it dips south at about 55°.

Character of the Ore.

The ore consists of chalcopyrite, pyrite, and magnetite as grains, aggregates, and thread-like streaks and lenses, sparsely, though uniformly distributed through a gangue composed of varying proportions of actinolite, garnet, epidote, calcite, and quartz. Chalcopyrite also occurs in larger and purer masses, but these are relatively rare. Magnetite occurs in irregular masses and lenses of considerable size, and often can be mined separately from the general ore: they are found both along the border and at various horizons in the ore body.

With the variation of gangue three types of ore can be differentiated: a siliceous where the lime-silicates predominate, a calcareous rich in calcite, and a ferruginous composed largely of magnetite.

Analyses of these types give the following results:—

	Siliceous	Calcareous	Ferruginous
Silica	44·23	20·10	27·33
Alumina	7·46	1·31	.....
Iron oxide	16·83	12·00	51·12
Lime and magnesia	16·03	34·00	10·26*

*British Columbia Mining Record, May 1902, p. 173.

Through the courtesy of the British Columbia Copper Company the writer is enabled to publish the following analysis by Mr. Frederic Keffer, the consulting engineer of the Company.

AVERAGE ORE OF THE MOTHER LODE MINE.

Silica	All calculated as combined as silicate		36·18
Alumina	" "		10·16
Lime (CaO)	Total 18·81 per cent.	As carbonate	9·34
		As silicate	9·47
Magnesia		"	2·59
Potash		"	0·25
Soda		"	0·32
Carbonic oxide (CO_2)		As calcium carbonate	7·34
Copper	As chalcopyrite		1·94
Iron	Total Fe is 14·36	In chalcopyrite	1·71
		In pyrite FeS_2	1·91
		As ferrous oxide	10·74
Sulphur	Total is 4·13	As chalcopyrite	1·95
		As pyrites	2·18
Oxygen		As ferrous oxide	3·06
Water	Total 1·11	As moisture	0·46
		Combined water	0·65
		Total	100·25

The copper, gold, and silver values are mainly in the chalcopyrite. The average assays of the ore give 1·1 to 1·3 per cent of copper, with $1.10 to $1.20 in gold and silver.

THE SUNSET MINE.

Location.

The Sunset mine is situated southeast of the Mother Lode and about a fourth of a mile from it. The same spur of the Canadian Pacific railway connecting the Mother Lode mine connects the Sunset with the main line at Greenwood.

Production.

From lack of data no authentic statement can be made regarding the production of the mine in the past. The mine apparently commenced shipping in 1901, but has been idle since 1908. It is probable that the total amount of ore shipped in the interval between these years is rather less than 100,000 tons.

Development and Equipment.

The mine is developed by a series of open quarries, a tunnel at the 100 foot level with a vertical two-compartment shaft from that level to the 300 foot level. The shaft was filled with water in 1910, and consequently the 200 and 300 foot levels were not examined. In all over 5,000 feet (lineal) of development work has been done.

The ore bunkers are situated on the same spur line as the Mother Lode and are connected by tracks to the quarries.

Geological Relations and Character of the Ore Bodies.

The ore bodies are irregular and comparatively thin, lying approximately horizontal, and with rather indefinite boundaries between the pay ore and lean gangue rock. They lie on a floor of the siliceous rocks—cherts and jasperoids—of the Knob Hill group (Section A-B—general map) and to a limited extent on small masses of granodiorite. All the ore with the exception of a body of magnetite near the portal of the tunnel, lies above the 100 foot level, the main stopes connecting with the easternmost quarry. The west body has a surface area of about 24,000 square feet with a variable thickness not exceeding 25 feet as the maximum. The east body has an area of about 12,000 feet and is rarely more than 25 feet thick passing to a foot or so. Both ore bodies are cut by dykes of pulaskite porphyry, and also show the effects of later movements in sheared and slickensided zones.

Character of the Ore.

The ore is largely of the magnetite type associated as a rule with a large amount of actinolite. The copper (chalcopyrite) content is relatively low as an average. The ore is cut by numerous small seams of calcite and quartz, and narrow brecciated zones have been cemented with quartz. Lenses or masses of chalcopyrite in garnet gangue were noted in the intermediate stopes, but apparently are of small size, though containing a greater amount of copper than the magnetite does. On the 300 foot level a vein was met with filling a fissure in the siliceous rocks of the Knob Hill group. The ore consisted of marcasite in quartz and was stated to carry high gold values. It has not been developed as yet.

THE CROWN SILVER MINE.

The Crown Silver mine lies to the east of the Mother Lode on the eastern edge of the Mother Lode zone. The development consists of a vertical shaft 250 feet deep with levels at 150 and 250 feet. A tunnel 86 feet below the collar of the shaft was driven in a westerly direction for about 300 feet, mostly in mineral zone.

No ore was encountered, the mineral zone carrying but trifling amounts of chalcopyrite. From the material on the dump it is evident that part of the lower shaft workings are in granodiorite.

THE QUEBEC COPPER COMPANY, LIMITED.

THE MARGUERITE MINE.

The Marguerite mine is situated near the eastern border of the map-area and is about 4000 feet east of the Mother Lode mine. It is owned by the Quebec Copper Company. The ore body or bodies have been developed by a shaft 150 feet deep, with a small amount of drifting and cross-cutting on the 100 and 150 foot levels. It is stated that magnetite occurred to the 100 foot level where two ore bodies were encountered 17 and 22 feet thick respectively. Assays are stated to have given good returns in copper, gold, and silver. From the material on the dump it is apparent that considerable work was done in a barren mass of granodiorite.

The ore is magnetite with actinolite, some garnet, calcite, and quartz. Chalcopyrite occurs as grains and streaks in the magnetite associated with calcite. Pyrite occurs massive in the magnetite, and also as veinlets filling fractures in the latter, with and without calcite. Veinlets of quartz are numerous, traversing the ore generally.

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CLASSIFIED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

Memoir 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley Mining district, British Columbia—by Charles Camsell.

Memoir 3. *No. 3. Geological Series.* Palæoniscid fishes from the Albert shales of New Brunswick—by Lawrence M. Lambe.

Memoir 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

Memoir 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

Memoir 7. *No. 6, Geological Series.* Geology of St. Bruno mountain, Province of Quebec—by John A. Dresser.

MEMOIRS—TOPOGRAPHICAL SERIES.

Memoir 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

Memoirs and Reports Published During 1911.

REPORTS.

Report on a traverse through the southern part of the North West Territories, from Lac Seul to Cat lake, in 1902—by Alfred W. G. Wilson. No. 1006.

Report on a part of the North West Territories drained by the Winisk and Upper Attawapiskat rivers—by W. McInnes. No. 1080.

Report on the geology of an area adjoining the east side of Lake Timiskaming—by Morley E. Wilson. No. 1064.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 4. *No. 7, Geological Series.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec—by W. J. Wilson.

Memoir 8. *No. 8, Geological Series.* The Edmonton coal field, Alberta—by D. B. Dowling.

Memoir 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

Memoir 10. *No. 10, Geological Series.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in southwestern Ontario—by J. W. Goldthwait.

MEMOIR 12. *No. 11, Geological Series.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906—by Anton Handlirsch.

MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs Published During 1912.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

MEMOIR 21. *No. 15, Geological Series.* The geology and ore deposits of Phoenix, Boundary district, British Columbia—by O. E. LeRoy.

MEMOIR 24. *No. 16, Geological Series.* Preliminary report on the clay and shale deposits of the western provinces—by Heinrich Ries and Joseph Keele.

MEMOIR 27. *No. 17, Geological Series.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911.

MEMOIR 28. *No. 18, Geological Series.* The geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario—by Charles D. Walcott.

Memoirs Published up to Oct. 15, 1913.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 18. *No. 19, Geological Series.* Bathurst district, New Brunswick—by G. A. Young.

MEMOIR 31. *No. 20, Geological Series.* Wheaton district, Yukon Territory—by D. D. Cairnes.

MEMOIR 17. *No. 28, Geological Series.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que.—by Morley E. Wilson.

MEMOIR 35. *No. 29, Geological Series.* Reconnaissance along the National Transcontinental railway in southern Quebec—by John A. Dresser.

MEMOIR 33. *No. 30, Geological Series.* The geology of Gowganda Mining Division—by W. H. Collins.

MEMOIR 38. *No. 31, Geological Series.* Geology of the North American Cordillera at the forty-ninth parallel—by Reginald Aldworth Daly. Part I.

Memoirs in Press, Oct. 15, 1913.

MEMOIR 25. *No. 21, Geological Series.* Clay and shale deposits of the western provinces (Part II)—by Heinrich Ries and Joseph Keele.

MEMOIR 37. *No. 22, Geological Series.* Portions of Atlin district, B.C.—by D. D. Cairnes.

MEMOIR 23. *No. 23, Geological Series.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C.—by J. Austen Bancroft.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.
MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.
MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. E. LeRoy.
MEMOIR 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks in southern Quebec—by J. A. Dresser.
MEMOIR 39. *Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.
MEMOIR 26. *Geological Series.* Tulameen Mining district, B.C.—by C. Camsell.
MEMOIR 36. *Geological Series.* Geology of the Victoria and Saanich map-areas, B.C.—by C. H. Clapp.
MEMOIR 20. *Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.
MEMOIR 29. *Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.
MEMOIR 30. *Geological Series.* Basin of Nelson and Churchill rivers—by W. McInnes.