IGNEOUS ROCKS & ORES
OF THE
SLOCAN MINING DISTRICT, B.C.

A STUDY

OF SOME OF THE IGNEOUS ROCKS

AND ORES

OF THE SLOCAN MINING DISTRICT, B.C.

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by

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CONTENTS.

A Study of Some of the Igneous Rocks and Ores of the Slocan Mining District, B.C.

Introduction - General

Among the several great metal-bearing zones of the globe, the western mountainous region commonly called the Cordillera of America, extending as it does, with the exception of minor breaks, from the tip of South America northward as far as Alaska, stands out pre-eminently as a producer of vast riches. Before the days of the Spanish invasion, gold and silver especially had been mined in very considerable quantities, principally in Peru and Bolivia, and adjoining regions, by the Incas, and in Mexico by the Aztecs. The case of Atahualpa, brother to the emperor in the early sixteenth century, will serve as an instance of the great riches won by the Incas. Atahualpa, an aspirant to his brother's throne, when captured and imprisoned by the Spaniards, offered, as a ransome, to fill his room, said to be 27 by 22 feet, with golden ornaments to the height he could reach upon the wall; this is calculated to represent over $500,000,000. at the present gold value; besides this he contracted to fill the house with silver. Unfortunately the Spaniards, becoming impatient of waiting, murdered and burned Atahualpa and collected but little of the treasure. In following the early history of America many such instances of the amazing wealth of the Cordillera are brought to light. The "gold rush" of '49 to California, —

which State has since yielded over $1,200,000,000 in gold — to the Cariboo in the sixties, and to Yukon in '97, serve as the most spectacular examples in more recent times. At the present day some of the world's principal ore bodies are situated in the American Cordillera; the immense copper reserves of Chuquicamata and Braden in Chile, the copper and other deposits in Peru, the tin, copper and silver ores of Bolivia, the platinum of Columbia, besides the numerous deposits of ores of gold, copper, silver, lead, zinc and minor metals in North America, are all representative of these.

British Columbia is not lacking in a share of these riches. Considerable quantities of gold have been produced from placers principally in the Cariboo district, and lesser amounts have been obtained from lode mines, usually as an accessory with copper. Copper ores are mined principally on the Pacific coast in the north at Anyox and also further south at Howe Sound. In the past, mines at Phoenix, Deadwood and at Rossland, in southern interior B.C., have been important producers, and mines in the last named district are still operating. Many other districts also contain deposits of copper ores. Silver generally occurs with lead and zinc, or with copper, as at Rossland. The silver-lead-zinc deposits are almost entirely confined to the interior portion of the Cordillera, and the principal producers are in southern B.C., the Sullivan mine at Kimberley, and a number in the Ainsworth and Slocan districts being the most important; the last named will be treated in greater detail in the succeeding paragraphs of this thesis.

The Slocan.

The region referred to in this thesis and designated the Slocan Mining Area lies within the Selkirk Mountain system, of British Columbia. It occupies a portion of the West Kootenay district, about 280 square miles in area, lying between Kootenay Lake on the east and Slocan Lake on the west, and including parts of the Slocan and Ainsworth mining divisions. The area is traversed by a valley running north-east from New Denver on Slocan Lake, and later swinging south-east to Kaslo on Kootenay Lake. This valley is occupied by Carpenter Creek on the west and by Kaslo Creek on the east. The country is rugged, ranging in elevation from 1730 feet at Slocan Lake to over 8600 feet on the summit of Mount Carlyle. Owing to lumbering operations and more especially to the devastation wrought by forest fires the country is but sparsely wooded.

Access to the areais effected by the Canadian Pacific Railway, either from Revelstoke in the north through Upper Arrow Lake and thence by rail to New Denver on Slocan Lake, or from Nelson in the south via Kootenay Lake and Kaslo. Kaslo and New Denver are also joined by rail, with a branch connecting with Sandon in the interior.

Mineral discovery in the Slocan dates from 1891, since which time mines in the district have yielded over $50,000,000. in lead, silver and zinc, with minor values in gold and copper.

To the end of 1924 the output of the three principal metals aggregated 38,000,000 ounces of silver, nearly 300,000,000 pounds of lead and nearly 122,000,000 pounds of zinc, and comprised over one-third of the silver, one-fifth of the lead and nearly one-quarter of the zinc, produced in the province up to that time.

Since the date of discovery a great many properties have shipped ore. Of these, many have been abandoned; some have lain idle for years, but will doubtless be re-opened when cheaper and more efficient methods of treatment make them deposits of economic value; while others are now producing in various quantities. Twenty-nine properties have shipped ore for 10 years or more. The Slocan Star, Silversmith, Ruth-Hope, and Rambler-Cariboo each has a record of 28 producing years, while the Whitewater mine produced in 29 different years, including a continuous period from 1900 to 1924. Peak production from the district was reached in 1918 when thirty-six mines shipped ore aggregating in value about $3,450,000, in silver, lead and zinc respectively in order of value.

Bibliography and Acknowledgements.

Owing to inability of the writer to visit the area, it has been necessary to make exceptionally free use of existing reports and memoirs on the district; all the introduction, description of the country and general geology being compiled from such sources, the principal of which are:

(1) Slocan Map Area, B.C. - M.F.Bancroft, Summary Report, 1919, Geol. Survey, Can.

(2) Slocan Mining Area - C.E.Cairnes. Unprinted manuscript.

Other publications dealing with the area are enumerated in the appendix attached to this paper. The writer is especially indebted to Dr. J.J.O'Neill who spent the summer of 1926 in the field collecting much valuable information on the ore deposits of the district, and who supplied all the specimens of ores and rocks used in the preparation of the polished and thin sections, upon the study of which this thesis is based. Thanks is also due to Professor R.P.D.Graham, who with Dr. O'Neill was of invaluable help to the writer in the microscopic study of the ores and rocks, and finally to Professor W.Erlenborn for his kindness and instruction in the preparation of polished sections.

Topography

The Cordilleran region of Canada embraces a great tract of country bordering the Pacific Ocean and extending from the International boundary north through British Columbia into the Yukon, with an average width of about 400 miles. This mountainous region is divided into several natural physiographic sections. These are, from east to west:

(1) The Rocky Mountain System.

(2) The Rocky Mountain trench.

(3) The Gold Ranges.

(4) The Interior Plateau.

(5) The Coast Range.

(6) Strait of Georgia - Queen Charlotte Sound Depression.

(7) Vancouver - Queen Charlotte Islands chain.

The Rocky Mountain System includes all those ranges lying between the plains on the east and the Rocky Mountain trench on the west. The most important of these are the Mackenzie Mountains in the north and the Rockies in the south. The system has a young and rugged topography, deeply dissected by stream erosion. The ranges form an overlapping series with a general north-west south-east trend, uplifted by the folding and crumpling of great thicknesses of Palaeozoic sediments, which in the eastern portion have been thrust north-eastward over the later beds, in the form of great fault blocks, having characteristic steep eastern faces with relatively gentle western slopes.

The Rocky Mountain trench, which separates the Rockies from the Gold Ranges, consists of a great, structural synclinal fold, enlarged by erosion, and varying in width between five and twenty miles. It has been traced intermittently from Montana, northward through British Columbia and the Yukon to the Alaska boundary, and is occupied by portions of several rivers, both north- and southward flowing. Among the rivers whose courses, in part, follow the trench are, the Columbia, Kootenay, Parsnip, Finlay, and Liard.

On the west of this depression rise the Gold Ranges, which include the following features, from east to west: the Purcells, the Purcell trench, the Selkirks, Selkirk valley, and the Columbia Mountains which grade into the Interior Plateau. These ranges have a characteristically youthful and rugged topography, several peaks in the Selkirks reaching elevations of

11,000 feet or over and many supporting local glaciers. The structural trend is mainly north and south. Selkirk valley, within which lie the Arrow Lakes, is a depression on the west of the Selkirk Mountains. The less rugged and rounded elevations of the Columbia range rise to over 5000 feet west of Selkirk valley, and, on their western side, merge into the Interior Plateau of British Columbia. This plateau, with a general elevation of 3500 feet is made up of three general levels; the deeply dissected river valleys; the broad uplands, remnants of an uplifted ancient peneplain, and, reposing on this, the residual monadnocks of a still more ancient eroded surface, the whole combining to produce a very irregular topography.

West of the Interior Plateau is the Coast range which borders the Pacific Ocean. This consists of an elongated granitic batholith, now unroofed by long continued erosion, and dissected by several through rivers, and by many comparatively short streams. Those streams, draining into the Pacific direct, have overdeepened, and partly drowned valleys, which form the high steep-walled fjords, which are the most imposing feature of the coast of British Columbia, which is widely famed for its rugged beauty.

The Coast Range is bordered on the west by a depression known as the Pacific downfold, now occupied by the Strait of Georgia and Queen Charlotte Sound. West of this are the partly submerged mountains of the Vancouver - Queen Charlotte Islands chain. This range consists of a belt of islands, paralleling the mainland. On the southeast Vancouver Island is bounded by a Tertiary coastal plain. In the interior the mountains become increasingly rugged and lofty as they extend northward, reaching a maximum of over 7,000 feet in the north of the island, and somewhat less in the Queen Charlotte group. It has been suggested that this range extends northward into the lofty mountains of the young St. Elias Range of Alaska.

Considering the topography of the Slocan area in detail, it is seen to present a very rugged aspect, the relief varying more than 6800 feet from the base level of 1730 feet on Slocan Lake. The region is deeply furrowed by several creek valleys, the chief of which is the Carpenter-Kaslo valley in the north, Carpenter Creek flowing south-west to Slocan Lake and Kaslo Creek south-east to Kootenay Lake. This valley is followed by the Canadian Pacific Railway line between Kaslo and New Denver, the tributary valley containing the upper reach of Carpenter Creek, serving similarly as a route for the branch line to Sandon. Another creek — the Silverton — enters Slocan Lake about three miles south of Carpenter creek, and rises inland to the east-south-east. With one exception — the Lucky Jim — the mines from which the specimens examined by the writer were obtained, are all situated to the west of Sandon. In this region the ground rises steeply from the bed of Silverton Creek in the south-east to an elevation of over 7600 feet at the summit of Selkirk peak, from where it descends again almost as steeply to Carpenter Creek, which, at Sandon, has an elevation of about 3400 feet. To the north of Sandon the valley wall rises steeply to a summit of over 8200 feet on Mount Reco, which supports a small glacier on its northern slope. From this point the ground slopes down to the north until an elevation of little over 3500 feet is reached on the divide between Kaslo and Seaton Creeks, the latter of which is tributary to the Carpenter. From the foregoing topographical sketch it is evident that the country is rough and the grades steep, as much as 3000 feet to the mile, or more, being not uncommon; thus, such roads as have been built must needs follow the valleys where possible, or search out a zig-zag route up the mountain sides. A motor road is now in use from New Denver to Sandon, and is to be completed this year (1927) to Kaslo.

General geology.

The Slocan district, being situated in the Selkirk mountain system, lies within the borders of a pre-Cambrian geosyncline, which was uplifted and eroded throughout Palaeozoic time until late Mississippian, when it was again submerged, and accumulated sediments of late Palaeozoic and Mesozoic age. The basal series of the district is the Ainsworth, called, by G.M. Dawson, the Shuswap, and mapped as pre-Cambrian, but now considered by M.F.Bancroft[1] and others to be Palaeozoic, probably Carboniferous. The next succeeding series is the Slocan, recognized by Dawson, but named in 1895 by R.G.McConnell[2]. Above this lies the Milford

[1] Summary Report 1919, Pt. B., G.S.C. (M.F.Bancroft).

[2] " " 1895, G.S.C.

Table of Formations[1]

Cenozoic	Quaternary	Recent Pleistocene	Stream gravels Glacial deposits
		Great Unconformity.	
Mesozoic	Upper Jurassic	Basic dikes Aplite " Nelson granodiorite	Period of long continued deformation and erosion.
	Jurassic	Intrusive contact	
		Kaslo schists Intrusive contact Milford series	
		Disconformity.	
Palaeozoic	Pennsylvanian	Slocan series[2]	Sedimentation
	Carboniferous or (pre-Carboniferous)	Ainsworth series	

[1]Modified from M.F.Bancroft, Sum. Rep. 1919, Pt. B., G.S.C.

[2]May be Mesozoic (see page 13)

series, generally conceded to be Mesozoic. The principal igneous rocks are the Kaslo schists and the Nelson granite batholith, with its many related dikes.

Ainsworth Series.

The Ainsworth series is a local name used by Schofield[1] to denote part of Dawson's Shuswap. The series outcrops along the west shore of Kootenay Lake, and extends northward across the Ainsworth district into the Slocan area. Lower beds are exposed as the series is followed northward, but no basal formation is exposed in the vicinity, although a thickness of over 10,000 feet is assigned to the series by Bancroft. Lithologically, the "series consists of mica schists, quartzites, siliceous limestones, thin bands of hornblende schists, and garnetiferous mica schists". The Ainsworth, and also the Slocan series locally have a general north-westerly strike. The Ainsworth series dips toward the west at angles of 30° to 50°. According to Drysdale[2] the contact of the Slocan-Ainsworth series is a steep normal fault, in which the Ainsworth series forms a <u>relatively</u> upthrust horst on the footwall side. He postulates this condition in part by the necessity of accounting for the relative position of the Kaslo schists, which he considers as principally volcanics, including ash beds, interbedded with some greatly metamorphosed sediments. Bancroft, on

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[1] Memoir 117, 1920, G.S.C.

[2] Summary Report 1917, G.S.C. and Map #1667.

the other hand, considers the Ainsworth and Slocan series to be conformable. This view he supports by field evidence obtained where the contact was visible, especially on ~~the~~ Milford Creek, where he found the basal limestone of the Slocan resting conformably on the hard mica quartzites, both dipping west at 30° in continuation of the Ainsworth monocline. A notable feature of the contact is the series of "strike ridges" formed by the outcropping of the slow weathering Slocan limestone, which is conspicuous on the mountain slope to the west of Kootenay Lake. The rocks of the Ainsworth series are interbedded and have transitional contacts. The limestones are often argillaceous, although bands of almost pure calcite, resembling marble, occur in some localities; in many instances beds have been metamorphosed to marble. The quartzites are generally thinly bedded and are often micaceous, although massive beds of pure quartzite are also found. Many of the rocks are much altered and schisted, due to intense regional folding as well as igneous intrusion. As previously stated, the Ainsworth series was provisionally correlated with the 'Shuswap' of Archean age, but in 1914 S.J.Schofield[1], as a result of a study of the rocks east of Kootenay Lake, found that the Purcell series (Beltian) passed conformably beneath these and thus precluded their being pre-Beltian. They are thus post-Beltian in age, and are now considered as Palaeozoic and probably Carboniferous, if, as Bancroft states, they conformably underlie the Slocan series. More recent

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[1] Sum. Rep. 1914, G.S.C.

evidence makes it seem possible at least that the series may be still more recent.

Slocan Series.

The Slocan series, so named by McConnell in 1895, "consists of argillaceous quartzites, limestones, and slates or argillites with gradational types". The slates are usually highly carbonaceous and where compressed become graphitic slates. The limestones are often crystalline while some beds are argillaceous and of a dark blue or gray colour. Fossils have been found in several localities in the limestones. The Slocan series underlies most of the region considered in this paper, extending from the area occupied by the Kaslo schists in the north-east to the contact of the granite batholith in the south and bordering Slocan Lake on the west. The series is much folded and metamorphosed, and like the Ainsworth has a general north-westerly trend, the dips varying from nearly vertical on the limbs of the folds to comparatively low angles where crests or troughs are exposed. Drysdale estimates the series to increase in thickness from 2000 feet on the Blue Ridge to a maximum of 15,000 feet in the west, but owing to the recurrence of lithologically similar beds and the complex folding and faulting, no accurate measurements have been secured. The lower limit of the Slocan series is a fossiliferous limestone (the Star limestone) which rests conformably on and grades into the uppermost bed of the Ainsworth series, locally represented by a schistose mica quartzite. Drysdale, in 1916, mapped the Slocan series as conformably overlying the Selkirk series (now the Kaslo schist), which he considered to be interbedded flows and volcanic ash, with some highly metamorphosed sediments, but according to Bancroft there is now no doubt as to the conformable relations of the Slocan and Ainsworth series. The age of the series he considers as Carboniferous and probably Pennsylvanian, which belief is based on the evidence of fossils collected from the limestone in several localities between 1916 and 1919. This conclusion confirms those of Dawson, Brock, Schofield and others who also believed the series to be of Carboniferous age. From the evidence of fossils collected more recently (1925), however, and determined by F.H.McLearn of the Geological Survey as Mesozoic, it would appear that this conclusion may have to be revised, and that possibly the whole series may be Mesozoic, which would explain the conformable (disconformable according to Bancroft) contact between the Slocan and overlying Milford series, which Bancroft places as probably Jurassic. These fossils were collected from the vicinity of Whitewater and Lucky Jim mines, and the south-eastern slopes of Shroeder and Jardine Mountains.

The slates and limestones of this series contain the most important ore bodies of the district, less important deposits occurring in the granite.

Milford Series.

This series was recognized and named by Le Roy, and consists of argillaceous quartzites and limestones, lithologically very similar to the underlying Slocan series. They occur conformably, or possibly disconformably, overlying the Slocan series in a narrow, northward striking belt between the outcropping of the Ainsworth series on the east and the Kaslo schists on the west. They form a synclinal trough with steep dips. The Milford series was separated from the Slocan series in 1919, by one lot of fossils reported by E.M.Kindle as Jurassic. From the conformable relations and lithological similarity of the Slocan and Milford series, one might be lead to speculate as to the possibility of the fossils collected in 1925 belonging to the latter series and thus account for their Mesozoic age; but as the writer has not been in the field there may be other evidence which would immediately refute this supposition.

Igneous Rocks.

Kaslo Schists.

This group consists of a variety of basic igneous rocks "including intrusive breccia, serpentine, augite and hornblende porphyrites, diorite and gabbro."[1]. These rocks are found in a belt extending north and north-west from below the southern edge of the Slocan map sheet (No.1667), crossing Kaslo

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[1]M.F.Bancroft, Sum. Rep., Pt. B., G.S.C., 1919.

Creek below the mouth of the Mansfield, thence following the north-east side of Kaslo Creek and forming the western slope of the Blue Ridge; toward the north the group widens to 3 miles and finally extends beyond the border of the map and underlies a considerable area in the Lardeau map sheet to the north. The term, "Kaslo schists," was introduced by R.G.McConnell[1] in 1894, as a local name for this group which was considered to belong to the lower Selkirk series. O.E.Le Roy[2] divides the group mainly into greenstone schists, "with subordinate quartzites, silicified ash rocks, breccias, limestones and phyllites," along with intrusives altered to serpentine; "where noted," he says, "the contact with the Slocan series has the character of a thrust fault along the axis of a sharp fold". Drysdale in 1916 also adheres to a similar view. But Bancroft[3] gives evidence at some length to show that the Kaslo schists (Kaslo volcanics of Drysdale) are of an intrusive nature, into the Slocan and Milford series. He states that the rocks near the contact have been altered by heat and pressure; the group, as a whole, has the "shape, size and mode of occurrence" of a batholith, with numerous apophyses and dikes injected into surrounding beds, particularly into the Slocan and Milford series within the Blue Ridge synclinal belt. The contacts on both boundaries of the schists are steep. He notes particularly that "the sedimentary beds <u>east</u> of the Kaslo schist contact on Kaslo Creek dip at high angles to the west, and the east contact of the

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[1] G.S.C., Vol. VII, 1894,

[2] Sum. Rept. 1910, G.S.C.

[3] Sum. Rept. 1919, Pt. B., G.S.C.

Kaslo schists in passing above also dips westward, but at a much lower angle," which "cross-cutting relation was hitherto overlooked in Slocan geology". Drysdale's section (map no. 1667) accounts for this by assuming an apparently conformable reverse dip for the Kaslo schists. This crosscutting relationship was also apparent on the west contact between Rossiter and Lyle Creeks. As mentioned above LeRoy considers this to be due to a thrust fault. The several sediments, included by LeRoy in this group, Bancroft refers to as roof pendants, from the eroded sediments formerly capping the intrusive, "flinty quartzites of the Milford series" being well represented. Several "dikes of green schistose rocks resembling types of the Kaslo schists" were noted in the Milford syncline. One of these, 100 feet wide, was traced from Schroeder peak to the head of Falls Creek, "where the Kaslo schist batholith cuts across the eastern limb of the syncline," and was finally followed to within a short distance of the Kaslo schists. What Drysdale reported as squeezed conglomerate, Bancroft considers as of igneous origin, describing it as an intrusive breccia, consisting of "rounded pebble-like, inclusions in a schistose matrix," the "pebbles" composed of "greenish, siliceous, igneous material in a soft, flaky matrix of the same colour".

It would seem probable from the above evidence that the Kaslo schist is an eroded batholith intrusive into the surrounding sediments. In the north it is cut by the Nelson batholith which places it as Jurassic or earlier in age.

Nelson Granite.

This great granitic intrusive, named after the town of Nelson, is uncovered for more than 1000 square miles, of which only a portion of the northern border appears on the Slocan map sheet, where it outcrops in two large masses in the south, forming a concave northern contact. There are numerous apparently isolated granitic outliers in the area which must be supposed to be connected to the main batholith in depth. In composition the rock ranges from a granite through a grano-diorite to a quartz diorite, described by Brock[1] as "a sort of granite representative of the monzonite group of rocks, intermediate between the alkali and lime-soda series of rocks, and about on the boundary between granite and diorite. One analysis, by J.C. Gwillim, shows as much as 8.24% of CaO, while another by Brock gives 3.43% CaO with soda and potash about equal. The rock is generally fresh and of a light grey colour, and is commonly distinctly porphyritic, with phenocrysts of orthoclase in a groundmass of quartz and plagioclase. The ferromagnesian minerals are varying proportions of hornblende and biotite, the latter often occurring as flakes included in the orthoclase phenocrysts.

Wall rock contact metamorphism is usually confined to narrow zones, the slates altering "to andalusite, hornblende and mica schists, the quartzites to quartz schists, and the limestones to crystalline types".

[1] Ann. Rept., Vol. XV, 1902-1903, G.S.C.

Among the minor intrusives, there are the older dikes related to the Kaslo schists, referred to above, and both aplitic and later basic dikes considered as derivatives of the Nelson batholith. The basic dikes comprise, principally, types of mica and hornblende lamprophyres, whose original constituents are in most cases highly altered, and replaced, especially by calcite. These will be dealt with more fully in a later section of this paper.

The mineralization followed this latter period of intrusion and will be dealt with under "Economic Geology."

Superficial Deposits.

The steep mountain slopes are mostly bare, but in the valleys glacial drift is common, together with re-worked river deposits and talus slopes. Several landslides have occurred in the region, notably the one near Sandon which, in 1896, buried a portion of the village and filled the valley to a depth of many feet.

Structural Geology.

The outstanding structural feature of the Gold Ranges is the north-south folding, which forms a series of more or less parallel synclines and anticlines, complicated by faulting, and greatly modified by river and glacial erosion. These ranges occupy the site of an ancient pre-Cambrian geosyncline, uplifted towards the end of the pre-Cambrian, and not again sumberged until Pennsylvanian, the final emergence occurring in the late

Jurassic; a mature topography was developed before the region was again uplifted, and it is now in process of active erosion. The Rocky Mountains did not emerge till the early Tertiary. They occupy the site of a great Palaeozoic and Mesozoic geosyncline, and were uplifted by a great lateral pressure from the southwest, which crumpled the thick sedimentary beds into a series of northwest-southeast trending folds in the west, and forced up great overthrust blocks further east. The region is dissected by several north-south valleys, most of which were formed by Tertiary and Quaternary stream erosion. The Purcell trench which separates the Purcells from the Selkirks is attributed, by many investigators,[1] to this cause, although Daly[2] believed it to be a downfaulted graben. Some depressions, on the other hand, follow the underlying structure, notably the Rocky Mountain trench, separating the Gold Ranges from the Rockies. This is now considered to occupy a downfolded area, since modified by erosion.

Locally - in the Slocan area - the structure is manifested by steep folds trending north-west and south-east, complicated by less evident northerly cross folding. The sediments are intruded in the north-east by the Kaslo schists (according to Bancroft) and in the south by the Nelson batholith and its aphopheses. During the folding the beds were often ruptured, forming numerous faults striking north-easterly or northwesterly. "Some of the faults have great length and are uniform in strike

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[1] S.J.Schofield, Mem. 117, Geol. Surv., Can., 1920. (P.62)

[2] R.A.Daly, Mem. 38, Geol. Surv., Can., Pt. 2, 1912.

and dip, particularly the north-easterly ones........ Faults of one trend show a tendency to terminate against or swing along those of another trend. Most of these faults are pre-mineralization tending to localize ore deposits. But post-mineral faulting also has been noted, in some cases movements having taken place along earlier fault veins. "Both normal and reverse faults have been recognized."

Geological History[2].

In order to arrive at a knowledge of the sequence of geological events in the Slocan district, an area wider than that under particular consideration must be studied. S.J.Schofield considers, from his field observations, that sedimentation has been continuous from pre-Cambrian (Beltian), when the Purcell series was laid down, until Pennsylvanian time, or possibly the Mesozoic. This interpretation, is, however, not universally accepted, as pre-Carboniferous sediments are lacking, and some geologists consider the region to have been emergent during the greater part of the Palaeozoic era. The Milford series is evidence of more recent sedimentation, so that the process may have been continuous into the Mesozoic. In the vicinity of the Arrow Lakes rocks older than the Purcell series are found, which represent part of the oldest land area of British Columbia and probably constitute the origin of the great bulk of the sediments laid down in succeeding time.

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[1] A.M.Bateman, Soc. of Econ. Geol., Pub. 47, Sept. 1925.

[2] Schofield, S.J., Mem. 117, 1920, G.S.C.

Palaeozoic.

The Purcell series (Beltian) and early Palaeozoic sediments are not exposed in the Slocan district. The oldest rocks are those included in the Ainsworth series. Schofield divides these into several formations, in his report on the geology of Ainsworth mining camp, namely the Point Woodbury, Early Bird, Princess, Ainsworth and Josephine, but since these beds differ locally these subdivisions will not be treated here. The sedimentation during the Ainsworth epoch seems to have been characterized by fluctuating conditions as is evidenced by alternating beds of quartzites, limestones and slates. Evidence of volcanic activity is seen by the presence, in the upper beds, of thin bands of hornblende schists, which Schofield considers to be metamorphosed ash beds. The Ainsworth series is now considered to be of Carboniferous age.

The Slocan epoch was apparently a continuation of the fluctuating marine conditions of the Ainsworth. Muds and limey muds were laid down principally and were later altered to limestone, slates and schists. Both the Ainsworth and Slocan sediments are believed to have been derived from the pre-Cambrian land mass to the west, now exposed in the Archaean Shuswap series.

Mesozoic.

No record of the Triassic is preserved in the area unless it be proved that the Slocan series may have been deposited at this time.

Jurassic. According to Bancroft, marine sedimentation is evidenced by the argillaceous quartzites and limestones of the Milford series, placed tentatively as Jurassic on the evidence of Belemnite fragments determined by E.M.Kindle in 1919. This period is, however, principally noteworthy, on account of the orogenic movements and igneous activity which characterized it. The orogenic movements consisted of folding and faulting of the sediments, with the consequent uplift of the surface. The weakening of the crest, thus caused, presumably provided a suitable condition for extensive igneous intrusions. These intrusions are often initiated by a basic phase, represented in this area (according to Bancroft) by the Kaslo schists, which were followed after an interval by the more acid granite and grano-diorite of the Nelson batholith and its accompanying stocks and dikes. Owing to the pressure of folding and the heat of intrusion, the sediments were considerably metamorphosed, the sandstones to quartzites, the limestones to marble or crystalline types, and the argillites and slates, in some cases, to andalusite and mica schists. The Jurassic is an all-important period economically, for it was during its latter portion, and following the Nelson intrusives, that the ore-bearing solutions were circulated to form the present economic deposits of silver, lead and zinc.

Cretaceous. During the Cretaceous period the Selkirks were eroded to a rolling topography, and the Nelson batholith was probably exposed. This profound erosion provided sediments for the Rocky Mountain geosyncline, which was still submerged.

Cenozoic.

Tertiary. The Tertiary period in the Selkirk Mountains was characterized by early peneplanation followed by uplift,and the commencement of the present cycle of erosion, which has formed the present deep river valleys and rugged peaks. The orogenic disturbances, which resulted in the uplift of the Rocky Mountains, were initiated in the Eocene contemporaneously with the elevation of the Selkirk peneplain.

Quaternary. The early Quaternary was marked by a cold climate and continental glaciation which has somewhat modified the topography, tending to form U-shaped valleys and truncate the spurs. Further evidence of glaciation is seen in the many glacial cirques at present forming lakes, and in the deposits of boulders and other morainic material in the valleys. Since the recession of the ice, if we except the remnants left on some of the higher peaks, the climate has become more temperate, and normal river erosion has resumed its work, modified from time to time by occasional avalanches, typical of an immature physiography.

Economic Geology.

The grouping of the ore deposits of the Slocan district shows a marked relation to the Nelson batholith, or to smaller granitic bosses which are presumably offshoots of the same underlying intrusive mass. The deposits occur, for the most part, either in the grano-diorite itself, or within a mile or two of its contact. Where apparently isolated veins occur, it is reasonable to suppose that the batholith may underlie the surface at no great depth, yet be unexposed in the immediate vicinity.

The ore deposits of the district fall into two general classes. These are the so-called "dry" and "wet" ores. The dry ores consist of veins, essentially quartz, with the principal values in silver-bearing minerals, which are associated with galena and zinc blende. They generally occur in the batholith, or nearer the contact than the wet ores; it is also found that the wet ores, in some veins, grade downward into the dry ores. From these relations it would seem that the latter had been deposited under conditions of rather higher temperature than the wet ores.

The wet ores comprise the predominant type of the region. These may be subdivided into the replacement deposits consisting primarily of zinc blende with occasional shoots of galena, which occur in the limestones, and lead-silver fissure veins, consisting of galena, with subordinate zinc blende, the bulk of the silver being in the form of argentiferous galena and argentiferous tetrahedrite (grey copper). It is these wet ores with which we are chiefly concerned in this thesis, and several examples will be dealt with in more detail in subsequent paragraphs.

In studying the distribution of the various types of deposit, a tendency to zonal arrangement[1] is noted. As stated in the preceding paragraph, the dry ores occur chiefly in the grano-diorite. "The minerals are quartz, tetrahedrite, argentiferous galena, with small amounts of sphalerite, ruby silver, chalcopyrite, pyrite, pyrrhotite, calcite, and siderite",[1] the total metallic content being small, with the principal values in silver. The ruby silver is a product of surface enrichment, but occurs to considerable depths (e.g. below 700' in the Hewitt and Van Roi). The ores in the sediments near the contact "contain more galena, sphalerite, siderite and calcite, with less tetrahedrite and ruby silver".[1] As the distance from the contact increases, the proportions of galena and zinc blende increase at the expense of quartz; siderite - the predominant gangue mineral of the wet ores - also becomes more abundant, while ruby silver and tetrahedrite are, proportionately, much reduced. Wet ores high in silver occur in the vicinity of intrusive granitic cupolas (e.g. Reco, Payne, etc.); while deposits further removed from the intrusive only average about an ounce or less of silver per unit of lead[2]. Processes of secondary enrichment are recorded, not only by the presence of ruby silver, but also by limited quantities of cerussite occurring in some deposits, much of which has probably been removed by glaciation.

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[1] A.M.Bateman, Notes on Silver-Lead Deposits of Slocan District, B.C.Can., Soc. of Econ. Geologists. Pub. 47, 1925.

[2] Sphalerite rich in silver at Ruth Mine (see under "Ores".)

The zonal distribution of ores is also exemplified in following some veins to depth. Where galena is the predominant mineral at the surface, it often gives way to zinc blende and increased siderite as depth increases. At greater depths siderite predominates, with occasional grains of zinc blende and galena. Finally the vein filling may consist almost entirely of quartz with disseminated specks of galena, zinc blende, pyrite and silver minerals, becoming a typical dry ore.[1] In some instances galena and zinc blende were apparently deposited in reverse order. This is probably due to either of two causes. Subsequent to the first mineralization, movement along the fissure may have taken place, causing considerable brecciation and providing paths for fresh incursions of mineralizing solutions, which would probably have cooled and deposited their loads at lower levels, thus depositing galena below the earlier zinc blende[1]. This would not be expected in veins which show no evidence of later movement. The second possibility is that the concentrations of the solutions may have varied from time to time, and deposition have been further affected by solution of the wall rock. In this case no subsequent movement is necessary to account for apparent reversal in order of deposition.

The predominant strike of the fissures is northeast or across the bedding of the sediments, while the dip is generally southeast. The beds, as stated earlier in this paper, are all more or less intensely folded, and from field observations[2],

[1] C.E.Cairnes, The Slocan Mining Area (unpublished)

[2] Dr. J.J.O'Neill, (field observations)

it appears probable that movement has continued, or recurred again, after the deposition of the ores; this is probably an important cause of the offsets met with in following many of the veins. Exceptions to these transverse fissures are generally located along zones of shearing following the strike of the beds. The main northeasterly trending fissures appear to be controlled by a system of jointing, along which no great movement has taken place. Fault jogs of small displacement are common occurrences along these veins, and may cause some vexations in mining.

The influence of the country rock on ore deposition is seen where a narrow vein enters a calcareous bed, when an extensive replacement of the wall rock may often result (e.g. Lucky Jim mine). The area is traversed by numerous dikes both granitic equivalents and more basic mica lamprophyres. Unlike the veins these generally trend parallel to the schistosity, and strike of the sediments. Both acid and basic dikes are cut by the veins, and are intermediate in age between these and the still earlier batholithic intrusion, with which they are probably genetically related.

The probable sequence of events, according to Bateman[1], was the intrusion of the batholith, accompanied by fracturing, the expulsion of the dike rocks along these planes of weakness, and finally the emission of the mineralizing solutions and de-

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[1]Op. cit.

position of the ores. Faulting and fissuring probably continued throughout this epoch, and lasted for some time after its close.

When considering the probable continuation of the deposits in depth, an understanding of the topography of the region is of primary importance. Bateman[1] estimates that many thousands of feet must have been eroded from the surface since the formation of the ore deposits in the Jurassic. The valleys must have been eroded below the general level, this would account for a removal of over 5000 feet from some deposits. The tops of the granitic bosses, in some instances, were considerably above the present ridge tops; again these coarsely crystalline rocks must have had several thousand feet of additional cover. Hence, the present erosional surface bears no genetic relation to the position of the ore deposits. The deep vertical range of the mineralization is further exemplified by the wide variation in elevation between the various mines. On the ridge between Carpenter and Silverton Creeks, the Bosun mine has an elevation of less than 2000 feet, while the Ivanhoe is situated in the neighbourhood of 6500 feet, and several lie in between these levels. The same condition exists in other parts of the region. Further these deposits continue some distance below the present surface. From the foregoing facts, it seems that where mines are situated in the higher slopes of the mountains, it does not necessarily follow that the deposit is

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[1] Op. cit.

finished when the original shoot pinches out, but rather that there is sound reason to believe that exploration at greater depth may bring to light a fresh supply of ore.

Petrography.

Dike Rocks.

The rock specimens, collected by Dr. O'Neill, and used in the preparation of the thin sections studied for this thesis, were obtained from several mines in the general vicinity of Sandon. These properties are the Ruth-Hope mine, owned by the Ruth-Hope Mining Company, and situated at an elevation of about 5000 feet, on the steep slope southwest of Sandon; and the Carnation group, which is under option to the Victoria Syndicate. This group consists of four properties, the Minnie Ha-Ha, the Carnation, the Read, and the Wakefield. The rock specimens studied were obtained from the first two mines. The Minnie Ha-Ha is situated a little over a mile west-southwest from Sandon, at an elevation of about 5000 feet, on a ridge between two creeks. The Carnation adjoins this property on the southwest, and is, in turn, connected by a tunnel with the Read, which lies to the southwest, just over the divide between Silverton and Carpenter Creeks. The Wakefield lies on the south of the Read. These all produce the "wet" type of ore.

The rocks studied in thin section consist of sediments, including a number of specimens of quartzite with one of limestone and one of shale, and dike rocks including quartz and feldspar porphyries and several varieties of mica lamprophyre. All the slides are altered, some beyond recognition of the original constituents. The fresher lamprophyres consist, essentially, of biotite and plagioclase, which ranges in composition from albite-oligoclase to labradorite, and, in one instance, is bytownite-anorthite; orthoclase is an essential constituent of some sections, and primary quartz is also common especially in the more acid types. Several accessory minerals recur in many slides: needles of rutile are characteristically developed in the biotite, forming hair-like aggregates oriented in three distinct directions, inclined at 60° to one another; laths of apatite are of frequent occurrence in minor amounts. The principal alteration products are carbonate - in most cases calcite - and sericite. Chlorite occurs in fourteen slides, probably in all cases replacing biotite. Epidote is less common but was observed in five or six slides replacing plagioclase and, sometimes apparently, biotite as well. Zoisite was identified in three slides as an alteration product of felspar. The felspars, where sufficiently fresh, were determined by the oil immersion method, using various oils of known index of refraction.

The mica lamprophyres fall into several more or less distinct groups, divided on the basis of the felspar composition. These again may be further subdivided, dependent on other characteristic constituents and typical alteration products, or variations in crystallization and texture.

Quartz Minette.

The most acid type is a quartz minette - or an apletic variety of minette - consisting, essentially, of orthoclase, some plagioclase, biotite, and variable quantities of quartz. This group may be further subdivided, on the basis of texture, into a porphyritic and a non-porphyritic variety. Other variations occur in the alteration products formed. In fact, taking the group as a whole, almost every gradation may be seen, the lamprophyre types themselves grading into true aplites and porphyries with almost a total lack of ferromagnesian constituents.

Variety 1 (porphyritic) - Type, Surface 6.

Specimens: Surface 6, S3, S5, 5 R-9, 5 R-10, 5 R-21, 5 R-22, 5 R-23, 5 R-24, M8, M9, M10, C4, C5, C5-1, M13, M16-2, 5 R-7, 5 R-8, S4, S2, Surface 4, R4, C5-2, C8-1.

Of the porphyritic variety of quartz minette surface 6, from the Carnation group, is a good example.

Macroscopic. The hand specimen is a medium grained grey rock with phenocrysts of felspar up to one tenth inch in length, and small nests of mica scales.

Microscopic. In general appearance under the microscope, the slide has a porphyritic appearance, consisting mainly of orthoclase, nests of biotite, often with regular boundaries, and quartz.

Quartz is abundant in allotriomorphic grains. Much of it is, apparently, primary, but some is eating into the orthoclase.

Orthoclase occurs abundantly in hypidiomorphic phenocrysts altering to sericite, epidote, and zoisite from the centre and sometimes replaced by quartz on the margins. Plagioclase is subordinate , and is less altered than the orthoclase. Its alteration products are carbonate, zoisite and epidote. Biotite occurs in porphyritic nests of minute flakes, with a tendency to rude orientation in some places. These nests often are sharply bounded as though they might have entirely replaced some former crystal. The biotite is little altered, except for occasional grains of quartz included within the nests. Scattered laths of apatite are present. Carbonate occurs, principally replacing plagioclase. Epidote and zoisite replace felspars. Sericite replaces orthoclase. Disseminated grains of pyrite are associated with, and probably replace biotite. An opaque white substance (carbonate?) is associated with the biotite. The Apatite is the earliest mineral, followed by biotite, orthoclase (?), plagioclase (?) and quartz. Carbonatization appears to have followed silicification.

S3 (also from the surface of the Carnation group) is another of this type. Macroscopically it differs from Surface 6 in having a lighter colour and a coarser grain. Microscopically kaolin is present among the alteration products of orthoclase. Biotite is more irregular and less abundant, and is associated with epidote in a manner suggestive of replacement. Sericite is more abundant, epidote scarcer. There has been little carbonatization, silicification being the main alteration. This is probably a leucocratic phase of surface 6.

S5, from the surface of the Carnation group, falls into this class. <u>Macroscopically</u>, it is a rather coarse grained light grey rock, with abundant felspar phenocrysts and nests of biotite. <u>Microscopically</u>, it is coarser in grain than the type, and poorer in biotite, Quartz occurs in large, clear, interstitial grains, much of it obviously secondary, and clearly replacing the felspars. Orthoclase is abundant and occurs in well formed phenocrysts, altering to sericite, with some carbonate. Plagioclase is oligoclase, and occurs in good phenocrysts, but less abundant than orthoclase; it is also altering to sericite and carbonate, but is generally fresher than the orthoclase. Biotite is fairly plentiful and appears to have crystallized later than, - or contemporaneously with (?) - the felspars. It is mostly altered to green chlorite, with subordinate carbonate and epidote. The carbonate is probably calcite. The principal alteration is silicification.

5 R-9 from #5 X-cut on the fifth level of the Ruth mine is a similar rock. <u>Macroscopically</u>, it is a dark grey fine grained rock with distinct phenocrysts of felspar. <u>Microscopically</u>, it is very similar to the type. Quartz is rather less abundant and replaces orthoclase. Orthoclase in well formed phenocrysts is highly altered to zoisite. Little plagioclase is present. This specimen differs from the type in that some of the biotite is altering to what appears to be titaniferous iron

ore surrounded by leucoxene. The texture is decidedly porphyritic.

5 R-10 was taken from the same rock (field notes), from the face of the South vein on the fifth level of the Ruth mine. Macroscopically, it is lighter in colour than 5 R-9 and of coarser grain, having the appearance of a quartz felspar porphyry. Microscopically, this specimen differs from the type in several respects. The felspar is principally orthoclase, although some oligoclase was determined by oil immersion; zoisite and epidote are absent, and the characteristic alteration is a matte of sericite; quartz and carbonate also replace the orthoclase to a lesser degree. Practically no fresh biotite remains, but it is evidenced by nests of chlorite flakes, which have parallel extinction and show deep blue birefringence; carbonate and a little pyrite are also associated with the chlorite. The texture of the specimen is coarsely porphyritic.

5 R-21, from new workings on the fifth level of the Ruth, is also of the porphyritic type. The hand specimen is missing. Microscopically, it is fairly coarse grained and porphyritic. It consists, principally of sericite, quartz and carbonate. Quartz is not abundant, and is being replaced by sericite and carbonate. Felspar was the predominant primary constituent, and was probably orthoclase; it occurs mostly in large phenocrysts now completely altered to sericite, and carbonate. Occasional bleached skeletons of biotite remain.

Scattered nests of chlorite, embedded in carbonate, probably are replacements of biotite. A few grains of pyrite are present. This specimen is too highly altered for definite correlation, and may be more of a felspar porphyry type.

5 R-22, from cross-cut on the fifth level of the Ruth, is similar to the last but slightly less altered. Macroscopically, it is a medium grained, greenish-grey, porphyritic rock. Microscopically, it differs in being less altered and richer in quartz. Much of the quartz has the appearance of fresh orthoclase until viewed in convergent light, when it gives a uniaxial figure. Orthoclase occurs in good phenocrysts, considerably sericitized, and sometimes replaced by calcite or quartz. Biotite is represented only by irregular, scattered nests of chlorite. The texture is medium grained and porphyritic.

5 R-23, probably frpm the same dike as 5 R-22, is very similar to it. Macroscopically, it is lighter grey, and apparently somewhat sheared. Microscopically, it is also very similar. Some of the quartz appears to have been crushed. Orthoclase is again highly sericitized, and partly replaced by quartz and carbonate. Biotite has apparently been replaced by chlorite and carbonate. In texture the section is also similar to the last. A broken veinlet of fibrous carbonate occupies a short fracture.

5 R-24, is from the same place as 5 R-9, but is more altered. Macroscopically, it is lighter in colour and apparent-

ly more felspathic than 5 R-9. Microscopically, it differs from 5 R-9 in having no fresh biotite, and no zoisitization of the felspar. Quartz is rather more plentiful, some being undoubtedly secondary, as it occurs in veinlets cutting felspar phenocrysts. The felspar is untwinned (orthoclase), and is only slightly sericitized, and corroded by quartz along the borders. Biotite is bleached and altered,in part to clouded carbonate. A complete pseudomorph of calcite after a perfect crystal of an earlier mineral occurs, surrounded by remnants of altered biotite. The texture is medium grained and porphyritic. Silicification appears to be the principal alteration.

M8, from station 2 in the Minnie Ha-Ha adit, is probably of this group. Macroscopically, it is a medium grained sheared mica lamprophyre, with abundant bronze biotite. Microscopically, it differs considerably from the type. Quartz is plentiful, a peculiar feature being large phenocrysts (as inclusions?), now consisting of carbonate and black specks (carbonaceous matter?), but which, when incompletely altered, have a central core of quartz; these are probably altered quartz phenocrysts. Felspar, where visible, is untwinned and is probably orthoclase, now altering to carbonate. The biotite is notably different in habit from the type, for it occurs in well defined lath shaped crystals, forming a loose lattice over the slide; the crystal boundaries are corroded and show evidence of resorption. The biotite is later than the altered quartz phenocrysts, as it surrounds them in company with secondary quartz. Needles of rutile, arranged in characteristic networks making angles of 60°, have formed abundantly in the biotite. Epidote and zoisite are again absent,and sericite is almost entirely lacking. The alteration consists of silicification followed by carbonatization. Veinlets of carbonate cut the section intersecting the quartz phenocrysts. The texture is porphyritic.

M9, taken at 25 feet from station 2 in the adit at the Minnie Ha-Ha, is similar to M8. Macroscopically, it closely resembles M8, but has more abundant altered phenocrysts. Microscopically, quartz is less abundant although the same altered phenocrysts are present, often containing specks of pyrite. The felspar, highly carbonatized and untwinned, is probably orthoclase. Biotite is plentiful but less regular in outline than in M8; it is partly bleached, and is being replaced by chlorite. The biotite may be in two generations, the earlier being rich in needles of secondary rutile. Apatite appears to be lacking. Some secondary quartz has been introduced, but carbonatization is the outstanding alteration. The texture is porphyritic and medium grained.

M10 is from half way between stations 2 and 3 in the Minnie Ha-Ha adit. Macroscopically it is a highly altered, sheared, porphyritic greenish rock. Microscopically,the section is badly altered by carbonatization, and it resembles M9 but is much further altered. Quartz is about equally plentiful, the carbonatized phenocrysts being abundant; some of these may have been felspars, but all remnants, which are sufficiently fresh, are quartz giving a uniaxial figure under crossed nicols. No twinned felspar is present. All the biotite has been replaced by chlorite with needles of rutile. Apatite is again lacking. Some sericite is present in the groundmass. The section consists, principally of carbonatized phenocrysts in a groundmass of calcite, quartz,altered orthoclase (?), and chlorite. The last three sections, M8, M9 and M10, appear to represent successively more advanced alteration and carbonatization of the same rock, all having the characteristic carbonatized phenocrysts which appear to be replaced quartz.

C4, from the Carnation mine, is very similar. Macroscopically, it is nearly identical with M9. Microscopically, it is seen to be highly carbonatized. The same peculiar alteration of the quartz phenocrysts to carbonate from borders inwards is again exhibited. No twinned felspars are in evidence. Biotite is corroded and somewhat bleached, and a little chlorite is developed. Rutile has formed in the biotite. Pyrite grains appear to segregate in and around the altered phenocrysts. This specimen is very similar to M9 in composition and texture.

C5, from the Carnation, is similar to C4. Macroscopically it is a porphyritic grey rock with flakes of bronze biotite. Microscopically, it also resembles C4, but has suffered considerable oxidation. Quartz is plentiful, both in the groundmass and in carbonate-rimmed phenocrysts. No twinned felspar is discernible. Biotite is bleached and corroded, a little chlorite has formed, and needles of rutile are common. The texture is medium grained with an orthoclase-quartz groundmass and quartz phenocrysts. Alteration is well advanced, both silicification and carbonatization; carbonate surrounding the quartz phenocrysts is rusty, and red hematite associated with it is probably oxidized pyrite.

C5-1, also from the Carnation, seems to be a similar specimen. Macroscopically, it is a fine grained, light grey, porphyritic rock. Micrescopically, it is seen to be very highly altered to carbonate, quartz, and pyrite. Quartz is fairly plentiful. No unaltered felspar remains. Biotite is represented by bleached laths, partly replaced by carbonate and pyrite. Needles of rutile remain in some of these remnants. Apatite is quite plentiful in fresh laths. Sericite with quartz makes up the groundmass. The porphyritic texture of the rock is less evident than in the less altered samples. Silicification has been followed by introduction of carbonate, which appears to replace quartz in a few instances.

M13, from the cross-cut at station 3 in the Minnie Ha-Ha, may belong to this variety. Macroscopically, it is a carbonatized, brecciated rock cemented with calcite. Microscopically, it consists principally of carbonate with considerable sericite, some large areas being entirely calcite. Quartz is entirely lacking, or may be replaced by carbonate. Distinct skeletons of felspar phenocrysts are present, entirely altered to sericite and carbonate. No biotite, and only a little chlorite is present. Some disseminated pyrite occurs through the section. The texture is decidedly porphyritic, but all the original constituents have been altered, principally to carbonate.

M16-2, from the Minnie Ha-Ha, seems to be of this type. Macroscopically, it is a light grey, fine grained rock. Microscopically, it consists of a fine grained groundmass of carbonate, sericite, and quartz, with altered phenocrysts of felspar. Quartz is not abundant and occurs in scattered grains. Felspars are untwinned, and completely altered to sericite and carbonate. A very little altered biotite and chlorite remain. Laths of apatite occur. A few disseminated grains of pyrite are present. Alteration is carbonatization and sericitization.

5R-7, from the Ruth mine, 110 feet back from the first drift west off #5 cross-cut, on the fifth level, is probably of this variety. Macroscopically, it is a light green, siliceous rock, cut by veinlets with carbonate borders and quartz centres. Microscopic. Under the binocular microscope the green mineral in the hand specimen is seen to be quite soft, and apparently little affected by cold 1:1 H.Cl. The slide consists principally of quartz and carbonate. The quartz is abundant, and probably partly secondary; it is mostly fresh, but in some instances is clearly being replaced by carbonate, and, apparently, also by sericite. No felspar is recognizable, but it may have been present before alteration. Pyrite and a grey mineral - probably galena - occur in scattered grains. The fissures are bordered by a carbonate of high refractive index, having apparent pleochroism from dark to light. This is probably siderite, as it is light brown in the hand specimen, and is the chief gangue mineral in the veins. The quartz, which fills the centre of the veinlets is clearly replacing the carbonate in a few instances.

5 R-8, from the north wall, of the first drift east off #5 cross-cut, is, from the field notes, apparently, from the same dike as the last, taken where it is cut by the south vein. Macroscopically, it is a sheared, brecciated, greenish rock, liberally mineralized with disseminated pyrite, and with galena and some sphalerite associated with carbonate in quartz veinlets. Microscopically, it consists of a matte of sericite, with occasional patches of quartz, and grains of carbonate, also being cut by several quartz stringers. Quartz occurs scattered through the sericite, and also in bunches of grains probably secondary. No felspar remains, but it is probably altered to sericite in the groundmass, and phenocrysts probably occurred where the large carbonate grains have formed. No biotite or chlorite are present. The carbonate has the same characteristics as that in the section from 5 R-7. Large grains of pyrite are plentiful, and are apparently later than the carbonate and replace it. A little galena occurs always associated

with, and probably later than, or contemporaneous with the carbonate. A few rust coloured, almost opaque grains of high refractive index, occur, especially near the pyrite; these may be a secondary titanium mineral. The structure of this specimen is difficult to determine due to intense alteration and mineralization, but it was probably porphyritic.

S4, from the surface of the Carnation group, is similar to the last. Macroscopically, it is a brecciated, greenish rock, cut by quartz stringers and impregnated with a brownish ferruginous carbonate, probably siderite. It is mineralized with pyrite, galena, and sphalerite (?). Microscopically, it is principally quartz and carbonate with much sericite. Quartz is partly primary, but much is evidently secondary as several stringers cut the section. A few phenocrysts appear to be altered orthoclase, now replaced by sericite; carbonate may also replace felspar. The carbonate has similar characteristics to that in 5 R-7 and -8, and is probably siderite, this carbonate is replacing some of the quartz, but is apparently earlier than the quartz stringers. No calcite was observed. A little pale green chlorite is present. Large grains of pyrite appear to replace the silicates, these have been subsequently strained and cracked, the fractures now being filled by chlorite and sericite. A bronze mineral occurs in occasional grains, probably pyrrhotite or possibly tetrahedrite, some grains having a rhombic outline in section. This specimen is probably from a mineralized dike near its intersection by a vein.

S2, from the surface of the Carnation group, is probably an acid porphyritic minette. <u>Macroscopically</u>, it is a fine grained, grey, siliceous rock with a weathered surface. <u>Microscopically</u>, it consists, essentially, of a fine groundmass of sericite, with abundant quartz grains, scattered prolifically throughout the slide. A few vague outlines, now completely altered to sericite, were probably orthoclase phenocrysts. No biotite is present, but it may be replaced by occasional flakes of green chlorite. Sericite may replace quartz to a slight degree. Opaque white, crystalline grains are probably carbonate. A little pyrite is present.

Surface 4, from the surface of the Carnation group, is probably a somewhat similar rock. <u>Macroscopically</u>, it is a fine grained, grey rock with occasional visible flakes of bronze biotite. <u>Microscopically</u>, it consists of a groundmass of sericite, carbonate, altered orthoclase (?) and a little quartz, with phenocrysts of plagioclase and orthoclase, and biotite. Quartz is not abundant. The felspar phenocrysts are altering to carbonate and sericite; orthoclase seems to be more abundant than plagioclase. Biotite is fairly plentiful, occurring in partly bleached and corroded laths, in part replaced by carbonate. A few laths of apatite occur. Needles of rutile are developed in the biotite. A finely crystalline, opaque, white carbonate (?) occurs in small grains, especially near the biotite. Occasional grains of pyrite are present.

The alteration consists of sericitization and carbonatization.

R4, from the Ruth mine, 610 feet from collar, on #5 cross-cut, is possibly of this class. Macroscopically, it resembles a fine grained, dark grey quartzite. Microscopically, it is seen to consist, principally of carbonate, quartz, and remnants of biotite. Considerable quantities of quartz are scattered through the section. Felspar of indeterminate composition is represented by crystal outlines and groundmass, now altered to sericite and carbonate. Biotite is all bleached, and replaced by carbonate. Needles of rutile occur in a few biotite remnants. Considerable apatite is present. The texture is fine grained, with some evidence of a porphyritic structure. The rock has been highly altered to carbonate and sericite. Considerable pyrite has also been introduced, and some of the quartz is probably secondary.

C5-2, from the Carnation mine, probably belongs to this group. Macroscopically, it is a grey rock with numerous flakes of bronze biotite. Microscopically, it is considerably altered to calcite and sericite. It is rather lower in quartz than others of this group. Felspar is mostly untwinned, although some have albite twinning and appear to be oligoclase. All felspars are partially altered to calcite and sericite. Biotite is deep brown, and is plentiful. The borders are corroded and numerous needles of rutile have formed within the crystals. A little apatite is scattered through the section.

Much disseminated pyrite, is present, often associated with the biotite. The texture is medium grained and practically non-porphyritic. The principal alterations are sericitization and carbonatization.

C8-1, from the Carnation mine, is a similar sample. Macroscopically, it is of lighter colour, and poorer in mica than C5-2. Microscopically, it is highly sericitized. It differs from most of this group in having very little quartz, and is probably a gradational type. The felspar is highly altered to sericite and less carbonate, but appears to be untwinned, and is probably orthoclase. Biotite is partly bleached and corroded, and is altering to chlorite, carbonate and pyrite, with the development of rutile. A fair amount of apatite is present. The texture is medium grained, and almost non-porphyritic. The last two sections described are gradational between the porphyritic and non-porphyritic types.

Variety 2 (non-porphyritic) - type, 5 R-11.

Specimens: 5 R-11, 5 R-3, 5 R-25, 5 R-26, C7, M3, M12, M11, Surface 7.

Of the non-porphyritic variety of quartz minette, 5 R-11, from the fifth level of the Ruth mine, is a good example. Macroscopically, it is a sheared, medium grained, greyish-bronze rock, composed, principally, of biotite. Microscopically, it is a fairly even grained rock, consisting, predominantly, of biotite, with considerable calcite and quartz. Quartz is in scattered, allotriomorphic grains, in part secondary, and appearing to replace biotite to some extent. Felspar is all untwinned and is probably orthoclase, now mostly replaced by calcite. Felspar does not occur in phenocrysts but forms a medium grained groundmass with quartz. Biotie is abundant, and may be in two generations, as some crystals, altered to chlorite, are surrounded by fresher biotite. Apatite was not observed. Needles of rutile are abundantly developed in the biotite. Pale green chlorite is replacing the biotite. Calcite is replacing felspar, and possibly some biotite, but does not appear to replace quartz. Pyrite was not observed. Paragenesis: Biotite is idiomorphic to the other constituents, orthoclase and quartz were formed later, followed by secondary chlorite and calcite.

5 R-3, from the Ruth mine, 540 feet from the collar on #5 cross-cut, is probably a similar rock. Macroscopically, it is a fine grained, grey, siliceous rock. Microscopically, is consists of scattered chlorite, in a fine grained groundmass of quartz and felspar, accompanied by carbonate and sericite. This section differs from 5 R-11 in that the groundmass is finer grained, and most of the biotite has been completely altered to chlorite with some carbonate, and it is less abundant. Felspar is probably orthoclase, as it is untwinned. Considerable apatite is present. No rutile is visible. A fair quantity of disseminated pyrite is present, often appearing to replace

biotite. Some specks of an undetermined black metallic mineral are present. Chlorite and carbonate are replacing biotite. Sericite and probably calcite replace orthoclase in the groundmass.

5 R-25, from the new workings on the fifth level of the Ruth, is similar. Macroscopically, it is an olive green sheared, medium grained rock. Microscopically, it has a schistose structure, and differs from the type in that the abundant biotite is almost completely altered to chlorite. Two or three large phenocrysts of quartz are present; these are beginning to be replaced by carbonate. No unaltered felspars remain, they having been replaced by quartz and calcite. Very little sericite is present. Numerous needles of rutile have developed in the biotite. These are less in evidence in the chlorite. Scattered grains of pyrite occur, often associated with the chlorite. Alteration consists of propyllitization, silicification and carbonatization.

5 R-26, taken from the vicinity of 5 R-21, may be classed with this variety. No hand specimen is available. Microscopically, the section is somewhat broken, and difficult to decipher. Felspar (probably orthoclase) with a little quartz and scattered sericite form the groundmass. Occasional bleached remnants and patches of chlorite are the only evidence of biotite. Bunches of carbonate probably replace orthoclase and possibly some quartz.

C7, from the Carnation mine, is of a similar type. Macroscopically, it is a fine grained grey rock. Microscopically, it consists of a fine grained groundmass of quartz, untwinned felspar and sericite, with scattered patches of carbonate and corroded laths of biotite. The biotite is often bleached and replaced by pyrite along cleavage cracks. The carbonate is also often associated with the biotite and pyrite. Needles of rutile have developed in the biotite. Alteration is principally sericitization and carbonatization. This section is cut by a vein of quartz, carbonate and pyrite. This slide is similar to C5-1.

M3, from the vicinity of station 3 in the adit of the Minnie Ha-Ha mine, is very similar. Macroscopically, it is a fine grained greenish-grey rock. Microscopically, it is similar to C7, but the biotite is altered to chlorite. Rutile was not observed, and pyrite is scarce.

M12 is from 10 feet before station 12 in the Minnie Ha-Ha, and may possibly be of this type, but is very doubtful, and may be a sediment. Macroscopically, it is a brecciated fine grained, grey, carbonatized rock, with graphitic slickensides. Field notes compare it to M3, which it resembles somewhat. Microscopically, it consists almost entirely of carbonate with less sericite as a fine groundmass, with pyrite, sometimes oxidized, and a little chlorite, possibly being alteration products of biotite. Apatite crystals are scattered through the section, and appear to be in process of replacement by carbonate, in some instances. A veinlet of carbonate, containing a nearly opaque brown mineral, cuts the section; this is probably limonite developed from oxidized ferruginous carbonate; grains of this mineral are also scattered through the section.

M11, from the Minnie Ha-Ha, half way between stations 2 and 3 in the adit, is similar to the last. Macroscopically, it closely resembles M3. Microscopically, it is more highly altered, principally to carbonate, but seems coarser grained. Little chlorite remains, it probably having been replaced by carbonate also. Texture is even grained. The section is cut by a veinlet of carbonate.

Surface 7, from the surface of the Carnation group, seems to belong to this variety. Macroscopically, it is a fine grained grey rock, cut by stringers of pyrite. Microscopically, it appears to be somewhat sheared, and consists of a fine grained groundmass of sericite, altered orthoclase (?), a little quartz and carbonate, with scattered patches of carbonate and chlorite. Carbonate and chlorite may replace biotite. Some of the carbonate is probably siderite, the rest probably being calcite. Scattered crystals of pyrite are present; the section is also cut by a stringer of carbonate and pyrite. The texture is even grained.

Variety 3 (highly silicified, aplitic) - Type, 5 R6-1.

Specimens: 5 R6-1, 5 R-12, S-1, Surface 1, S6.

5 R6-1 is classed by Dr. O'Neill with this variety.

The hand specimen is missing. <u>Microscopically,</u> it very much resembles a felspathic quartzite, with a somewhat schistose structure. It consists, predominantly, of fairly evenly sized, irregular <u>quartz</u> grains. A small percentage of partly sericitized <u>felspar</u> is present; this is mostly untwinned. Some felspar grains, separated and apparently eaten into by quartz, extinguish almost simultaneously, thus possibly being remnants of one large phenocryst, now nearly completely replaced by quartz. Scattered crystals of <u>apatite</u> occur. A few small greenish crystals, with strong pleochroism, and maximum absorption perpendicular to the plane of polarization, are probably <u>tourmaline.</u> One small crystal of <u>zircon</u> was observed. <u>Sericite</u> is scattered through the section, with a very little <u>carbonate</u>. Disseminated cubes of <u>pyrite</u> are also present. This specimen is probably a highly silicified aplite, or aplitic differentiate of the minette, with no remaining biotite.

5 R-12 is very similar to the last, and was taken from a 3 foot dike. <u>Macroscopically,</u> it is a fine grained, greyish, siliceous rock. <u>Microscopically</u>, its general appearance is more like a quartzite than the last. It is composed, predominantly, of quartz grains similar to R6-1, and sericitized remnants of felspars, mostly untwinned, are apparently being replaced by quartz. Some sericite and a very little carbonate are present. A little disseminated pyrite occurs. This appears to be a quartzite under the microscope, but the field relations show it to be a dike, probably a highly silicified aplitic differentiate

of the quartz minette similar to R6-1.

S1,. from the surface of the Carnation group, is probably a similar type. Macroscopically, it is very different from the last; it is a fine grained, dark grey siliceous, rock very much like a quartzite, and breaks along two sets of plane joints inclined at about 80° to one another. Microscopically, it closely resembles 5 R-12. Several small brown flakes occur, probably biotite. Pale green chlorite, sometimes iron stained, is common. At least one grain of zircon is present. The quartz and felspar grains are cemented by later black iron oxide, altering to hematite. This slide looks like a quartzite, but from its similarity to 5 R-12, a known dike, it is classed as an aplite.

Surface 1, from the surface of the Carnation group is similar. Macroscopically, it is a fine grained, grey rock, apparently quartzite. Microscopically, it is very similar to 5 R6-1, also having a schistose structure. The quartz grains are all interlocked. Some sericitized orthoclase is present. Scattered flakes of biotite occur, often fresh, but sometimes altered to chlorite. Disseminated pyrite grains are present. A little sericite and carbonate are found. This rock is less like a quartzite than others of this variety, for the quartz grains are interlocked, and the structure is more cataclastic due to squeezing.

Minette - Kersantites.

This group includes all the more basic specimens, as these are difficult to differentiate due to gradations from one variety to another. The felspathic constituents range from albite, with orthoclase, to one ultra-basic section containing bytownite-anorthite. The structures are usually more or less porphyritic, and generally medium to fine grained.

Variety 1 (normal minette) - Type, M4.

Specimens: M-4, M16-1, 4 R-1, S7.

M4, from the Minnie Ha-Ha mine, is taken as the type of this variety. Macroscopically, it is a dark grey fine grained rock, with numerous flakes of dark biotite. Microscopically, it consists of abundant biotite, and phenocrysts of plagioclase and fewer of orthoclase in a crystalline groundmass of orthoclase and quartz. Quartz is not abundant, and occurs as interstitial grains in the groundmass. Orthoclase occurs abundantly in the groundmass, and in large, usually idiomorphic, crystals, partly altered from the centre to a matte of sericite, carbonate and kaolin. The plagioclase is oligoclase. It is more abundant than the orthoclase, and occurs in smaller and fresher phenocrysts, usually of idiomorphic outline, and often zoned. Biotite is abundant, dark brown and strongly pleochroic, and sometimes slightly corroded and green on the borders. It occurs in small irregular flakes throughout the slide, and in occasional larger phenocrysts, which may be of slightly earlier crystallization. Scattered crystals of apatite occur. Epidote is abundant, generally occurring in irregular grains but occasionally with crystal outline. It is pale olive green and only slightly pleochroic. It replaces oligoclase, orthoclase less frequently, and often appears in close association with biotite, which it may also replace. Carbonate - probably calcite - occurs in scattered patches, probably replacing the felspars and possibly biotite. Sericite and kaolin occur with carbonate as alteration products of orthoclase phenocrysts. Scattered grains of pyrite generally occur in association with biotite. The texture is porphyritic and medium grained. The section is fairly fresh, epidotization and less carbonatization being the principal alterations.

M16-1, from the Minnie Ha-Ha, is almost identical with M4. The hand specimen is missing. Microscopically, it can hardly be differentiated from M4. There may be less orthoclase, but it is similarly altered. The abundant plagioclase is oligoclase. Epidote is again the principal secondary product.

4 R-1, from the fourth level of the Ruth, is similar. Macroscopically, it is a fine grained, grey, sheared and slickensided, micaceous dike. Microscopically, it is medium and even grained, with less biotite and more quartz than the type. Orthoclase and plagioclase are present in about equal

quantities. Quartz is abundant, but some of it is secondary and eats into the felspars; some of it shows strain shadows. The felspars are only slightly altered, orthoclase chiefly to sericite and some carbonate, and plagioclase - which is oligoclase-andesine, - chiefly replaced by carbonate. Biotite is in irregular, deep brown flakes. Apatite is present in scattered laths. The carbonate is probably calcite and occurs in good sized, clear patches, in some places, in sharp contact with plagioclase, quartz and biotite, while in others it appears to replace any or all of these, especially the plagioclase. Sericite is frequent, and usually appears to replace orthoclase. Muscovite flakes also occur. A very few grains of epidote occur in the plagioclase. Abundant pyrite and possibly pyrrhotite, surrounded by black borders (black iron oxide?) appear to replace biotite. The texture of this specimen is practically non-porphyritic; there is evidence of crushing both in the hand specimen and in the strain shadows of the quartz. Silicification with subordinate carbonatization, are the principal alterations.

S7, from the surface of the Carnation group is similar to 4 R-1. Macroscopically, it is a fine grained,grey rock with much disseminated pyrite. Microscopically, it resembles 4 R-1, but is more highly altered. It is finer grained, with a groundmass of felspars - orthoclase and some oligoclase - , which are altering, in part probably, by silicification, and in part by sericitization, with a subordinate amount of carbonate. Biotite is paler and corroded. Apatite is present in considerable quantity. Needles of rutile are developed in the biotite. Much pyrite (and possibly some pyrrhotite?) is present as an alteration product of biotite.

<u>Variety 2.</u> (monzonite porphyry - no biotite) - Type 5 R-1,
<u>Specimens:</u> 5 R-1, 5 R-2.

This variety is similar in felspathic constituents but poorer in quartz and lacking biotite.

5 R-1, the type, is from the collar of #5 cross-cut on the fifth level of the Ruth mine. <u>Macroscopically</u>, it is a very light grey, medium grained porphyry. <u>Microscopically</u>, it consists of perfectly idiomorphic phenocrysts of plagioclase and fewer of orthoclase, in a fine grained groundmass of felspar and quartz. <u>Quartz</u> is subordinate in the fine groundmass, and occurs in one or two patches of coarser grains, apparently replacing orthoclase. <u>Orthoclase</u> occurs in the groundmass and in a few large well formed phenocrysts, altering to sericite. <u>Plagioclase</u> - albite by oil immersion - is more abundant, and occurs in phenocrysts, often of perfect crystal outline; both carlsbad and albite twinning are clearly exhibited. A little <u>apatite</u> is present. <u>Sericite</u> replaces both the felspars and is also scattered through the groundmass. <u>Carbonate</u> - probably calcite - occurs principally in the groundmass, and is sometimes associated with a little <u>chlorite</u> and occasional grains of <u>pyrite</u>

and may have replaced biotite. This section is comparatively fresh; sericitization is the principal alteration with subordinate carbonatization, and possibly a slight silicification.

5 R-2, from 330 feet south of the collar of #5 crosscut, is very similar to 5 R-1, Macroscopically, it is almost identical. Microscopically, it is also nearly identical. Quartz replaces plagioclase. There appears to be less orthoclase. Plagioclase, by extinction angle, appears to be about oligoclase to andesine, thus being more basic. Sericitization and carbonatization are somewhat more advanced. This is probably a slightly more basic segregation of the same dike as 5 R-1.

Variety 3. (Kersantite) - Type M17.

Specimens:- M17, M1, Surface 5.

This variety consists, essentially, of biotite and andesine, or more basic plagioclase in a fine grained groundmass, with little if any orthoclase or quartz. It is similar to M4 and M16-1, but more basic.

M17, from half way between stations 5 and 6 in the Minnie Ha-Ha adit, is taken as the type. Macroscopically, it is a fine grained, dark grey rock, flecked with biotite flakes. Microscopically, it consists of biotite, abundant plagioclase phenocrysts and fewer of orthoclase, in a fine grained groundmass of felspars. Quartz is absent. Orthoclase often shows carlsbad twinning, and occurs in idiomorphic phenocrysts, often entirely fresh, but, in some instances, altered from the centre to a matte of kaolin, and sericite with a little carbonate. Plagioclase — andesine - labradorite — is more abundant, and occurs in well formed phenocrysts, exhibiting carlsbad and albite twinning, and often zoned; it is generally quite fresh, but occasionally is partly altered to sericite and carbonate. Biotite is scattered through the section plentifully, in deep brown irregular flakes, and occasional well formed crystals, usually slightly corroded around the borders. Apatite is scattered through the slide in good crystals. Sericite occurs as an alteration product of the felspar phenocrysts and in the groundmass. Carbonate is chiefly associated with, and probably replaces, biotite. A little epidote also appears to be an alteration product of biotite. Occasional grains of pyrite also replace biotite. The section is fairly fresh, and distinctly porphyritic. A carbonate veinlet cuts the specimen.

M1, taken 27 feet from the portal of the Minnie Ha-Ha adit, is very similar to the last. Macroscopically, it is slightly coarser in grain than M17. Microscopically, it contains a few grains of quartz, and the groundmass is coarser. There is less orthoclase. Plagioclase is the same — andesine - labradorite —. Biotite is altered to carbonate and pyrite. There is less apatite. Very little epidote is present. Little, if any, kaolin has formed, the principal alteration of the felspars being sericitization.

Surface 5, from the surface of the Carnation group, belongs to this variety. <u>Macroscopically,</u> it is very similar to M17. <u>Microscopically,</u> it is less porphyritic. A very few interstitial quartz grains may be present. A very little orthoclase occurs in small phenocrysts. The section consists, predominantly, of small phenocrysts and grains of basic plagioclase, which, by oil immersion (checked by extinction angle, and by sign in convergent light, it being negative) is bytownite-anorthite. The crystals show carlsbad, and, less frequently, albite twinning, and are often zoned. The biotite is altered similarly to M17. Muscovite has developed, usually cutting across aggregates of biotite. This section probably represents a very basic phase of the Kersantites.

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From the foregoing petrographical descriptions of the dike rocks encountered in the several mines mentioned several inferences may be reached.

1. There appear to be no distinctly separate types, but all are rather gradational phases from the same magma. The presence of biotite, as the one and only primary ferromagnesian mineral, in nearly all the specimens, is particularly noteworthy in this connection. Although the predominant felspars are orthoclase and the more acid plagioclase, yet some specimens carry the more basic varieties, usually associated with some orthoclase; the section, surface 5, with bytownite-anorthite is the extreme variety.

2. The predominant type of alteration is that characteristic of the intermediate vein zone, namely, sericitization with the introduction of more or less carbonate, and the combination of the iron in the biotite, with introduced sulphur, to form pyrite. Silicification is less persistent, but is clearly operative in many instances. Epidotization is a less frequent alteration, while zoisitization is infrequently met with. A type of alteration more frequently associated with veins deposited nearer the surface, namely, prophylitization with the characteristic formation of chlorite and pyrite, with carbonatization is depicted by a few specimens.

3. There is a type of rock, referred to as a silicified aplitic variety of minette which is almost indistinguishable from quartzite, and has been placed in this category, almost solely, on the presence and condition of the felspars and their apparent replacement by quartz.

The Sedimentary Rocks.

The sediments underlying the area under consideration, as stated above, are principally quartzites, argillites and limestones with gradational varieties; of these quartzites are predominant among the specimens studied for this thesis.

Quartzite (felspathic) - Type, surface #2.

Specimens: Surface 2, S6, C8, M15, 4 R3, 4 R2.

Surface 2, from the surface of the Carnation group, is a dark grey, fine grained quartzite with no visible bedding. Microscopically, it consists, essentially, of rounded and sub-angular quartz grains embedded in a finer grained matrix. Quartz occurs in fresh, small, rounded and sub-angular grains, having a considerable range of size; most grains are single, but some are made up of several intergrown individuals. Orthoclase is scarce, and occurs in small grains, partly altered to sericite. Plagioclase appears to be more abundant and fresher, but is partly altered to carbonate and sericite. One rounded grain, probably of zircon, was observed. A few flakes of muscovite are present. Sericite is an alteration product of the felspars. Carbonate, replaces felspars, and probably quartz to a lesser degree; veinlets of carbonate cut the section; these appear to have come in before complete consolidation, for grains of quartz, often project across and break up the carbonate stringers. Limonite forms a cement between grains and may, in part, replace felspar. The structure appears to be typically clastic, but very closely resembles some specimens classed as silicified aplitic variety of quartz minette.

S6, from the surface of the Carnation group, is very similar. Macroscopically, it appears to be a dark grey, fine grained quartzite, with fissures but no visible bedding. Microscopically, it closely resembles surface 2. It consists of rounded and sub-angular single and intergrown quartz grains, with minor quantities of orthoclase and plagioclase partially sericitized. Occasional scattered grains of biotite are seen. One small tourmaline grain is present. Several grains of a black mineral - iron ore (?) - are present. Silicification has occurred, some quartz replacing plagioclase. There is less carbonatization than in surface 2. This slide is doubtful and may be a silicified aplite.

C8, from the Carnation, is very similar to the type. Macroscopically, it is a dark grey, fine grained quartzite. Microscopically, it consists, essentially, of ill assorted, subangular and rounded quartz grains with subordinate orthoclase and plagioclase. A little biotite occurs between the quartz grains. Occasional flakes of muscovite also occur, possibly secondary. The felspars are altering to sericite. Very little carbonate occurs, and this is mostly associated with limonite in one section of the slide. The clastic structure of this specimen is somewhat more distinct than of the last. Evidence is provided, especially, by the presence of rounded grains, which, when examined between crossed nicols, are seen to be composed of parts of several intergrown crystals. The section is divided by the presence of a narrow band of much finer texture than the remainder of the slide.

M15, from the Minnie Ha-Ha in the cross-cut from station 5, is a similar rock. Macroscopically, it is a dark grey, very fine grained, quartzitic rock. Microscopically, it is similar but the grains are less rounded, and the composition is more felspathic. Quartz grains are often intergrown and sometimes appear to eat into the felspars. Orthoclase and plagioclase are both plentiful; both are altering to sericite especially the former. Considerable brown and greenish tourmaline grains are scattered through the slide. Grains of a mineral similar to epidote occur less frequently. A very little carbonate cement occurs. This is less obviously clastic than C8, but seems more like a quartzite than an aplitic rock.

4 R-3, from the hanging-wall of the vein at the bottom of the winze, on the fourth level of the Ruth, is another quartzite. Macroscopically, it is a fine grained, light grey, quartzitic rock. jointed, but without visible bedding. Microscopically, it differs in having no recognizable felspar, but considerable sericite is present and may have replaced it. Sericite also appears to replace quartz to a limited degree. A few large coarse grained quartz lenses occur. A few flakes of muscovite are present. Scattered carbonate occurs, and a stringer cuts the slide. Grains of pyrite are disseminated through the section. The grains are smaller and more intergrown than in the type for this group, but the structure appears to be clastic.

4 R-2, from the fourth level of the Ruth, is a somewhat similar specimen. Macroscopically, it is a fine grained, grey, banded quartzitic rock, with graphitic slickensides. Microscopically, it differs from the type in being finer grained, containing no recognizable felspars, and containing much chlorite,

some in bands. The groundmass appears to be fine grained intergrown quartz, with abundant sericite appearing to replace the quartz. Abundant green chlorite, with parallel extinction and deep blue birefringence is scattered through the section; some flakes are partly replaced by sericite. A narrow band (or veinlet) of chlorite, partly replaced by sericite, cuts the section, this has been displaced by faulting. A wide band of chlorite and sericite occupies one edge of the section. Scattered grains of pyrite, pyrrhotite (?) and black iron ore occur; some grains have the appearance of chalcopyrite, but may be tarnished pyrrhotite (?).

Calcareous Sandstone - Type, surface #3.

Specimens: ~~S3~~ Surface 3 Mla.

This type consists, essentially, of quartz sand, cemented by carbonate. Surface 3, from the surface of the Carnation group, is a typical example. Macroscopically, it is a dark grey, fine grained, quartzitic rock. Microscopically, it consists of ill assorted grains, mostly of quartz, cemented by carbonate. Quartz is in rounded or sub-angular, separated grains. A fair amount of orthoclase is present, and very occasional grains of plagioclase. Occasional grains of brown and greenish tourmaline occur. Fewer grains which resemble zircons, were also observed. Carbonate is abundant, and, with sericite, forms the cementing material and replaces felspar, and also appears to replace quartz to a slight degree around the margins of grains. The structure of this section is undoubtedly clastic.

M1a, from the Minnie Ha-Ha, near a dike, is also a calcareous sandstone. Macroscopically, it is a dark grey, fine grained, calcareous, quartzitic rock. Microscopically, it is finer grained and more carbonatized than surface 3. Small quartz grains are cemented by an equal or greater quantity of carbonate. A very little biotite is present. Carbonate appears to replace quartz in a few instances, and has replaced all felspar, if any was present. Disseminated grains of black iron oxide are present. This is an undoubted sediment.

C6, from the Carnation, is a similar though more quartzitic specimen. Macroscopically, it is a fine grained, greenish, fissured rock. Microscopically, it has a somewhat bedded structure. It consists of small quartz, and possibly some felspar, cemented and partially replaced by carbonate. Pyrite occurs in disseminated grains. Along one border of the section occurs a band of coarser grained, pure silicified quartzite, with no calcareous cement. From this evidence it would appear that the calcareous portion must have been felspathic or impure and thus more easily carbonatized.

Ferruginous carbonatized quartzite - Type, C2.

Specimens: C2, C1.

This type consists, essentially, of quartz grains cemented and replaced by carbonate and limonite. C2, from the Carnation, represents this type. Macroscopically, it is a fine grained, grey, quartzitic rock. Microscopically, it consists of small <u>quartz</u> grains, cemented and replaced by <u>carbonate</u> and <u>limonite</u>. The limonite probably is an oxidation product of a ferruginous carbonate. A quartz stringer cuts the section and is partly replaced by the ferruginous carbonate and partly by later carbonate - <u>calcite</u> (?). Still later fissures cut this and are filled by calcite. The quartz veinlet is older than the ferruginous carbonate, and the calcite stringers are younger than this. The structure is clastic.

C1, from the Carnation, is probably the same rock. <u>Macroscopically,</u> it is a brecciated highly oxidized rock, cemented with calcite. <u>Microscopically,</u> it is very similar to C2, but more ferruginous. Calcite is again later than the ferruginous material.

<u>Schisted sandy shale</u> - 5 R5.

5 R5, from the Ruth at 1070' from the collar of #5 cross-cut, is, apparently a schisted sandy shale. <u>Macroscopically,</u> it is a very fine grained, black, schistose rock. <u>Microscopically,</u> it is very fine grained and extremely schistose, and appears to be composed of fibrous <u>sericite</u> and <u>chlorite,</u> enclosing fresh <u>quartz</u> grains, forming a typical "augen" structure around the larger ones. Some bands are richer in chlorite to the exclusion of sericite. Much fine black <u>carbonaceous</u> (?) material is present, and <u>pyrite</u> is disseminated throughout the section. A quartz stringer cuts the specimen transversely to the schistosity.

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The majority of the sediments collected are quartzites, usually more or less felspathic, and sometimes sericitized or carbonatized, especially near the contacts of veins.

The Ores.

The polished sections of ores, studied for this thesis, were prepared from specimens collected by Dr. O'Neill from the Ruth-Hope, Lucky Jim, and Hewitt mines. The Lucky Jim is situated near the headwaters of Seaton Creek, on the valley slope, above, and about half a mile south of Zincton. It is owned by the Lead and Zinc Company, Limited, of Spokane. The ores are principally replacements of zinc blende in a band of limestone. The Hewitt is situated on a spur of Eight Mile ridge, south of Silverton Creek, and less than three miles southeast of Silverton, from which it is reached by road and trail. It is owned by Hewitt Mines, Limited, of Spokane. The deposit occurs at the contact of the Nelson batholith with argillaceous sediments, and the ores are principally of the dry type.

The study, which was carried out by the author, of the polished sections of the ores, constituted his initiation into the science of mineragraphy, and consequently a good deal of difficulty was experienced in the accurate determination of some of the minerals encountered. The method adopted was that set forth in Davy's and Farnham's "Microscopic Examination of Ore Minerals," (McGraw-Hill). The reagents used in the microchemical tests were: 1:1 HNO_3, 1:1 HCl, 20% solution of K C N, 20% solution of $FeCl_3$, saturated solution of $HgCl_2$ and saturated solution of K O H.

The specimens, examined, may be divided into three general types: (1) those consisting predominantly of galena, (2) those consisting predominantly of sphalerite, and (3) those of the dry type.

Galena type.

Specimens: 5 R-12, 5 R-12-1, 5 R12-3, 5 R19.

5 R-12 from the Ruth, is of this type. It consists, in paragenetic order, of magnetite (?), pyrite, chalcopyrite and sphalerite, pyrrhotite, tetrahedrite, and galena. Magnetite (?) consists of one idiomorphic pseudo-hexagonal grain embedded on the contact of galena and chalcopyrite. It is hard, dark grey, and unaffected by reagents. Pyrite occurs surrounded by, and corroded by chalcopyrite. The grains are irregular, cracked and eaten into by chalcopyrite. Chalcopyrite occurs in large irregular masses, enclosing and replacing residual grains of pyrite, It also occurs along the contacts of galena and sphalerite, and as finely disseminated specks in the latter. Sphalerite occurs in large irregular grains in the galena, and is being replaced by it. It appears to replace chalcopyrite in part, and is probably nearly contemporary in age, as the chalcopyrite, in other places appears to eat into the sphalerite. A few minute fissures in the chalcopyrite are filled by pyrrhotite. Disseminated specks of tetrahedrite - pale creamy white and hardly dis-

tinguished from galena before etching - occur in the galena; its age is uncertain but it is earlier than the galena. Galena makes up the bulk of the specimen and is the youngest ore mineral present, and replaces both sphalerite and chalcopyrite.

5 R12-1, also from the Ruth, has a similar composition. Paragenesis: Pyrite, chalcopyrite and sphalerite, tetrahedrite, and galena. The specimen is predominantly of massive fine-grained galena. The pyrite again occurs in corroded residual grains. The chalcopyrite is not as abundant as in the last, and occurs finely disseminated in the galena. The sphalerite, often in association with the pyrite, occurs as irregular remnants in the galena. Tetrahedrite occurs as good sized grains, and as finely disseminated specks in the galena, often segregated around the borders of the sphalerite, and appearing to eat into it, thus being later in age. The galena is again the last ore mineral to be formed. One small speck of a light grey mineral was observed, in association with carbonate, filling a small crack. This mineral is soft, has a red powder, and reacts for ruby silver - probably proustite. This is probably secondary. Carbonate gangue - probably siderite - occurs sparingly especially with the sphalerite.

5 R12-3, from the Ruth, is also of massive galena, with pyrite, chalcopyrite, sphalerite, tetrahedrite, and pyrrhotite (?). Pyrite, in occasional, small grains again appears to be the oldest mineral. Chalcopyrite is scarce, and occurs in irregular grains,

being replaced by galena. A little also occurs in minute cracks in galena and in tetrahedrite. Sphalerite is probably contemporary, and is more plentiful. It often is associated with the pyrite. Tetrahedrite occurs in minute specks, and also as large pitted grains. Pyrrhotite follows cracks in the tetrahedrite, but is of infrequent occurrence. Galena is again the predominant mineral. Evidence of a possible secondary cycle of mineralization is shown by the presence of chalcopyrite in fissures in the galena.

5 R19, also from the Ruth, is predominantly squeezed, gneissoid galena, with considerable sphalerite and tetrahedrite and a little pyrite and chalcopyrite. Pyrite again appears to be the oldest mineral, and occurs as occasional grains, usually in or near the sphalerite. Sphalerite occurs in good-sized, irregular, residual grains in process of replacement by galena. Chalcopyrite occurs very sparingly in minute fissures and scattered grains in the tetrahedrite, and is probably later than it. Tetrahedrite occurs in irregular grains, earlier than the galena. Galena is the principal mineral and the last to form. It has a gneissoid structure, probably caused by squeezing. After etching the galena, vague, disseminated, light specks, almost submicroscopic in dimensions appear, which are unaffected. These are too small to determine, but may be tetrahedrite, or a silver mineral. Carbonate occurs sparingly, mostly in the sphalerite and tetrahedrite.

5 R20, from the Ruth, consists of two samples, both

of this type. One is mostly galena, with abundant irregular grains of tetrahedrite of uncertain relative age. Sphalerite also occurs in irregular grains and is probably earlier than galena, although some appears to be intergrown with it. A few residual pyrite grains occur in both the sphalerite and tetrahedrite. The other sample is principally tetrahedrite, and also contains a little chalcopyrite, which seems to fill cracks in the carbonate gangue, and is, therefore, probably of later deposition.

5 R18, from the Ruth is principally tetrahedrite, but is of a similar type of ore. This specimen differs from the preceding ones, in that the tetrahedrite contains disseminated, irregular grains of a silver white colour which are probably argentite (?) (or less probably dyscrasite (?). These may be later than the enclosing tetrahedrite. Occasional small grains of chalcopyrite also occur in the tetrahedrite. Galena occupies all of one side of the specimen.

Sphalerite type.

Specimens: L1, Rx.

L1, from the Lucky Jim, is a typical sample of the sphalerite ore. It consists almost entirely of massive sphalerite, with occasional minute blebs of pyrite and chalcopyrite. The pyrite and probably the chalcopyrite are older than the sphalerite.

Rx, from the Ruth, is also of massive sphalerite. This sample is from ore which is said to assay 101 oz. silver per ton. The sphalerite is much cracked, the macroscopic fractures being empty, although chalcopyrite fills some of the microscopic ones, and is therefore later in age than the sphalerite, although minute blebs also occur disseminated through the specimen.

Dry ore type.

Specimens: H, K.

Specimen H, from the Hewitt is of the dry type. It consists of galena, sphalerite, chalcopyrite, pyrite, tetrahedrite (?) and native silver (?) in a gangue of carbonate - mostly siderite - with subordinate quartz. The pyrite occurs in a few small grains in the sphalerite and antedates it in time of deposition. Sphalerite occurs in large irregular grains, of uncertain relative age, embedded in, and often enclosing grains of galena. Chalcopyrite is probably later than the sphalerite, and occurs in it as blebs and as fillings of fractures. Small grey-white specks, unaffected by reagents, occurring in the galena, are probably tetrahedrite. This specimen is unique in that the galena, in the neighbourhood of a grain of sphalerite, contains minute, white, dentritic growths, which are tarnished by HNO_3, and are probably embryonic crystals of native silver, but are too small for definite determination.

Another sample of the dry ore type consists of sphalerite, tetrahedrite, and subordinate pyrite and chalcopyrite, in a gangue of quartz, with a minor quantity of carbonate. The most significant fact observed in this specimen, was the replacement of sphalerite, by branching dendritic growths of tetrahedrite.

A few minute blebs of chalcopyrite and pyrite occur in the sphalerite, the pyrite generally being associated with quartz. Quartz is later than the sphalerite, but may antedate the tetrahedrite.

. . . .

Due to the author's lack of experience in the science of mineragraphy, the foregoing observations and conclusions may not be as precise or as exhaustive as might be desired, but with additional experience and more time available much might be learned of the occurrence and paragenesis of these ores. At least it is clear that galena, sphalerite and tetrahedrite (usually argentiferous) constitute the bulk of the ore. In general the paragenesis of the ores is as follows:- Pyrite, sphalerite, tetrahedrite and chalcopyrite, and galena, although some variation in the order of deposition of the sphalerite,tetrahedrite and chalcopyrite seems to occur.

A notable feature of the study was the apparent lack of ruby silver in the dry ores studied, although this mineral is plainly visible in several of the hand specimens from the Hewitt mine.

Appendix.

Bibliography.

M.F.Bancroft, G.S.C. Summary Report, Part B, 1917.

" " " " " 1919.

A.M.Bateman, Notes on Silver-Lead Deposits of Slocan District, B.C., Canada. Soc. of Econ. Geologists, Pub. #47, 1925.

C.E.Cairnes, G.S.C., The Slocan Mining Area, (unpublished).

C.W.Drysdale, G.S.C., Summary Report, 1916.

" Map. No. 1667 (out of print).

O.E.LeRoy, G.S.C., Summary Report, 1910.

" " " " 1911.

R.G.McConnell, G.S.C., vol. VII, 1894.

" " " VIII, 1895.

W.L.Uglow, Economic Geology, vol. XII, No. 8, 1917.

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A. Joanes, Draughtsman.

Longitude West from Greenwich

Publication No. 1841

LEGEND

Culture

Streets, roads and buildings

Roads (not well defined)

Trails

Railways

Mine tramways

Aerial tramways

Bridges

Cemeteries

Quarries

Mine tunnels

Wharves

Water

Rivers and lakes

Lakes and streams (shown approximately)

Watercourses (with intermittent flow)

Glaciers

Submerged marshes

Relief

Contours (showing land forms and elevations above sea-level) Interval 100 feet.

Contours (not well determined)

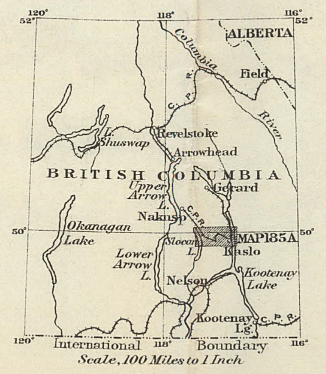
Figures (showing heights in feet above sea-level)

Names of mines and mining properties shown thus.......IVANHOE

Geographical position subject to revision.

Approximate magnetic declination, 24°30' East.

MAP 185 A



SANDON

(SLOCAN AND AINSWORTH MINING DIVISIONS)

KOOTENAY DISTRICT

BRITISH COLUMBIA

Scale, $\frac{1}{48,000}$

Miles

Kilometres

4000 FEET TO 1 INCH

TOPOGRAPHY

W.H. BOYD, (IN CHARGE)	1909, 1910.
W.E. LAWSON,	1910.
A.C.T. SHEPPARD,	1910, 1911.


5R23
5R22
#10 Ruth N. Vein
5R24
5R9
5R12
5R7
5R8
5R25
5R21
5R26
#6 Ruth
Silversmith
#11 Silversmith
#10 Silversmith
#9 Silversmith

RUTH MINE