# Ore Deposits of the Eastern side of the Coast Range Batholith (with special reference to Atlin District.)

by

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## Table of Contents.

## Foreword.

This thesis is divided into two parts. The first deals with the entire area under consideration, while the second describes the Atlin district. This division was deemed necessary because of the greater familiarity of the author with the Atlin district, where he spent two summers doing geological work for a mining company. Thus the Atlin district is described in a greater detail than it was possible to describe the rest of the area, where the only sources of information were reports and the memoirs of the Geological Survey of Canada, and the Minister of Mines reports.

The thesis, except the part dealing with the Atlin Ruffner mine, does not represent original work, but is a compilation of geological data assembled during the last 20 or 30 years. The literature on the subject is so extensive, that a great deal of time and attention was required to separate the geologically important from the insignificant and unproven.

The conclusions are summarized and briefly stated in the Part I of the thesis. They represent thoughts which were raised in the author's mind while reading and comparing facts observed in different parts of the area. These conclusions are by no means of equal value. Some are obviously true, some are just speculations. They were put down not so much for their own value, but rather as notes for further reference and study.

Not enough is yet known of the composite nature and history of the great Coast Range Batholith, very little is known of the country to the east of it. Until more is known, all generalizations are dangerous, but as Dr. Schofield said: "If well directed progress is to be made in the future, generalizations are necessary."

I wish to thank all those who helped me with the work of writing this thesis, particularly Dr. S. J. Schofield whose detailed and extensive knowledge of the subject made his advice exceptionally valuable; I also wish to thank Mr. C. L. Hershman, manager of the Engineer and Atlin Ruffner Mines, whose interest and knowledge of geology made it possible for me to study the geology in the vicinity of the mines in far greater detail than would ordinarily been possible for a mine geologist.

The general geological map, included with the thesis, was compiled on the basis of reports of the Geological Survey of Canada, issued during the last 10 years, and so represents the latest and most accurate knowledge of the area. I believe this is the first map, on which the eastern contact of the Batholith, was plotted along its entire length, from field observations.

# PART I.

## Introduction and Summary.

Along the entire western coast of the American continent extends a long and rugged system of mountain chains and ranges--the Cordillera of North and South America.

The westernmost ranges in British Columbia, belonging to the Cordillera, are the Coast Range and the Island Ranges.

The Coast Range is made of granitic intrusive rocks and is flanked by older sedimentary and volcanic rocks, folded and metamosphosed by crustal movements and heat of intrusion.

Along the margins of this granitic body, called the Coast Range Batholith, are found numerous ore-deposits. It is believed that these ore-deposits were formed by emanations arising from the intruded granitic magma.

It is the object of this paper to summarize what is known about the geology of the ore deposits along the eastern contact of the Batholith, not so much in the desire to bring out original hypothesis on their origin, but rather to bring together geological information scattered in the copious literature on the subject.

In order to do this intelligently it is necessary to get acquainted not only with the geology of the separate ore-deposits, but also with the general geology and physiography of the district, and the various hypothesis brought forward to explain the observed facts.

## Physiography and Topography.

(Summary)

The Coast Range extends along the western coast of British Columbia; in the south it is separated from the Cascade Range by the valley of Fraser River, and in the north connects with the mountain systems of Alaska.

To the east of the Coast Range lies the Interior Plateau, made mostly of sedimentary and volcanic rocks. The Coast Range itself is made almost entirely of grano-diorite of Upper Jurassic age.

The Coast Range and the Interior plateau are the two main physiographic provinces of the area under consideration.

The Coast Range is rugged, with bold outlines and irregular erosion features. It is also of a greater average height than the Plateau to the east,

The plateau, as its name implies, is a more or less flat surface, with deep valleys cut in it, with soft rounded outlines, and is considerably lower in elevation that the Coast Range.

There is no sudden break between the Plateau and the Coast Range, as the Plateau gradually rises to the average level of the Range. The general uniformity of elevation, and the fact that streams cut through the Coast Range suggest the idea that the Coast Range and the Plateau behind were peneplanated and then gradually uplifted.

Glaciation has played an important role in the sculpturing of the present topography, and even now glaciers are still found in the Coast Range.

## General Geology.

The rocks of the Eastern side of the Coast Range may be subdivided into three main divisions. These divisions are:

(1) Pre-batholithic rocks.

(2) The Coast Range Intrusives and satellites.

(3) The post-batholithic rocks.

The Pre-batholithic rocks form the great bulk of formations to the east of the great Coast Range Batholith. They are both sedimentary and volcanic rocks, and range in age from Pre-Cambrian to Lower Cretaceous. As the Batholith was not intruded in the same time throughout its length it is impossible to say definitely where the border between pre-batholithic and post-batholithic rocks should be drawn. In some areas the Lower Cretaceous is definitely post-batholithic, while in others, the intrusives cut the lower members of the Lower Cretaceous, and so make it pre-batholithic. The older rocks, the Pre-Cambrian and the Palaeozoics are found in the north; the Pre-Cambrian in the Yukon and Atlin Districts, and the Palaeozoics go as far south as Stikine and Iskut Rivers. They appear again in the south as the Cache Creek and Bridge River series. From Stewart to Bridge River Area in the southern British Columbia the rocks are prevailingly Mesozoic. The Triassic is represented in the Stikine and Iskut Rivers areas in the north, and in the Bridge River and Gun Creek areas in the south.

The Jurassic is well represented throughout, and therefore represents an important period of sedimentation.

The main geological feature of the district under consideration is the Coast Range Batholith. The Batholith represents a large somewhat curved mass of grano-dioritic rocks extending from the Fraser River in the south well into Yukon territory, a distance of about 1000 miles. It is anywhere from 60 to 100 miles wide. Apparently it does not represent a single period of intrusion, but was intruded during several periods; it also varies lithologically from point to point, and therefore is composite both in age and in composition. The greater part of it, however, was intruded during the Upper Jurassic time and this period therefore is considered to be the period of intrusion. The earliest intrusion, however, probably occurred in Lower Jurassic or even Triassic age, and the separate intrusions of parts of the main Batholith, and smaller satellitic Batholiths continued into Cretaceous and possibly later.

The Batholith is made chiefly of light gray, granodiorite; but all gradations from gabbro to true granite exist. It is possible that, as the changes from one rock to the other are abrupt, the different material represents different times of intrusion.

The eastern and western contacts differ materially from each other, the main difference being the degree of metamorphism, and width of metamorphic zone; that on the eastern contact being quite narrow and less affected than the one on the western side. This difference had very pronounced effect on ore deposition, and is treated in considerable detail farther down.

The post-batholithic rocks have no importance from the view point of economic geology since the great majority of ore deposits are connected with the intrusion of the Batholith. But to make the description complete it may be said that the Upper Cretaceous is represented at several points, and that the Tertiary is represented mainly by volcanic flows, scattered in the Interior Plateau region. The Quaternary deposits consist mostly of glacial tills, clays and gravels, and some dyke rocks and lavas.

## Economic Geology.

### Summary.

The ore deposits along the eastern side of the Coast Range Batholith are invariably genetically connected with the Coast Range Intrusives or the smaller batholiths in the interior plateau. It is quite possible that these smaller batholiths are directly connected with the main batholith, but there is no evidence for this except the lithological similarity. As is stated, in the chapter on the Coast Range Batholith, the age of this intrusion is placed in the Upper Jurassic Time, although certain parts of the Batholith seem to have been intruded in Lower Cretaceous and Tertiary time. The satellitic batholiths in the interior are considered by some to be contemporaneous with the Coast Range Batholith, while others place them as late as the Laramide revolution. Probably there is quite a variation in age among them, and the Batholiths were intruded at various times from Jurassic to the Laramide and maybe later.

It is therefore reasonable to consider that the ages of different ore deposits also differ, within these limits. It may be well at this point to consider the interesting possibility that the type of ore deposit, i.e. its mineral content, may be influenced by its age, or rather by the age of the parent intrusive mass. There are indications that this may be the case.

Dr. S. J. Schofield has applied the zonal theory of formation of ore deposits, and has shown that the prevailing minerals on the eastern flank of the Coast Range Batholith are gold, silver, lead and zinc; and on the western flank--copper. This generalization is very valuable because it explains in a broad way the general conditions of ore deposition. But at any particular place the general law may be offset by local conditions. These local conditions are:

(a) The composition of granitic magma in this locality.

(b) The character of country rock.

(c) Distance of the deposit from the contact.

It is a well established fact, that the composition of the granitic magma varies considerably from place to place in the Coast Range Batholith. It is also well established that the Batholith is composite, and that different portions of it may be of different age. Dr. Schofield has distinguished three phases, the Britannia, the Columbia, and the Caledonia phase, and there may be more. It is quite possible that these different phases were characterised by different metallic minerals.

In the Whitehorse district, D. D. Cairnes said that the Contact Metamorphic Copper deposits are definitely older than the silver--lead--gold deposits. It is not possible that copper was brought by the earlier phases of the intrusion, which did not reach the present surface, thus producing only mesothermal and epithermal vein deposits? In some cases it is definitely shown, that the older granite had to be fractured before this second stage occurred.

If in a certain locality the intrusions are of a latter phase than the first, copper phase, the silver--gold--lead minerals would predominate.

The second point, the character of the country rock, does not seem to influence the deposits very much, as the same general type of deposits occur in different formations.

The third point,--distance from the contact is very important, but it is partly included in the first part--the age of intrusive; however, besides that, its effect is very simple, and results only in a local distortion of the main zonal arrangement. Thus copper deposits extend in a narrow belt almost all way along the eastern contact of the Batholith, although according to the general zonal arrangement this should have been a gold--silver--lead side.

But all this, as I said before, has effect only locally, while the zonal arrangement deals with the Batholith as a whole. And if we consider the producing mines, it will be clearly seen that the mines on the western flank are copper producers, while the ones in the east are producers of gold, silver, lead and zinc.

Another variation in mineralization is indicated in north-south direction. Thus the deposits in the north are prevailingly silver-lead or antimony-gold type, while to the south the gold quartz veins predominate in importance.

To sum up the peculiarities of the economic geology of the eastern side of the Batholith it is best to tabulate the different facts.

## Conclusions.

By studying the ore deposits on the eastern side of the Coast Range Batholith the following points were noted.

(1) The ore deposits are genetically connected with the Coast Range Intrusives which apparently range from Upper Jurassic to Tertiary in age. No ore deposits are found in the interior region, far away from the intrusives.

(2) The presence of mineralizing body, like the Batholith, is not sufficient in itself to produce commercial ore deposits. It is necessary in conjunction with it to have structural conditions which would tend to concentrate the available minerals at a point.

In connection with this shear zones and fissures appear to be especially important.

(3) No commercial deposits have been found close to the contact with the Coast Range Batholith.

(4) Satellitic batholiths are important, several deposits are found right in the batholiths, and other deposits often differing from the conventional types are found near the satellites.

(5) Deposits may be found in different formations, but certain gradation of "favourability" may be observed. Schofield grades the rocks as follows: 1. limestones, 2. granitic rocks, 3. diorite-gabbro family, 4. volcanic tuff, 5. quartzites, 6. slates.

The age of the formation, provided it is pre-batholithic, does not seem to play any part.

(6) The ore deposits of the Eastern contact may be divided into two main groups, (1) High temperature deposits, mostly contact metamorphic copper deposits, (2) Intermediate and Low temperature deposits, forming veins, with galena, lead, zinc, gold, silver, stibnite and iron as important metallic elements. There are indications that these two groups belong to two periods of mineralization, one immediately following the intrusion,--producing the copper deposits; and the other some time later, may be connected with the next movement of the magma, which did not reach the present surface, and so produced only deposits of intermediate or low temperature. The second stage might have occurred only after the core of the already consolidated magma was fractured by latter movements. D. D. Cairnes says: "From the evidence so far accumulated the age of the vein deposits cannot be definitely determined. That they are of considerably later age than the contact metamorphic deposits seems to be in little doubt. They are later than the period of consolidation of at least a part of the granitic magma." In Taku district Dr. Mandy considers that two periods of mineralization are indicated. It is also indirectly supported by the following words of Dr. Schofield: "The closing stages of the Coast Range Igneous activity has been most important in the formation of mineral deposits in B. C."

(7) The copper deposits of the eastern contact are confined to a narrow belt near the contact, mostly in limestones and in

the granite itself. They occur all along the contact from Whitehorse, through Atlin, Gun Creek, and Bridge River Areas to Coguihalla Area, mostly as contact metamorphic, but sometimes as vein deposits. None of them have been worked with any success.

(8) It seems that gold is more important mineral in the southern part of the area under consideration, and that silver-lead is more abundant to the north. This again brings out the possibility that intrusions of various age are likely to bring different minerals; and that difference in mineralization is brought about not only by zonal arrangement but by differences in the parent magma itself.

(9) Secondary enrichment played an important role in formation of workable ore deposits.

(10) From the commercial standpoint the Eastern side of the Batholith is essentially a belt of gold, silver, lead and zinc minerals. The occurrence of copper is interesting only geologically.

(11) All important ore deposits of the eastern flanks are true vein type occurring either in fissures or shear zones.

(12) In several cases the mineralized fissures have a very constant strike and dip, which in connection with their great length, indicates that these fissures were formed by compressional stresses. The N.E. or N.W. strike suggest that the ppessure was coming from the west.

(13) Dr. S. J. Schofield says:# "The fissures striking north-westerly are generally characterized by the presence of copper minerals, while those striking north-easterly are known for their gold, or silver-lead content."

# S. J. Schofield, "Fissures Systems in B. C." Bull. Can. Inst. Mining & Met. July, 1925.

# PART II.

## Ore Deposits of the Eastern Side of the Coast Range Batholith.

## General Topography and Physiography.

British Columbia lies in the Cordilleran belt of North America. The Canadian Cordillera are part of a great mountain system which extends along the Pacific Coast and is continuous from the northern part of North America to Cape Horn of South America.

The Canadian Cordillera are classified as follows:

Nomenclature of Mountains in Western Canada, 1918.

**Western Belt.**

| | |
|---|---|
| (a) Pacific System | (Cascade Range<br>(Coast Range. |
| (b) Insular System | (Vancouver Island Range<br>(Queen Charlotte Island Range<br>(St. Elias Range. |

**Central Belt.**

| | |
|---|---|
| (a) Columbia System (Gold Ranges) | (Selkirk Range<br>(Cariboo Range<br>(Monashee Range |
| (b) Interior System | (Fraser Plateau<br>(Nechako Plateau |
| (c) Cassiar System | (Babine Range<br>(Stickeen Range. |
| (d) Yukon System | (Yukon Plateau. |

Eastern Belt.

| | |
|---|---|
| (a) Rockies System | (Rocky Mt. Range<br>(MacKenzie Range<br>(Franklin Range<br>(Foothills Range. |
| (b) Arctic System | (Richardson Range. |

This classification can be simplified considerably for the purpose of this paper, since only the Eastern side of the Coast Range is considered. We may therefore make a general subdivision as follows:

(a) The Coast Range.

(b) The Interior Plateau.

The Interior Plateau will include all the region immediately east of the Coast Range proper, and such plateau regions as the Yukon, Nechako and Fraser Plateaus. That such general division is justifiable will be seen from further discussion.

## The Coast Range.

The Coast Range is made of several parallel ranges, trending northwest and southeast.

In general the Coast Range is very rugged, presenting a complex of needle like peaks, saw-toothed ridges, and deep canyon like gorges. In places the outlines are more rounded, or even flat, but as a whole the most characteristic feature of the Range is the irregularity and sharpness of its forms. This can be partly explained by the fact that the Coast Range is made almost entirely of the granitic rocks of the Coast Range Batholith, and as no bedding planes are present the weathering and erosion produces most fantastic forms.

The elevation of the Coast Range varies from South to North. In the south the Range is higher, and separate peaks reach the elevation of 12,000 feet, while in the north the elevations are around 5,000 feet.

This change in altitude, though great, is so gradual that it does not break the apparent uniformity of summit level, which, however bears no relation to structural features. This terrane has thus been considered by a number of geologists who have studied it topographically, to represent a peneplanated, or at least a mature to old surface of erosion, subsequently elevated.

## Interior Plateau System.

To the east of the Coast Range lies a wide upland region, which in various parts of the province is given different names such as Fraser Plateau, Nechako Plateau, Yukon Plateau, but is essentially the same physiographic province throughout, and can be best named as the Interior Plateau.

It is an undulating and in places hilly region about 3,500 to 4,000 feet in elevation.

In places some well defined ranges lie within this region and many single peaks and minor ranges rise above the plateau level.

Into this upland surface the main drainage courses have incised channels varying from 3,000 to 4,000 feet in depth, thus producing a very irregular topography. The summits of unreduced hills and ridges, lying between the waterways, mark a gently rolling plain which slopes toward the north and northwest.

When viewed from one of the adjacent peaks of the Coast Range the steep, narrow valleys are entirely lost to view and the intervening areas appear as a comparatively level plain broken only in a few places by low, rolling hills or an occasional sharp volcanic cone of recent origin.

In some areas the Interior plateau is more than ordinary ily level owing to the widespread flat lying Tertiary lava flows upon which lies a mantle of glacial till of surprisingly uniform thickness.

Cockfield, describing the plateau between Atlin and

Telegraph Creek says: "Well rounded or flat-topped hills, and wide, deep valleys are the characteristic forms. The plateau continues to the northwest where it is known as the Yukon plateau, but the southern part of the area is a vast lava plateau dissected to some extent, age of which relative to that of the plateau to the north is unknown; it may be considerably younger."

Along the northern portion of the Coast Range, the general summit level merges into that of the Yukon plateau, in a manner suggesting the synchronous planation of these two provinces, a view that is held by Brooks, Spencer, Cairnes and others; but during the various vertical movements that have affected these terranes, the uplift has been greatest along the axis of the Coast Range and least along that of the Yukon plateau province, which terrane is thus given the contour of a huge flaring trough whose median line is, in a general way marked by the present position of the Yukon River from near its headwaters in northern British Columbia to Bering Sea.

A third physiographic feature is recognized by some writers, notably V. Dolmage and J. R. Marshall[#], to which they give the name "Transitionsl Zone."

Quoting Marshall, "Between the Coast Range and the Interior Plateau there is a transition zone characterised by rounded, flat-topped mountains whose elevations gradually change from 3,000 feet in the east to 6,000 and even 7,000 feet in the west. The axes of the ridges in this transitional zone all trend at right angles to the axes of the Coast Range, i.e., northeast and southwest, and the ridges appear to project from the Coast Range as a series of spurs. The width of this zone is approximately 15 miles. Each ridge is a separate massif separated from its neighbours by broad, steep sided "U" shaped valleys, also running northeast and southwest. The smooth, rounded outlines and gentle east slopes of these several blocks, together with their complete isolation, form one of the striking topographic features of the district.

The ridges forming this transitional zone undoubtedly once formed part of the Coast Range and possessed features similar to it. Following the partial retreat of the continental ice-sheet, which covered even the highest peaks in the

# J. R. Marshall. Sum. Rept. 1925. p. 144
V. Dolmage. Sum. Rept. 1924. p. 61.

area and left in its wake more or less smoothly rounded summits, huge tongues of ice remained on the higher summits, and in the pre-existing valleys.

These coalesced to form an ice-sheet of lesser extent than that of the continental ice-sheet at the time of its maximum development. Well-defined glacial terraces and smoothly truncated slopes on almost all of these ridges at approximately 2,800 feet above the valley bottoms are evidences of the effective action of these ice tongues in carving the present topography.

Glaciation has been the dominant factor in moulding the present topography throughout the area."

Another interesting feature of this zone is, that numerous streams start in the Coast Range proper, flow eastward through the "Transition Zone," and then turn abruptly and flow west cutting the Coast Range, to the Pacific Ocean.

The fact that the main drainage channels cut through the Coast Range is a good argument in favour of peneplanation, and the gradual uplift of the area.

The smaller streams flowing eastward are probably more recent, and flow east because the Coast Range has higher elevation that the Plateau region; this drainage was undoubtedly developed after the uplift. The theory that the main drainage system antecedes the uplift is further supported by the fact that numerous of these east flowing secondary streams are captured by the main streams and thus made to flow westward.

The higher elevation of the Transition Zone, can possibly be explained by two factors.

(1) The rocks have been hardened by the heat during the intrusion of the Batholith, and so withstood the erosion better.

(2) The intrusion of the Batholith uplifted the sedimentary and volcanic rocks in its immediate vicinity.

## Geological History of B. C.

Farther down a table of formations, compiled from different places along the eastern contact of the Batholith, and a brief description of these formations will be found. From these it may be clearly seen that a fairly complete geologic record exists in the Plateau region of British Columbia.

The lower Paloeozoic is rather poorly subdivided, but starting with Devonian, every period is well represented.

It is not the object of this thesis to go into details of the geological history of the district, but a brief description of the main points is necessary.

It was early recognized by G. M. Dawson, that one of the main problems to be solved in British Columbia, is to establish the source from which the sediments came. G.M. Dawson then brought forward his hypothesis that the Shuswap terrane represented the original source of sediments. Similar views, in a general way, were later held by Daly. However, the explanation was not quite satisfactory, because of the evidence that the sediments came from the west.

Then S. J. Schofield presented his hypothesis of the Cascadia Land in the Pacific, which agrees very well with the field evidence.

The Geological Record of the Cordillera in Canada, by S. J. Schofield.
Transactions of the Royal Soc. of Canada, vol. XVII. ser. iii, 1923. P. 79.

"This hypothesis supports the occurrence of a land mass, Cascadia, since Beltian time in an area now occupied by the waters of the Pacific Ocean.

(1) During Beltian times a narrow basin of sedimentation stretched northwestward through the eastern part of British Columbia to the Yukon and Alaska as defined by Daly.

(2) A Palaeozoic and early Mesozoic basin of sedimentation extended from this old land of Cascadia eastwards to the Canadian Shield. The eastern shore line of Cascadia during these and later periods, stretched in a northwesterly direction just west of the present coast line of North America. The northern border of Cascadia extended in a westerly direction just south of the peninsula of Alaska.

(3) During the Jurasside revolution, four great mountain chains appeared in this basin.

(a) The Vancouver Island--Queen Charlotte Island Range. The Coast Range of British Columbia.

(b) The Sierra Nevada Range.

(c) The Selkirks and their extension northwards and southwards--into the Bitterroot and Clearwater Ranges.

(d) The Alaskides on the northern border of Cascadia.

(4) The granito Batholiths which accompanied the Jurasside revolution were invaded during Upper Jurassic times.

(5) Basins of Cretaceous sedimentation occurred on both flanks of these Jurassic mountains.

(6) These basins in Canada at least, were affected by the Laramide revolution, which was accompanied also by igneous intrusions.

(7) Small Tertiary basins of sedimentation with local outpourings of volcanic material marked the Lower Tertiary which was brought to a close by local mountain building and igneous intrusion at the end of Oligocene.

(8) Down faulting and down folding probably at the close of the Miocene, have buried the ancient land mass of Cascadia beneath the waters of the Pacific Ocean. Vast floods of lava were outpoured in British Columbia and Oregon.

(9) The vulcanism of late Tertiary, Pleistocene, and the present periods is associated with the sinking of Cascadia, which has caused and is causing a period of tension along the Pacific Coast."

This covers all the important phases of the geological history of British Columbia, and no more need be said about it.

## The Coast Range Batholith.

The dominant geologic feature of the western part of British Columbia is the Coast Range Batholith. For this reason it is considered separately from the other formations. It is of a paramount importance in relation to the ore deposits, since the great majority of ore deposits along its western and eastern contacts are in direct connection with the intrusion of this enormous granitic mass.

It ranges from the International boundary in the south to the Yukon district in the north. It is about 100 miles wide in the south and gradually tapers northward. The average width may be taken as approximately 60 miles.

In composition the Batholith varies considerably. The variation is more pronounced transversely than longitudinaly.

The core is usually grano-diorite, but nearer the contact true diorites, quartz-diorites, and quartz-monzonites occur. In places true granites have been reported; but in general it may be said, that unsufficient data is still available in regard to the petrology of the Batholith. It is now considered by most geologists that the Batholith is composite, and was intruded not as a whole mass, but rather gradually; the final result being a composite batholith, which may be regarded as several smaller interlocking batholiths.

In Southeastern Alaska the composition varies from quartz-diorite in the western part of the Batholith to a quartz-monzonite on the eastern flank, the core being typically grano-diorite. This indicates that successive rock belts from west to east contain increasing amounts of alkali feldspars and quartz, and decreasing amounts of basic constituents.

Also, accompanying this change, there is a marked increase in silica content as the eastern border is approached. These changes are not at all gradual but take place rather abruptly. This feature would tend to suggest the existence of a group of closely interlocking Batholiths.

In the Atlin District Cairnes[#] reports that a typical specimen from the eastern border is on the border-line between a grano-diorite and a quartz-monzonite.

Dalmage[@] in describing about 150 miles of the Batholith concluded that there was a tendency for the more acid types to lie along the central part of the Batholith.

Another feature exhibited by the rocks is that of a gneissoid character which is fairly common. This structure, a primary one, was probably formed before and during the process of consolidation. Two important factors[ø] which give raise to this gneissoid character are:

(1) the parallel orientation of the mineral particles, and

(2) the relative segregation of the light and dark minerals.

In addition to this there are also the injection and reaction gneisses.

[#] Cairnes D. D. Geol. Surv. Can. Mem. 37, p. 57 - 59.

[@] V. Dalmage, Geol. Surv. Can. Sum. Rept. 1922, P. 16 A.

[ø] Buddington, A. F. N. S. Geol. Bull. 800, p. 238.

The Coast Range Batholith is composite not only due to its composition but also due to different times of intrusions. F. A. Kerr Says: "The Batholith in the Stikine River area is composite in that it was developed during several intrusive periods rather than one."

By looking at table corelating the different formations it is quite clear that the Batholith, in its main portion at least, was intruded during the Upper Jurassic time. And this is the general opinion of all geologists who worked on the eastern contact of the Batholith. However, there are indications that some portion of the Batholith may have been intruded before and after this main period of intrusion. So F. A. Kerr# says: "The composite nature of the Batholith clearly indicates that its development took place over a long period of time. Granitic masses cut Palaeozoic sediments and Triassic volcanics, and dykes that may have originated with such masses penetrate even Upper Cretaceous sediments. The basal member of the Jurassic series contains an abundance of granitic boulders, clearly indicating that part of the Batholith had been developed and unroofed before that period. Although there may have been intrusions of even Palaeozoic age in this section, it is believed that development of the Coast Range Batholith proper began early in the Triassic and continued throughout the greater part of the Mesozoic era. Possibly dying phases of this igneous activity may have contributed in some small way at even later

# F. A. Kerr, Geol. Surv. Canadian Sum. Rept. 1928, p. 28.

periods. In the map area it has been possible to separate the Batholith into sections that are clearly of markedly different ages, but there does not appear to be any systematic arrangement of these sections."

It may be pointed out, however, that the occurrence of granitic boulders and pebbles in the Lower Jurassic is not conclusive evidence in regard to the time of the intrusion of the Batholith, as the boulders may have easily come from the old mountains of Cascadia.

It may be well to remember here that D. D. Cairnes, placed on the same evidence the Laberge series, as post intrusive, which later Cockfield has definitely shown to be pre-intrusive, and occupying Lower Jurassic.

Much better evidence is available, that some portions of the Batholith were intruded in post Jurassic times. V. Dolmage# states: "The age of Coast Range Batholith is not definitely known. The Batholith has been found in several localities to cut the Hazelton formation which contains Middle Jurassic and possible Upper Jurassic fossils, thus indicating the age of the Batholith to be not earlier than Upper Jurassic. In the vicinity of Tatlayoko Lake and in Bridge River map area, small Batholiths, similar in composition to the Coast Range Batholith and situated only a few miles from it, cut rocks containing Lower Cretaceous fossils. In Taseko Lake district what appears to be the main Coast Range Batholith cuts a thick

# V. Dolmage, G. S. C. Summ. Rept. 1925, p. 161 A.

series of coarse, fragmental volcanic rocks in which the writer found plant remains, determined by Prof. Edward W. Berry, of Johns Hopkins University, to be of Cretaceous age.

In the Bella Coola--Tatla area the main Batholith intrudes, at many places, rocks containing fossils of Lower Cretaceous age. This evidence proves that this part, at least, of the Batholith is younger than the lowest Cretaceous, and the evidence found in Tatlayoko Lake, Taseko Lake and Bridge River districts strongly suggests that much of the eastern part of the Batholith is of post-basal Lower Cretaceous."

One interesting general feature with the Coast Range Batholith, is that as we go north, the Batholith cuts progressively older rocks.

Referring to the map, it is seen that in the south, with the single exception of Coguihalla and Bridge River areas, the Batholith cuts Mesozoic rocks, from Portland Canal northwards Palaeozoics appear; and finally in the Atlin district and in the Yukon the Batholith cuts Pre-Cambrian rocks.

This is important both from physiographic and structural viewpoints.

As has been mentioned before, the Coast Range Batholith was greatly responsible for formation of ore deposits along its contacts, and also for metamorphism of the rocks with which it came in contact. In regard to both these points it is best to quote Dr. S. J. Schofield.#

# S. J. Schofield. Ore Deposits of British Columbia, Geol. Surv. Canada, Mem. 132, p. 63.

"There are two main mineral belts in British Columbia separated from each other by an elongated and curved area of granite Batholiths, belonging mainly to the early part of Mesozoic era. This mass includes the Coast Range Batholith and the majority of the Batholiths occurring in the southern part of British Columbia. The belt which follows along the Pacific Coast, including the island fringe on the western side of the Coast Range Batholith, may be called the Pacific mineral belt; that along the eastern side of the same Batholith, the Interior mineral belt. It will be remarked that the two belts differ in the mineralogical composition of their ore-bodies. The ore deposits of the Pacific belt are sought mainly for their copper content; those of the Interior belt are sought mainly for their gold, silver and lead content......"

"The reason for the separate occurrence of copper on the one border and of gold, silver, and lead on the other border of the great complex of igneous intrusions is not at once apparent. A fact that may throw some light on the subject is that copper ore deposits are not confined to true fissure veins, but resemble impregnations of the country rock by minerals such as pyrite, pyrrhotite, chaleoprzrite, which indicate conditions of high temperature and pressure, even bordering on those of contact deposits, whereas the gold-silver and silver-lead deposits are usually, though not always, associated with fissure veins filled under conditions of a moderate temperature and pressure, the gold-silver being characterized by the presence of such minerals as gold, silver, argentite, pyrargyrite, etc., in a quartz gangue and the silver-lead by galena, zinc blende, tetrahedrite in a gangue of calcite, siderite and sometimes quartz......."

"Not only is there a contrast between the ore deposits on the two sides of these Batholitic masses, but also a contrast in the degree of metamorphism exhibited by the pre-batholitic rocks......."

Dr. Schofield offers the following explanation for the facts cited above:

"It is well known that the roof of a Batholith is always intensely metamorphosed by the ascending hot solutions from the underlying molten magma. On the other hand the deeper and more vertical contacts do not show contact matamorphism to the same degree not only as regards intensity but also as regards areal extent. If the Batholith and the intruded rocks are exposed in a plane normal to the vertical plane of the Batholith, the plane would consist of a core of granite surrounded by a contact zone of approximately the same width.

On the other hand, if the Batholith and the intruded rocks are cut obliquely, the roof rocks will be preserved higher up on the low side, whereas on the high side the highly metamorphosed roof rocks will be entirely removed and the contact will be undulating and fairly even. The contact metamorphic zone will be very narrow on the high side and very wide and irregular on the low side. In addition the low side will be marked by many roof pendants of all sizes, whereas the high side will be almost free from them. Examination shows that the two sides of the Coast Range Batholith correspond to the above distribution as can be seen by the following table:

| Eastern Flank. | Western Flank. |
| --- | --- |
| 1. Smooth flowing contact. | 1. Very irregular contact. |
| 2. Few roof pendants. | 2. Many roof pendants. |
| 3. Very narrow metamorphic zone. | 3. Wide metamorphic zone. |
| 4. Slates, sandstones & tuffs characteristic. | 4. Schists and gneisses characteristic. |
| 5. Moderate temp. conditions. | 5. High temp. conditions. |
| 6. Gold-silver and silver-lead deposits of medium temperature and pressure. | 6. Copper deposits of high temperature and pressure. |
| 7. Intruded rocks of roof type, gneisses and schists reach the same elevation as the unaltered rocks along the steeply pitching contact. | |

"These facts show that erosion on the western side of the Coast Range Batholith has not entirely removed the roof rocks, and that the contact between the Batholith and these rocks is almost flat. This conclusion is supported by the presence of a large number of roof pendants and the very irrigular contact between the granite and the intruded rocks.

On the eastern flank, however, erosion has exposed a deeper portion of the Batholith, the roof being entirely removed, so that the margin of the Batholith plunges very steeply beneath the intruded rocks. Also, the contact is smoothly undulating and the roof pendants are absent.

This points either to greater uplift on the eastern

# TABLE OF FORMATIONS.

| | Aishihik Lake District. Summ. Rept 1926 | Sixtymile and Ladue rivers Area Summ. Rept. 1921 | Atlin and Whitehorse Districts. | Stikine & Iskut Rivers Area Summ. Rept. 1928-29 | Salmon River Area Mem. 132 | Prince Rupert to Burns Lake Summ. Rept. 1924 | Groundhog Coal Area Summ. Rept. 1912. | Eutsuk Lake, Whitesail & Tetla Lakes. Summ. Repts. 1924 & 1925. | Tetla Bella Coola and Chilko Lake. Summ. Repts. 1924 & 1925 | Gun Creek and Bridge river Mem. 130 and S.R. 1928. | Coquihalla Area. Mem. 139. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pleistocene and Recent | Superficial deposits Dyke rocks. | Superficial Deposits | Superficial Deposits, Basalt, andesite & tuffs. | Lavas. | Gravels & sands Glacial drift. | Boulder clay and gravel. | River deposits Glacial deposits. | gravel, silts glacial till. | Till, clays, river gravels, white silts gravels. | Recent alluvium glacial drift. | |
| Tertiary | | Acid volcanics. Newer volcanics. Kenai series: shale, s.s. conglom. & lignite. | s.s, shale, tuff. Acid volcanics, and porphyries. Basic Newer volcanics. | lava flows, fine congl. s.s., shale, conglom. | | | | Basalt and tuff. | Basalt and Andesite quartzite. Granodiorite, gabbro | Basalt and Andesite flows. | |
| U.Cretaceous | | | | thin layer of volcanics. conglom, ss, shale. | | | Bulkley eruptives Granodiorite. | | | | |
| L.Cretaceous | | Coast Range Intrusives | Granitic Intrusives. | Coast Range Intrusives. | | Skeena formation argillite, s.s, shale, conglom. with granodior. pebbles. | | | | Coast Range Intrusives granite to grano-diorite. | |
| Jurassic. | Coast Range Intrus. older volcanics. | older volcanics. | Coast Range Intrusives. older volcanics. Tantalus conglom. Laberge series. | Coast Range Intrusives. calcareous limestone. volcanics conglomerate. | lamprophyre dykes Coast Range Intrusives Premier sills. Hess form. - slates. Salmon R. " - conglom. Bear R. " - agglom. & tuffs. | Coast Range Intrusives. Hazelton group. (volcanics, argillites, quartzites) | Skeena series Hazelton group. | Coast Range Intrusives. Hazelton group. Andesitic & Rhyolitic lava l.s. and breccias. | Coast Range Intrus. s.s. conglom, argillite, breccia Coast Range Intrusives | volcanic rocks mostly pyroclastics. Eldorado series argilite, s.s, l.s, conglom. Augite-diorite & andesite. | Coast Range Intrusives. |
| Triassic | | | | Coast Range Intrusives argillites, shale, limestones, volcanics. UNCONFORMITY | | | | | Andesite, basalt, s.s., volcanic flows, breccia, tuff. argillite, limestone. | Cadwallader series. | Ladner Group. Tulameen Group. |
| Permian | | | Limestone more or less dolomitic | limestone. | | | | | | | |
| Carbonif. | | | | | | | | | | Bridge Riv. series. | Cache Creek Group. |
| Devonian. | | Taku Group. Gold series. | Taku Group slates, qtzite Gold series, peridotites | metamorphosed sediments, shists, slates, quartzites. | | | | | | | |
| Silurian. | | | | | | | | | | | |
| Ordovician. | | | | | | | | | | | |
| Cambrian | | | | | | | | | | | |
| Pre-Cambr. | Yukon Group. schists, gneiss, l.s. | Mount Stevens Group. | Mt. Stevens Group. shist, gneiss, limestone. | | | | | | | | |

## Description of Formations.

### Pre-Cambrian.

The oldest rocks along the eastern contact of the Coast Range Batholith are found in the Aishihik Lake, the Whitehorse district and the Atlin district.

These rocks fall into two groups, the Yukon group and the Mount Stevens group, and were identified by Cairnes# as probably Pre-Cambrian in age.

The Yukon group of the Aishihik district includes both sedimentary and igneous types, and represent probably different ages within the Pre-Cambrian, but they have been so highly metamorphosed that in many cases it is difficult to ascertain the nature of the original rocks and consequently, to determine their history. The group is represented by mica schist, quartz-mica schist, chlorite schist, granite gneiss, and crystalline limestone. This group forms, for the greater part of the area, the rocks into which the Coast Range Batholith was intruded, and, therefore, the degree of metamorphism is high.

The Mount Stevens group includes a number of members widely different in appearance, composition, and possibly in age. They are, however, all old and so extremely altered that their mode of origin and succession are obscured. They consist of sericite and chlorite schists, greenstone schists, sericitic quartzites, gneissoid quartzites, hornblende gneisses, and crystalline limestones.

# Cairnes D. D. G. S. C. Mem. 67, p. 40 - 44.

No fossils have been collected from any of the members of the Mount Stevens group and there is consequently no direct evidence as to their age, but from the evidence afforded by later igneous rocks which cut them, they are in all probability the oldest rocks in the district. Cairnes# in his later work along the international boundary, north of Yukon river, was able to demonstrate that the schistose rocks of that region were pre-middle Cambrian and in all probability Pre-Cambrian in age.

# Cairnes D. D. G. S. C. Mem. 67, p. 40 - 44.

Devonian.

Two groups of rocks, occurring in the Whitehorse and Atlin district, the gold series and the Taku group have been provisionally assigned to the Devonian. The Gold series occurs in two relatively small areas in the Whitehorse district, the Wheaton district and on a ridge just north of Mount Michie. This series, which is composed principally of pyroxenite and peridotite, has a trend parallel to that of the Batholith in this district and is characterized by reddish-brown weathering of its rocks which make it most conspicuous. The rocks of this series also occur in the Atlin district, and a description of them is given in Part III, on Atlin district.

Cairnes# proposed the name Taku for a series of cherts, slates and cherty quartzites, which have been referred to the

# Cairnes, D. D. G. S. C. Mem. 37, p. 52 - 55.

Gwillim, J. C. G. S. C. An. Rept. Vol. XII.

Cache Creek group of the southern interior of British Columbia.

In the Whitehorse district these rocks occur principally in the vicinity of Tagish Lake. The members of the series grade into one another, and, in places, are much folded and disturbed.

These rocks underlie limestones which are probably Carboniferous in age, and, therefore, have been considered as Devonian in age.

Another group of rocks, which might be grouped as Devonian, outcrop in the Stikine River area. This group is considerably folded and metamorphosed and consists of a great thickness of slates, schists, quartzites, and limestones.

Kerr in his description does not definitely put in the Devonian but merely places it as older than Permian.

Carboniferous.

The Carboniferous rocks occur in the northern section of the area under consideration in the Aishihik Lake district, the Whitehorse district, and in the Atlin District. In the south they occur in the Bridge River area and the Coguihalla area.

Cockfield in the Aishihik Lake district and D.D.Cairnes in the Atlin District and the Lewes and Nordenskiold Rivers Coal District found outcrops of crystalline limestone which can possibly be classed as Carboniferous in age.

An important member of the Carboniferous rocks has been called the Braeburn Limestones. This name was first applied in the Braeburn-Kynocks area by D. D.Cairnes,in mem.5 of the G.S.C.

These limestones occupy a large area in the vicinity of Taku Arm, Windy River, and Tagish Lake of the Atlin and Whitehorse districts.

These limestones are generally finely textured and range in colour from greyish blue to almost white.

Mr. Dawson collected Fusilinae from the limestones which extend along the east side of Windy Arm, showing these beds at least to be Carboniferous, so the whole series is thought probably to belong to this age, although no other fossil remains of a definite character have been discovered.

The Carboniferous members which occur in the southern section of the area under consideration appear in the Bridge River and Coguihalla areas.

The Bridge River series comprises nearly seventy-five percent of the rocks of the map area. This series estimated to be about 9,500 feet thick, is composed mainly of contorted, thin-bedded cherty quartzites separated by thin films of argillite schist, dark, coloured altered agrillites, crystalline limestone lenses, and arenaceous schists; flows of black and green metabasalt. In the vicinity of the intrusive rocks the rocks have been metamorphosed to quartz mica schist, squeezed conglomerate and sandstone, phyllite, talcose, sericitic and chlorite schists.

The Coguihalla is represented in the Carboniferous by the Cache Creek group. This group is represented by three distinct rock types which differ greatly in their mode of origin. These types are volcanic greenstones, cherts, and fine grained, argillaceous and calcareous sediments. The greenstones are composed, for the most part, of andesitic lava flows which contain some pyroclastic deposits. The cherts and sediments are generally so intimately interbedded that a definite division is not feasable. The thickness of these rocks by C. E. Cairnes#, is about 16,000 feet, 11,000 of which is composed of greenstones, and the remainder of cherts and other sedimentary rocks. A considerable portion of the area occupied by these rocks has been partly concealed by younger rocks.

# Cairnes, C. E. Mem. 139.

## Permian.

Kerr, in summary reports for 1928 and 1929, describes limestones in the Stikine and Iskut Rivers areas, which he places in the Permian. These are the only Permian rocks occurring along the eastern contact of the Coast Range Batholith.

## Triassic.

The Triassic is represented in the Stikine and Iskut Rivers area, in the Chilko Lake and the Bridge River districts by the Cadwallader series and in the Coquihalla area by the Tulameen group.

The rocks in the Stikine and Iskut Rivers area, according to Kerr, are argillites, slates, limestones, coarse breccias and conglomerates, and volcanics. This series is cut by the Coast Range Batholith.

The Cadwallader series occurs as a narrow belt along the western part of the Bridge River map area.

It has a total thickness of 2,100 feet, and is comprised of great thickness of basaltic and andesitic greenstone, conglomerate, sandstone and shales with subordinate thin-bedded limestones and dolomite. A series of rocks# occur in the Chilko Lake district are very similar to the Cadwallader series and can be correlated to them.

The Tulameen group of the Coquihalla area comprise a large part of the map area in the southeastern section and also a small portion in the extreme northern end. Primarily they are composed of sediments and volcanic rocks. The former are principally gray or black slates, which include a few thin limy beds. The volcanic rocks form the bulk of the group and are commonly dark green, and include schistose, as well as massive varieties. Alteration has progressed far in all the schistose volcanic rocks, and, to a less extent, in the more massive types. The secondary minerals consist of chlorite, and edidote, p zoisite, green amphibole, calcite. One of the members of this series is a crushed granite porphyry occurring as belts of sills up to a several yards in width.

# V. Dolmage, Chilko Lake and Vicinity. Sum. Rept. 1924.

## Jurassic.

Jurassic was a very important period in British Columbia. Great thicknesses of sedimentary rocks were deposited in a large basin of sedimentation, that once occupied the whole of British Columbia and Alberta and extended at least as far east as Moosejaw.

Volcanism was also active; but the most important event from the viewpoint of economic geology was the intrusion of the great Coast Range Batholith. As this event was of paramount importance to formation of ore deposits in British Columbia it is described under a separate heading.

In Aishihik Lake district the Jurassic is probably represented by a group of rocks known as the older volcanics which consist of green to red andesitic rocks with associated tuffs and breccias. Their age is rather indefinite but they are found to be younger than the Yukon group of Whitehorse district and, as they are cut by the granitic intrusives wherever the two come in contact they are probably early Jurassic in age and may even be older.

Portions of the older volcanics are definitely intrusive into the Laberge beds, and may therefore be considered younger. Cockfield considers them to be Lower or Middle Jurassic.

The Whitehorse and Atlin districts are represented here by the Laberge series, the Tantalus conglomerates, and the older volcanics.

The Laberge series is the most extensive geological terrane in Taku Area belt, and its members outcrop in a general way throughout the central, southwestern and northwestern portions of the district. The group of hills east of Taku area and south of Graham Inlet; the greater part of the area north of Fantail Lake and south of Tutshi Lake, on the west side of Taku area; and Sunday Mountain and the western portion of Taku mountains, are all largely composed of these rocks.

The Tantalus conglomerates are probably best included with the Laberge series, because they overlie the Laberge rocks conformably.

In Wheaton district, where the most detailed work done in the district was undertaken, and where the best exposures of typically marine sediments occur, Cairnes# recognized a threefold division of the Laberge beds, as follows, or if, as in the present case, the Tantalus conglomerate be included, a fourfold division:--

Tantalus Conglomerate:-- Thickness 1,800 ft.

Conglomerate, shale, sandstone, and coal.

Laberge Series:--

| | | | |
|---|---|---|---|
| Upper beds---thickness | | 1,500 ft. | sandstone |
| Middle beds-- | " | 1,700 ft. | shales,s.s.,arkose. |
| Lower beds--- | " | 1,800 ft. | arkose and tuffs. |
| | total | 6,800 ft. | |

Following Cockfield:--

"Fossils have been collected from the Laberge beds in Wheaton, Atlin, Whitehorse and Tantalus areas. In the collections from Tantalus area, three forms were specifically identified, viz., Trigonia dawsoni, Nerinea maudenesis, and Rhynchonella orthidioides. The specimens were regarded by Whiteaves as Jurassic or Cretaceous but two if not all three of these species are now regarded as Jurassic forms.

# Cairnes D. D., Wheaton Distr. G.S.C. Mem. 31, p. 54 - 56.

Fossils collected by Gwillim in Atlin District were reported on by Stanton as follows: "These may possibly be Triassic, but I think it more probable that they are early Jurassic. They are certainly not as late as the Cretaceous."#

"Thus it appears to be very well established## that the Laberge beds range in age from Middle Lower Jurassic to Lower Middle Jurassic."

The older volcanics are fairly abundant in these districts along the margin of the Coast Range intrusives and are similar in character to those found in the Aishihik District.

The Salmon River area is represented in this period by three main formations. The Bear River formation, a volcanic member which is over 2,000 feet in thickness and consists for the most part of agglomerates and tuffs. The Salmon River formation, which is about 300 feet thick, consists mainly of fine conglomerate bearing pebbles of the underlying volcanic member and lies conformably between the Bear River formation and the Nass formation. The Nass formation consists mainly of argillites which show a distinct slaty clearage especially as the contact of the Coast Range Batholith is approached. The thickness of this formation is thought to be slightly more than 1,000 feet.

Intruded along the bedding plane of the tuffs of the Bear River formation are sills of grano-diorite porphyry,

# Gwillim, T. C. G. S. C. Ann. Rept. XII, pt. 3, p. 23 - 27.

## W. E. Cockfield & A. H. Bell, G.S.C. Mem. 150, p.22.

varying in thickness, but in no case more than 500 feet thick. Schofield and Hanson#, in their report on the district say "The name Premier sills is given to a series of tabular igneous bodies that were intruded along the bedding planes of the tuffs of the Bear River formation, when these tuffs were in horizontal position. Later the sills and tuffs were tilted into their present position and were subsequently exposed by errosion."

The area between Skeena and Stewart and also the Eutsak Lake district are represented in the Jurassic by the Hazelton group. The rocks here are chiefly tuffs, breccias, and flows, and have been divided into four formations:

The lower volcanic division consists of fine grained, well-stratified, red tuffs 500 feet thick lying conformably below marine sediments. Below these red tuffs there is about 4,000 feet of andesitic tuffs, breccias and lava flows.

The Middle sedimentary division consists of argillites, quartzites, and argillaceous quartzites in beds usually a few feet thick. This division is about 500 feet thick and abundant fossil evidence gathered from it places it in the middle Jurassic.

The Upper volcanic division is chiefly composed of lava flows and thick massive beds of coarse breccia, all of an andesitic nature, and varies in thickness from 2,000 - 3,000 feet.

The Upper sedimentary beds, which are about 1,000 feet thick, are composed of argillite and lesser amounts of quartzite, argillaceous quartzite, and conglomerate.

# Schofield S. J. and Hanson, G. Mem. 132, p. 21.

Some of the middle strate hold several coal seams.

Pre-batholitic rocks of Jurassic age are absent from the Chilco Lake district but occur again in the Bridge River area and in the Coguihalla district.

The occurrence in the Bridge River area is in the form of augite-diorite stock enclosed within the Cadwallader series and forms the chief country rock of the gold-quartz veins in the region.

The Ladner group of rocks are the dominant rocks of the Jurassic in the Coquihalla area and they may be divided into two groups. The lower group which occupies over ninety percent of the area covered by the series, is composed chiefly of slaty rocks, and is known in that district a "slate belt." The upper group is conformable with the rocks of the slate belt and is composed of conglomerates, tuffaceous greywackes, and an equal proportion of more slaty rocks.

The rocks which have been under discussion and which have been classed as Jurassic in age have striking resemblances to the Porphyrite group of Dawson, and as they contain the rich gold and silver deposits of the eastern contact belt, a great deal of work has been done on correlating them to Dawson's Porphyrite group# which he defined in 1875 as follows:

"This name may be provisionally employed to designate a series of rocks, chiefly feldspathic and often porphyritic, though also including diorites of varied texture, the reference of which to any of the groups formerly defined, seems uncertain.

# Dawson, G. M. G.S.C. Dept. of Progress 1875-76, p. 250.

They are best seen about Tatlayoco Lake, where they overlie uncomformably the Cascade Crystalline rocks, and appear to underlie the beds of the Jackass Mountain series. The whole of the rocks of this group seems to be made up of igneous origin, though some of them may owe the arrangement of their material to water."

Schofield and Hanson,# in a summary of a number of facts concerning this correlation, bring out the following facts.

(1) "The areas where the fossil evidence concerning the age of the Porphyrite group is most complete are those described by Dawson in the vicinity of Tatlayoko Lake and by Malloch in the groundhog coal field, and in both cases a Jurassic age is indicated.

(2) No evidence is submitted by any of the workers of a structural unconformity between the Porphyrite group and the overlying Skeena series, which is Kootenay in age, although in many places a heavy conglomerate containing pebbles of the underlying Porphyrite group marks the base of the Skeena series.

(3) The Porphyrite group in the vicinity of the Coast Range Batholith contains a great thickness of andesitic and andesite breccia which in the east gives way to waterlaid sediments consisting of sandstones and shales with tuffs. The regional strike of the Porphyrite group is northwest-southeast and is of Cordilleran trend. This points to a linear source of supply for the Porphyrite group in the area now occupied by the Coast Range Batholith.

# Schofield, S. J. and Hanson, G., Mem. 132, G.S.C. P. 20.

(4) Dawson's conclusions of 1876 that the Porphyrite group bridges the gap ordinarily found between the Jurassic and the Cretaceous is substantiated to some extent.

(5) The grano-diorite of the Coast Range proper cuts the Porphyrite group, and pebbles of this grano-diorite are found in the Lower Cretaceous of Fraser river# and in the Laberge series of Northern British Columbia and the Yukon##.

The presence of these pebbles in the Lower Cretaceous rocks supports the conclusion that the grano-diorites of the Coast Range were intruded and solidified before the Lower Cretaceous strata were deposited. This dates the intrusion of the Coast Range Batholith as post-Porphyrite group and pre-Lower Cretaceous; therefore, in very late Upper Jurassic time. Hence the Porphyrite group must be older than the Lower Cretaceous beds exposed in Fraser River and the Yukon."

This synopsis sums up, very clearly, the relation of these sedimentary and volcanic beds with the Porphyrite group and also their relation to the Coast Range Batholith.

The Post Batholithic rocks are of comparatively little importance to economic geologist, since the great majority of ore deposits are connected with the intrusion of Coast Range Batholith and its satellites. However, for the sake of completeness, it was deemed advisable to mention the Post-Batholithic--Cretaceous and Tertiary deposits.

# Dawson, G. M., G.S.C. Sum. Rept. Vol. VII 1896, p. 147 - 156.

## Cairnes, D. D., G. S. C. Mem. 31, 1912.

Cretaceous.

Upper Cretaceous rocks occur in the Stikine and Iskut Rivers area, these rocks are mostly conglomerate and sandstone with a thin layer of volcanics on top. In the Salmon river area, Lamprophyre dykes are considered to be lower Cretaceous in age.

An area of post-batholithic Cretaceous rocks is found near Skeena River, and is known as the Skeena formation. This formation consists of argillites, sandstones, shales and conglomerate with pebbles of grano-diorite.

In the Tatla Bella Coola and Chilco Lake areas, the Lower Cretaceous sediments are considered by Dolmage to be Pre-batholithic and consist of sandstones, conglomerates, argillites and breccia. Farther south the Cretaceous rocks are represented by volcanics, mostly pyroclastics and some andesite and basalt. These volcanics are cut# by Coast Range Intrusives, consisting of granite, quartz monzonite, diorite, quartz-diorite, etc. The intrusives are placed as Upper Cretaceous.#

#Mem. 130. G. S. C. and Sum. Rept. for 1928..

Tertiary.

The Tertiary in British Columbia was a period of great volcanic activity. Throughout the Interior Plateau region are extensive flows of these Tertiary volcanics. The volcanics are both of the Acid and Basic type; according to the present knowledge of the area the acid volcanics are more important in the north; in the south beginning with Eutsuk Lake and further to the south the flows are chiefly basaltic and andesitic. This fact can be well observed on the included table of formations.

Quaternary.

The Quaternary with the exception of a few dyke rocks, and lavas is almost entirely represented by glacial and fluvial deposits of muds, tills, and gravels. The deposits are scattered all over British Columbia, particularly in river valleys and Lake flats.

## Economic Geology.

In describing the economic geology of the eastern contact of the Coast Range Batholith it was considered best to start from the north, and move southward along the contact. The Atlin district is left out of this description, as it is described in greater detail in the second part of this paper.

It was decided not to describe separate claims and separate properties, but rather compile the geology, and thus present a more generalized description of the eastern contact. Unfortunately, in the available literature, the geology is treated only locally, very often in relation to a single group of claims, and so considerable amount of work was necessary to separate the geologically interesting and important facts from such irrelevant facts as number of claims, capitalization, etc. It was also decided to pay more attention to the producing, or producing in the past, properties, and pass over the small prospect claims, so as not to overload this essay with apparent and not well established facts.

One of the most interesting ore deposits in the north is that of Keno Hill, Mayo District, Yukon.#

"Mayo district lies within the Yukon plateau. The hills are prevailingly flat topped and separated by broad deep valleys. Keno Hill is a typical wedge-shaped ridge, lying between Lightning, Christal, Faith, and Laduc Creeks. The greater part of Mayo district is underlain by schists, which

# Geology and Deposits of Keno Hill, Mayo District, Yukon. W. E. Cockfield, Sum. Rept. 1923, p. A.

are intruded by sills and laccoliths of greenstone, and by dykes and sills of granite porphyry and quartz porphyry. The schist series consists of quartzite, quartz-mica schist, graphito schist, sericite and chlorite schist.

The greenstones intruding this schist series are themselves largely sheared and altered. The quartz and granite porphyries are massive and fresh in appearance and are believed to be offshoots from a granite mass which outcrops some miles to the east, and which probably extends under a considerable part of Mayo district.

The quartzite, quartz-mica schist, and graphite schist are believed to belong to the Nacina series, described by McConnell in his report on Klondike district. This series has been referred by Cairnes to the Pre-Cambrian.

The ore deposits of Keno Hill area are practically all fissure veins, that is, they represent vein material deposited in fault fissures. The faults which gave rise to these veins are all of normal type, and this applies also to post-mineral faults.

The veins may be divided into two classes, which may be termed longitudinal and transverse,# depending on whether they follow the trend of the strata or cut across the strata. These two fault systems represent two stages of mineralization, the longitudinal faults being the earlier.

# Cockfield, W. E. G. S. C. Sum. Rept. 1920, P. 3 - 4.

Stockwell, C. H. Galena Hill, Mayo Distr. Sum. Rept. 1925.

The earlier mineralization consists of quartz, arsenopyrite and pyrite. After being filled, the longitudinal fissures remained planes of weakness affected by subsequent movements. When the transverse fissures were mineralized, they probably acted as the main circulation channels for the ore bearing solutions and considerable amounts of the ore minerals were deposited in them. The chief minerals of the second stage are siderite, freibergite, galena and sphalerite.

The following minerals were identified from the Keno Hill deposits.

| | |
|---|---|
| Native elements | Silver. |
| Sulphides | Argentite, galena, sphalerite, covellite, chalcopyrite, pyrite, arsenopyrite. |
| Sulpho-salts | Pyrargyrite, freibergite, polybasite, jamesonite. |
| Oxides | Quartz, limonite, manganite. |
| Carbonates | Siderite, calcite, cerussite, malachite, azurite |
| Sulphates | Barite. |

## Genesis.

By far the greater number of veins on Keno Hill represent a simple filling of fault fissures. Replacement of wall rock operated only to a slight extent, except in the Sadie-Treadwell vein. The ore minerals in most cases are fastened to the polished walls of the fault fissures, but do not project into them. It is not believed, however, that at the time of mineralization the faults existed as open fissures 4 to 6, or more, feet wide, but rather that the small openings formed by the faults grew in width as the ore minerals were deposited. It has been demonstrated that the force exerted by a crystal in growing is equal to that required to crush it when formed. Whether this force was active or whether the force exerted by the mineralizing solutions was sufficient to open the fissures, is unknown.

In certain cases there is evidence of solution of wall-rock. This is shown in No. 9 vein of Keno Hill, Limited, where large, drusy cavities lined with crystals of siderite and galena occur in the foot wall.

Replacement of wall-rock in the Sadie-Treadwell vein, presents many characters not exhibited in the other veins of the area. This vein, or rather "mineral zone," follows an old line of weakness represented by quartz-arsenopyrite veins.

It was probably re-opened by a fault which branches frequently and re-unites, with cross-faults between the main fractures. The country rock in the vicinity was badly shattered and the jointing emphasized, and the ore-bearing solutions penetrated each minute crack, widening it, and, in places, replacing the country rock. In places the mineral zone is a network of tiny veinlets of siderite enclosing fragments of country rock. As a rule these fragments lie in their original positions, but in certain instances the particles of rock were rotated. These veinlets represent on a small scale what has taken place on a large scale. Veins of ore project out into the country rock, in many cases at right angles to the main trend of the ore zone. Examination of thin sections has shown that these veins grew by replacement of the country rock. Fragments of quartzite or residual masses of granulated quartz and feldspar are included in siderite. In some cases, also, individual grains of quartz are seen with siderite projecting into them.

It is consequently believed that the Sadie-Treadwell ore zone represents a fault complex along which the deposit grew by widening of fissures as the minerals were deposited, and by replacement.

Source of Mineralizing Solutions.

The veins in Keno Hill area traverse quartzite schists and greenstone alike. The greenstones must, therefore, have been consolidated sufficiently to permit of fracturing at or before the time of mineralization. Moreover, the greenstone bodies by reason of their small size would be unlikely to hold solutions for long periods, particularly after the development of the faults. The acid dykes carry small amounts of galena, pyrite, and tetrahedrite. As these were not injected until long after the greenstones were consolidated, and even sheared, it is doubtful if the greenstones had any effect on their mineralization.

The presence of certain of the ore minerals in the quartz and granite porphyries suggests that these rocks may have been the source of the ore deposits. It is not thought, however, that these small bodies of acid intrusives caused the extensive mineralization of Keno Hill, but rather that they and the mineralizing solutions had their origin in a larger body of magma. A large mass of granite occurs to the east of Keno Hill, and other masses occur along a line running northwest and southeast. It is probable that these represent the peaks of a Batholith which extends under much of Mayo area. The age of these granites has not been closely determined, owing to the lack of sedimentary rocks. They have usually been considered contemporaneous with the Coast Range intrusives which in Yukon range from Jurassic to Upper Cretaceous. The ore deposits are younger, but cannot be placed more definitely with regard to age.

## Whitehorse District.

All known ore deposits of Whitehorse district have probably formed later than the intrusion of the Coast Range Batholith. This intrusion probably took place in late Jurassic time and possibly continued through a part of Lower Cretaceous time. Two contrasting types of deposits occur,--contact metamorphic and hydrothermal.

McConnell, R. G. "Whitehorse Copper Belt" Geol.Surv.Can. 1909.

Cairnes, D. D., Geol. Surv. Can., Mem. 31, 1912.

Cairnes, D. D., "Economic Possibilities of Yukon" Can. Inst. Met. Trans. vol. XVIII, P. 63, 1915.

W. E. Cockfield and A. H. Bell. Geol. Surv. Canada, Mem. 150 "Whitehorse District, Yukon."

## Classification of Deposits.

| Deposit. | Occurrence | Mineral Association. |
|---|---|---|
| Antimony Silver | In Coast Range Intrusive rocks and in Chieftain Hill andesites and volcanic breccias. | Gangue chiefly quartz; barite and calcite subordinate. Stibnite, sphalerite, jamesonite, arsenopyrite, tetrahedrite. |
| Gold-Silver | Chiefly in Coast Range Intrusives, also in schists of Mount Stevens group. Occur as fissure fillings. | Quartz, calcite, galena, pyrite, chalcopyrite, gold sylvanite. |
| Silver-Lead | In Laberge rocks, as metasomatic replacements, geodes and vugs common. | Quartz, calcite, galena, arsenopyrite, sphalerite, pyrite, chalcopyrite. |
| Contact-Metamorphic. | At contact of Coast Range Intrusives with country rock, chiefly limestones. | Magnetite, specularite, chalcopyrite, quartz, calcite, epidote, actinolite, garnet, wollastonite, limonite, azurite, malachite occur in oxidized zone. |

The contact metamorphic deposits are chiefly confined to a narrow belt about 15 miles long, parallel to Lewes river in the vicinity of Whitehorse. The larger aggregates of metallic minerals occur in limestone or along the contact of limestone and granitic rocks, but numerous small bodies and scattered grains are found wholly enclosed in granite and many are at a considerable distance from the limestone. The development of non-metallic minerals is probably greater in the granite than in the limestone, and the areas affected are wider and more extensive. In places the original contact is completely obscured owing to the replacement of both rocks by similar minerals. The extensive and simultaneous mineralization of both the intruding and intruded rock may be explained by assuming that it was effected by hot solutions moving upward and that it took place after magma had solidified to some depth. The replacement of ore material of granitic dykes connected with the main granite area is also significant in this connection.

Contact metamorphic effects such as the marmorization and silification of limestone were noted by Dr. W. E. Cockfield at various points in the eastern half of Whitehorse district, but nowhere were associated deposits of metallic minerals in evidence. The only other ore deposit of this type known in the area is that situated on the Fleming claim in Wheaton district. The ore materials occur in hornblende gneisses of the Mount Stevens group (possibly of Pre-Cambrian age) near their contact with the Coast Range Intrusives.

It is clear from the published date that there has been a period of mineralization in Whitehorse district closely following the intrusion of the Coast Range grano-diorites. Ores of resulting type are generally supposed to have been intruded under conditions of high temperature and high pressure and in this respect contract strongly with other types of ore deposits in the region. The available evidence points to a late Jurassic or early Cretaceous age for the intrusion of the grano-diorite, and hence it may be concluded that this first metallogenic epoch also belongs in the Upper Jurassic.

The ore deposits of Whitehorse district, other than the contact metamorphic deposits, have been classified by Cairnes into three divisions, gold-silver, antimony-silver, and silver-lead veins. Of these, the first class is "of wide distribution in southern Yukon and constitutes the major portion of the ore deposits, not only of Wheaton district but also of Windy area district to the southeast."

The genesis of these three types of vein deposits has been discussed by Cairnes in his memoir on the Wheaton district. The conclusions reached are:

(1) That they have all been deposited by ascending hydrothermal solutions emanating from an intrusive magma below.

(2) That they belong in the "upper vein zone," that is, they have been deposited under conditions of relatively low temperature and pressure.

These conclusions are based on: (1) mineral associations; and (2) the fact that the wall-rock is altered only slightly.

From the evidence so far accumulated the exact geological age of the formation of the three types of vein deposits cannot be definitely determined. That they are of considerably later age than the contact metamorphic deposits seems to be in little doubt. They are younger than the period of solidification of at least a part of the granitic magma, and they antedate the eruptions grouped under the head of Newer volcanics. This evidence tends to show a late Jurassic to early Tertiary age for these deposits, and depends upon the length of time required for the cooling and solidification of the Batholith. That the interior of the Batholith remained in a heated and fertile condition for a considerable period of time there can be little doubt. The three different types may or may not be contemporaneous; a simultaneous origin can well be presumed by ascribing their distributions in zones to differences in the parent magma, a case of magmatic segregation.

The distribution of ore deposits in Whitehorse district shows the significant fact that they are all close to the borders of areas of granitic rocks. This fact should be borne in mind in future prospecting work in Whitehorse district.

Farther south on the other side of the provincial boundary, lies the Atlin district. Since its geology and mineral deposits are treated in considerable detail in Part III of this paper, we will pass over it at present.

It may be well to say at this place though, that in general there is much similarity between the deposits of Atlin and Whitehorse districts. This is no doubt due to the great similarity of the general geology of the two districts.

## Taku River Area.

Not very much geological work has been done in Taku River Area, and what has been done, was mostly in the way of reconaissance work. However, the more important features are already discernible.

The Coast Range grano-diorite batholitic rocks constitute the bulk of the lower area of Taku River, from its mouth to within 5 miles west of the International boundary-line. There the contact crosses the river, striking in a northerly direction, and apparently follows this course about 6 miles west of the Tulsequah River. The rocks east of the contact consist mainly of the older igneous groups, probably Triassic or Jurassic, with some limestone and altered sedimentaries. This series is intruded by younger rhyolite, dacite, and felsite dykes and sills which in turn are intruded by basic rocks of lamprophyre type.

Folding and evidence of acute stress is observed near the contact west of the International boundary. Easterly this condition is gradually minimized, and the structure, well defined in certain localities, assumes the more stable and definite character that would be conducive to the confined circulation of mineralizing solutions and the deposition of sustained ore-bodies.

Taku River District, B. C. F. A. Kerr, Sum. Rept. 1929.

Taku River Area, J. T. Mandy, Minist. of Mines, Rept. 1929, P. C. 133.

Major fracturing, accompanied in places by well-defined shearing, has occurred along both a north-easterly and a north-westerly direction.

The mineralization of the chief ore-bodies, according to Dr. Mandy is of two main types:--

(1) Copper, zinc, lead, and iron sulphides carrying appreciable gold and silver values in a barite, calcite, quartz gangue.

(2) Antimony and iron sulphides, with very minor quantities of copper, lead and zinc, but carrying decided gold values, and practically negligible silver contents in a quartz gangue.

## Ore-Bodies of Type 1.

The Tulsequah and Manville ore bodies belong to this type. These occurrences are characteristic replacement ore-bodies in shear-zones. In places, generally in the central portions of the zones, the sulphides have totally replaced the sheared rock.

Two main directions of fracturing occur, one striking north-easterly and the other north-westerly.

The shear-zones occur in what appears to be an inter-formational sheet of altered pyritized rhyolite in an andesitic country-rock of dense texture. The formation has been subjected to comparatively gentle folding along north-south striking axes.

The ore bodies of this type are probably medium to low temperature deposits, formed at an appreciable depth below the old surface from sluggishly circulating solutions. Replacement probably emanated from the centre of the zones with lateral temperature segregations. Mineral deposition is probably related to the concluding period of the Batholith intrusion.

Ore-Bodies of Type 2. (Stibnite gold)

The ore-bodies of this type are characterised by a main metallic content of stibnite, with accompanying pyrite and very minor quantities of galena, in a fine-grained quartzose gangue. This stibnite occurs in a massive granular form in reticulated structure in the vein matter, and also as a fine dissemination of minute needle crystals in the gangue-matter. The pyrite is in fine grained scattered dissemination through the gangue. The typical ore-bodies of this type appear to be confined to a diabasic rock, cut by numerous felsite and small quartz-rhyolite dykes. They seem to favour the area somewhat closer to the Batholith contact than the ores of type 1. The deposits occur in well-defined replacement shear-zones along the course of felsite dykes. These dykes have probably formed lines of weakness in the surrounding country-rock along which the fracturing and shearing has been readily carried and sustained. The typical deposits are characterised by a high gold content and abnormally low silver values. Adulteration with arsenic and copper seems to be practically absent. These ore-bodies are probably of low temperature origin, formed comparatively near the surface. The structure indicates that they were formed from rapidly circulating solutions covering at least two impulse periods. Although the definite genesis of these deposits could not be established in the field, they are probably related to the final thermal activities of the batholithic intrusion and later in origin than the ore-bodies of lead-zinc-silver type.

## Stikine and Iskut River Area.

This large and little studied area extends from Taku to about Unuk River, a distance of some 150 - 200 miles. On the west it is bordered by the Coast Range Batholith, to the east it is underlain by unclassified Palaeozoic and probably some Mesozoic rocks. It seems that all along the contact, and farther from it, forming a belt about 25 miles wide, metallic minerals have been found. This is to be expected. However, because of the relative inaccessibility of the region, comparatively little prospecting and development was done.

The work that has been done shows that the district is mineralized, and that more work is warranted.

F. A. Kerr in his report on Stikine River area says: "There are four different kinds of deposits found in the area:

(1) magnetite-pyrrhodite

(2) zinc

(3) lead

(4) copper.

In some places the various kinds are completely isolated, whereas in others two or more kinds may be present intermingling or grading into one another."

F. A. Kerr. Sum. Rept. 1926. p. 14 G. S. C.
" " " " 1929, p. 11 G. S. C.
" " " " 1929, p. 30 G. S. C.

"Deposits of the magnetite-pyrrhotite type appear to lie directly on the igneous rock or in it, rather than in the sediments. Altered sediments are generally found associated with these, though in some places the mineralized masses seem to occur as lenses in the granite itself."

This is then a contact metamorphic type of deposit.

"Galena and sphalerite usually occur intermingled or closely associated.......
The mineralization is generally in the sediments at or near the contact.......
Some deposits are clearly replacements of the sediments by gangue and sulphides."

All these deposits are very small, and probably have no commercial importance.

The copper type of deposit, represents a lens-like body of chalcopyrite in bedded limestone. It is also small and does not exceed a few feet in any direction.

From what has been said it seems, that all these deposits are too small, and too patchy to be of any great interest.

However their position along the eastern contact of the Batholith, indicates, that this portion of the contact is mineralized, and that therefore there is no reason why larger deposits should not exist.

It seems clear though, that the presence of mineralizing body, like the Batholith, is not sufficient to produce large ore deposits. It is necessary in conjunction with it to have structural conditions which would tend to concentrate the available minerals at a point.

## Salmon River Area.

The Salmon River Area with the neighboring Bear River and Stewart River area has received considerable amount of attention. This is probably due to the fact that the district is fairly accessible and that several promising ore deposits have been discovered,--such as Premier, Big Missouri, and Dolly Varden.

Dr. S. J. Schofield#, in his report on the district in Mem. 132 of the Geol. Surv. of Canada thus summarises the economic geology of the area:

"In the mines of Salmon River area, the values up to the present have been mainly in silver and gold, although many of the deposits contain economic quantities of galena, zinc blende, chalcopyrite, and pyrite in a quartz gangue, which constitute what is known as a complex siliceous ore.

The mineralization of the district is associated with the closing stages of the Coast Range igneous activity--that period which has been so important in commercial ore deposition in British Columbia."

The ore deposits are connected with the "Premier sills." These are tabular masses of quartz porphyry intruded between the bedding planes of the tuffs of the Bear River formation. Their maximum thickness is in the neighborhood of 1,300 feet. The rock is grey massive, and in hand specimens shows in some cases phenocrysts of orthoclase and small, irregular masses of quartz in a fine-grained ground mass.

# S. J. Schofield and G. Hanson, G. S. C. Mem. 132.

The sills were intruded prior to the mountain-building, and, therefore, while the tuffs were horizontal.

Since the time of intrusion, they have been subjected to folding along with the containing rocks, and now occupy varying positions which deviate from the horizontal.

"The ore deposits are of three main types:

(1) Base metal type

(2) Silver-gold type

(3) Gold type.

Base Metal Type.

The usual mode of occurrence of this type is that of replacement and dissemination in certain beds of tuffs and tuffaceous conglomerates, although veins occur containing the base metals. The deposits are roughly tabular, since they correspond in strike and dip with the beds with which they are associated.

In Big Missouri ridge, there beds strike along the ridge and dip at a low angle to the west and since the slope of the hillside down to the Salmon River glacier is steeper than the dip of the tuffaceous beds, the mineralized zones form long, linear outcrops on Big Missouri ridge. These weathered outcrops, coloured brown by the presence of limonite, are a marked feature of the ridge.

The minerals present in these bands are pyrite, chalcopyrite, sphalerite, and galena in a gangue of quartz. Nearly all the examples of this type occur on Big Missouri ridge. The groups of claims from south to north are as follows: Indian, Big Missouri, Hercules, and Forty-nie, all of which contain mineral deposits similar to the description given above.

The alteration or metamorphism of the rocks on Big Missouri ridge makes their determination very difficult, if not impossible in many cases, so that the contact between the quartz porphyry and the tuffs was not definitely recognized, and it is certain that over the greater part of Big Missouri ridge this contact is buried underneath the tuffs and the tuffaceous conglomerates.

## Silver Gold Type.

The ores of this type occur in veins and vein-like replacements in quartz-porphyry and at the contact of the porphyry and the tuffs. The large ore-chutes are lenticular. The minerals present are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, freibergite, pyrargyrite and other sulpho-antimonides and sulpho-arsenides, native silver, and gold. The gangue is rather abundant and is almost entirely quartz. The ore-bodies of the Premier mine belong to this type.

The native silver is found almost entirely associated with faults and shear zones and was not seen in the unfractured vein material. In addition the fractures show a strong downward movement of water and contain considerable amounts of limonite. The silver occurs as thin leaves or plates filling small cracks in the ore. Some occurs in hair like forms (wire silver) and nuggets in small quartz drusses. The localization of the silver to the immediate vicinity of the fractures points to a secondary origin for the native silver, or, in other words, the native silver is due to secondary enrichment.

## Gold Type.

A single ore-body in No. 2 tunnel of the Premier Mine is of this type. It is a siliceous, heavy sulphide deposit. Quartz and pyrite are the predominating minerals. Small quantities of chalcopyrite, sphalerite, and galena are present. Assays show high values in gold, but practically no silver."

## Origin of the Ores.

Dr. Schofield considers that the ore bearing solutions emanating from the granite during the final stages of cooling entered the fissures and shear zones and at favourable localities formed ore-bodies of commercial size.

The ore-bearing solutions which formed the ore bodies on Big Missouri ridge evidently spread laterally along favourable horizons in the tuffs and tuff conglomerates. In other cases, as at the Premier Mine, the ore-bearing solutions found the sheared contact between the quartz porphyry sills and the tuffs a favourable place for ore deposition.

The evidence available points out, that this occurred probably in Upper Jurassic time.

## Alice Arm District.

The area is on the eastern border of the Coast Range Batholith and the mineral deposits are part of the great mineralized belt which extends with few interruptions along the eastern contact. An hiatus occurs in the belt at Nass River where no mineral deposits are known.

Alice Arm is at the southern end of that part of the belt that extends northward and that includes the mineral deposits of Portland Canal, Unuk and Stikine rivers, and Atlin.

The mineral deposits of Alice Arm district can be classified under five headings:

(1) Molybdenite deposits.

(2) High grade silver-bearing veins in argillite.

(3) Silver lead deposits in volcanic rocks.

(4) Sphalerite deposits.

(5) Chalcopyrite deposits.

The high grade silver bearing veins in argillite are quartz veins 6 feet or less in width, which are mineralized with primary silver minerals. The silver-lead deposits in volcanic rocks are vein like, usually much wider than 6 feet, consist of quartz, barite, and country rock, and are mineralized with silver-bearing galena and tetrahedrite. Owing to secondary enrichment some of the deposits of this type contain rich silver ore.

(George Hanson. "Mineral Deposits of Alice Arm District." Geol. Sur. Canada, Sum. Rept. 1928, p. 27.)

The sphalerite deposits are vein-like and consist of quartz, calcite, country rock, and resin coloured sphalerite. The deposits vary considerably in size and are usually in sedimentary rocks.

The chalcopyrite deposits are vein-like and consist of quartz, country rock, and chalcopyrite. The deposits are mostly in volcanic rocks. In many respects they closely resemble the sphalerite deposits and may be closely related to them in origin.

Hanson concludes, that the deposits have not been studied sufficiently yet, to be able to formulate any satisfactory theory to account for the various distinct types of mineral deposits.

The deposits are very numerous, and considerable work has been spent on development, but so far the Dolly Varden Mine is the only one which produced an appreciable quantity of metal (1,300,000 oz. of silver).

But some as Hanson says, have outstanding potentialities.

## The Skeena and Neighboring Districts.

A large body of pyrite with associated chalcopyrite, occurs some distance up Ecstall River, but except for this occurrence very few mineral deposits of importance are known between Prince Rupert and Terrace.

North and south of Terrace along the eastern border of the main body of the Coast Range Batholith, mineral bearing veins are numerous. No large ore bodies are known, but the veins though narrow are commonly very rich. They are quartz-sulphide veins containing free gold, and the value in most instances is almost entirely in gold.

A short distance east of Terrace, bornite-free gold quartz veins occur, as well as other deposits of a more complex nature. East and west of Skeena River, in the neighbourhood of Fiddler and Lorne Creeks, gold quartz veins are again the rule. In the vicinity of Hazelton are numerous small to moderate-sized veins containing a great variety of minerals, among which may be mentioned gold, jamesonite, walframite, scheelite, molybdenite, safflorite and the common minerals of copper, lead, zinc, silver, iron, and arsenic.

On Hudson Bay mountain the veins are mostly small, and are mainly of the silver-lead type. Veins containing arsenic and gold are also present.

Hanson also mentions a vein near Francois Lake which contains bitumen and phosphate minerals, but as little is

(G. Hanson. "Prince Rupert to Burns Lake, B. C."
G. S. C. Summ. Reptl 1924, p. 38.)

known about it, nothing more has to be said.

Near Hazelton occurs an interesting deposit of Tungsten, described by M. E. Hurst, in G. S. C. Summ. Rept. for 1924.

This deposit, together with these of arsenic, copper, lead, etc., occur in Rocher Deboule mountains, southeast of Hazelton. The deposit occurs along a shear zone, in the grano-diorite. Presence of such minerals as wolframite and scheelite indicates high temperature and pressure conditions.

The interest of this deposit lies mostly in the fact, that deposits of other than conventional type may be expected, farther from the main Coast Range Batholith, in connection with the satellitic batholiths, and that therefore the satellites warrant more attention than has been heretofore given them.

Another mineral deposit, described by Lang# is also connected with a small satellitic batholith.

The deposits constituting the Owen Lake mine, are veins filling shear zones and fractures in the micro-diorite and in included blocks of anderite.

A single vein, and replacement deposits in the matrix of conglomerate, are exposed on a prospect on Tsa-lit mountain. Because of its proximity to the granite stock on Mount Nadina, this mineralization is believed to be associated with the granitic intrusion.

The veins are roughly parallel, filling shear-zones and fissures in micro-dioriti. They vary from mere stringers to

# A. H. Lang. "Owen Lake Mining Camp." G. S. C. Summ. Rept. 1929. p. A. p. 62.

irregularly mineralized shear zones of 5 to 6 feet wide.

There are two general types of mineralization: chalcopyrite-sphalerite and sphalerite-galena, but gradations between the two types occur, and as yet no zonary arrangement has been observed.

The chalcopyrite-sphalerite veins have high silver content, and a moderate gold content. The gangue minerals are: rhodochrosite, quartz, chalcedony, and barite.

The sphalerite-galena type contain moderate silver values and a low gold content.

The veins are of the epithermal origin, which is supported by the following evidence:

(1) Propylitization is a typical alteration accompanying epithermal deposits.

(2) Chalcedony is a characteristic gangue mineral of epithermal veins.

(3) Metallic and gangue minerals are of epithermal type.

The age of the micro-diorite stock, with which the deposits are associated, is considered by Jang to be post-Lower Jurassic.

Quoting Marshall:--

"As yet very little prospecting has been done in this region, and only along parts of the trunk streams. The discoveries so far made prove that mineral deposits occur and that there exists at least one well-defined mineralized zone of considerable extent.

Gold, silver, lead, zinc, and copper have been found in veins on Chikamin ridge, south of Whitesail Lake, and on Sweeney mountain north of Tahtsa river.

The silver-lead-zinc deposits on Chikamin and Sweeney mountains are the important discoveries so far made.

The silver-lead deposits on Chikamin ridge are in beds of altered and sheared waterlain tuffs which outcrop near a number of small intrusive masses.

Those of Sweeney mountain occur both in the sedimentary and volcanic members. The most interesting showing, that in the Emerald group of claims deserves more detailed description.

Sweeney mountain is formed of rocks of the Hazelton group, lithologically similar to rocks of the same group on Chikamin Ridge. West of the westernmost peak of the mountain, the Coast Range intrusives invade the members of the Hazelton group. The mineral deposit occurs in beds of sheared and altered tuffs and argillites.

Quartz fills fractures in the tuffs, forming veins up to 18 inches wide. The quartz is fractured in all directions,

J. R. Marshall, Whitesail-Tahtsa Lakes Area,
G. S. C. Summ. Rept. 1924, p. 52 A.

and these fractures are filled with cubical and steel galena, and subordinate amounts of pyrite, chalcopyrite and sphalerite.

The total length of the deposit from adit portal to the crest of the ridge is at least 2,000 feet, and the difference in elevation about 900 feet.

## From Eutsuk Lake to Chilco Lake.

The extensive, several hundred miles long, tract of land from Eutsuk Lake to Chilco Lake has been very poorly prospected, and no great discoveries have been made. There are only three properties that deserve some attention. These are:

(1) A deposit of auriferous arsenopyrite, situated about 2 miles north of Perkins Peak.

(2) A deposit of Hematite 1 mile south of Perkins Peak, and

(3) The Morris mine or the Tatlayoko Lake Gold Mines Ltd.

The gold-arsenic deposit is situated at an elevation of 7,500 feet near the brow of the steep, northward-facing side of the deep valley immediately north of Perkins Peak.

(J. R. Marshall, Eutsuk Lake area, B. C. G. S. C. Summ. Rept. 1925, p. 144 A.)

(V. Dolmage. Tatla-Bella Coola Area, B. C. G. S. C. Summ. Rept. 1925, p. 155 A.)

(V.Dolmage. Chilco Lake, B.C. G.S.C. Summ.Rept. 1924, p.70 A)

The deposit is reached by a branch trail leading from One Eye Lake to Perkins Peak. The ore bearing veins occur in a series of sedimentary rocks composed of black argillites, dark brown argillaceous sandstones, and fine, cherty conglomerates overlain conformably by thick beds of coarse volcanic breccia which form the summit of Perkins Peak. The strata strike north 60 to 70 degrees east and dip southeast 40 to 45 degrees. Fossils found in the near vicinity of the veins are reported to be of Lower Cretaceous age. The rocks are cut by the Coast Range Batholith, the contact of which makes a U shaped bend around the southwest side of Perkins Peak and is 2 miles southeast, 4½ miles southwest, and 1½ miles northwest of the deposits. A small diorite stock, less than one-fifth of a mile in diameter, similar to and probably a part of the Batholith, outcrops in a small cirque ¾ mile southeast of the deposit.

The mineral is in large quartz veins or silicified zones which strike north and are nearly vertical and, therefore, extend up the steep valley wall.

Arsenopyrite is disseminated in quartz. The showings are quite large, but the amount of contained gold unfortunately is small.

A deposit of exceptionally pure Hematite occurs in a large cirque on the southeast side of Perkins mountain. It is situated near the bottom of the cirque on the north side at an elevation of 7,500 feet. It is reached by a good trail from One Eye Lake or Klina Ekin flats, both on Bella Coola trail.

The Hematite occurs in a bed of tuff, which, with other types of volcanic rock, is interbedded with Lower Cretaceous sediments. The tuff bed is 10 to 30 feet thick and is, in places, completely replaced by Hematite. Small veins of quartz and specularite cut it and adjoining beds. The beds strike south 70 degrees east and dip 20 degrees south. The sedimentary and volcanic beds lying between the Hematite deposit and the contact of the Batholith, which is about 1 mile to the south, are thoroughly impregnated with pyrite, and along certain well developed shear-zones near the iron-bearing tuff the rocks are completely altered to talc and sericite schist containing a large amount of pyrite.

The most important deposit near Chilco Lake is the Tatlayoko Lake Gold Mine, better known as the Morris mine.

The deposit is situated 3 miles southeast of the south end of Tatlayoko Lake. It is at an elevation of 5,900 feet, just above timber line, and 3,200 feet above the lake.

The deposit consists of three quartz veins outcropping on the sides of a steep rocky gulch. The veins cut Triassic sediments, chiefly argillites and fine sandstones, but with one thin bed of fine cherty conglomerate. A short distance northeast of the veins is a stock of quartz diorite probably related to the Coast Range Batholith, the edge of which is situated a few miles to the south. Many dykes cut the sediments and range in composition from diorite to basalt, the majority being basaltic. Many, if not all, are younger than the veins.

The veins consist of quartz, through which is disseminated fairly evenly arsenopyrite, pyrite, stibnite, and two or three undetermined minerals visible only under the microscope, but which, judging from the assays are probably silver bearing.

These minerals are closely associated with the stibnite which tends to occur in the central parts of the veins, whereas the gold, arsenopyrite and pyrite are more plentiful along the margins. The rock adjoining the veins has been altered to a very dense greyish green material resembling chert.

## Taseko Valley.

Limonite is found in the Taseko Valley. The deposits are situated in the upper portion of the valley and in the valleys of several tributaries, the total area in which the beds of limonite are found being about 50 square miles.

The rocks underlying the limonite deposits are an assemblage of basaltic flows and pyroclastics with some quartz diorite porphyrite dykes and sills, the whole known as the "Taseko formation."

This volcanic formation of Tertiary age, overlies unconformably the previously eroded surface of the great Coast Range Batholith.

The deposits known as bog-iron ore, are situated in seven different localities. They consist of sheets of brown limonite of varying shape, size, and thickness, built up of thin layers of brown, cellular, and generally loose-textured limonite lying parallel to the surface of the ground on which they rest. The limonite when dug forms a large percentage of lines; most of it breaking into pieces of less than half an inch, and much of it breaking to the fineness of sand.

The iron is derived from finely divided pyrite which impregnates greatly silicified and sericitized tuffs of the Taseko formation. The iron sulphate solations formed by the oxidation and leaching of this pyrite trickle down the mountain slopes and deposit at the first favourable location, building up a bed of limonite.

J. D. MacKenzie. "The limonite deposits in Taseko Valley." G. S. C. Su m. Rept. 1920, p. 42 A.

## Gun Creek Area.

There are no producing mines in the Gun Creek area at present, but several interesting copper and gold deposits occur. The most important deposits of Gun Creek area, are four low-grade copper-gold deposits, situated in the Coast Range Batholith along its contact with the Cretaceous volcanics.

The mineralized part of the Batholith is a normal granodiorite composed of fresh andesine, hornblende, biotite, orthoclase, and magnetite.

The segregation of the ore minerals in this particular part of the Batholith seems to be dependent on the development of peculiar orbicular structure. The granodiorite occurs as nodules or "pillows" from 10 to 18 inches in diameter, having well formed, smooth surfaces, but no visible internal radial or concentric texture. The interiors of the nodules consist of normal massive granodiorite similar to the adjoining non-orbicular parts of the Batholith. The internodular portions are made up of miarolitic granodiorite together with quarts and chalcopyrite. The miarolitic cavities are lined with well-formed crystals of quartz, orthoclase, laumontite, and chalcopyrite. In places there is considerable chalcopyrite disseminated in the quartz, and occassionally blebs of this copper mineral up to 3 inches in diameter. Chalcopyrite is also sparsely disseminated in the marginal portions of the nodules. Small amounts of pyrite are associated with the chalcopyrite.

(V. Dolmage. "Gun Creek Area, B. C." G. S. C.
Summ. Rept. 1928. p. 78 A.)

No gold or silver minerals have been observed in the sulphides, though assays show these metals to be present in small amounts. The deposit is exceedingly low grade averaging 1% in copper.

## The Bridge River Area.

"The most important ore deposits of the Bridge River area, and in fact the entire Lillooet mining division of British Columbia, are the gold-quartz deposits."

But this is not the only type of deposits and the deposits may be classified as follows:--

(1) Gold quartz deposits.

(2) Placer gold deposits.

(3) Silver copper deposits.

(4) Antimony deposits.

(5) Chromite deposits.

(6) Nickel-iron deposits.

(7) Non-metalliferous deposits.

In this paper we are only concerned with the metalliferous deposits of the lode type, and so will disregard the placer deposits and the non-metallics.

The gold-quartz deposits of the Cadwallader Creek belt, occur as vein fillings in well defined fissures in an augite-diorite stock.

The Lorne, Coronation and Pioneer mines are located on this body.

(W. S. McCann. "Geology and Mineral Deposits of the Bridge River Map-area, B. C." G. S. C. Memoir 130, 1922.)

Many of the important fissures of the district show sheeted structure in that the walls of the veins contain parallel jointing planes which are themselves parallel to the main fissures.

The compressive forces acting from the west, which were responsible for the folding and crumpling of the Cadwallader series on the western limb of the Bridge River anticline, could have produced fissuring similar to that noted in the augite-diorite.

The veins are fillings of well developed fault fissures in the augite-diorite. They are characterised by frequent pinches and swells along their entire length. Those of greatest economic importance display a banding or ribbon structure due to subsequent movement along the plane of the veins, and the sheeting of the quartz veins along what may have been lines of original sulphide deposition. The hydrothermal solutions have had a profound effect upon the wall-rock close to the fissure, having altered it to a light coloured, greasy-feeling rock containing pyrite and arsenopyrite in crystals.

The gangue minerals are: quartz, calcite, sericite, siderite and dolomite. The metallic minerals are: gold, which occurs as particles scattered through the quartz of the veins, and sometimes in richly concentrated ore shoots or pockets, where it is easily seen with naked eye. Sometimes it occurs as thin plates or coating on slikensided partings in sheeted or ribboned veins. It also occurs finely distributed throughout the sulphides in minute films and particles. Free milling gold is found associated with pyrite, arseno-pyrite, chalcopyrite, tellurium minerals, and stibnite, and all these minerals are found to be usually indicative of the presence of high values of gold in the veins.

The presence of tellurium indicates that the deposits may be classed as gold-tellurium type of deposits, and it would be interesting to compare them with the similar deposits farther north, like, for instance, the Engineer Mine, in Atlin district.

The veins are oxidized to a depth of about 100 feet.

There has been movement along the planes of the veins since they were formed, but the dimensions of this movement were small.

The solutions from which the vein materials were precipitated are believed to be genetically related to the augite-diorite intrusion, the veins constituting the result of the last phase of magmatic differentiation within the magma from which was derived the augite-diorite.

A sufficient length of time must have intervened between the intrusion of the augite-diorite and the formation of the veins, to have permitted of the solidification of the intrusive to such an extent that it would yield to deforming stresses by fracturing.

The augite-diorite has been intruded by light-coloured albitite porphyry dykes which are considered to be a later differentiate of the augite-diorite magma, and the veins themselves, which cut across these dykes, are believed to have been the last manifestation of igneous activity of the intrusive, and, therefore, of the same general age as the augite-diorite, but slightly younger than the dykes.

The augite-diorite is much more metamorphosed than the Bendor quartz-diorite which is only 2½ miles away, and the quartz-diorite does not contain gold-quartz veins. The augite-diorite is not known to have intruded formations younger than the Cadwallader series, which is Upper Triassic age, whereas the Bendor quartz-diorite intrudes sediments of known Lower Cretaceous age. The augite-diorite, therefore, on account of its lithological characters, its greater metamorphism, and its relation to intruded formations, is considered to be older than the Bendor batholithic quartz-diorite, and its age is placed as late Jurassic.

## Silver-Copper Deposits.

In view of difficulties of transportation, climatic conditions, and the low tenor of the ore in sight, the copper-silver deposits have not been actively developed.

The most persistent vein of this type is found on the side of McGillivray mountain, whence it may be traced for over a mile northwestward.

It displays banded structure due to filling of the fissure by crustification. The metallic minerals have been deposited in thin, banded aggregates parallel to the walls. "Comb Structure" and drusy cavities render the vein permeable to surface waters, which have penetrated it, thereby causing the oxidation of the tetrahedrite. The resulting carbonates of copper, azurite, and malachite, have stained the quartz to a marked degree.

The gangue mineral is entirely quartz, and contains tetrahedrite, azurite, malachite and galena in small amounts.

From the mineralization of the vein and its field relations, it is probable that it was formed at intermediate depths and is genetically related to the intrusion of the Bendor quartz-diorite, the vein materials being the expression of the last phase of igneous activity.

The silver is contained in the galena, which, as far as is known, occurs in but small amount.

Antimony Deposits.

The antimony deposits are closely related to the intrusion of diorite-porphyry dykes. The ore occurs in a quartz gangue in shear zones bordering the dykes and is distributed for the most part in irregular lens-shaped masses through the quartz.

They appear to be confined to a narrow belt on the western limb of the Bridge River anticline, and have been found only within the Bridge River series.

Chromite Deposits.

A small deposit of chromium ore occurs on the northern slope of Taylor basin in the northwestern corner of the map-area. It is associated with a small outcrop of serpentine rock. Occurring as films along the fracture planes, and as fillings of cavities in the chromite is a white, compact hydrated silicate of magnesium.

Microscopic diamonds were found in the chromite.

The close association of the chromite with the serpentine rocks points to a genetic relationship. It undoubtedly represents a basic concentration by magmatic differentiation within an originally olivine-holding magma, the chromite probably being the first metallic mineral to crystallize. The small diamonds which are imbedded within it, must have crystallized out first of all and represent dissolved carbon in the molten magma.

**Coquihalla Area, B. C.**

Strictly speaking, the Coquihalla area should not be included in this thesis, since it lays outside the Coast Range, and belongs to the Cascade Range. But as it shows the same properties as the other deposits of British Columbia, it was decided to give a brief description of the economic geology of this area. Following C. E. Cairnes:--

"The economic minerals and metals in their present decreasing order of importance include: gold, silver, copper, molybdenite, arsenic, platinum, lead, manganese, and iron. They occur in both detrital and lode deposits. In the former gold and platinum are the only minerals of importance.

The lode deposits of commercial value include: gold, silver, copper and molybdenum.

Gold ores are the most important and characteristic of the district. They occur in two distinctly separate sections of the area and in quite different geological associations. Their most important development is confined to gold-quartz veins in the Ladner slate belt and the underlying andesite greenstone member of the Cache Creek series. Their origin in the vicinity of the slate contact is attributed to a large diorite intrusive which closely follows this contact. Other gold quartz veins seem, however, to be genetically related to smaller and more acid porphyritic dykes and sills, intruding

(C. E. Cairnes. "Coquihalla Area, British Columbia." G. S. C. Memoir 139. 1924.)

the slates. The quartz veins occur as combinations filled and replacement vein.type. They are commonly bedded with the slates or occupy irregular fissures in either slates or greenstones. They also occur in shatter zones in either of these rocks and appear as a network of linked veinlets forming a zone many yards wide and persistent over many hundred and possibly thousand feet. In all these types, gold values are very irregularly distributed, but are commonly highest where arsenopyrite, and to a less extent pyrite or chalcopyrite, are most abundant.

The gangue consists of milky white quartz, with in some cases a little calcite and a still smaller proportion of albite. Sulphide minerals are disseminated either in aggregates of fine grains or in larger individual crystals, but never in solid masses. They include pyrrhotite, pyrite, arsenopyrite, and chalcopyrite, named in order of abundance, and deposition. Pyrrhotite is, however, not as common in the quartz veins themselves as in the adjoining wall-rock. Very locally small proportions of galena, blende, and stibnite are encountered. Gold is chiefly associated with the arsenopyrite and occurs either in the free state or so finely mixed or intergrown with this or other sulphides as to be even microscopically invisible.

Gold ores also occur at the Aufeas mine where the ore minerals are massive auriferous arsenopyrite. Chalcopyrite and pyrite are associated in varying amounts in a quartz gangue. The minerals occur in well-defined veins occupying shear zones in a moderately coarse-grained, basic plutonic rock that varies from quartz-diorite to diorite and is regarded as of Upper Jurassic age. The veins are of intermediate character as regards both temperature and depth of formation. Arsenopyrite is sufficiently abundant and massive in character to justify its separate treatment for arsenic. The origin of these ore deposits is referred to batholithic intrusions which intersect the older plutonic rocks.

Silver ores are of present[X] commercial importance only at the Eureka Victoria mines on Silver peak. They occur as vein deposits of intermediate and low temperatures in fracture zones following joint fissures in a massive Cretaceous conglomerate. The gangue includes siderite, limonite, and quartz in this order of decreasing abundance. The principal ore mineral is an argentiferous tetrahedrite carrying a varying proportion of lead.

Secondary concentration of the vein material by surface waters has resulted in the differential enrichment of the silver and lead at the expense of the other metallic and gangue minerals. Values up to $700 a ton have been obtained from these enriched shoots or ore pockets. Average values in the primary vein deposits very up to about $60, but are as a rule less.[#]

X 1924.

# Cairnes, C. E. Mem. 139. 1924.

The only copper ores of economic value occur at the Independence mine. They form veins and replacement deposits in fractures or fissures in a large granite porphyry dyke cutting the Eagle granodiorite and rocks of the Tulameen group. This property was examined by Camsell who regarded the ore deposits as strongly resembling the Butte type. The gangue includes altered granite porphyry and secondary quartz, calcite, and sericite. The principal ore mineral is chalcopyrite, but pyrrhotite and pyrite are abundant and some chalcocite, cuprite, blende, and molybdenite were observed. Tetrahedrite is also reported to occur here.

One important molybdenite deposit has been discovered on the Dominion Mineral Group in the Cretaceous granite on the summit west of Iago. The sulphide occurs in a high temperature quartz lens of pegmatitic origin and is also impregnated through the adjoining granite. The molybdenite occurs in large flakes and lumps in the quartz and in disseminated smaller flakes in the country rock. Some secondary oxidation to yellow molybdite has occurred. No other ore minerals were observed."

# PART III.

## Atlin District.

## Atlin District. Physiography.

The Atlin district presents two distinctly different physiographic provinces. One is that of the Coast Range, and the other the Yukon plateau.

The Coast Range is extremely rugged, consisting mainly of knife like ridges, needle summits, and abruptly incised valleys, and everywhere considerable ice and snow are to be seen throughout the entire year.

The Yukon Plateau is a gently undulating upland which is best viewed from a summit at or near the elevation of the plateau surface. From such a point the observer is struck by the nearly level character of the upland sweeping away in all directions to the horizon and broken only here and there by isolated residual masses that rise above the general level. This horizontal surface might in places be taken for a surface of construction, but it is readily seen that it truncates alike rocks of widely varying degrees of resistance. The upland stands at an average elevation of 5,000 feet.

The transition from the plateau to the Coast Range mountain system is very gradual, so much so, that it is, in places, difficult to determine where one ends and the other begins.

The wide difference between the topography of the Coast Range and that of the Yukon plateau seems to be due mainly to three causes. In the first place, the Coast Range is composed largely of massive granitic rocks which do not possess bedding planes, nor alternating hard and soft layers to be emphasized by erosion, so that sub-aerial agencies have had no regular control and have thus produced very erratic forms. The irregular jointing planes in these rocks have also in places assisted in the production of bold irregular topographic forms. Secondly the granitic rocks are harder and erode less rapidly than the rocks of the plateau and, therefore, have caused the Coast Range in this district to retain a greater general elevation than the region to the east.

'Thirdly, since, for various reasons involving differential erosion and uplift, the Coast Range is now higher than the Plateau region, it still contains glacial ice, although the glaciers have long ago vanished from the plateau region. Thus once a line of demarcation was established between these two terranes, their features have steadily become more and more contrasted.

It is believed that the region has suffered several cycles of uplift and erosion. During Jurassic, the Coast Range Batholith was intruded and the Coast Range stood high. Cretaceous saw a period of erosion. Quoting Schofield:#

"Throughout the Cretaceous, these four great mountain chains, Vancouver Island, Queen Charlotte Island Range, the Coast Range of British Columbia, the Sierra Nevada Range, the Columbia-Selkirk Range and the Alaskides, as well as Cascadia, were areas of <u>erosion</u>, supplying sediments on both flanks of

# S.J.Schofield. The geological record of the Cordillera in Canada. Transactions of the Royal Soc. of Can. Vol. XVII, 1923, Sec. IV.

these highland masses....... The granite pebbles which occur in Cretaceous formation of B. C. prove that the granitic cores of the great Jurassic mountain chains were at that time unrooted.

Erosion and sedimentation with a little volcanism continued almost without interruption until the Laramide revolution in early Tertiary time....."

"The presence of Cretaceous rocks in the valleys in the Coast Range, such as those of Harrison Lake and Kitsumgallum River, shows that the Coast Range may have been in part submerged by the close of the Cretaceous. From this it may be concluded that the four great Jurassic mountain chains were reduced to a condition approximating peneplanation by the close of the Cretaceous period."

"In early Tertairy time, orogenic movements of primary importance "the Laramide revolution" affected the whole region of the Cordillera and the Great Plains. The peneplaned surface of the great Jurassic mountains was uplifted, thus starting a new cycle of erosion while the basins of sedimentation were folded and formed new mountain chains, thus producing mountains for the first time in those parts of the Interior Plateau and the Rocky Mountain region which escaped the folding of the Jurasside revolution."

Over considerable portions of the district, the plateau surface has been almost if not quite destroyed by later erosion, and in such places the topography consists of irregularly distributed, rounded hills, many of them gently contoured and with summits that are in many cases remarkably uniform in elevation.

Two main valleys of the district are occupied by Taku Arm of Tagish Lake, and Atlin Lake. Numerous cross valleys join the main valleys. Very often these cross valleys are also submerged or have small separate lakes, or remnants of lakes, streams and marshes.

These valleys were apparently old stream channels, which were later accentuated by glaciation.

The main ice-masses occupied the master depressions such as Atlin Lake, and both straightened and planned their slopes, and widened and lowered their floors. The valleys thus produced were wide, deep and steep sided. The ice also, in places filled the floor of the valleys with glacial silts, sands and gravels, boulder clays, etc.

D. D. Cairnes considers that the formation of such lakes as Taku Arm and Tutchi Lake, which now occupy the portions of the valley-bottoms that were last occupied by these glaciers, is owing to the fact that the ice retreated up the valleys so rapidly that only the lower portions were filled with glacial debris, causing reversed slopes and effectually impounding the water above.

Following D. D. Cairnes": "The "U" shaped, steep-walled character of all the main valleys, and the reversed slopes of many, causing lakes to form in them, are due, mainly at least, to glacial action.

The upwarp of the district, gave the streams renewed life and energy, and they immediately began vigorously sinking

" D. D. Cairnes, Mem. 37, G. S. C.

their channels in the uplifted surface. Throughout the area deep V shaped incisions were rapidly made, and these in Pleistocene time, were invaded by glaciers from the mountains to the south, southwest and west, which have profoundly effected the topography of the district.

"When a broad ice-sheet covers a district, it moderates the topographic features and reduces the relief, by eroding material from the higher elevations and depositing it in the depressions, but where the ice occupies only the valleys, as was the case over the greater part of Atlin district much greater results are seen and of a different kind; the interstream areas maintain their even character unaffected by ice, while the valleys are widened and deepened, the maximum effect being produced in areas which have been previously prepared to receive the ice by having deep valleys already made in which the ice can operate. Taku arm belt is believed to have been so prepared, and in it V-shaped valleys have been transformed into wide, deep "U" shaped depressions, and hanging valleys, cirques, roches montonnées, and other well-known glacial forms have been produced."

Hanging valleys form a very conspicuous feature of the entire district. Beautiful examples are found on Atlin mountain, and in all valleys.

Some of these hanging valleys are at least 2,000 feet above the bottom of the main valleys.

Cirques are also quite frequent; even in the lower and softer contoured plateau region numerous cirques of various size are found on almost all mountains starting with 5,000 feet elevation.

In some of them the snow does not melt the whole summer, while some become sources of small streams and in a few cases infinitely beautiful lakes appear at the end of the summer.

Of particular interest are terraces which are found in almost all the valleys of the district.

Various reasons were advanced for their occurrence. Cairnes explains them by daming of the Yukon by retreating ice; but Cockfield denies this because the terraces do not seem to have corresponding elevations in different parts of the country, and tries to explain the formation of terraces by the action of the ice itself.

## Atlin District.

### General Geology.

A great variety of rocks, both sedimentary and igneous and ranging in age from Pre-Cambrian to Recent, outcrop in the Atlin district, and districts north of it in the Yukon.

As the same rocks outcrop both in the Yukon and the Atlin district it was considered best to adopt the classification proposed by Cockfield, as being based on more recent and detailed work.
(W. E. Cockfield and A. H. Bell--Whitehorse District, Yukon. Geological Survey of Canada, Mem. 150.)

## Table of Formations.

| Era. | Period. | Formation. | Lithological Characters. |
|---|---|---|---|
| Quaternary | | Superficial deposits. | Gravel, sand, boulder clay, silt, much morainal materials, volcanic ash, soil. |
| | | Acid Volcanics | Rhyolite, granite porphyry, related volcanics, with associated tuffs & breccias |
| Tertiary | | Newer volcanics. | Andesite, basalt, & related dyke rocks, Champrophyre ?) with associated tuffs & breccias. |
| | Upper Jurassic or Later. | Coast Range Intrusives. | Granitic rocks ranging in composition from granite to diorite, with associated porphyritic phases. |
| | | Older volcanics | Andesite, diabase, basalt, & related volcanics with associated tuffs and breccias. |
| Mesozoic | Lower and Middle Jurassic | Tantalus conglomerate | Conglomerate, with sandstone, shale & seams of coal. |
| | | Laberge series... | Argillite, shale, sandstone, arkose, greywacke, tuff, conglomerate. |

Table of Formations. (contd.)

| Era. | Period. | Formation. | Lithological Characters. |
|---|---|---|---|
| | Triassic (or, and) Carboniferous(?) | Limestone | Limestone more or less dolomitic |
| Palaeozoic | Devonian(?) | Taku group | Slates, cherty quartzite, etc. |
| | | Gold series (?) | Pyroxenite, peridotite |
| Pre-Cambrian(?) | | Mount Stevans group | Sericite and chlorite schist, mashed basic to semi basic volcanics, gneissoid quartzites, hornblende gneiss, and limestone. |

## Description of Formations.

### Mount Stevens Group.

The Mount Stevens group includes a number of members widely different in appearance, composition, and possibly in age. They are, however, all old and so extremely altered that their mode of origin and succession are obscured. They consist of sericite and chlorite schists, greenstone schists, sericitic quartzites, gneissoid quartzites, hornblende gneisses, and crystalline limestones.

No fossils have been collected from any of the members of the Mount Stevens group and there is consequently no direct evidence as to their age, but from the evidence afforded by later igneous rocks which cut them, they are in all probability the oldest rocks in the district. Cairnes# in his later work along the international boundary, north of Yukon River, was able to demonstrate that the schistose rocks of that region were pre-middle Cambrian and in all probability Pre-Cambrian in age.

The rocks of the group occur in the westermost part of the district, close to the contact of the main Coast Range Batholith. They outcrop around Fantail Lake, then cross Taku arm below Golden Gate and extend in a narrow belt along Edgar and Nelson Lakes to the end of Torres channel, and beyond where they finally disappear under the Llewellyn Glacier.

# Cairnes, D. D. "Yukon Alaska International Boundary." Geol. Surv. Canada, Mem. 67, p. 40-44.

## Gold Series.

### Pyroxenite and Peridotite.

The pyroxenites and peridotites are found in the central part of the district, grouped in general around the town of Atlin. The main body extends from the shore of Atlin Lake up the valley of Pine Creek and then northward, till it meets the old limestones at head waters of Fourth of July and Consolation Creeks. On one side the formation is cut by granite of the Leonard mountain Batholith.

Smaller masses of these rocks are scattered over the district. The more important are found on Atlin Mountain and Chikoida Mountain.

The rock as a whole is very massive and no major structural features were noted except jointing and faulting, neither of which is very prominent.

Fresh surfaces in some cases appear granular, and in others no granular texture is visible. The rock is dark green to black in colour.

The weathered surface is coarsely pitted and has a bright-reddish brown colour due to presence of iron oxide.

## Taku Group.

The name Taku group was proposed by Cairnes, for a series of cherts, slates and cherty quartzites, which have been referred to the Cache Creek group of the southern interior of British Columbia.

These rocks occupy a large portion of the district. They are bounded by the B. C. Yukon boundary in the north, Atlin Lake in the west, Nakina River in the south and Teslin Lake in the east.

In the central part the series is cut by satellitic batholiths, and small areas of limestones, volcanics, and the Gold series.

Narrow belts occur on the west side of Atlin Lake.

The members of the Taku group are mainly cherts, and slates. The cherts range in colour from dark grey to black, but in places they are reddish on weathered surfaces, due to oxidation of small amounts of contained iron ore. The rocks are massive, hard, and brittle and break into sharp edged, irregularly shaped fragments.

The rocks of the Taku group underlie the Carboniferous (?) Braiburn limestones and appear to correspond with the members of Lower Cache series, of more southerly portions of British Columbia; they have therefore been considered to be probably of Devonian age.

(Cairnes, D. D., Geol. Surv. of Canada, Mem. 37, p. 52-53)
(Gwillim, J. C. "Report on Atlin Mining District."
G.S.C. Ann. Rept. Vol. X11, pt. B, p. 17)

## Braeburn Limestones.

"Braeburn limestones occupy the entire northeastern corner of Taku Arm belt and are extensively developed thence to the north and east.

They thus extend up Taku arm to the mouth of Tutshi river on the west shore, and continue southeasterly to include the northeastern part of Peninsula mountain, and the hills immediately to the east of Sunday peak.

These limestones are generally finely textured and range in colour from greyish blue to almost white. The name "Braeburn limestones" was first applied in the Braeburn-Kynocks area, # from where these rocks have been traced continuously to Taku Arm belt. These limestones are also the same as those included under the Upper Cache Creek series of Conrad mining division.

Dr. Dawson collected Fusilinae from the limestones which extend along the east side of Windy arm, showing these beds at least to be Carboniferous, so the whole series is thought probably to belong to this age, although no other fossil remains of a definite character have been discovered.

(D. D. Cairnes. Mem. 37. G. S. C. P.53.

# Cairnes, D. D. "Preliminary memoir on the Lawes and Nordenskiold Rivers coal district, Yukon Territory." Geol. Surv., Dept. of Mines, Can. Mem. No.5, 1910, p. 28-30.

## Laberge Series.

The Laberge series is the most extensive geological terrane in Taku Arm belt, and its members outcrop in a general way throughout the central, southwestern and northwestern portions of the district.

The group of hills east of Taku arm and south of Graham Inlet; the greater part of the area north of Fantail Lake and south of Tutshi Lake, on the west side of Taku arm; and Sunday mountain and the western portion of Taku mountains, are all largely composed of these rocks.

The Tantalus conglomerates are probably best included with the Laberge series, because they overlie the Laberge rocks conformably. In Wheaton district, where the most detailed work done in the district was undertaken, and where the best exposures of typically marine sediments occur, Cairnes# recognized a threefold division of the Laberge beds, as follows, or if, as in the present case, the Tantalus conglomerate be included, a fourfold division:

Tantalus conglomerate: thickness 1,800 feet.
Conglomerate, shale, sandstone, and coal.

Laberge Series:

| | | | |
|---|---|---|---|
| Upper beds: | thickness | 1,500 ft. | sandstone |
| Middle " : | " | 1,700 ft. | shales, s.s., arkose. |
| Lower " : | " | 1,800 ft. | arkoses & tuffs with shales & conglomerates. |
| total | | 6,800 ft. | |

# Cairnes, D. D. "Wheaton District" G.S.C. Mem. 31, p. 54-56.

Following Cockfield:--

"Fossils have been collected from the Laberge beds in Wheaton, Atlin, Whitehorse and Tantalus areas. In the collections from Tantalus area, three forms were specifically identified, viz. Trigonia Dawsoni, Nerinea mandensis, and Rhynchonella Orthidioides. The specimens were regarded by Whiteaves as Jurassis or Cretaceous but two if not all three of these species are now regarded as Jurassic forms.

Fossils collected by Gwillim in Atlin district were reported on by Stanton as follows: "These may possibly be Triassic, but I think it more probably that they are early Jurassic. They are certainly not as late as the Cretaceous".#

"Thus it appears to be very well established that the Laberge beds range in age from middle Lower Jurassic to lower Middle Jurassic."¢

# Gwillim, J. C.; G. S. C. Ann. Rept. Vol. Xll, pt. 3, p. 23-27 (1899).

¢ W. E. Cockfield and A. H. Bell. "Whitehorse District, Yukon." G. S. C. Mem. 150, p. 22.

## Older Volcanics.

These rocks are typically compact, finely textured, and dark green, but red, brown and blue types also occur. They are prevailingly porphyritic, with feldspur crystals 1/8 inch or more in length, in an aphanitic ground mass.

The older volcanics extend as a belt from Peninsula Mt. on the shores of Taku Arm to Table Mountain, opposite Taku Landing on Graham Inlet.

At first they were subdivided by Cairnes into the Perkins group, and Chieftain Hill group, but later (in 1915) this subdivision was dropped, and the rocks were correlated with the older volcanics of White River district.

Portions of the older volcanics are definitely intrusive into the Laberge beds, and may therefore be considered younger.

Cockfield considers them to be Lower or Middle Jurassic.

Cairnes, D. D. "Upper White River District.
G. S. C. Mem. 50, p. 87-93.

Cairnes, D. D. G.S.C. Sum. Rept. 1915.

## Coast Range Intrusives.

The western portion of the district is occupied by the Coast Range intrusives. Besides the larger areas a number of smaller exposures occur in various localities through the district. Apparently all these granitic masses are a part of the same Coast Range Batholith.

The Coast Range intrusives are for the most part fresh and unaltered in appearance, are predominantly greyish in colour, and have the general appearance of typical, medium to coarsely textured granites.

The orthoclase is locally sufficiently prominent to give these rocks a pinkish colour, but this is exceptional. In places these intrusives become porphyritic in structure and contain numerous large felspar phenocrysts as much as 1½ to 2 inches in length.

Another type is much finer grained, and contains no quartz, approaching true diorite in composition. Hornblende, biotite and augite are generally present and are in most cases readily visible to the unaided eye.

As found by latter work of D. D. Cairnes and W. E. Cockfield the intrusives cut Laberge series and even Tantalus conglomerate.

Cairnes at first was mislead by the fact that the Laberge beds contain dioritic pebbles similar to the Coast Range Batholith material, but since rocks of lower Palaeozoic age containing dioritic pebbles have been found on the Alaskan coast, this is no longer an argument to suppose that the Batholith was intruded in pre Laberge time. It is much safer, concludes Cockfield, to consider the Coast Range intrusives with respect only to the rocks which they cut.

From this it seems that the intrusives are not earlier than the lower part of the Middle Jurassic. The Batholith may be regarded as Upper Jurassic or later.

## Newer Volcanics.

Small areas near the town of Atlin, in the valleys of Ruby Creek and other creeks draining into Surprise Lake, and farther north in the valley of Silver Creek are covered with very recent lavas. Some of these overlie gold bearing gravels.

The lavas are Tertiary and Quaternary in age.

In general the volcanic action must have been very recent, as hot springs and mineral springs are found in several places in the vicinity of Atlin. These evidently indicate after volcanic action.

## Recent Sediments.

Those are mostly found in the valleys, and are made of coarse sands of granitic origin, and gravels of glacial and post glacial origin. In the valleys of some of the creeks the gravels are underlain by "hard pan" made of fairly well consolidated tillite. In places tillite overlies older gravels which are also sometimes gold bearing. The gravels in Pine Creek Valley cover the peridotites and pyroxenites of the gold series.

## Economic Geology.

### Atlin District.

For quite a while after its establishment in 1898 as a gold producing camp, Atlin did not pay much attention to anything but placer gold deposits. But it is easy to change from placer gold prospecting and start looking for the origin of the metal, and so turn to quartz prospecting.

Prospecting and geological work done in the district by Prof. Gwillim in 1901, have shown that the district is unusually favourably located, for occurrences of ore deposits.

Several types of deposits are found, and are classified by D. D. Cairnes in G. S. C. Memoir 37 as follows:

Ore Deposits.

(a) Gold-tellurium quartz veins.

(b) Gold-silver veins

(c) Cupriferous silver gold veins

(d) silver lead veins

(e) copper veins

(f) antimony veins

(g) contact metamorphic deposits.

It is clearly seen from the list, that to produce such a difference in types of ore deposits, considerable difference in geological conditions must exist. This is quite true, and the Atlin District is very rich indeed, in examples of various structures and rocks.

We have the effect of the Coast Range Batholith, the smaller satellitic batholiths, and the varying influences of sedimentaries and volcanics. It is therefore clear that a variety of chemical and physical conditions was available for the formation of these different types of deposits.

It seems almost impossible to generalize for the district as a whole, except may be, that majority of deposits seem to be connected with the intrusion of the Coast Range Batholith, and the smaller Batholiths in the Plateau region. The smaller Batholiths may or may not be of the same age as the Main Batholith, although Cockfield states that lithologically the Batholiths are similar, and that therefore it is probable that they are of the same age.

In describing the deposits of the District I intend to follow in general way Cairne's plan, i.e., describe them by types, but adding new information, added since Cairnes has written his report on the District. These changes will apply particularly to the Engineer Gold Mines, and the Atlin Ruffner Mine, since these properties received considerable amount of attention during the last years, while very little work was done on the rest.

One notable exception among the mineral deposits of Atlin District is the Atlin Ruffner Mine. This deposit is definitely post Jurassic, and possibly Tertiary in age.

More detailed description of the property will be found farther down, but it might be well to state the general reasons for placing the formation of the deposit as Post Jurassic.

The country rock, is the typical quartz diorite or granodiorite of Jurassic age. This granodiorite was fissured by compressional stresses, apparently acting during the Laramide Revolution. The fissures were then filled with Lamprophyre and quartz porphyry. After consolidation these dykes were fissured again, and mineralized. This mineralizing period could have occurred only after Laramide revolution, i.e. during Tertiary.

Atlin District. Ec. Geology.

General.

| Type of Deposit. | Occurrence. | Age? | Mineral Association. |
|---|---|---|---|
| Gold Tellurium Engineer Mine. | Jurassic Laberge series, argillites, greywackes | Jurassic batholith | Quartz, calcite, mariposite gold |
| Gold Silver Vein Happy Sullivan | in hornblende diorite | ? | Quartz, calcite, galena, pyrite chalcopyrite |
| Cupriferous Silver Gold Veins The Petty Group | in Andesite of Jurassic Age. | Jurassic | Quartz, calcite, galena, chalcopyrite, pyrite, malachite. |
| Silver Lead Veins. Atlin Ruffner Mine | Dykes in Quartz Diorite and Diorite | Post Jurassic. possibly Tertiary | qtz, calcite, galena, sphalerite, pyrite, pyrrhotite, arsenopyrite, ruby silver |
| Copper Veins | Olivine basalts | Jurassic | calcite, native copper, malachite, cuprite. |
| Antimony Veins | Shales of Laberge series. | Probably Jurassic | quartz, stibnite, galena. |
| Contact Metamorphic Deposits. | Mt. Stevens Pre Cambrian | Jurassic | magnetite, hematite, chalcopyrite tetrahedrite, erythrite, yellow garnet, biotite. |

## Gold-Tellurium Veins.

### General.

Gold-tellurium quartz veins have been discovered in Atlin district in only one locality which is situated on the east side of Taku arm above Golden Gate. The greater number of the veins occur at the Engineer mines where the bulk of the rich ore in this type of deposits have been found. Veins containing pockets of good ore, however, have also been discovered on the adjoining claims.

### The Engineer Mines.#

# taken from confidential report to the Mine Manager by Dr. W. E. Cockfield. The author visited the mine and rechecked all the observations a year later.

**The Engineer Mine.** by W. E. Cockfield.

The Engineer Mine is situated on Tagish Lake, approximately 12 miles south of Golden Gate, where the route to Atlin turns to the east. This property has been known for a long time and has frequently aroused interest on account of its spectacular gold showings.

There has, however, been comparatively little written with regard to the geology of the property in recent years. The earlier developments are described by Cairnes# and descriptions of the property have also been given in the Annual reports of the B. C. Minister of Mines. A few years ago the first attempt was made to mine this property on a large scale and a great deal of money was spent on the development of the mine and in improvements to the camp, but the veins containing the high grade ore did not furnish sufficient tonnage to justify operations on the scale on which they were attempted and the venture ended in failure. Since that time a small crew has been working to explore certain possibilities of developing a large tonnage of low grade ore which has been indicated by some of the development carried out on the high grade veins. Lately the property has been closed down due to financial troubles, but it is anticipated that it will be re-opened at an early date.

The country rock in the vicinity of the Engineer Mine consists of Jurassic argillites, greywackes, etc., belonging to

# Cairnes, D. D. Geol. Surv. Canada, Mem. 37, p. 73 - 89.

the Laberge series. These are pierced some distance back of the property by a stock of granodiorite which forms Engineer Mt. On the property itself and towards its southern end are two small outcrops of granodiorite, apparently part of the same stock which has been barely deroofed.

The vein system is intricate and it is largely because of the amount of development work which has been done by Engineer Mines Ltd. that the relations show as clearly as they do. In the central part of the property are two Hubs of quartz; one of these being situated 200 ft. east from the shore of the lake, and the other about 1,400 ft. east of the first. These are known as Hubs "A" and "B" respectively. Hub "A" is the larger of the two and is approximately 240 ft. long by 160 ft. wide, and is composed of a number of veins of quartz of country rock and included country rock; the whole forming a stockwork.

Hub "B" is approximately 120 x 80 ft., and is similar in character to Hub "A". There zones have been extensively tested, but so far have not been proved to carry commercial values.

There are also a number of veins which were originally thought to radiate out from these hubs but more recent work tends to throw some doubt on this theory. The principal veins are the Double Decker, Engineer, Jersey Lily, Boulder, Andy, and Blue veins. In addition there are a number of others which have been more or less neglected in the recent developments.

Running from the granodiorite outcrops near the south end of the property towards Hub "A", there is a shear zone which is marked on the surface by a pronounced topographic depression and which is well shown in the underground workings. Instead of the veins radiating out from the Hubs of quartz previously mentioned, it would appear that they are connected with this zone of shearing from which they appear to be given off at different angles. This shear zone divides the veins into two groups--the Double Decker, Engineer and Jersey Lily veins lying to the west, and the boulder, Andy and Blue veins lying to the east of this zone. Its relation to the veins is not quite apparent; none of the veins have been traced into the shear or across it. They all apparently start a short distance from this zone.

There are two sets of dykes on the property. One of these is roughly parallel to the direction of the shear zone and the other roughly parallel to the Engineer and Double Decker veins. These dykes are believed to be satellitic to the granite and the two sets are believed to be essentially contemporaneous. On account of the lack of outcrops near their points of intersection this could not be definitely determined but neither set of dykes apparently offsets the other. Both setz of dykes are older than the vein system. This is easily seen from the underground workings where the dykes are cut and offset by the veins. In places the dykes are heavily impregnated with pyrite.

The veins are characteristically narrow and range from mere stringers up to two feet or more in thickness. The better mineralized parts of the veins are in many cases only 6" to 8" thick. Most of the veins are filled with quartz. The Engineer vein, however, has a calcite-mariposite filling.

The workings above the fifth level are largely stoped out and were not visited. The main workings at the present time consist of the fifth, sixth, seventh and eighth levels.

The fifth level forms the main entry to the mine. This level has been driven from a point somewhat over 100 feet above the lake level, and was at the time of the writer's visit 1450 feet long. This adit encounters the Double Decker vein at 625 ft., and the Engineer Vein at 1185 ft. and was being continued to intersect the shear zone. From the point where the adit encounters the Double Decker vein, a drift has been run on this vein 640 ft. in southwesterly direction and 360 feet in a northeasterly direction, and is continued in this direction to crosscut the shear zone. Throughout this distance the vein varies from a narrow stringer to about 2 feet, and consists of quartz carrying values in free gold. Occasional spectacular values are encountered. The gold apparently follows cracks and crevices in the quartz.

The Engineer Vein has been drifted on 1100 feet southwest from the adit and 220 feet northeast. This latter drift is continued as a crosscut through the Jersey Lily vein, the shear zone, and to the Andy, Boulder and Blue veins with a considerable total of drifting on the latter three veins. From the southwest drift a shaft has been sunk to the 800 foot level with intermediate levels at 600 and 700 feet.

The Engineer Vein ranges in width from a seam to nearly two feet. It differs from the other veins of the property in being mineralized with calcite, mariposite (chrome mica), allemontite (a compound of native arsenic and native antimony) and free gold. The gold is associated with the mariposite.

The Boulder vein where cut by the 500 foot level is 4 feet wide and has been drifted on for 600 ft. It maintains this width over a considerable part of this distance. It consists of quartz, with included fragments of country rock and carries in spots high values in gold. It lies on eastern side of the fault zone and trands away from it at an angle of 30 degrees.

The Andy and Blue veins are somewhat similar to Double Decker vein. The latter has an indicated length on the surface of 400 ft., but was not visited in the underground workings owing to ventilation difficulties. These veins do not, so far as is known, contain the spectacular values found in some of the other veins.

The Jersey Lily vein from surface and underground workings has an indicated length of 1400 ft. but it has not been traced continuously over this distance. It is inclined to the fault zone at 30° towards the southwest. It also does not, so far as known, contain spectacular values in gold.

The workings below the 500 level are full of water and consequently could not be examined. The following information, however, kindly made available by Mr. Hershman, gives an outline of the work done.

On the 600 level the Engineer vein has been drifted on for 160 ft. S.W. from the shaft and for 80 ft. N.E. from the shaft. On the 700 foot level the Engineer Vein has been drifted on for 260 ft. S.W. from the shaft and 320 ft. N.E. On the 800 foot level the Engineer Vein has been drifted on 320 feet S. W. from the shaft and for 280 ft. northeast from the shaft.

In these workings this vein shows essentially the same characteristics as to width and mineralization as in the upper levels.

On the 800 foot level there is a crosscut 380 ft. long to the Double Decker vein with a drift on the latter 400 ft. long; the greater part of this distance lying to the northeast of the crosscut. The Double Decker vein shows a definite widening on the 800 level where it has an average width of 2 feet and a maximum of about four feet. This drift continues until it cuts the shear zone and from it the shear zone has been drifted on for 330 ft. to the northwest and for 500 ft. to the southeast, the drift being only partly in the shear zone and largely in the dyke which accompanies it.

The shear zone is one of the most important features of the property. As indicated by the topography it is quite persistent and underground it has been opened at several points. On the 500 foot level it is crossed by the Double Decker and Engineer drifts and on the 800 level by the Double Decker drift. At each point where cut by the underground workings it is well mineralized with quartz heavily impregnated with pyrite and carries values in gold. The width of this zone varies; but including the dyke, which in many cases accompanies it, is as much as 65 feet wide. Of this 20 to 28 feet is well mineralized with quartz and pyrite. Good values have been indicated over widths of 6 to 14 feet with lower values over the whole zone.

The property has interesting possibilities, while it may be definitely stated that there is not sufficient ore in the vein system to maintain a large operation, yet there is sufficient to permit the property to be worked in a small way. The definite widening of the Double Decker vein on the 800 level and the widening of the Boulder vein on the 500 level indicate that there may be a possibility of the veins increasing in width with depth. The increase in width so noted have not been accompanied by a definite trend toward lower values. Further the Double Decker and Engineer veins are inclined so that if this altitude be continued they will intersect.

The most interesting possibility, however, is the chance that within the shear zone a concentration of workable grade and width of ore will be encountered. A large part of this shear zone has not been explored. It has an indicated length of about 4000 feet and may be much longer and as this shear zone was likely the main circulating channel for the mineralizing solutions there is a possibility of concentrations of ore along it which might supply the necessary tonnage to make the property a success. The values indicated in places are encouraging and further work on this zone is justified by the results already obtained.

Any further work which is done on this property will be watched with interest for it is unlikely that such shear zones would occur singly. As there are several properties in the vicinity which exhibit seams of high grade gold ores, there is a possibility that these occur in connection with similar zones of shearing.

If the zone on the Engineer can be proved to carry ore bodies of commercial size and grade much more work would be justified on these outlying deposits than has been the case in the past.

## Gold-Silver Type.

Several ore deposits in the district belong to this type, and have been found at a number of points, the most important of which are: White Moose, Rupert and Happy Sullivan groups on the Taku arm, the Lawson group on Bighorn Creek; at the Beavis Mine near the Town of Atlin; the Imperial Mine on Munrae Mountain east of Atlin; and on the Brothon and Alvine claims on Haboe Creek near the Lead of Torres Channel, an arm of Atlin Lake.

Generally these veins consist mainly of quartz, but some also contain calcite as an associated gangue mineral. Galena and pyrite are the most common metallic minerals but in addition Chalcopyrite and Tetrahedrite frequently occur, and native gold and native silver are occasionally found. The ores are generally of value mainly for their gold content, but they always contain more or less silver which in places even exceeds gold in value.

## The Imperial Mines.#

The Imperial Mines are located on the Munro Mountain, some 5 miles from the town of Atlin. A good automobile road is followed for 4 miles to Half-way House on Pine Creek, and from there a trail to the foot of Munro Mountain. The author visited the mine in 1931, but as the workings were half caved in no

# Robertson, W.F., Report of the Minister of Mines, B.C. 1900-04.
Gwillim, J.C. "Report on the Atlin Mining District, B.C." G.S.C.
Cairnes, D. D. G.S.C. Mem. No. 37.

attempt was made to examine them in detail. Large quantities of milky white quartz were noted on the dump. D. D. Cairnes describes the mine as follows:

"---The entrance to the lower tunnel is 1030 feet in elevation above Atlin wharf------"

"All work at these mines has been expended in developing a single quartz lode which occurs in a finely-textured rock that ranges from hornblende-diorite to a hornblende-diorite porphyrite. The lode strikes N. 70° E. and dips at angles of 50° to 60° to the southeast.

This deposit includes two or three close, parallel, mineralized fissures which contain an aggregate thickness of 2 to 3 feet of vein material consisting mainly of quartz, sparsely distributed through which are particles of galena, chalcopyrite, pyrite, malachite, and occasionally, native gold. A considerable portion of the quartz is thought to contain from $10 to $30 per ton in gold and silver, the silver being relatively small in amount. Two cross-cut tunnels have been driven, which tapped the vein at 25 and 112 feet respectively, and from these over 400 feet of drifts have been driven.

The formation at the Imperial Mines appears to be chiefly a dark greenish to brownish green, dense, finely textured, rock that is either megascopically entirely aphanitic or contains visible hornblende phenocrysts in an aphanitic groundmass, and ranges from a hornblende diorite to a hornblende-diorite porphyrite. Under the microscope a typical sample proved to be composed largely of plagioclase and pale brownish hornblende, with some accessory iron ore, the hornblende occurring in shreds and irregular prismatic forms imperfectly terminated and constituting nearly half of the rock mass.

Description of Veins.--All the work on these claims has been expended in developing one main vein or lode which strikes approximately N. 70° E., dips from 50° to 60° to the S.E., contains where it has been exposed, from 1 to 7 feet of vein-material, and has been traced for a distance of over 500 feet. The vein is not simple in form but includes, in most places, the quartz and associated minerals which have been deposited in several close parallel fissures, and have also replaced more or less of the original intervening wall rock. The vein is thus a compound vein, or since replacement has been effective to a considerable degree in altering the intervening and intercalated rock portions, the term lode is probably most appropriate.

On account of its compound nature this vein naturally varies considerably in thickness and is also irregular in strike and dip. The main mineralized fault zone which constitutes this lode is fairly persistent; but the various small included members are quite erratic and in most places the lode is divisible into two or more distinct parts.

The vein material appears to have an average thickness of from 2 to 3 feet and consists mainly of quartz which is often iron stained or rose coloured, and frequently exhibits crustification and comb structures, but is also in places quite massive in appearance.

Sparsely distributed through the quartz are particles of galena, chalcopyrite, pyrite, malachite and free gold. Pockets or shoots occur, however, in which these metallic minerals occur plentifully."

The contact of the intrusive batholith, is only a short distance back of the mine in a Northern direction.

Another Gold silver property is the Happy Sullivan Mine.

Minister of Mines Report, 1930.

Minister of Mines Report, 1930.

Happy Sullivan Mine.

Gold-Silver Type.

This property, owned by Clarence Sands and associates, of Atlin is situated about 3 miles north of the Engineer and about 2 miles from the south end of Taku Arm, Tagish Lake. The claims are at altitude 3700 feet on the north side of Sheep Creek and about 2 miles from the shore of the lake.

The ore occurrence is a large pyritized shear zone containing gold values in quartz stringers, occurring in bedded sandstone of the Laberge series of Lower or Middle Jurassic age. Surface trenching and a limited amount of tunnelling carried out under former option are not conclusive regarding the potentialities of the property.

## Atlin District. Economic Geology.

## Cupriferous Silver Gold Veins.

Ge

### General.

The veins considered under this heading have been found in Atlin District on Table mountain which is situated on the north shore of Graham Inlet opposite Taku Landing. The only two deposits on this mountain that have been at all developed occur on the Petty and Dundee groups respectively, and occur in granite-porphyry which is intrusive in Chieftain Hill andesites and andesitic tuffs. The veins consist mainly of quartz, calcite, galena, chalcopyrite, pyrite, malachite, and azurite, which minerals occur also to some extent disseminated through the wall rocks. The Petty vein where exposed is from 6 inches to 2 feet in thickness and has been traced for over 100 feet; the Dundee vein has a maximum known thickness of 2.5 feet, but has not been followed more than 50 feet.

### The Petty Group.

The Petty group consists of two claims which are situated on the southeastern corner of Table Mountain, overlooking Graham Inlet, and are about 3½ miles in north-westerly direction from Taku Landing.

The rock formation in this vicinity consists mainly of the Chieftain Hill volcanics which are here prevailingly greenish andesites and andesitic tuffs. These have been extensively invaded by dykes of granite-porphyry, belonging to the Klusha intrusives.

(D. D. Cairnes, G.S.C., Mem. 37, p. 106).

Only one main vein has been so far exploited on the Petty group, and this occurs in the granite-porphyry, strikes N. 30° E. and has an average dip of about 40° to the northwest. The vein consists mainly of quartz, calcite, galena, chalcopyrite, pyrite, malachite, and azurite, and one small cavity was found to be lined with small crystals of the rare mineral linarite (a basic sulphate of lead and copper).

The quartz is generally rust stained and occurs associated with varying amounts of calcite which in places even exceeds quartz in amount. Galena and chalcopyrite are the most abundant ore minerals present, and occur in approximately equal amounts and in sufficient quantity in places to constitute the greater portion of the vein-material. This vein has a thickness, at the widest point so far discovered, of about 2 feet, but rapidly diminishes to 6 inches or less within a distance of 50 feet in each direction, and has not been followed for over 100 feet.

It is possible, however, that farther development may show the vein to extend a somewhat greater distance. In addition, several other mineralized fissures occur in places on both sides of this main fissure, and within distances of 1 to 2 feet from each wall; and the rock between these is to some extent replaced and impregnated with various ore-materials; so that at the main shaft the ore might be considered to have a total thickness of 3 feet at the surface, but towards the bottom of the shaft its thickness is much less. The ore is claimed to contain four or five dollars per ton in gold, with the main values in silver and copper; but so few tests have been made, that it is uncertain what average amounts of these metals the ore carries."

The Dundee group consists of 2 adjacent claims to the Petty group and its geology is very similar to the above.

## Atlin District.

### Silver Lead Veins.

As an example of the silver lead type of deposit in the Atlin District, the Atlin Ruffner Mine, previously known as the Atlin Silver Lead Mine has been chosen. The author spent two summers on the property, and it was therefore deemed best to incorporate in this essay his report on the mine, as presented to the mine manager.

But as the report deals only with the geology of the mine proper, a few words have to be added in regard to location, and general geology.

The Atlin Ruffner Mine is located on Leonard Mountain, better known locally as the Vanghan Mountain.

### Surface Geology.

The Vaughan Mountain is one of a series of peaks, comprising a range running in a general N. or S. direction. This range gradually loses height towards Atlin Lake.

The Range is separated from other parallel Ranges by the Valley of 4th of July Creek towards W. and Valley of Silver Creek to the East. The main portion of the Vaughan or Leonard mountain is made of coarse quartz-diorite, the summit from about elev. 6000 ft. up of fine-grained diorite.

Both the quartz-diorite and the Diorite are cut by a series of parallel lamprophyre dykes and another series of smaller aplite dykes. The dykes strike about No. 40 E. and dip from $65^{\circ} - 70^{\circ}$ N. West.

The basic dykes vary considerably in size, from a few inches to about 40' in width. As far as is known they run continuously for a distance of several miles. The dykes, especially the larger ones, can easily be traced, because of abundant float, frequent outcrops, and troughs which were formed by a more rapid erosion of the softer dyke material.

The erosion of the mountain in general has been considerable, and it represents an old and partly eroded glacial cirque.

The mountain was step faulted at a comparatively recent date, and in some places very good fault escarpments can be observed. This is true of nearby country as well, and is probably best shown on the neighboring Steamboat Mnt. where the scarps are very well preserved.T

The surface of the mountain is covered with a great quantity of loose boulders, which hide the rock underneath. This made it impossible to determine accurately the quartz-diorite-diorite contact, and it was only possible to draw an arbitrary line, within 100' of the true contact.

The distance by automobile road from Atlin is about 17 miles. This road follows the valley of the 4th of July Creek, following alternately its opposite banks.

(V. J. Okulitch. "1931 Geology of Atlin Ruffner Mine." report of the Mine Geologist.)

## GEOLOGY.

General Geology. The examination of the mine, the 4100 and 4300 workings, and the surface geology from 4100 M.X.C. to beyond the Crater Creek has shown that:

1) The country rock is a coarse grained hornblende quartz-diorite. This rock is the same in 4100 M.X.C. in the 4300 level, the 4500 level, and the surface from the main cross-cut to beyond Crater Creek.

The size of grain varies somewhat but is essentially the same throughout. The rock seems to be composed of plagioclase, Hornblende, quartz, and Biotite in subordinate quantities. Orthoclase if present, can not be separated from the other felspar by examination of hand specimens. Therefore it is possible that the rock may be (in case orthoclase is present) a granite or a grano-diorite. But my opinion, and it was supported by Dr. J. T. Mandy, that the rock is a quartz-diorite rich in hornblende. This type of rock is fairly common in the Coast Range batholith.

Throughout the country rock are patches of darker and finer grained material representing the more basic phases.

At about 6000 feet elevation the country rock changes from quartz-diorite to true hornblende diorite. This rock is much finer grained. It was impossible due to gravel and boulder cover to determine the contact exactly, but careful "interpolation" has narrowed the possible contact zone to about 100 feet each way. The contact apparently passes just above 2C Shaft and runs southward, passes just below 4AA tunnel and continues south, crossing the Fourth of July Valley somewhere in the vicinity of the First Canyon of the Creek.

The other granite rock, the true porphyritic granite, mentioned in reports of the Canadian Geological Survey has not been found anywhere in place and must have been brought to the Vaughan Mountain by ice.

It should be noticed that a change in country rock, from quartz-diorite to diorite may or may not have an effect on ore deposits. What information we have from the 4AA tunnel seems to point that galena is more massive, and there is less sphalerite and arsenopyrite. But this point has not been proven definitely yet. No information is available which way the contact dips.

2) DYKES. The granitic rock (quartz-diorite and diorite) is cut by numerous parallel basic dykes striking northeast. The dykes are hornblende-lamprophyre. They range in width from a few inches to about 40 feet. Some of the dykes are mineralized, others, especially the smaller ones are entirely barren. It seems that there is no difference in the dykes themselves, and that the mineralization of the larger dykes is due to longitudinal faulting and fissures, which developed, because the larger dykes were less competent than the small ones.

It has been shown by the 4100 level that at depth the lamprophyre dyke may change into a quartz-porphyry. This change does not affect the entire dyke. In case of the #2 Dyke the quartz-porphyry is on the hanging wall side of the dyke, while the normal basic material is on the foot-wall side.

This change in composition apparently represents further differentiation of the dyke material, and does not seem to affect the mineralization. The smaller dykes at the same horizon do not show this feature. More information about this change in dyke composition will be gained, after raising from 4100 to 4300 level. The contact of quartz-porphyry dyke and lamprophyre dyke should be watched for very closely as it is likely that the change will be gradual.

The dykes have been faulted both longitudinally and transversely. In addition slight movements have taken place longitudinally without causing displacement. All these movements have crushed and ground the dyke, and subsequent seepage of water has oxidized and decomposed the dyke to a great depth, resulting in bands of gauge. The longitudinal movements apparently preceded the mineralization, while the transverse were post mineralization. The longitudinal fissures provided the path for mineralizing solutions to come upward, and later provided channels for water to percolate down and cause secondary enrichment near the surface.

The dykes are not uniform in width, but pitch and swell. In some cases off-shoots are given out at low angles to the main dyke. Granite horses are frequently inclosed within the dykes.

Besides the basic dykes, the country rock is cut by a set of Aplitic dykes. These dykes are mostly narrow, not over 2 feet in width, and in no case have been observed to be mineralized. They are cutting the basic dykes at a fairly high angle, and are later than the lamprophyre dykes. Probably these dykes represent the acid end phase of the quartz-diorite.

ORE DEPOSITS.

The ore, with exception of the Granite Vein, occurs in veins within the dykes. In general the veins are well defined, though they are bordered by some replacement of the dyke rock and in some places, of the granite itself. In width they vary from a few inches up to five feet and in a few cases are even wider. Although sometimes occuring in the interior of the dykes, they show a preference for the walls and for the margins of slab-like inclusions or horses of granite.

The chief sulphides are arsenopyrite, sphalerite, galena, pyrite, chalcopyrite and pyrrhotite. Tetrahedrite occurs sparingly, while covellite, chalcocite, proustite and probably some other silver sulphides and arsenides are probably secondary. The predominant gangue mineral is quartz, glassy in appearance. The veins are usually tight, but occasionally quartz lines vugs or shows comb structure. The mineralization varies from filling of pure quartz and coarse grained sulphides to replacement of the dyke rock by quartz carrying fine grained arsenopyrite and pyrite with grains of other sulphides.

Contrary to the implication of the term "mineralized dykes" the ore is confined largely to true veins within the dykes and the silicified dyke rock grades into entirely unmineralized dyke material.

The silver appears to be entirely with the galena, this holds true of upper and lower levels as has been shown by numerous assays. Gold is either free in the gangue, or associated with arsenopyrite. There is no definite ratio of gold to silver. The silver to lead ratio commonly is 1 oz. per 1% Pb.

Examination of several polished sections under microscope, and corelating the sequences of mineralization indicates several periods of mineralization in the following manner:

1) Crystalline quartz
2) Galena
3) Sphalerite
4) Pyrite, Pyrrhotite, Arsenopyrite
5) Chalcopyrite
6) Quartz
7) Galena
8) Pyrite
9) Marcasite
10) Pyrargyrite
11) Quartz (chalcedonic filling fractures)
12) Calcite.

This sequence indicates several generations of quartz and might mean that three mineralizing periods were experienced. But this should not be regarded as definite and further work will have to be done.

The development work in 4300 level, has shown that the high grade ore body in 4500 level is changed to arsenopyrite and pyrrhotite carrying very low values. Practically the same condition exists in 4A and 4E tunnels. The high grade ore shoot of 4A changes to Arsenopyrite in 4E. It is therefore possible that this may be an indication of a general condition. That is, that high grade ore shoots are terminated by heavily mineralized shoots of arsenopyrite and pyrrhotite. If this is correct it would be advisable, while continuing the drifts in 4100 level to raise, or drill, on well mineralized shoots of iron sulphides, in the hope of getting into high grade galena-sphalerite lenses above.

The Granite Vein. The Granite Vein presents an entirely different type of vein from the veins found in dykes. So far only one vein of this kind is known on the property. The vein fills a shear or fissure in the quartz-diorite itself. The gangue is quartz. The sulphides are well crystallized, and are low in iron.

Its occurrence close to the main #2 vein, dip, and strike and presence of large well formed crystals of pyrite and galena at first suggested secondary origin, by leaching of the main #2 Vein, and redeposition in a fissure; but more careful examination of the quartz seems to contradict this view. A more definite answer could be obtained by a microscopical examination. It seems that it is a true quartz vein, carrying galena, sphalerite and pyrite. The gold is low. Drifting on this vein should give valuable information as regards to its continuity and values.

GEOLOGICAL HISTORY.

Early in the Mesozoic Era - In Upper Jurassic time - The Coast Range Batholith was intruded into earlier sediments throughout the whole distance from the Yukon southward into United States. The granite of Vaughan Mountain was probably part of this great batholitic intrusion and solidified under cover of hundreds if not thousands of feet.

Atlin Ruffner Mine.

It was believed by several geologists that visited the mine, that crustal adjustments involved in the cooling and transfer of so large a mass of material caused fracturing in the recently solidified granite and the fractures so formed were filled with more basic material coming up from depth and forming the lamprophyre dykes. This idea implies that the dykes were essentially contemporaneous with the granitic intrusion and came from the same source.

However, more detailed study of the problem suggests a different course of events. W. Lindgreen in his "Mineral Deposits" on Page 166 states:

"In the literature many authors attribute fissure veins in effusive rocks to contraction, but usually without sufficient reason. The tensile stresses cannot produce long fissures with regular strike and dip" and further on page 170.

"...the rocks which have formerly been far below the surface of the earth, but which have been exposed by erosion are usually traversed by more or less regular joint systems, persistent over large areas." These joint systems Lindgreen, Leith and other prominent geologists attribute to regional compressional stresses.

It is therefore clear that the fissures which were later filled with dyke material originated long after the consolidation of granite, probably during the next mountain building period. i.e. Laramide revolution or later.

After the dykes solidified they themselves underwent fracturing. Localizing of the fractures and the dykes was due in part to the contraction of the dyke rock on cooling and in part to the continued application of the same forces which originally opened the fissures. In other words, the dyke fissure continued to be a line of weakness and was reopened after cooling of the dykes.

Into the fissures in the dykes so opened the ore depositing solutions ascended. It follows from the above that mineralization was post Jurassic, probably post Laramide, and occurred sometimes during Tertiary, very likely during the Oligocene, which is considered by Schofield# to be the next mineralizing period after Jurassic.

Their origin was probably the same magma which furnished the dyke rock but the differentiation which produced the ore-bearing solutions occurred in depth and not within the dykes themselves. These solutions carried silica, sulphur, arsenic and the metals iron, zinc, lead, copper, silver and gold, besides certainly some fluorine and probably other mineralizers which have escaped from the solution in gaseous form. This

# S. J. Schofield, Ore Deposits of B. C. Mem. 132, p.63.

solution not only deposited silica and metallic minerals in the fissures themselves but in the dyke rock and to some extent the granite, replacing the wall rock by quartz and other ore minerals. Apparently the mineralizing solutions came up not once but about three times depositing new minerals and replacing the older ones. There was some differentiation in the vein, so Galena and sphalerite came higher than the iron sulphides. There was a deep cover of rock overlying even the highest part of the present surface at the time the veins were formed, and this has been removed by erosion which followed the elevation of the Coast Range in early Mesozoic and the subsequent re-elevation of early Tertiary time when the Rockies were formed.

The veins have all the characteristics of ore deposits formed at intermediate temperature and pressure (mesothermal deposits) whose depths of formation Lindgren describes as from 8000 to 12,000 feet. The heat and pressure accompanying batholitic intrusion may have made it possible for deposits of this sort to form somewhat nearer the surface in some places.

It is possible to place the temperature range even more definitely and to say that it approached the hotter end of intermediate temperature. The regularity of the veins, absence of brecciation and crustification and presence of pyrrhotite exclude the possibility that the veins are of low temperature origin. On the other hand, the absence of such minerals as garnet, amphibole, pyroxene, etc., coupled with the presence of tennantite and the appearance of the quartz exclude a high temperature (hypothermal) origin. The coarse texture of the sulphides, general absence of vugs and rarity of comb structure and occurrence of pyrrhotite point toward the warmer end of intermediate temperature.

Further it is possible to say that the high temperature end was towards west, which explains greater amounts of pyrrhotite and arsenopyrite, and less massive galena carrying lower values in silver. It is therefore reasonable to expect better grade silver-lead ore farther east, which will also extend to a greater depth. This has been well demonstrated both by the 4100 tunnel and the surface workings higher up on the mountain.

The significance of the fact that the deposit is of an intermediate temperature type, is, that mesothermal deposits are in general more persistent than those of low temperature.

Mineralization of the same general type in veins of this nature is known in many parts of the world to persist throughout a vertical range of 1000 feet and in some cases even 2000 feet or more and horizontally for distances of many thousands of feet, though any single vein does not necessarily persist throughout the entire range. Experience has shown that in such ore copper values often increase in depth, which has been demonstrated by our 4100 level, though the difference in elevation necessary to produce any noticeable change is relatively large--on the order of 1000 feet or more.

On the other hand, primary deposits of bonanza silver ore are formed at lower temperature, and if found in a deposit of this type would occur nearer the original surface or farther out from the center of mineralization. Any extremely rich ores found here will probably be of secondary origin.

Secondary Enrichment.

The high silver values so far found are in ore that lies near the surface and in all cases shows more or less oxidation. The specimens from 4500 level open cuts and adit which gave assays of 500 oz. and over consist either of earthy black oxidized material or of galena carrying visible ruby silver. The latter mineral is a stranger to primary ore of the higher temperature mesothermal type and may best be explained by enrichment. The earthy ore carrying little lead may have its values in finely disseminated native silver, chlorides or silver sulphides.

The occurrence of the best secondary ore in the lowest exposures so far opened up may at first seem anomalous but may be understood when the topography is considered. In the first place, deep fracturing which greatly facilitates enrichment may have also been a vital factor in influencing erosion to form a valley in this place. Secondly, the glacial planing of the early period may have removed secondary ores from the higher parts of the hill. Thirdly, erosion on the higher part of the hill may have been so fast as to have overtaken enrichment.

If enrichment under modern climatic conditions may be considered it must also be remembered that high on the hill the ground is perpetually frozen.

Even in late summer and at distances of 100 feet or more below the surface the open fractures are all filled with ice, and abandoned tunnels soon become lined up with ice crystals. Thus frost is retarding if not altogether preventing ground-water circulation in the upper parts of the hill while at lower elevation vadose circulation continues. Slight climatic changes from century to century would shift the line of frozen ground water up or down. Still another consideration that must not be overlooked is that all the open cuts and underground workings so far driven on the upper slopes of the hill have been where surface showings were best, hence where the erosion has been least deep, and consequently the areas of deepest fracturing have been automatically avoided.

Secondarily enriched ores have so far shown such high values that they richly repay active search, particularly as the depth to which they extend is not known and may be such as to offer very considerable tonnages.

The determining factors for secondary ores seem to be:

1) Presence of galena furnishing silver values in the primary ore.
2) Fracture zones along which enriching solutions may pass downward.
3) Presence of Galena, sphalerite or chalcopyrite as a precipitant.
4) Protection from glacial or rapid surface erosion which has removed enriched ore.

In prospecting for enriched ore it would be well to raise on any galena-rich shoots encountered in deeper workings in the hope of finding enrichments near the surface. Until conditions are better understood, it would also be a wise experiment to raise sphalerite shoots, even though they may not show good silver values in the primary ore, since sphalerite is an active precipitand of secondary minerals and may be enriched near the surface.

## POSSIBILITIES.

Number 2 dyke has been traced for more than 6000 ft. horizontally, and 2000 feet vertically. #4 dyke has not been definitely traced for the same length, but its size where exposed, makes it highly probable that it continues as far as #2.

Taking #2 dyke from elevation 4100 to the surface and comparing its total area, with that part of it which has been opened up, it is apparent, that only a very small portion of the dyke has been explored. It comes to approximately 6%. In this 6% of the area of the dyke several ore bodies have been discovered, and at least one definitely blocked out. It is therefore probable that other ore bodies exist in the unexplored portion of the dyke. In addition to the portion of the dyke above 4100 level, the type of deposit makes it possible for ore to extend farther down for a considerable distance.

In several places along the surface, namely 2A, 2B, & 2C shoots of high grade ore have been found. None of these ore shoots has been tested for its extent downward; but the 4100 level gives us evidence that galena and sphalerite are extending for at least 1000 feet below the surface.

No. 4 vein has the same potential possibilities as #2 vein. And there are indications that galena is more massive in this vein.

Between #2 and #4 veins lies a large area, whose topography seems to indicate certain possibilities. The low saucer like depression in the centre, and a trough connecting it with the #2 vein system might indicate an area where erosion has been more rapid because of possible series of faults or fissures. As shown elsewhere on the property such depressions usually indicate presence of dykes. It is therefore possible, that one or several dykes of the basic type, or maybe "Granite" type may occur in this region.

It must be remembered that this is only a conjecture, and that there are no positive indications of dykes on the surface. But as it is planned to drive a cross-cut from #2 to #4 veins this is an interesting possibility. If it turned out as hoped, it would add greatly to the value of the mine.

The ore shoots are in general short, and the high grade lenses narrow. There are indications that they might follow in eschelon, but so far no information in regard to controlling factors of ore body locations is available.

The distance between ore bodies, as shown on the surface is about 2000 feet.

## SUMMARY.

1) Veins are usually associated with basic dykes, but may also be in quartz-diorite.
2) Chief gangue minerals are quartz and calcite, in some cases sulphides are disseminated in dyke itself.
3) Veins prefer margins of the structures, and usually are on the footwall side of the dyke. In case of 4100, the best mineralized part of the vein is on the contact of quartz-porphyry and lamprophyre.
4) Ore bodies are terminated by arsenopyrite and pyrrhotite.

5) High values may be found near the surface overlying strong lenses of galena and sphalerite. Advisable to raise on such lenses.

6) Silver accompanies galena. Common ratio is 1 oz. Ag per 1% Pb. Gold is either free in the gangue or accompanies arsenopyrite.

7) Galena and Sphalerite are primary and may be expected through a vertical and horizontal range of several thousand feet.

8) The ore was formed under conditions of intermediate temperature and pressure.

9) Better grade ore is more likely to occur farther east, and go deeper there than at 4300 level, because the higher temperature seems to have been west of present workings.

10) Ore shoots are comparatively short. Borders of commercial ore can be best determined by assaying.

11) Ore shoots are spaced about 2000 feet, horizontally from each other, as at present indicated by surface workings.

Atlin District.

## Copper Veins.

"Copper veins occur on the southwestern corner of Copper Island in Atlin Lake. The rock formation consists of reddish and greenish, prevailingly coarsely textured, olivine basalts and tuffs; the tuffs, however, predominate and in places consist almost entirely of basaltic fragments, but grade into rocks containing a predominance of sedimentary materials.

The reddish basalts range in colour from brownish red to greenish red, and are distinctly basaltic in habit. The groundmass is always cryptocrystalline and contains phenocrysts of olivine and augite as well as particles of iron and occasionally native copper, all of which are readily visible to the unaided eye. In places the groundmass becomes relatively small in amount, causing the rocks to have a decidedly granular appearance.

The greenish basalts are characteristically dark olive-green in colour, and differ from the reddish varieties, chiefly in containing much less iron, to which is due the red colouration.

The Veins. A number of veins from a fraction of an inch to 6 inches in thickness occur in fissures in these basaltic rocks, and consist mainly of calcite, but also, in places contain particles and masses of native copper, the largest of which known to have been found, is reported to have weighed about 40 pounds. A certain amount of malachite as well as rare (D. D. Cairnes. G. S. C. Mem. 37. p. 114 - 116).

particles of cuprite and tenorite occur as oxidation products of the native copper."

D. D. Cairnes concludes from his examination of the deposits that the copper was deposited in a native state.

In regard to the origin of copper he says: "As this mineral intimately associated with the iron which is decidedly primary to the basalts, it might be supposed that the copper had the same origin. However, the copper both in the veins and walls is quite the same, and that in the veins in a calcite gangue is unquestionably secondary to the basalts. Some have supposed that the vein copper has been leached from the adjoining walls where this mineral is thought to be a primary constituent. If this were so there would be a decreasing amount of copper in the walls as the veins are approached. Instead, quite the opposite appears to be the case, and the copper is much more plentiful in the basalts adjoining veins and other fissures. It, therefore, seems evident that all the copper both in the walls and veins was deposited at the same period and was introduced by uprising solutions, probably deriving their mineral content from the still heated lower portions of the basaltic magma, and that the great amount of iron ore in the upper cooler portions of the basalts caused the copper to deposit in the native form."

The last statement, in regard to copper coming from the same basaltic magma does not seem very convincing. It seems much easier to attribute the formation of this deposit to the Coast Range Batholith, which is just a few miles west of the occurrence.

The basalts themselves are older than the granitic intrusion, and I believe that there are no known mineral deposits associated with rocks of this age in the district.

## Antimony Veins.

A deposit of this type is known to exist about 10 miles north of Golden Gate. The ore occurs in form of bedded veins, in the dark, finely textured shales of Laberge series. The main vein is made of quartz and stibnuite with some galena.

Very little development has been done, so that practically nothing else is known about the deposit.

## Contact Metamorphic Deposits.

Contact-metamorphic deposits of economic interest have been found in Atlin district only in one locality which is situated on Haboe Creek near the upper end of Torres Channel, an arm of Atlin Lake.

The Valley of the creek is underlain partly by schists, quartzites, limestones, etc., of the lower Mt. Stevens group, the age of which, Cockfield places tentatively to "Pre-Cambrian."

Adjoining these rocks on the west are the Coast Range granitic intrusives. The contact metamorphic ore deposits are included in the Mt. Stevens rocks near their contact with the granitic intrusives.

Ore deposit. The ore deposit is at one point approximately 150 feet in thickness, and wherever a section of the rocks below the granitic intrusives has been seen, at least 30 to 40 feet of ore-material has been found; this consists mainly of magnetite, hematite, chalcopyrite, tetrahedrite, malachite, cobalt bloom, and various silicates including considerable yellow garnet, apparently grossularite, and some biotite.

The rock that has been altered and replaced in the formation of the ore-materials appears to have been mainly, if not entirely, the limestone which occurs in bands of various thick-

(Robertson, W. F. Report on the Minister of Mines, 1904)
(D. D. Cairnes, G. S. C. Mem. 37. p. 117.)

ness in the Mt. Stevens series, but in places the limestone has suffered merely recrystallization and marbleization.

The best showing is on the French claim, on which a cross-cut tunnel 188 feet long has been driven, of which more than 130 feet is in the ore-body; this assays from 1.65% to 6% copper, and it is thought that a considerable portion of it will average between 2% and 4%. The deposit extends up to within a few feet of the granodiorite contact which is about 50 in elevation above the valley.

Other showings do not show the same high grade ore, but this is not conclusive since only a few short outcrops are known. The rest of the contact is covered with drift.

## Genesis and Age of Deposits.

"In studying the genesis of these deposits a number of striking and definite points have been noted. In the first place, the minerals constituting the ore body or ore bodies are chicfly magnetite, specularite, hematite, chalcopyrite, tetrahedrite, pyrite, yellow garnet, and other complex silicates. This combination of Hematite and magnetite with sulphides is very characteristic of contact metamorphic deposits and is practically unknown in fissure veins. Further, when these minerals occur with yellow garnet and related silicates an association is produced which is diagnostic of contact-metamorphism.

Further, these ore-minerals occur only near the intrusive grano-diorite contact, and have distinctly been produced by replacing the limestones intercalated in the Mt. Stevens series.

There thus appears to be little or no doubt, but what these ores owe their origin to the neighbouring granodiorites and that the materials composing them were derived from the granodiorite magma, as the limestone and adjoining schistose rocks do not contain the necessary iron, copper, and sulphur for their production.

The contact ore-materials on these properties are, therefore, in all probability due to magmatic vapours, rich in iron, copper and sulphur, which were derived from the granitic intrusive body. If this is true the deposits were formed during the cooling period of the granitic batholith, which as explained under "general geology," is thought to have occurred in Jurassic and probably late Jurassic time.

# PART IV.

## Bibliography.

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## Bibliography.

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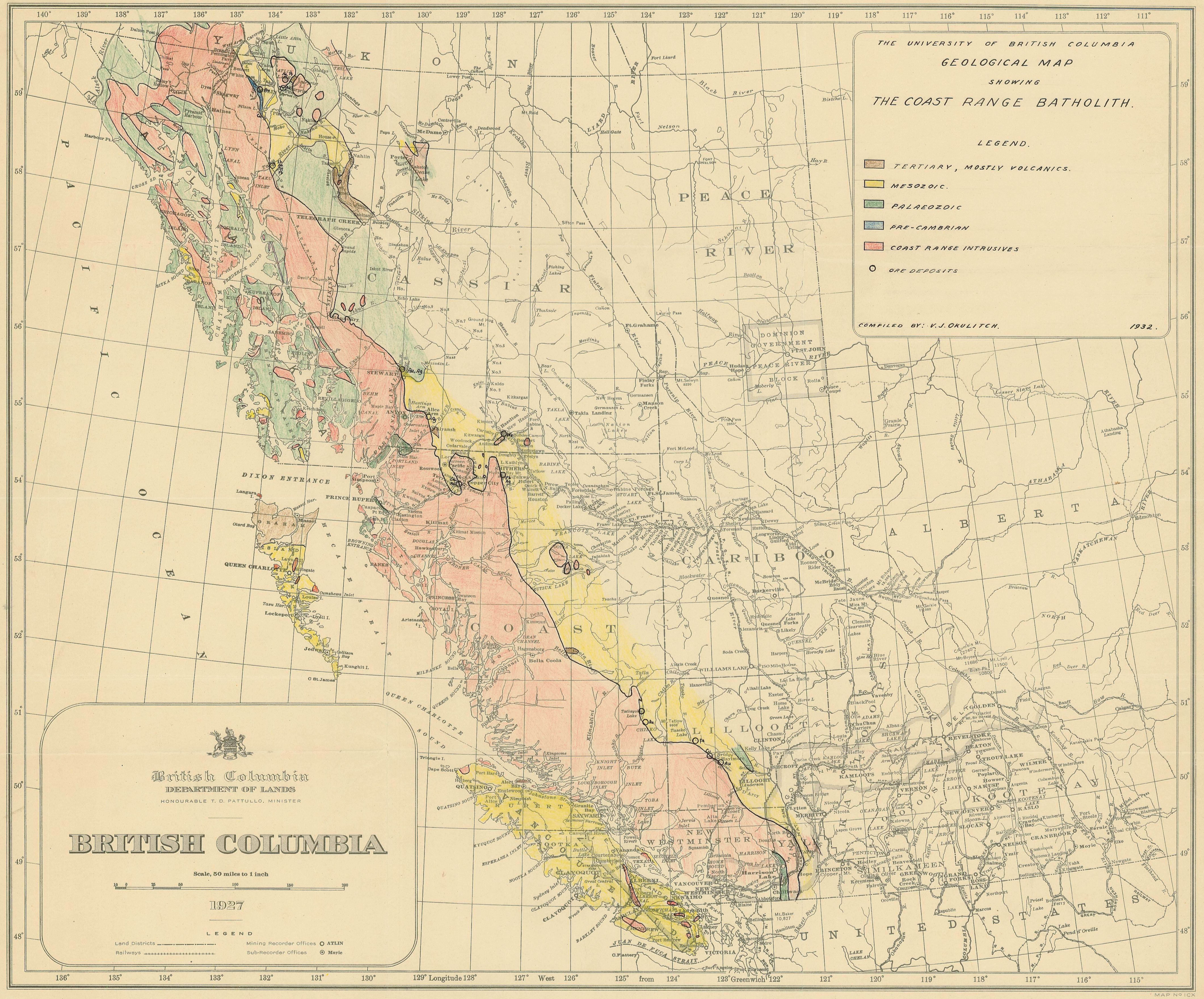
THE UNIVERSITY OF BRITISH COLUMBIA
GEOLOGICAL MAP
SHOWING
THE COAST RANGE BATHOLITH.
LEGEND.
TERTIARY, MOSTLY VOLCANICS.
MESOZOIC.
PALAEOZOIC
PRE-CAMBRIAN
COAST RANGE INTRUSIVES
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COMPILED BY: V. J. OKULITCH.
1932.
British Columbia
DEPARTMENT OF LANDS
HONOURABLE T. D. PATTULLO, MINISTER
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Mining Recorder Offices ATLIN
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ALBERTA
KOOTENAY
UNITED STATES
Longitude West from Greenwich
MAP No 1CX