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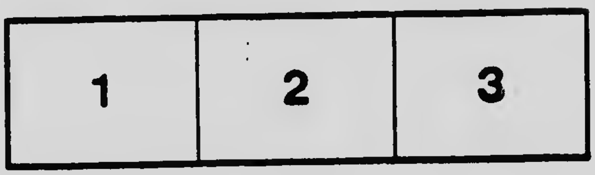
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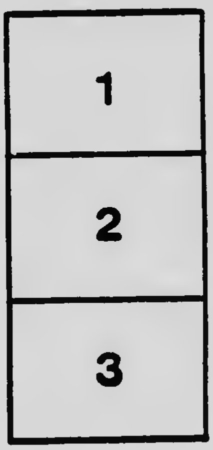
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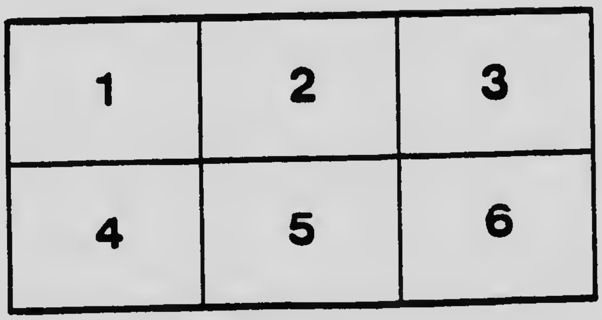
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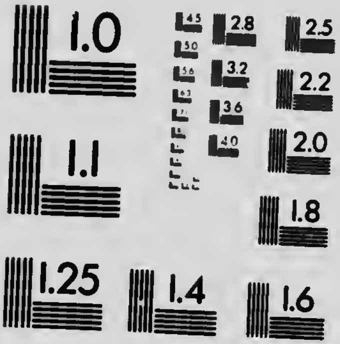

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GEOLOGICAL SURVEY

MEMOIR 79

No. 65, GEOLOGICAL SERIES

Ore Deposits of the Beaverdell Map-Area

BY
Leopold Reinecke

OTTAWA
GOVERNMENT PRINTING BUREAU
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PLATE I

Explanation of Plate I

The Sally mine and Bunk house, Wallace mountain

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CONTENTS.

CHAPTER I.

PAGE

Introduction 1
General statement 1
Field work and acknowledgments 2
Location and area 3
Transportation and communication 3
History 4
Previous work and bibliography 7

CHAPTER II.

Summary and conclusions 9
Topography 9
General geology 9
Description of formations 9
Economic geology 14
Future of the district 17

CHAPTER III.

General character of the district 18
Topography 18
Regional 18
Interior plateaus 18
Local 19
Beaverdell area 19
Climate and agriculture 22
Animal life 23
Timber and vegetation 24
Inhabitants 26
Commercial possibilities 27

CHAPTER IV.

General geology 29
Regional 29
Geology of the Beaverdell area 31
Table of formations 32
Wallace group 33
Distribution 33

PAGE
Lithology and metamorphism 34
Structure 38
Relations to other formations 39
Age and correlation 40
Westkettle quartz diorite 41
Distribution 42
Lithology of the batholith and its related dykes 42
Metamorphism 44
Structure 45
Relation to other formations 46
Age and correlation 46
Beaverdell quartz monzonite 48
Distribution 48
Lithology of the batholith and its related dykes 48
Structure 50
Relations to other formations 50
Age and correlation 51
Augite syenite porphyry 52
Lithology 52
Curry Creek series 53
Distribution 53
Lithology 53
Metamorphism 54
Structure 55
Relations to other formations 55
Age and correlation 56
Nipple Mountain series 57
Distribution 57
Lithology 57
Metamorphism 58
Structure 58
Relations to other formations 59
Age and correlation 60
Glacial deposits 61
Distribution 61
Lithology 62
Structure 62
River deposits 62
Distribution 62
Lithology 63
Structure 63
Historical geology 63
Wallace group 63
Westkettle batholith 64

PAGE

Beaverdell batholith 67
Curry Creek series 69
Nipple Mountain series 70

CHAPTER V.

Economic geology. Ore deposits 73
Mineralogy 74
Table of minerals arranged according to zones of deposition 75
Detailed description of minerals 77
The mineralized shear zones 86
Description 86
Definition 86
Distribution 86
Mineralogy 86
The country rock 87
Restriction of the shear zones and galena ores to quartz-diorite 87
Variations in the country rock 88
Dykes in or near shear zones 89
Structural features of the shear zones 90
Textural features of the deposits 91
Paragenesis 91
Localization of the ore masses within the shear zones 93
Variations of values in depth 94
Faults 95
Surficial alteration and secondary deposition 100
Genesis of the ores 101
Agent of deposition 102
Temperature and pressure of the solutions 102
Process of deposition 105
Cavity filling and replacement 105
Influence of the country rock 107
Variations of the ore in depth 108
Processes of secondary deposition 109
Shallowness of the zone of secondary deposition 110
Source of the metals and age of the deposits 111
Development and mining 113
Production 114
Future possibilities 114
Detailed description of mines 115
Introduction 115
Sally group 116
Location 116
History 116
Production 116

	PAGE
Development and mining methods	116
Geological relations	118
Character of the ores	119
Commercial possibilities	120
Rambler claim	120
Duncan and Bounty Fraction claims	122
Geological relations	123
Bell claim	124
Buster claim	124
Standard claim	125
Bounty claim	125
Wabash claim	125
Kokomo claim	125
Gold Drop claim	126
Homestake claim	126
Carmi mine	126
History and development	126
Geological relations	127
Commercial possibilities	127
Butcher Boy claim	128
Claims on Arlington mountain	129
Stocks	129
Description	129
Definition	129
Distribution	130
Mineralogy	130
The country rock	130
Structure of the stocks	130
Textural features	131
Secondary oxidation	131
Genesis of the stocks	131
The pyrrhotite-bearing stocks	131
Future possibilities	132
Prospects located on the stocks	132
Nepanee claim	133
Tuzo's claim	133
Ellsworth or Big Strike claim	133
St. John claim	134
Burns' and Larson's claims	134
O.K. group of claims	136
Mogul claim	136
Silver Dollar claim	136
The contact metamorphic deposits	137
Description	137

PAGE

Definition 137
Location 137
Mineralogy 138
Geological relations 138
The ore-body 138
Texture 138
Secondary alteration 140
Genesis 140
Lottie F. claim 141
Scheelite 142
Serpentine and asbestos 143
Road materials 144
Index 171

ILLUSTRATIONS.

PAGE

Map 37A, No. 1183, geological and topographical, Beaverdell . . . . . in pocket
Plate I. The Sally mine and bunk house, Wallace mountain Frontispiece
" II. The forest covered, flat bottom of the Westkettle valley, and Beaverdell village 147
" III. Recently burned area with thick growth of underbrush . . 149
" IV. Banded tuffs of the Wallace group 151
" V. Variations in the Westkettle batholith 153
" VI. Terraces in the Westkettle valley at Carmi 155
" VII. Banded ore from the Gold Drop claim 157
" VIII. Shaft house and cabin on the Rambler claim 159
" IX. Ellipsoidal cavities in the contact metamorphic ores on Copper creek 161
" X. Microphotograph showing the occurrence of scheelite in an altered limestone 163
" XI. Boulder of brecciated augite andesite, Wallace group . . . 165
" XII. Variations in the Beaverdell batholith 167
" XIII. Nipple Mountain lavas at the mouth of Copper creek, Kettle river 169
Figure 1. No. 1530. Silver-lead mines on Wallace mountain 90
" 2. Chart showing directions of strike of faultplanes in the Beaverdell area 96
" 3. Stereogram of the Sally No. 1 tunnel 98
" 4. Vertical projection and plan of the Sally No. 1 tunnel and stopes 99
" 5. Vertical projection and plan of the Rob Roy No. 7 tunnel . . 117
" 6. Vertical projection and plan of the Rob Roy No. 6 tunnel . . 119
" 7. Plan of workings on the Rambler claim 121
" 8. Main workings on the Duncan and Bounty Fraction claims 123
" 9. Sketch map of the topography and geology of the Lottie F. claim 139

Beaverdell Map-Area.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

The Beaverdell area on the Westkettle[1] river, lies within a relatively unknown portion of southern British Columbia. Attention was called to this district through the finding of promising prospects of silver, gold, and copper about the year 1897. The subsequent development of small but rich bodies of silver-lead ore upon the Westkettle river indicated that the valley might become the centre of permanent and extensive mining activities. In 1909, therefore, the Geological Survey undertook the mapping of an area including the mining camps, and a study of the ore deposits, in order that information regarding the ores and other natural resources of the district would be available for the use of those visiting the valley upon the completion of the railway up the Westkettle river and in order to extend the knowledge of the geology of this region, already gained by surveys near the International Boundary.

As the region was practically unmapped a topographic map was made of an area covering about 165 square miles and upon it the boundaries of the geological formations were afterwards laid down.

The results of the study of the ore deposits within this area are contained in this report and with them has been included a brief account of the general character of the region and of the geological formations.

An account of the physiography of the region has been published in Museum Bulletin No. 11.

[1] By ruling of the Geographic Board the name "Westkettle" replaces the name "West Fork" which has been used in previous reports and maps.

In this report it is pointed out that the silver-lead ores on Wallace mountain are confined almost exclusively to one formation, the Westkettle quartz diorite, and an explanation is advanced for their absence from other rock types. The suggestion is also made that the silver-lead ores on Wallace mountain may change in depth to low grade gold-bearing ores like those found at Carmi. The faults so far as they could be determined ha been mapped, and are shown in Figures 1 to 8. The amount of faulting and the direction of displacement of the ore-bodies represent the greatest single problem which will have to be solved in future mining operations; and it is hoped that this work may be of some assistance in that respect.

FIELD WORK AND ACKNOWLEDGMENTS.

The work upon the topographic map was begun in the autumn of 1909 and was completed in the summer of 1910. The primary control was obtained by transit triangulation from a measured base, and points in the secondary control were located by intersection with a plane-table and alidade. Details were filled in by traverse with a plane-table and 300-foot chain, the thick underbrush practically prohibiting the use of stadia for measuring distances; and the aneroid was used to carry elevations along the traverse lines between secondary control points. About 10,000 traverse stations, 300 feet apart, were located in this way on the map. Every fifth station was plotted upon the working sheets used in the geological mapping, and surveys along the geological boundaries were in that manner readily tied to fixed points. The boundaries of the formations are, therefore, believed to be located as closely as the available number of outcrops allowed. The geological field work was done in the summer of 1911 and the report prepared during the winters of 1913 and 1914.

The topographic parties included S. I. Wookey, F. H. McCullough, and L. W. Berry in 1909; F. H. McCullough, Charles Galloway, Ernest Bartlett, William Hughson, Karl M. Clark, and John Stansfield in 1910. Mr. Stansfield also assisted in geological work during that season. In 1911, the writer was

assisted by W. J. Wright. A great deal of credit is due these gentlemen for their interest and painstaking work. The writer's thanks are due to many friends in the district who have helped him in various ways, especially to Mr. Ed. G. Smith of Carmi, from whom he received information regarding the history of the region and several excellent photographs. Mr. G. M. Turnbull of the Granby Consolidated Company at Trail, B.C., kindly furnished plans and profiles of the mine tunnels on the Sally and Rob Roy claims. He is especially indebted to Professors L. V. Pirsson, J. D. Irving, Isaiah Bowman, Joseph Barrell, and Dr. W. M. Bradley of the Geological staff at Yale university for help and criticism in the preparation of the general report. The chapter on "Economic Geology" was prepared under the supervision of Professor J. D. Irving, and mineralogical work upon the ores was done with the help of Dr. W. M. Bradley.

LOCATION AND AREA.

The mining camps of Beaverdell and Carmi are situated on the Westkettle river in southern British Columbia. Carmi lies 5 miles up the river from Beaverdell. Penticton, at the southern end of Okanagan lake, is about 25 miles west of Carmi, the base of the Midway mountains of the Columbia system 15 miles to the east, while 30 miles, as the crow flies, to the south of Beaverdell, is the International Boundary.

The Beaverdell map embraces an area of 163 square miles between north latitudes 49°25′ and 49°37·5′, and west longitudes 118°55′ and 119°10′. The quadrangle takes in a part of the valley of the Westkettle river and Beaverdell and Carmi lie in the southwestern corner of it. The area is on the eastern and near the southern border of the Interior plateaus of British Columbia.

TRANSPORTATION AND COMMUNICATION.

Beaverdell and Carmi are connected with Midway by a wagon road which follows the bottom of the Kettle and Westkettle rivers from Midway, through Rock creek and Beaverdell, to Carmi. It is built on a low grade and was in excellent condition in the summer of 1911. The distances from

Carmi and Beaverdell to Midway along this road are about 50 and 45 miles respectively. At Midway connexion was made with the Canadian Pacific and Great Northern railways. Another road proceeded from this one up the main Kettle river to a point almost directly east of Beaverdell. A switchback road connected Beaverdell with the Sally mine on Wallace mountain, and government pack trails proceeded from Beaverdell to Penticton, Kelowna, and the Kettle river. In October of 1910 grading began upon the Kettle Valley railway which, when completed, will connect Beaverdell and Carmi with Midway to the south and with the Okanagan valley and the main line of the Canadian Pacific railway at Spence Bridge to the west. The building of this railway was being vigorously carried on in 1911 and 1912, and it will doubtless be completed before this report is published.

HISTORY.[1]

Although white fur traders had settled in the neighbouring Okanagan valley early in the nineteenth century, there are no records of the presence of white men on the Westkettle river until much later. The district, unlike the Okanagan, lay outside the lines of travel and was probably visited only occasionally by Indian hunting parties or trappers. Following the discovery of gold upon the Thompson in 1857, a great rush of Californian miners began to the interior of British Columbia. Great numbers of them entered the country by way of the Columbia and Okanagan valleys, often prospecting the creeks as they passed. In this way streams tributary to the Okanagan were explored and seven out of nineteen creeks entering the upper part of the valley were found to contain gold-bearing gravels. From one of these, Mission creek, which lies to the northwest of

[1] The history of prospecting on the Westkettle river was obtained for me partly through the kindness of Mr. Ed. G. Smith, who has trapped in the Westkettle country for many years; other references follow:

Bancroft, Hubert, H., "History of British Columbia," 1792-1887.

Dawson, G. M., "Mineral Wealth of British Columbia," Ann. Rep. Geol. Surv., Can., Vol. III, 1887-1888, p. 130 R.

Brock, R. W. Preliminary report on the Rossland, B.C. mining district, Geol. Surv., Can., No. 939, pp. 10-13, 1902.

Brock, R. W., Preliminary report of the Boundary district, British Columbia, Geol. Surv., Can., Ann. Rep. 1902-1903, Vol. XV, pp. 136-137.

the Beaverdell area, the miners cleaned up from $2 to $40 per man per day in the seasons of 1859 and 1860. At this time also (1859-1860) gold was discovered upon Rock creek, which enters the Kettle about 2 miles north of the International Boundary and 30 miles south of Beaverdell.

Active exploration of the gravels on Rock creek continued with some setbacks from 1860 to 1870, and a great deal of gold was extracted. It was probabl during this period that the Kettle river and its tributaries were prospected nearly to their headwaters, and small quantities of gold were found upon it, as recorded by Dawson.[1] Evidences of the working of gravels upon the Westkettle are to be found at China creek in the Beaverdell area, where parts of an old flume are still in existence. The name of the creek is highly suggestive, for a great deal of work upon gold-bearing gravels in southern British Columbia has been done by the Chinese. Placer mining was carried on in a desultory way in Rock creek for many years after the first rush, but whatever prospects were found farther up the river were soon abandoned.

The first lode claim in southern British Columbia was staked upon Rock creek in 1884. Between that date and 1892 a number of lodes of copper and gold, which later on became important ore producers, were staked in the Boundary district and at Rossland. Active development of the gold ores in Rossland began in 1894, and the results were so favourable that the town was connected by railway to the south in 1896. The success of the Rossland camp started another rush into southern British Columbia and a small army of prospectors found their way up the Westkettle river between 1896 and 1900. The first claims were staked on Wallace mountain in 1889 before the boom, but were allowed to lapse. All the more important claims on Wallace mountain were located between 1896 and the following year, and in the next four years numerous claims were worked on this mountain, at Carmi, near the Triple lakes, and on Arlington mountain. Three small settlements sprang up on the Westkettle at that time, and another on the Kettle river east

[1] Dawson, G. M., "Mineral wealth of British Columbia," Ann. Rep., Geol. Surv., Can., Vol. III, 1887-1888, p. 130 R.

of this area: they were called Carmi, Beaverton, and Rendell, and the one on Kettle river, Cañon City. Later, Rendell and Beaverton, which were only one mile apart, were united under the composite name Beaverdell. As many as 1,000 prospectors are said to have come up the river by the pack trail which then connected Beaverdell with the outside world. They spread into the hills on both sides of the Westkettle and left evidences of their occupancy in the numerous prospect holes which are found on the upland to-day.

Development work began in the Carmi mine in 1899, and in the Sally group on Wallace mountain in 1900. These two small properties were more or less continuously developed between 1900 and 1909. The larger of them was shut down early in the year 1910, and had not been opened when the writer left the district in 1911. The Carmi was worked in 1899 and 1900, and again in 1904, but no work was done on it from that time until 1911.

The slump in mining operations which began at Rossland in 1899 affected prospecting on the Westkettle river as well as all over the southern part of British Columbia. The mining population quickly disappeared, leaving empty shacks and abandoned townsites behind them, and in the summer of 1910 a few of the old timers alone remained to await the return of prosperity. During the following year, however, there was another turn of the tide. The Kettle Valley railway which, when completed, will connect Beaverdell and Carmi both with Midway to the southward and the Okanagan and Vancouver to the west, was begun in the autumn of 1910. Its effects began to be felt in 1911, when surveying parties and others engaged in preparing for railway building began to invade the district. During the winter of 1911 and 1912 tenants appeared for the deserted cabins in Carmi and Beaverdell, and the district took on a new lease of life. The next few years will doubtless see a great many changes in the district and it is possible that a permanent town of some size may grow upon the site of Beaverdell or Carmi.

PREVIOUS WORK AND BIBLIOGRAPHY.

Very little geological information upon this district had been published before the beginning of the work embodied in this report. Mr. William Fleet Robertson, the provincial mineralogist of British Columbia, paid a visit to the Westkettle in the summer of 1901 He examined the more important claims at the Triple lakes, upon Knob hill, at Carmi, and upon Wallace mountain, and some valuable data regarding their geology, development, and ore values are given in his report.

The district was visited in 1900 by Mr. Horace F. Evans who published an account of a reconnaissance up the Westkettle, in the Mining World magazine. Scattered accounts of the mineral production of the mines at Beaverdell and Carmi appear in the publications of the Department of Mines at Victoria, B.C.

The following is a list of the publications upon the geology of this area:

1. Dawson, G. M., "Mineral Wealth of British Columbia," Ann. Rept. Geol. Surv., Can., Vol. III, 1887-1888, p. 130R.
2. Robertson, Wm. Fleet, "Ann. Rep. of the Minister of Mines of British Columbia for the year 1901," pp. 1135-45, 1902.
3. Ann. Rept. of the Minister of Mines of British Columbia for the year 1903, p. H. 168.
4. Ann. Rept. of the Minister of Mines of British Columbia for the year 1904, p. G. 216.
5. Ann. Rept. of the Minister of Mines of British Columbia for the year 1906, pp. 159-160.
6. Ann. Rept. of the Minister of Mines of British Columbia for the year 1907.
7. Ann. Rept. of the Minister of Mines of British Columbia for the year 1909, p. 132K.
8. Evans, Horace, F., "Reconnaissance up the West Fork of Kettle River," Mining World, Vol. 27, pp. 65, 317, 1909.
9. Reinecke, L., "Beaverdell District, West Fork of Kettle River, British Columbia," Sum. Rept. Geol. Surv., Can., for 1909, No. 1120, pp. 118-122, 1910.

10. Reinecke, L. "Silver and Gold Deposits on the West Fork of Kettle River, B.C.," Quart. Bull. Can. Min. Inst., No. 12, October 1910, pp. 135-139.
11. Reinecke, L. "Beaverdell District, West Fork of Kettle River, B.C.," Sum. Rept. Geol. Surv., Can., 1910, No. 1170, pp. 120-122, 1911.
12. Reinecke, L. "Beaverdell Map-Area, Yale District, B.C.," Sum. Rep. Geol. Surv., Can., for 1911, No. 1218, pp. 130-132, 1912.

CHAPTER II.

SUMMARY AND CONCLUSIONS.

TOPOGRAPHY.

The Beaverdell area lies within the southeastern corner of the Interior plateaus of British Columbia. The district is drained by the Kettle river and its tributary, the Westkettle, and the mapped area lies nearly entirely in the basin of the Westkettle. The maximum relief within the area is 3,250 feet. About two-thirds of the district is upland and the remainder consists of steep sided valleys. The upland is rolling, with average slopes from hilltops to main drainage lines of about 200 feet to 300 feet to the mile, and the maximum relief within the upland is nearly 2,000 feet. The main valleys are steep sided with flat terraced bottoms and the streams within them are of low grade; evidences of a recent disorganization of the drainage are plentiful upon the upland.

GENERAL GEOLOGY.

Description of Formations.

The oldest rocks in the district are those of the Wallace group, parts of which have been correlated on the ground of lithological and structural similarities with the Phoenix volcanics, and with the Triassic-Jurassic Nicola series, which outcrops in the Kamloops map-area. The Wallace underlies about one-third of the Beaverdell area and the greater portion of it lies upon the higher upland. Two large areas of the Wallace group lie in the southeastern portion of the map-area and upon St. John ridge, other and smaller strips occur along the sides of the Westkettle valley and in other places.

The series is made up of a complex of rocks of which probably over 95 per cent are of igneous origin. The oldest are white to grey, coarse, crystalline limestones, and fine-grained, grey hornfels. Over these lie banded, dense, hornblende andesite tuffs of variegated colour and dark grey augite andesite lavas, which in places intrude both sediments and tuffs. Hornfels, tuffs, and lavas are all very fine-grained and hard to distinguish in the field. A number of basic, coarse-grained intrusives, black hornblendites, pyroxenites, saxonites, and saxonite porphyries, and dark grey olivine gabbro, are probably of nearly the same age as the augitie andesite, for some of them seem to be the cores of a large body of augite andesite. The youngest members of the series are dykes of grey hornblende diorite porphyry, for they intrude all other members of the series. Green hornblende schists of andesitic and dacitic composition are partly facies of the diorite porphyries and partly of unknown origin and relative age. Nearly all the igneous rocks weather to a rusty brown.

The limestone lies in beds and irregular masses, the maximum thickness measured being 200 feet; tuffs occur in thinly banded or more massively bedded forms, the maximum thickness being at least 1,100 feet; and the augite andesite lavas whose thickness was not determined, are in sheet-like forms, sometimes in dykes and small stocks. Saxonite porphyry lies in the form of a thick sheet or sill and the other basic intrusives in irregular fragmentary patches. The schists are in irregular areas and the hornblende diorite porphyries generally in the form of dykes.

The whole series has been metamorphosed, the limestones recrystallized and the calcite replaced in part by contact metamorphic minerals, the hornfels and the augite andesites recrystallized and the augites of the andesites altered partly or wholly to hornblende. The coarse-grained intrusives have suffered metamorphism of the same kind as have the augite andesites, while the hornblende diorite porphyries have been mashed and, in certain outcrops, generally recrystallized. The schists show the effects of more intense mashing than the other rocks; they probably represent mashed facies of several of the other types.

The whole series has been faulted and the more brittle members brecciated. The only folds detected involved the tuffs which have been thrown into a number of anticlines and synclines.

Within the area mapped as Wallace group, the several units of the group lie scattered in the most haphazard manner and it was the practical difficulty of separating them in the field which led to the mapping together in this series of formations which probably represent at least two geological systems.

The Wallace group has been intruded by a batholith of quartz diorite here called the Westkettle batholith. Partly because of the metamorphism it has undergone, and largely because of its similarity to Jurassic batholiths in the great Okanagan composite batholith to the southwest, it has been referred to the Jurassic. The Westkettle quartz diorite underlies a wide area along the Westkettle river and smaller patches of it occur in the hills up the Beaver valley and east of Goat peak.

The average quartz diorite is a medium and even-grained grey rock of granitoid texture in which biotite, hornblende, feldspar, and quartz can usually be determined with ease in the hand specimen. Locally it varies from this type to one in which there is less biotite and more feldspar or more hornblende and less feldspar and quartz. On the tops of certain hills and especially near its contact with the Wallace series a fine-grained type is developed (Plate V). Four types of dykes: light coloured, granitic aplites; grey porphyritic, quartz latite-porphyries; rather even textured, quartz monzonite porphyries; and hornblende, andesite porphyries are apparently offshoots from this batholith; some of them cut the batholith itself and all of them are intruded into the Wallace group. The Westkettle batholith is gneissic, that is, has a foliated or banded structure in certain places. The gneissic phase occurs near many of the contacts of the younger Beaverdell quartz monzonite batholith and in such cases the direction of foliation is generally roughly parallel to the line of contact. Gneissic phases of the batholith are also developed near its centre, far from the intrusion of Beaverdell quartz monzonite. Along certain shear zones it has been severely metamorphosed, with the development of sericite, epidote, and chlorite. The batholith is extremely irregular in outline, with numerous lateral projections into the nearby Wallace group, and small wedge-shaped masses of Wallace in places lie inside the quartz diorite, far from the outside contact. It has been faulted in east-west, as well as north-south, northeast-southwest, and northwest-southeast directions. The faults are of the block type, such as are presumed to have formed from vertical strains rather than lateral thrust.

Another batholithic intrusion, the Beaverdell quartz monzonite, follows the quartz diorite. It is unfoliated and is, therefore, believed to have been formed after the pre-Eocene orogenic disturbances which took place throughout the western Cordillera. Certain of its pebbles occur in Oligocene sediments and it is, therefore, Eocene.

The Beaverdell batholith occupies about 60 square miles of the map area, a long lobate area lies in the northeastern part of the quadrangle and two smaller areas are found, one near Crystal mountain and the other at Beaverdell.

The average quartz monzonite is a medium, even-grained, white, granitoid rock in which a few small biotites are the only dark minerals visible, the rest of the rock being made up of feldspar and quartz. In the stock at Beaverdell the rock is coarsely porphyritic with large phenocrysts of orthoclase many of which are 2 or 3 inches long. These large, pink feldspars are very characteristic of the batholith as a whole, and the average even-grained rock grades locally into a more porphyritic type in which the larger feldspars are developed Near Collier lakes and north of them, a fine-grained holocrystalline roof facies, a quartz syenite aplite, is developed on top of the average, medium-grained, quartz monzonite (Plate XII). This batholith has very much smoother contact lines than that of the Westkettle. It seems to vary in mineral composition in a vertical direction, while the older rock body apparently does not. The quartz monzonite is unfoliated and comparatively unaltered, except in so far as it has been altered by the processes of weathering. It is faulted in directions which vary, but lie largely from north to north 22 degrees east.

A large intrusion of augite syenite porphyry holds inclusions of Beaverdell quartz monzonite, but is cut by apophyses of that batholith. It is taken to be a contemporaneous intrusion and, therefore, of Eocene age. Augite syenite porphyry occurs in a narrow strip on the eastern edge of the map-area north of Collier lakes. It is a chocolate to grey, porphyritic to holocrystalline rock. The bulk of the rock is a dark coloured porphyry which contains phenocrysts of greenish augite and biotite, in a dense groundmass; the coarser facies is grey, holocrystalline, and composed of feldspar, biotite, and augite. The rock mass has been brecciated but is comparatively unmetamorphosed.

Unconformably over the Wallace group and Westkettle batholith lies the Curry Creek series of sediments which carry pebbles of the Wallace group as well as Westkettle and Beaverdell batholiths. Plant remains of Tertiary age are found in this series and it is so similar to the Oligocene Kettle River series of Midway and similar series in the Boundary Creek district, from 15 to 30 miles to the south, that there can be no doubt that it is of Oligocene age.

The series outcrops on an area of about 4 to 5 square miles on Wallace mountain, and on the ridge south of Cañon creek. It is composed of about 2,500 feet of coarse, thick-bedded conglomerates, with interbeds of finer material, overlain by 200 feet of exceedingly thin-bedded, dense, white dacitic tuffs. The conglomerates dip westward at angles of 45 degrees at their base and flatten higher up in the section. The tuffs lie practically flat. They have both been severely faulted but are not intensely metamorphosed.

The tuffs of the Curry Creek series and some of the older formations are overlain unconformably by the Nipple Mountain series of lavas which resemble part of the Midway lavas to the south that have been tentatively classed as Oligocene. The lavas of the Beaverdell area are placed in the Miocene because of the unconformity with the Curry Creek series.

This series outcrops in a large area upon Nipple and Ferroux mountains and in smaller patches on Wallace mountain, near Lassie lake and at other places. It is composed of trachyte, biotite andesite, dacite, hornblende andesite, augite andesite, and basalt, which were extruded more or less in the order named. They are all somewhat porphyritic with phenocrysts lying in a groundmass which is often glassy, but sometimes wholly or partly crystalline. The trachyte, biotite andesite, and dacite are in many cases white or light coloured, the hornblende and augite andesite red or black, and the basalts black; but the same type of rock has more than one color. The lavas have been folded and some of them are brecciated.

The youngest deposits occur as a mantle of glacial drift over the upland, and terraced river deposits on the valley bottoms. The glacial drift consists of unconsolidated deposits of rounded boulders and sand, with, in places, a little clay, lying usually in unsorted masses upon the upland and in irregular hummocks and long ridges in certain spots where erosion is not actively at work. The river deposits lie in terraces upon the floors and sides of the valleys; they are made up of an unconsolidated mass of boulders, sand, and clay, certain terraces being very largely composed of boulders.

ECONOMIC GEOLOGY.

Three types of metallic ore deposits have been found in the district. They have been named "mineralized shear zones," "stocks," and "contact metamorphic deposits"; of these only the mineralized shear zones have, up to the present time, been mined at a profit.

The mineralized shear zones are found in an area of about 3 square miles on Wallace mountain, at the town of Carmi, and upon Arlington and King Solomon mountains. Nearly $100,000 worth of rich silver-bearing ore had been shipped from Wallace mountain by 1910, and, outside of one shipment from the Carmi mine, this represents the total output of the district up to that date. The shear zones on Wallace mountain carry values in silver and consist of galena, sphalerite, pyrite, tetrahedrite, and pyrargyrite in a gangue of quartz and sericite; native silver, calcite, chlorite, and kaolin, are secondary. At Carmi, the ore minerals are chalcopyrite, sphalerite, and pyrite, in a gangue of sericite, quartz, and ankerite. The country rock is in nearly all cases quartz diorite, for well-defined, mineralized shear zones are not found in the Wallace group, and in the few places where galena ores are found in the Wallace group they occur in small deposits. Dykes of andesite and aplite are found in the shear zones, and were intruded prior to the formation of the ore. The shear zones consist of partly replaced fragments of country rock, quartz, and the ore minerals, lying between two well-defined walls. They are from 1 to 10 feet wide, strike east and west, and dip to the south at angles varying from 50 degrees to vertical. The ore is partly a replacement of the country rock, but the greater part of it forms, with quartz, the filling between fragments of altered country rock in the shear zones. The order of formation of the minerals in the silver-bearing deposits is sericite, quartz, barite, pyrite; then sphalerite, galena, and tetrahedrite, accompanied by more quartz and pyrite; then pyrargyrite; and, lastly, native silver accompanied by chlorite, iron oxide, and calcite. Sericite has been formed by replacement of the country rock: quartz, and pyrite partly by replacement but largely as cavity fillings· he other minerals were seen only as cavity fillings, never as replacements. Native silver, calcite, kaolin, and iron oxide were formed long after the rest of the minerals. The paragenesis of the minerals in the shear zones at Carmi and other places was not determined.

The ore-bodies are tabular in shape, and their outlines are largely determined by the closely spaced fault planes which displace them. They are pockety, that is, they vary rapidly in value in a lateral direction; in certain places they carry as much as $200 to the ton in silver. It is believed that the galena ores on Wallace mountain change in depth to deposits resembling those at Carmi. The ores have been displaced by a great number of closely spaced faults; these strike from north by west to northeast and generally dip to the west. The faults with low dip appear to have caused the largest amount of displacement. The portion of the ore-body east of the fault plane is generally offset to the south.

The depth of the zone of oxidation is not great, but surface alteration proceeds farther down along fault planes. Glacial action is thought to be responsible for the practical absence of oxidized material on the surface.

The ore-bodies in the mineralized shear zones were formed by hot ascending solutions derived from the magma of Beaverdell quartz monzonite. Those at Wallace mountain were deposited within a few thousand feet of the surface; at Carmi they were at least 1,000 feet deeper. The country rocks apparently exerted no chemical influence on the ore-bearing solutions, but the Westkettle quartz diorite, by shearing into well-defined fractures, allowed the ore solutions to pass freely through it, and the ore minerals to be deposited within cavities in the shear zones.

The Wallace group, on the other hand, acted as a blanket which stopped the further circulation of the solutions from below. The ores were deposited partly by metasomatic replacement, but more largely by cavity filling. They were preceded by the intrusion of the Beaverdell quartz monzonite in the Eocene and were followed by the north-south faulting which had begun at the end of the Oligocene. They are probably of Eocene age, closely following the intrusion of the batholith.

The "stocks" are ore-bodies of indefinite shape which are found in the Wallace group, and often carry the sulphides pyrrhotite and pyrite. With the "stocks" are included all the ore-bodies which cannot be classed as mineralized shear zones or contact metamorphic deposits. They, therefore, include ores which have originated in different ways. They are found in various places in Wallace rocks, the more important being on St. John ridge and in the neighbourhood of the Triple lakes. The country rock is generally some member of the Wallace group. The ores vary from place to place; they always carry pyrite, and in different places the pyrite is accompanied by pyrrhotite or by chalcopyrite, arsenopyrite, and molybdenite. The gangue is generally quartz, sometimes with calcite and epidote. They lie in masses of quartz or disseminated through belts of sheared rock. The pyrrhotite ores were formed at great depth by hot ascending solutions and they may have been caused by the intrusion of the Westkettle quartz diorite. Others of the stocks may have been formed by hot solutions from the partially consolidated Beaverdell quartz monzonite batholith.

A "contact metamorphic deposit" is found on the Lottie F. claim on Copper creek just northeast of the map-area. It is made up of chalcopyrite, bornite, malachite, azurite, garnet, epidote, wollastonite, quartz, calcite, and an undetermined calcium silicate. Bornite and garnet crystallized together and after the formation of epidote. The unknown calcium, iron, manganese, sodium, aluminum silicate occurs as a lining to ellipsoidal cavities in the rock body. The country rock is limestone and diorite of the Wallace group. The deposit is probably the result of the intrusion of a large igneous mass below the present ore-body. This mass was not seen, but it is inferred to be Beaverdell quartz monzonite.

Occurrences of scheelite on Arlington mountain, and asbestos on the west side of Hall creek, are of interest rather than of immediate value.

Future of the District.

It is probable that the rich but pockety ores in the shear zones on Wallace mountain and the lower grade ores at Carmi may both be mined at a profit. The mineralized shear zones have been displaced along closely spaced fault planes and the chief problem in mining is the location of these faulted blocks of ore. Exploration for faulted ore-bodies will probably be costly, but they should be found more easily as the faulting becomes better understood. If enough ore can be found on Wallace mountain it should be possible to mine and transport it to the Kettle Valley railway at a comparatively low cost. At the Carmi mine the cost of mining will be increased by the cost of pumping from the start of operations. The ores run much lower in value than those on Wallace mountain and mining will have to be carefully done in order to show profits.

The ores in the "stocks," and the contact metamorphic deposit at Copper creek have been prospected, but not mined. They are nearly all at some distance from the new railway, and their future depends upon the opening up of larger bodies of ore than have been uncovered so far.

The non-metallic products of the district have not proved of value up to this date. The discovery of scheelite and asbestos is interesting, but not as yet of economic importance. The altered augite-andesites and tuff of the Wallace series will make good road material, and so will nearly all members of the Nipple Mountain lavas.

CHAPTER III.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

REGIONAL.

The Beaverdell map-area lies within and near the south-eastern corner of the Interior plateaus of the British Columbia cordillera. Near the International Boundary and from there north to the 55th parallel of latitude, the Canadian cordillera consists of three divisions; a broad mountainous belt to the east, a more compact mountainous unit along the Pacific ocean to the west, and a lower and relatively flatter region between.

At the International Boundary the broad eastern belt includes the Rocky Mountain system and the Purcell, Selkirk, and Columbia systems; the western belt consists of the Coast ranges and the subordinate ranges upon Vancouver and Queen Charlotte islands; the flatter region in between is known as the Interior plateaus.

Near the 49th parallel of latitude, the cordillera, excluding the mountains on Vancouver island, is about 400 miles wide, farther to the north it narrows somewhat.

Interior Plateaus.

The region of Interior plateaus is about 500 miles long by 100 wide and trends northwest from the International Boundary to about the 56th parallel. It consists essentially of areas of rolling upland separated from each other by deep valley trenches. Unlike other units of the cordillera its boundaries are not everywhere well defined, and in places the uplands seem to rise to meet the mountains.[1] To the west of it lie the Cascade and

[1] Camsell, Chas., "The geology and ore deposits of the Hedley mining district, British Columbia": Geol. Surv., Can., Memoir No. 2, p. 30; see also p. 9.

Coast ranges; to the east the Columbia system; on the north it is bounded by a group of irregular ranges, which lie between the Coast range and the Rocky Mountain system and whose southern limits are near the 56th parallel of latitude; to the south it ends in wedge-shaped form against the Hozameen, Skagit, and Okanagan ranges of the Cascade system, and the Colville mountains of the Columbia system.[1]

In the southern part of the plateaus the uplands lie from 4,000 to 6,000 feet above sea-level. They are said to decrease in general elevation to the north. The main valleys lie from a few hundred to over 4,000 feet below the upland, and a few rugged hills rise several hundred feet above the surface. The total relief within areas of a few hundred square miles is probably nowhere over 5,000 feet, and is generally less than 4,000.

The greater part of the Interior plateaus drains south and west into the Pacific by way of the Fraser and its tributary, the Thompson. A portion at its northern end drains into the Skeena river. The southern and southwestern end is drained by the Similkameen, Okanagan, and Kettle rivers, whose waters all flow into the Columbia.

The walls of the deep valleys which separate the Interior plateaus into irregular blocks have much steeper slopes than those prevailing on the uplands between them. The junction of upland and valley wall is generally abrupt, and the plateaus are thus divided into *upland* and *valley* portions which are topographically distinct. Shallow valleys also occur upon the upland but these are considered as forming a part of that surface. The areal ratio of upland to valley is about three to one.

LOCAL.

Beaverdell Area.[2]

The part of the Interior plateaus included within the Beaverdell map-area consists of a rolling upland with a relative relief of 2,000 feet. It is drained for the greater part by the West-

[1] Daly, R. A., "The nomenclature of the North American Cordillera between the 47th and 53rd parallels of latitude"; The Geographic Journal, vol. 27, No. 6, June, 1906, pp. 586-606, 1 map.

[2] A more detailed description of the Beaverdell topography and of the physiographic development of the Interior plateaus is published in Geological Survey Museum Bulletin No. 11.

kettle river whose bottom lies from 1,000 to 1,500 feet below the surface of the upland, increasing the total relief to about 3,250 feet. The Westkettle flows southerly and joins the main Kettle river, which is roughly parallel to it, and 12 miles to the east, about 16 miles south of the area. The Kettle flows south along the eastern foot of the Midway mountains to a point near the International Boundary, where it turns east and finally enters the Columbia south of the Rossland mountains. In its north-south course the deep valley of the Kettle forms the eastern border of the Interior plateaus, which wedge out a few miles south of the International Boundary.

The rolling surface of the high country is diversified by buttes and mesas of Miocene lavas, often surrounded by high cliffs which lend a rugged element to the scenery. It consists of broad ridge areas trending north to northeast, each of which is a composite of a number of small, parallel ridges. These major ridges slope gently down to more or less steep, bounding valleys. Their crest lines are in some cases nearly flat for several miles, but in others pitch strongly toward a valley, or from a lava-covered butte. The average elevation of individual flat topped ridges ranges from about 4,000 feet, near the deep Westkettle valley, to 4,700 feet in most of the country east of it, and to over 5,700 feet near the large volcanic-covered area of Nipple mountain. Nipple mountain, the highest point on the map, is 5,758 feet high. Nipple mesa, north of it, and Red mountain, 3½ miles to the southwest, both outside the quadrangle, are at about the same elevation. Goat peak, a volcanic plug on Wallace mountain, is 5,675 feet high, while lava mesas to the northeast of it are over 5,500 feet.

Many local irregularities in slope occur within the uplands; small, parallel, steep sided ridges are common within areas underlain by plutonic batholiths; contrasts of flat hilltops and sheer cliffs are often seen within the lava areas and some of the cliffs, as in the Goat Peak region, reach a height of several hundred feet. The soil covering is irregular in thickness and everywhere characterized by the presence of rounded pebbles foreign to the rock formation below. These erratics are found upon the highest point in the quadrangle. The upland surface cuts across contact surfaces between the formations older than the Tertiary lavas at all angles. Tertiary lavas, however, generally occupy higher ground than the adjacent, older rock formations; very many of the contacts occur at the base of a lava cliff, cliffs of this character being the rule rather than the exception.

To the west the upland surface appears to rise gradually to the watershed between the Okanagan and Kettle rivers; on the east of the quadrangle it ends at the canyon of the Kettle river; northward it appears to become less rugged; but about 20 miles north of the quadrangle, the flat surface is interrupted by a high ridge coming from the northeast, known as the Black ridge, with Ptarmigan mountain apparently near its southwest end; to the southwest the upland is rugged and apparently much broken by canyons, while to the southeast the Plateau surface ends or merges into the Midway mountains.

The Westkettle river occupies a steep sided, flat bottomed valley which crosses the western half of the quadrangle in a north-south direction. It falls from an elevation of over 3,000 feet on the northern to about 2,500 feet at the southern end of the quadrangle. Its tributary, Beaver creek, drains a large part of the quadrangle to the east and occupies the same type of valley in the lower 5 miles of its course. Numerous streams coming from the broad troughs on the upland surface flow through V-shaped canyons into the larger valley bottoms of the Westkettle and the Beaver. The upland valleys resemble a flattened V, in cross section, and are a part of the upland surface. The change from valley side to upland slope is abrupt and forms a distinct knee in profile. Corresponding to this there is a steepening of stream grade upon going from upland to canyon bottom.

The Westkettle Valley floor is made up of a series of terraces which occur in irregular patches upon its bottom, or as fragments perched far up on the valley sides; similar terraces occur in the tributary valleys. The terraces are complicated or obscured by alluvial fans, where side streams enter the valley, by rock outcrops, and by morainal deposits and kettle holes. Unmodified glacial deposits are rarely met with. A number of lakes occur upon the upland and in the valley bottoms. They are small and generally quite shallow. Some of them occupy rock basins, but in many cases their lower ends appear to be held up merely by local deposits of loose glacial detritus or by beaver dams.

CLIMATE AND AGRICULTURE.

No records of either the variations in annual rainfall or the annual ranges in temperature have been recorded for the West-kettle valley, but such records are available for Penticton and Kelowna on Okanagan lake and for Midway on the International Boundary.[1] Penticton lies 25 miles west and Kelowna 45 miles northwest of Beaverdell. They are about 1,400 feet in elevation below Beaverdell. Midway is about 40 miles south of Beaverdell and 550 feet in elevation below it.

The average precipitation at Kelowna during 1878, and from 1899 to 1912, was 9·68 inches of rain and 39·9 inches of snow, that is 13·67 total inches of water, per year. At Penticton, the average between 1908 and 1913 was 9·60 inches of rain and 18·7 inches of snow or 11·47 total inches of water per year. At Midway, it was 9·26 and 29·9 inches of rain and snow, respectively, giving a total precipitation of 12·25 inches of water per year.

Midway, Penticton, and Kelowna are all situated in the bottoms of deep valleys. The uplands near them probably have a slightly higher annual rain and snow fall, but they lie in a drier belt than the watershed of the Westkettle. This is indicated by a more luxuriant forest growth and the comparative absence of open grass covered slopes in that valley.

A record of the temperature conditions at Kelowna during the years 1899 to 1912 show that the average temperatures for the winter months were as follows, in degrees Fahrenheit: November 36·4, December 30·3, January 23·6, February 25·7, March 36·7; the average temperature in April was 46·6. For the summer months: May 55·4, June 61·2, July 66·7, August

[1] Details of climatic conditions in British Columbia and other parts of Canada may be obtained on application to R. A. Stupart, Dominion meteorologist, Toronto, Canada.

63·7, September 54·8; the average October temperature was 44·8. The extreme highest temperatures attained during these years were 96 in July and 95·4 in August, and the extreme lowest 8·6 below zero in November, 3 below zero in December, 22 below zero in January, 18·5 below zero in February, and 5·5 below zero in March. In no other month did the temperature attain the zero mark, but in all of them except June and July it reached the freezing point. It should be remembered that the extreme temperatures mentioned may have been reached only once or twice during the thirteen recorded years.

The Westkettle valley is decidedly cooler in summer than the region near Kelowna on Okanagan lake, and such is especially the case on the upland where there is a delightful summer climate. On the other hand the winters are much colder and the tempera-ture undoubtedly falls down to thirty and even forty below zero for a day or so in the winter months.

Apples and other fruits have been successfully grown at Rock creek, about 35 miles south of Beaverdell in the Kettle valley, and large apple orchards were laid out there a few years ago. On the Westkettle, fruit raising is in the experimental stage. The occurrence of summer frosts and rather low average temperatures are the obstacles with which pioneer fruit growers have to contend. Hay, wheat, and vegetables have been successfully grown along the Westkettle and Kettle River bot-toms, within, and just east of, the mapped area. The amount of land which he farmed is not, however, very great, for only about one-t t is valley bottom and a great deal of that is stony, so tha acreage of tillable ground is restricted. The upland and steep valley sides are in general unsuited for cultiva-tion, both because of lack of soil and great elevation. While, therefore, a certain amount of farming will probably be done in this district in the future, it will be confined to a very small acreage along the river flats.

ANIMAL LIFE.

Before the ad of the railway the watershed of the West-kettle river was well stocked with game, especially deer and grouse. Fur-bearing animals are steadily decreasing in numbers and for the last ten years trapping has not been very profitable. Many of the smaller animals still exist in great numbers, however, and fish abound in certain lakes, although they are not very plentiful in the creeks or upper parts of the river.

Blacktail or mule deer were abundant throughout the valley in 1910 and 1911. Whitetail or Virginia deer were said to have existed in certain of the brushy bottoms a few years ago but have apparently been exterminated or driven out. Occasionally, woodland caribou and mountain goat wander into this region but they are not often seen.

Three species of grouse are found in the district, the spruce partridge, the ruffed grouse, and the blue grouse. Ducks appear in small flocks only.

Of the fur-bearing animals those most sought after, the lynx, fisher, and martin, are becoming very scarce. Coyotes are quite plentiful in certain places and an occasional black bear and cougar roam through the district. Beaver, for which there has of late been a closed season, are probably the only fur-bearing animals which have increased in numbers.

In certain of the lakes there is an abundance of trout. They are not plentiful in the Westkettle river or its tributaries, although good fishing may be had upon the Kettle. The trout seldom weigh over one pound.

Of the larger birds, loons are the most in evidence. The Great Horned owl was seen upon one or two occasions and there are many varieties of hawks. The Golden eagle was never positively identified although some of the larger hawks could readily be mistaken for eagles when seen at a distance.

TIMBER AND VEGETATION.

The Westkettle valley, as well as other portions of the southern portion of the Interior plateaus, is entirely covered with forest (Plates I, II, and VI). In some of the drier belts of the plateaus, near the International Boundary, notably in the hills near Midway, the forest thins out or disappears and the mountains are covered with bunch grass, and again on the tops of the higher ridges and peaks, at elevations of 6,000 feet and over, above sea-level, the tree growth becomes stunted. Along the Westkettle and its tributaries, however, these conditions obtain only very locally. The thinning out of the forest trees can be seen on southern hillsides as on the south nose of King Solomon mountain, and the gentle slopes of Knob hill; but otherwise areas recently burned over are the only breaks in the forest cover. The timber line must be over 6,000 feet within this district, an altitude which is not reached by any of the ridges within the map-area.

The principal varieties of the larger trees are the bull pine (*Pinus ponderosa*), fir or Oregon pine (*Pseudotsuga mucronata*), tamarack (*Larix occidentalis*), spruce (*Picea engelmannii*), balsam (*Abies lasiocarpia*), cottonwood (*Populus tricocarpa*), birch (*Betula papyrifera*), and quaking aspen (*Populus tremuloides*) are occasionally met with. The bull pine grows in the valley bottoms and on southern hill slopes up to an elevation of about 3,600 feet. Some of the trees are 3 or 4 feet through at the butt; they attain a height of perhaps 80 feet and make excellent lumber. Very few of these trees were seen north of the town of Carmi. Firs grow upon the high ridges as well as in the valleys, and are found everywhere but in the swampy flat areas which exist in parts of the upland. They rival the pines in size. The tamaracks grow with firs upon the hillsides and in the dry valley bottoms. They are tall, straight trees and often grow to great size in the valleys. Spruces are found in numbers only in swampy portions of the upland, like the area in the upper part of Maloney valley, and on the edges of small lakes. They attain a height of 30 to 50 feet and form a thick forest in the wet bottoms. Balsam and cottonwood trees are rare, the balsam occupying high and cool ground like the north slopes of the higher peaks, and the cottonwoods small flats in the low valleys. Birches grow in the valley bottom of the Kettle river to the east. They are practically absent from the upper Westkettle.

Probably more than half of the country drained by the Westkettle has been burned over in the last fifteen years and these burned areas are generally thickly grown over with jack-pines which attain heights of 60 feet in places, but are rarely a foot through at the butt.

Flowering plants are common on open hill slopes, and in June and July they blossom in great profusion.

The universal forest prevents the development of extensive grass land. Bunch grass grows on dry southern slopes where the trees are thin, and in the wetter swamps a thick, hard grass takes the place of the forest. Everywhere else the ground is covered in the spring and summer by a thin carpet of grass locally known as pine grass.

Lumbering has been carried on in a small way in the bottom of the Westkettle and Kettle valleys for a number of years, and during 1911 tie timber was taken out from the hill sides flanking the valley. Bull pine has been the most sought after, but fir and tamarack are also used. More extensive cuts will probably be made in the future with the cheapening of transportation by the new rail connexions to the coast. It is probable that about one-half of the map-area has been burned over recently enough to prevent large timber being found there. Of the timber that is left standing the greater part is under 2 feet in diameter at the butt. In the valley bottoms, however, the trees grow to larger size.

The large acreage that has been burned over deserves a word here. Plate III is a photograph of a recently burned area, and shows the kind of thicket that is found on such areas within a year or two after the fire. Areas that are burnt over are veritable "waste places," for not only do the fires destroy the marketable timber, but the seedlings are supplanted and choked down by thickets of jack-pine and alder bushes. Timber trees apparently do not gain a foothold again until many years after, and in places where the soil is thin and where several fires have passed, they do not grow at all. When one considers that a very large part of this district will never be of value from an agricultural standpoint, but will grow valuable timber if forest fires are kept out of it, the urgent need of adequate protection from fire becomes apparent.

INHABITANTS.

There are no records of Indian settlements in the Westkettle valley although hunting parties are said to have come over from Okanagan lake in seasons when the deer were plentiful. White men have probably trapped through this country since about 1860, and have prospected more or less actively in the neighbouring hills for the last twenty years. Between 1896 and 1900 there are said to have been nearly 1,000 prospectors in the hills on both sides of the river. In 1911, the population had dwindled to about 50, but the building of the Kettle Valley railway up the Kettle and Westkettle valleys brought about a turn of the tide and the forerunners of a fresh influx of railway workers and others began to reach Beaverdell and Carmi in the autumn of 1911.

The majority of the white men who lived in the Westkettle before the building of the railway were engaged in trapping and prospecting or mining. Many of them staked out ranches and worked these more and more as the returns from furs or prospects became smaller. A number of them are typical frontiersmen who came to the valley during the boom and stayed on, partly because of the attractiveness of the country and their liking for the frontier conditions which obtained there, and partly through a dogged desire to stay until prosperity should return.

COMMERCIAL POSSIBILITIES.

The upper reaches of the Westkettle valley do not hold out very great promise of agricultural development. The area of land that can be tilled is small, and the climate is too severe for any but hardy crops. The dense forest and consequent scarcity of good grass will also place a limit upon the quantity of stock which can be raised. The district does, however, possess more than the average acreage of unburnt timber. It is a natural haunt for game, and several of its smaller lakes swarm with fish. The scenery around some of the lakes is exquisite, and the climate in summer delightful.

Mining is still in the prospective or, rather, exploratory stage. Small bodies of rich ore have been found upon Wallace mountain, and one is justified in believing that other bodies of the same type will be found there. The chief obstacle to profitable mining has been the cost of exploring for blocks of ore which have been displaced by the numerous faults that intersect the ore-bodies. If the displaced blocks can be located by some means less expensive than driving cross cuts underground, it should be possible to develop one or two paying mines on Wallace mountain and perhaps at Carmi. Prospects in other parts of the district are less promising. It must be remembered, however, that the future of the mining industry is dependent on a great many factors, and several of them are at present unknown and can only be guessed at. The above suggestion as to its possible future development should not, therefore, be taken as a statement of fact.

CHAPTER IV.

GENERAL GEOLOGY.

REGIONAL.

The cordilleran system in southern British Columbia may be divided, upon geological grounds, into two belts which have been called the Eastern and Western geosynclinal belts respectively. The exact dividing line between the two has not been definitely determined; it probably lies within the Selkirk range. The Eastern belt is made up nearly entirely of sediments which range from the Pre-Cambrian Beltian system to the Permian. The total thickness of the sediments is more than 50,000 feet, and only a few local unconformities have been found between the formations within the section. The Western belt consists of discontinuous areas of metamorphosed sediments and lavas, of great batholithic intrusives, and of later unmetamorphosed sediments and lava flows. The Beaverdell area lies within the Western geosyncline, which stretches for hundreds of miles north and south along the cordillera. This general account is confined to that portion of the belt which lies between the Selkirk mountains on the east and the Coast ranges, and between the United States boundary and the main line of the Canadian Pacific railway.

The oldest rocks known within this belt are a series of Pre-Cambrian metamorphosed sediments and greenstones called the Shuswap series. Their total thickness is at least 30,000 feet, of which the younger greenstones form about one-third. They are typically developed at Shuswap lake on the Canadian Pacific railway and underlie large areas in the Columbia and Selkirk mountains.

Scattered through the Interior plateaus and along the International Boundary south of the Selkirk and Columbia mountains are a number of detached areas of metamorphosed rocks, in several of which Pennsylvanian fossils have been found. Palæozoic rocks older than the Pennsylvanian are probably present; but, since most of the metamorphic series are unfossiliferous, their age is a matter of doubt. Correlations are made very largely on lithological similarities. A number of series so correlated by Daly[1] with neighbouring fossil-bearing rocks of marine Pennsylvanian age, are largely of sedimentary and subordinately of volcanic origin. The Cache Creek series, which was one of the first of these groups to be described, consists of argillites, cherty quartzites, volcanic materials, and limestones, with a total thickness of 9,500 feet. It occurs west of Kamloops, on the border of the Interior plateaus.

Unconformably upon the Pennsylvanian lie, in certain localities, less intensely metamorphosed lavas with subordinate sediments which are of Mesozoic age. Dawson[2] described a series of this type on the Thompson river, which is largely Triassic and partly of Jurassic age with a thickness of 13,600 feet; he called it the Nicola formation.

The metamorphosed rocks are intruded by great batholithic masses which range from gabbros to granites, but of which the great bulk approach granodiorites in composition. The larger part of these exposed at the surface to-day were probably intruded during the Jurassic, but some of the more basic bodies are older and a number of batholiths are intruded into Tertiary rocks.

Thick, narrow prisms of coarse Cretaceous sediments are found in a few places. They carry marine fossils and land plants. The next sediments are coarse conglomerates, sandstones, and tuffs of Oligocene age in which only land flora and insects are found, and they are accompanied and followed by abundant outpourings of lava, some of which is of Miocene age. With Miocene lavas are in places interbedded shaly sediments containing plant remains. Over all lies a blanket of glacial drift.

Very little is known of the geology of the district immediately surrounding the Beaverdell area. Detailed work has been done

[1] Daly, R. A., "Geology of the North American Cordillera at the 49th parallel": p. 554.
[2] Dawson, G. M., "Report on the areas of the Kamloops map-sheet, British Columbia": Ann. Rep., Geol. Surv., Can., Vol. VII, 1894, p. 53B.

in a small area 30 miles to the east of Beaverdell, and more extensive surveys have been made along the boundary to the south and southwest, but to the north there is a long stretch of which nothing is known. On the Canadian Pacific railway in that direction the Shuswap series covers a wide area. Dawson[1] in a reconnaissance along Okanagan lake describes rocks there which resemble certain of the Beaverdell formations. It is probable that the country for 30 or 40 miles to the south, east, and west, and for some distance to the north, is underlain in the main by the rock types outcropping in the Beaverdell area, and in addition perhaps by representatives of the Cache Creek group.

GEOLOGY OF THE BEAVERDELL AREA.

Within the Beaverdell area occurs the Wallace group of volcanic rocks with subordinate sediments, schists, and coarse-grained intrusives, the greatest part of which has been tentatively referred to the Mesozoic. They have been intruded and metamorphosed first by the Westkettle quartz diorite batholith of Jurassic age, and later by the Beaverdell quartz monzonite batholith probably of Eocene age. The Curry Creek series of Oligocene conglomerates and tuffs lies unconformably over the older rocks. The youngest rocks are a series of lavas probably of Miocene age which overlie the Curry Creek as well as the other formations unconformably. A blanket of unconsolidated glacial drift overlies the upland, and terraces of river alluvium are found upon the valley floors.

The following table includes the various formations met with in this area. The main divisions have been mapped as separate units except in the case of the glacial deposits. The latter, when found near the bottom of river valleys, were included with river alluvium in the recent deposits, and outside the immediate river bottoms they were mapped only when thick and extensive enough to cover rock outcrops over a considerable area.

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[1] Dawson, G. M., "Preliminary report on the physical and geological features of the southern interior portion of British Columbia, 1877": Geol. Surv., Can., Ann. Rep. for 1877-1878, pp. 101-105 B.

Table of Formations.

Age.	Formation	Lithological characters.	Thickness in feet.
Quaternary		River alluvium. Glacial deposits.	100+
Miocene	Nipple Mountain series	*a* Olivine basalt *b* Augite andesite *c* Hornblende andesite *d* Dacite *e* Biotite andesite *f* Trachyte	4000 to 5000
Oligocene	Curry Creek series	White dacitic tuffs............ Conglomerates, with some sandstones and agglomerates	200 2500+
Eocene ?	Beaverdell batholith	Augite syenite porphyry. Quartz monzonite	
Jurassic ?	West Fork batholith	Quartz diorite	
Mesozoic	Wallace group	*a* Hornblende diorite porphyries. *b* Andesite and dacite schists *c* Basic intrusives: Olivine gabbro, saxonite, saxonite porphyries, pyroxenite, and hornblendite. *d* Augite and hornblende-andesite	200+
		e Hornblende andesite tuffs with some augite andesite tuffs and non-volcanic sediments......	1100
Carboniferous ?		*f* Hornfels....................	100+
		g Limestone..................	200

WALLACE GROUP.

The Wallace is a complex composed largely of andesites and andesitic tuffs accompanied by basic intrusives which occur in dykes and small stocks. Among these igneous rocks are found small and irregular bodies of crystalline limestone and hornfels. The greater part of the formation is more or less intensely metamorphosed. The preceding table gives in descending order the formations which make up this group and the approximate thickness of the sediments and tuffs.

Limestone appears to be the oldest formation present and after it came hornfels and tuffs which are in places interbedded. Both sediments and tuffs are cut by andesite dykes and they in turn are intruded by hornblende diorite porphyries. Certain of the schists are also intruded by hornblende diorite porphyries, others grade into them. From their manner of occurrence and position, the basic intrusives are thought to form the deep-seated and more coarsely crystalline portion of a large body of augite andesite; but the evidence upon this point is not definite.

Distribution.

The Wallace group occupies about one-third of the map-area. The greater part of it outcrops upon the higher upland and it is especially well developed in the southeastern part of the area. Two large areas lie between Cedar creek and the Kettle river and on St. John and Mosher ridges; another occupies the south side of Curry mountain and part of the west flank of Wallace mountain. Smaller detached areas are found on both sides of the Westkettle valley north of King Solomon mountain. All of these areas are extremely irregular in outline. Within the Wallace areas the different units of the series are grouped in a very haphazard and patchy manner. Andesites and tuffs occupy about 80 per cent of the area mapped as Wallace, while the combined areas of the sediments would probably be less than 5 per cent of the whole.

Lithology and Metamorphism.

Limestone. The limestones are generally white, but in places have dark bands and in one outcrop the rock was black. They are generally crystalline, rather coarse-grained and massive, although often banded, and in one case finely foliated. Certain outcrops appear to be made up almost entirely of calcite; others contain more or less quartz, garnet, epidote, and diopside.

The limestones have been metamorphosed by mechanical strain as evidenced by their occasional foliated appearance and by the deformation of the calcite grains observed in certain specimens of massive limestone examined under the microscope. More often and especially close to outcrops of younger intrusive bodies, contact metamorphism has taken place, the rock has been injected by quartz, and the silicate minerals, garnet, epidote, and diopside have taken the place of the calcite grains.

Hornfels. The hornfels are very dense, fine-grained, grey to reddish grey rocks in which no individual minerals can be distinguished. It is only by microscopic study that they can be separated from the tuffs. They have evidently all been completely recrystallized and have lost their original texture in the process, so that they appear under the microscope as granular mosaics of quartz, feldspar, and biotite.

Tuffs. The tuffs are dense, grey, reddish grey to black rocks generally banded (Plate IV) but in places massive. They are difficult to distinguish from the hornfels and andesite in the field and their composition can only be determined under the microscope. The tuffs are either hornblende andesite or augite andesite tuffs, the former of which occur in far greater amount. Hornblende andesite tuff is made up essentially of broken fragments of hornblende, plagioclase, and quartz, and in places they contain bands of very fine-grained black material. An outcrop of augite andesite tuff near Cañon creek contained rounded fragments of augite andesite, hornblende andesite, brown volcanic material, and single crystals of feldspar and hornblende. They have been metamorphosed in the same manner as the andesite flows described below.

Basic Intrusives. The basic intrusives in this group are defined as pyroxenite, hornblendite, saxonite, saxonite porphyry, and olivine gabbro.

The pyroxenites are greenish black, coarse-grained, granular rocks. They are occasionally foliated and grade into a black schist. Pyroxene, hornblende, and feldspar may be seen in certain outcrops and occasionally the rock is entirely without feldspar. A thin section from Arlington mountain consisted of magnetite, apatite, titanite, green augite, secondary hornblende, and epidote. Nine-tenths of the mass was made up of augite and secondary hornblende.

The hornblendites are black, coarse-grained rocks made up almost entirely of hornblende and biotite. The hornblendes are lath shaped and often 2 inches long. A thin section of the rock consisted of magnetite, titanite, biotite, hornblende, and plagioclase. The hornblende occupies 90 per cent of this section.

The saxonite is a coarse-grained, black rock with large glistening faces of hypersthene containing a few grains of olivine. It is made up of magnetite, spinel, olivine, hornblende, hypersthene, phlogopite, pyrite or pyrrhotite, chlorite, serpentine, and sericite.

The only occurrence of saxonite porphyry in the area has been very largely altered to serpentine. It is a grey black fine-grained rock with bands of green serpentine and in places veinlets of fibrous serpentine or asbestos running through it. The banding is generally horizontal and the asbestos veins more noticeable near the weathered surface. None of the asbestos veins seen were over one inch in thickness. Under the microscope the rock appears to consist of partly altered olivine and enstatite lying in a dense groundmass which has been entirely altered. The alteration products are serpentine, magnesite, chlorite, talc, and magnetite.

The olivine gabbro is dark grey, coarse-grained, and weathers to a characteristic rusty brown. In this regard, it resembles the coarser phases of the augite andesites. It is made up of magnetite, bytownite, olivine, phlogopite, hornblende, pyrrhotite or pyrite, and serpentine. Crystals of hornblende include grains of the bytownite feldspar, of olivine and of augite, in what is known as poikilitic intergrowth. Hornblende and olivine are the minerals which can most easily be detected in the hand specimens.

The basic intrusives have in places been mashed, in others, injected by feldspathic dykes. The augite has in many cases been altered to hornblende and they have all been more or less severely brecciated. The metamorphism they have undergone can best be ascribed to accession of heat and pressure which took place while the rocks were deeply buried. The depth of their cover or the degrees of heat and pressure which obtained were not, however, great enough to cause flowage and complete foliation of the rock mass.

Andesites. The great bulk of andesitic flow rocks in this area are augite andesites approaching the basalts in composition. Subordinate to these are hornblende andesites. The augite andesites are dark grey and weather to a rusty brown. They are generally dense or somewhat porphyritic but occasionally granitoid phases appear. Under the microscope, they are found to be made up of magnetite, labradorite, augite, hornblende, epidote, chlorite, and biotite. Of these minerals only augite, hornblende, and feldspar can as a rule be distinguished in the hand specimens. Microscopic examination shows that the hornblende is practically always a secondary alteration product after augite and that the rock as a whole has been recrystallized and the edges of the constituent minerals intimately intergrown. The proportion of the constituent minerals is approximately as follows: labradorite feldspar 40 per cent, augite and hornblende 40 per cent, other constituents 20 per cent.

The hornblende andesites consist of magnetite, titanite, hornblende, andesine, orthoclase, and quartz. In one section examined under the microscope the proportions were roughly andesine feldspar 33 per cent, orthoclase 20 per cent, hornblende 40 per cent, quartz and magnetite 7 per cent. These rocks are a lighter grey than the augite andesites but resemble them closely in appearance. They approach the latites in composition.

The andesites and andesitic tuffs have as a rule been thoroughly broken up or brecciated. Under the microscope the constituent minerals are sometimes bent and frayed, very seldom finely granulated, but the rock is never foliated. The augites are as a rule partly or wholly altered to secondary hornblende and the feldspar to biotite and to dirty looking masses probably largely epidote. The metamorphism is such as would be produced by accessions of pressure and heat accompanied by circulating waters, and can best be explained as the result of the intrusion of the huge Beaverdell quartz monzonite batholith, which has broken up and partly altered the andesites and has caused rock flowage and foliation in less resistant masses of quartz diorite near the andesites.

Schist. The schists are more or less thinly foliated rocks genera[illegible] or grey in colour. They are made up of feldspar, hornb[illegible] and other minerals in varying proportions. They split [illegible] along their foliation planes and one may distinguish feldspar, hornblende, and biotite, when the latter is present, upon the cleavage faces. One type of the schists from King Solomon mountain, consists of about 50 per cent andesine feldspar, 35 per cent hornblende, 10 per cent of quartz, and 5 per cent of magnetite. Other types contain 80 per cent of hornblende with feldspar and no quartz.

The foliated appearance of the schists is caused by the arrangement of the hornblendes and biotites with their longer axes lying in parallel planes and by the segregating of the black and white minerals into parallel bands. They are all metamorphosed rocks which have been subjected to intense pressure and heat. This caused recrystallization of the biotites and hornblendes with their long axes parallel and the granulation and slicing of the feldspars and quartz.

Hornblende Diorite Porphyry. These rocks are dull grey on a fresh surface and weather to a brown grey. They are holocrystalline, fine-grained, and inclined to be porphyritic. In the hand specimen large crystals or clusters of hornblende and biotite lie in a groundmass in which the individual crystals are seldom recognizable. The whole rock surface has a dull appearance and individual crystals a blurred look and in that respect they differ from the fine-grained facies of quartz diorite which has a clean cut "pepper and salt" appearance. A thin section of a specimen from the Idaho claim on Wallace mountain, consisted of 50 per cent labradorite feldspar, 25 per cent hornblende, 10 per cent of quartz, 15 per cent of biotite, and a small amount of magnetite and apatite.

The diorite porphyries have all been metamorphosed but to different degrees. Some of them are foliated like the schists; and in one body of rock one may trace a gradation from a foliated portion through rocks in which the feldspars and other minerals are bent, sliced, and granulated, but in which the parallel arrangement is not perfect, to a more massive portion in which no parallel arrangement is noticeable although the rock is often brecciated and microscopic study reveals the effects of mechanical strain and partial recrystallization. They have, in fact, like all members of the Wallace group, been subjected to accessions of heat and pressure, the degree of their alteration probably depending on their position in regard to the sources from which the heat and pressure were derived. The main agent of metamorphism of the Wallace group is thought to be the intrusion of the Beaverdell quartz monzonite batholith.

Structure.

The original structure of the limestone has been obscured by the recrystallization the rocks have been subjected to. They are often banded, the bands varying in colour and mineral composition and these bands probably correspond to bedding planes, but bedding planes are in most outcrops not easily detected. They are not often brecciated but occasionally foliated or schistose.

The hornfels and tuffs are in most cases banded, the bands being from a few millimetres to several inches in thickness (Plate IV). The banded tuffs are in places quite thick and they have been thrown into a number of irregular open folds with their axes trending roughly north-south. The strike of the beds on the sides of the folds often correspond to the contacts of nearby and younger intrusive igneous masses. The hornfels and tuffs are generally very thoroughly brecciated.

The andesites, of which the great bulk are augite andesite, occur as dykes, as irregular masses, and in sheet-like form.

In places there are large stocklike masses of augite andesite, notably one at China and another at Cañon creek. The augite andesite at China creek appears to grade into a number of basic intrusives which outcrop 1,000 feet below the andesites, and they may form part of the same mass; if that be the case the augite andesite has been intruded as an irregular stock. The Cañon Creek occurrence is also stock-like in form.

All the andesites are thoroughly brecciated (Plate XI), and the planes of fracture are in many places so closely spaced that it is difficult to get a fresh surface of any extent from an outcrop. They are never foliated.

The coarse-grained, basic intrusives are dykes, sheets, and irregular bodies of rock which generally lie in detached patches. They are all more or less brecciated and occasionally schistose. This applies to the hornblende diorite porphyries as well as to the ultra basic rocks like pyroxenite, hornblende, saxonite, and olivine gabbro.

The schists occur in small bodies, in many instances near the contact of a large intrusive mass. They are in many places made up of several original rock units now all metamorphosed together and not separable without microscopic study. They are characteristically thinly foliated with individual bands, at times less than one-fiftieth of an inch in thickness. The strike of the planes of foliation is in most instances roughly parallel to the line of contact of a nearby younger intrusive mass. If the schists are far from intrusive masses the foliation planes appear to have a general trend to the northwest or not far from it. This corresponds to the trend of foliation planes in certain parts of the Westkettle batholith and may indicate regional metamorphism. The planes of the foliation generally dip at high angles in the greater number of outcrops. The amount of schistose rocks in the whole area is very small.

Relations to Other Formations.

The Wallace group comprises the oldest rocks within the area. The hornblende diorite porphyries may closely precede the intrusion of the next succeeding quartz diorite batholith, while the limestones are much older. Into this group there has been intruded both the Westkettle and Beaverdell batholiths and their associated dykes. The conglomerates of the Curry Creek series contain pebbles of all the members of the complex, and this series with the Nipple Mountain lavas following it, overlies the Wallace in several places.

Age and Correlation.

In the absence of fossils this group must be correlated with others on lithological grounds. The geological history of that part of the Interior plateaus which lies between the Coast and Columbia ranges south of the Canadian Pacific railway appears to have been much the same throughout. Rock formations in this area not only resemble each other lithologically but have the same relations to the formations preceding and following them. This geological province includes also the transverse ranges of mountains which extend along the International Boundary from Midway to Rossland. Daly[1] in his work along the International Boundary has divided the metamorphic rocks found there into two groups; a lower group, which consists of intensely metamorphosed rocks dominantly of sedimentary origin and sandy and argillaceous in character, and an upper group in which the rocks are less intensely metamorphosed, that is, they are brecciated but not often foliated. In the upper group the formations are largely tuffs and lavas of volcanic origin with very few true sediments. The lower division includes, amongst others, the lower part of the Rossland group in the Rossland mountains, 50 to 70 miles east by south of Beaverdell; the Sutherland schists directly west of the Rossland mountains; the Attwood series of the Boundary district 30 miles southeast of Beaverdell, and the Anarchist series 30 miles directly south of that place. They have been classed as Carboniferous, and Pennsylvanian fossils have been found in the lower part of the Rossland group. With these may be correlated the limestones and some of the schists in the Wallace group. The andesitic flows and tuffs and the coarse-grained basic rocks of the Wallace resemble very closely

[1] Daly, R. A., "Geology of the North American Cordillera at the 49th parallel": Part II, pp. 553-554, also various sections of Part I.

the upper part of the Rossland group in the Rossland mountains and the Phoenix volcanic group of the Boundary district both in their lithological characters and in the degree of metamorphism they have undergone. The upper part of the Rossland group and the Phoenix volcanic group are placed in the Mesozoic by Daly.

The hornblende diorite porphyries of the Wallace group are younger than the other formations in that group. They resemble the Westkettle quartz diorite batholith which follows them and may be a part of the general intrusion which produced the batholith. This intrusive is tentatively placed in the Jurassic.

The members of the Wallace group may, therefore, belong to three different geological periods.

Correlations based on lithological similarities and the degree of metamorphism which formations have undergone, are not wholly conclusive, but it seems probable that further work will prove that the Phoenix Volcanic group and a portion of the Wallace group 30 miles from them, belong to the same formation.

The Nicola series of the Nicola valley, described by Dawson, which is partly Triassic and partly Jurassic, resembles the Wallace group lithologically. Similar series are described from the Oroville-Nighthawk[1] mining district in the Okanagan valley just south of the International Boundary and from the Blewett[2] mining district in the Cascade mountains in central Washington.

WESTKETTLE QUARTZ DIORITE.

The Westkettle quartz diorite is a grey, granular rock resembling granite. It outcrops along the greater part of the valley bottom of the Westkettle river from Trapper creek to the south end of the map, and underlies about one-third of the area of the Beaverdell quadrangle. It is of especial interest because it contains the silver and gold ores of the district, and is in fact the only formation in which commercially valuable ores have been found up to the present time.

[1] Umpleby, Jos., "Geology and ore deposits of the Oroville-Nighthawk mining district." Washington, Geol. Surv. Bull. 5, pp. 67-68, 1911.

[2] Weaver, Chas. E., "Geology and ore deposits of the Blewett mining district, Washington." Washington, Geol. Surv. Bull. No. 6, pp. 30, 31, 1911.

A series of dykes of four different types occur with the batholith and are evidently related to it.

Distribution.

In the map-area the quartz diorite occurs as a more or less connected mass along the Westkettle valley and as irregular outliers among the other formations to the east. The boundaries of all these masses are extremely irregular; tongue-like offshoots from the main mass occur but one can describe no characteristic form to any of these patches. A conception of their number and irregularity may be gained from a study of the map.

Lithology of the Batholith and Its Related Dykes.

The quartz diorite is a grey or rather black and white, even-grained, granular rock, containing feldspar, quartz, biotite, and hornblende. The black and white minerals of which it is composed, stand out in sharp contrast giving the rock a characteristic "pepper and salt" appearance. This serves to distinguish it from the dull grey hornblende diorite porphyries of the Wallace group which otherwise resemble its fine-grained phases. The lighter coloured quartz diorites are distinguished from the Beaverdell quartz monzonite by the presence of hornblende in the quartz diorite. The main mass of the batholith is medium grained with crystals from one-eighth to one-fourth of an inch in diameter; from this type it grades into a finer grained variety with crystals one-quarter that size. The proportion of constituent minerals also varies although such variation is not generally marked enough to be conspicuous in the field except over small areas.

The medium-grained type is the one generally found in the lower ground along the sides and bottom of the Westkettle valley. Measurements of the proportions of the constituent minerals in a thin section from near Wallace lake gave the following results. Labradorite feldspar 50 per cent, orthoclase 2 per cent, quartz 29 per cent, biotite 15 per cent, hornblende

4 per cent, magnetite and apatite less than 1 per cent. The chemical analysis of this rock, made by Mr. M. F. Connor of the Department of Mines in Ottawa, is given below.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	MnO
64·80	15·74	2·29	2·44	2·09	5·20	3·55	2·17	1·40	0·40	0·10
										—100·18

The rock at the Sally mine on Wallace mountain is of a more acid type and contains 17 per cent of orthoclase feldspar, and 10 per cent less biotite than the average medium-grained rock.

The fine-grained type is more generally found on the tops of the hills or near a contact with rocks of the Wallace group, as is the case at the Buster mine. The fine-grained phase is made up of the same minerals, but their proportions differ from those given for the coarser types. Labradorite, orthoclase, and quartz exist in nearly equal amounts and form about 75 per cent of the rock by weight; hornblende and biotite make up the rest.

Other conspicuous variations of this batholith are a black basic variety on Arlington mountain and a gneissic phase generally found near the contact with the Beaverdell batholith. The three principal phases are illustrated in Plate V.

Four varieties of dykes occur with the batholith and are evidently related to it. They are granitic aplites found near the edge of the batholith, quartz latite porphyries cutting the batholith but older than the next Beaverdell batholith; quartz monzonite porphyries and hornblende andesite porphyries, both of which cut the Westkettle batholith, but are from their position believed to be related to it, rather than to the Beaverdell quartz monzonite batholith.

The aplites are distinguished by their white colour and the absence of ferromagnesian minerals. They consist mainly of orthoclase and quartz, the ferromagnesian minerals being present in very small amount. The quartz-monzonite porphyries cannot, in the hand specimen, be distinguished from the fine-grained phases of the quartz diorite, and the microscope work shows that they resemble each other closely. The dykes appear to carry a slightly larger percentage of orthoclase in some cases, but it is quite possible that they do not in all cases. The quartz latite porphyries are more porphyritic, with a fine-grained groundmass, than the quartz monzonite porphyries; they generally have more quartz, often in distinct phenocrysts, and might be taken for quartz porphyries in those instances where their phenocrysts are not very conspicuous. The hornblende andesites are dark grey rocks characterized by an abundance of lath-shaped hornblende phenocrysts, a few feldspar phenocrysts, a lack of quartz, and a dark, fine-grained groundmass.

Metamorphism.

The Westkettle quartz diorite has been metamorphosed in comparatively small degree. Gneissic structure occurs over small areas in several places, but the greater part of its mass is not banded. In some cases in and near breaks and shear zones the rock has been altered to a greenish-white, altered looking mass. This alteration is intense in places but is generally confined to narrow zones. Along these altered zones sulphides of the metals have been deposited and the silver ores upon Wallace mountain occur in them. Generally the rock is not weathered to a very great depth, and comparatively fresh material can be obtained within an inch or two of the surface.

In most cases the gneissic phases of the quartz diorite occur near masses of Beaverdell quartz monzonite and their planes of foliation lie roughly parallel to the line of contact with these masses. The banded structure has probably been produced by the intense heat and pressure caused by the intrusion of the Beaverdell batholith which mashed the surrounding rocks and injected heated and mineral laden waters into them. The hot waters not only helped the rocks to recrystallize in banded form, but they moved along fractures in the broken rock mass and produced such altered masses of rock as are found filling the "shear zones" in the mines on Wallace mountain.

Structure.

The batholith has an almost fantastically irregular outline. It seems to consist of a central body from which numerous irregular fingers and knuckle-like masses protrude upward and laterally into the surrounding rocks. Small domes have developed locally in the roof and wedges of the upper rocks project downward into the batholith. There is no indication of the forceful pushing aside of the older rocks to make way for the intruding quartz diorite, but a great many smaller roof blocks have evidently been pried off and have sunk in the molten batholithic mass as it moved upward.

The variations in texture and composition within the batholith do not appear to have affected the deposition of the ore-bodies in the district and they are, therefore, not discussed any further in this report.

The foliation or banding of the quartz diorite along the edges of the mass has been mentioned in a preceding paragraph dealing with the metamorphism of the rock body.

Faulting. In certain localities the batholith has been intensely faulted and faulting in a lesser degree has proceeded throughout the mass. The absence of datum planes prevents the measurement of the displacement of these faults, except at the mines of the Sally group on Wallace mountain, where underground work has opened up certain persistent veins which have been displaced by faulting. These furnish datum planes, although somewhat unsatisfactory ones. The faulting in the tunnels of the Sally group is described in detail in the chapter on "Economic Geology", page 95, and is illustrated in Figures 3, 4, 5, 6. Three systems of faults have been recognized there and it is probable that the same systems are found in other parts of the batholith. The oldest is an east and west system dipping from 40 to 90 degrees to the south. The fault zones in this system have smooth walls within which lie zones of crushed and altered rock with quartz and mineral filling. The silver ores of Wallace mountain are found in the "shear zones."

A second system with strikes varying from 5 degrees west of north to 50 degrees east of north, displaces the first east-west system. The fault planes of the second system dip to the west at angles of from 20 to 50 degrees.

Finally, a third system with about the same strike as the second but with steeper dips, offsets certain fault planes of the second system. It may be of nearly the same age as those of the second system. The actual displacement along fault planes is difficult to measure. On Wallace mountain the western sides of north-south fault planes have very generally been offset to the north. There has also been vertical displacement along the larger fault planes and a vertical adjustment of blocks of rock between the larger faults. The greatest measured offset on any one plane was about 50 feet and vertical heave not less than 50 feet.

Relations to Other Formations.

The quartz diorite batholith and its dykes have been intruded into the Wallace group and fragments of the Wallace are included within quartz diorite. The latter often lies as a discontinuous fringe between Wallace rocks and the younger batholith of Beaverdell quartz monzonite. The quartz monzonite generally has a dense, sometimes a porphyritic and occasionally a coarse-grained edge at the contact between the two. Blocks of quartz diorite are occasionally found included in the quartz monzonite. Pebbles of quartz diorite are found in the Curry Creek conglomerates and dykes resembling the Miocene lavas cut the quartz diorite in many places. It is, therefore, older than all the formations in the area except the Wallace group.

Age and Correlation.

The Westkettle batholith is younger than the Wallace group which has been tentatively classed as Mesozoic; it is older than the Curry Creek series of early Tertiary, probably Oligocene age. We shall correlate it with certain members of the Okanagan composite batholith.

The Okanagan composite batholith lies within 35 miles of the Westkettle batholith at Beaverdell, and since it is 60 miles wide at the Boundary, there is every reason to believe that the composite batholith stretches far to the north and approaches closely to the Beaverdell area. Since the Westkettle batholith is nearly the exact equivalent of the Remnel and Osoyoos members of the Okanagan batholith in composition, it is, if we take the vastness of batholithic bodies in this region into account, not far fetched to assume that these three igneous bodies are derivatives from the same magma. The supposition is strengthened by the fact that all three are preceded by intrusions of hornblendite, peridotite, and gabbro, and succeeded by more acid batholiths. The Osoyoos and Remnel batholiths are thought to have been irrupted nearly simultaneously and are placed by Daly as pre-Cretaceous and probably Jurassic.

The fact that the planes of foliation of certain gneisses in the Westkettle batholith trend northwesterly like certain of the Wallace schists and that these foliated areas cannot be ascribed to igneous intrusions or other local causes, indicates that the region was subjected to stresses of regional magnitude at a period after the batholith had been intruded and cooled. Vast disturbances of the earth's crust at the end of the Cretaceous severely mashed the Okanagan batholith or that portion of it situated along the International Boundary. According to a well known law of mechanics we are justified in assuming that such widespread forces acting over the cordillera would cause intense shearing and mashing along certain zones and leave other large rigid blocks of the crust comparatively unaffected. Reasoning upon the basis that the east-west mountains on the International Boundary are zones of weakness in the crust and that the broad upland at Beaverdell and east of it is underlain by comparatively rigid blocks, we may ascribe the slight regional metamorphism in the Westkettle batholith to the same forces which mashed the batholiths on the Boundary at the end of the Cretaceous, and, therefore, assume that the Westkettle batholith antedates the end of the Cretaceous.

Because of its lithological similarity to the Remnel and Osoyoos batholiths, which lie not far from it, and of the probability of its having been affected by the same regional disturbances, this batholith is tentatively correlated with them and, therefore, placed in the Jurassic.

BEAVERDELL QUARTZ MONZONITE.

Distribution.

A great mass of quartz monzonite occupies the northern part of the map-area and a branch of this mass runs down the eastern side as far as Triple lakes. A smaller area is found on Crystal mountain, and a still smaller oval-shaped area on the sides of the Westkettle at Beaverdell.

No ore-bodies have been found in the quartz monzonite, but the ores in Wallace mountain and at Carmi are believed to have been formed by hot waters which accompanied or followed the intrusion of the oval shaped mass at Beaverdell.

Lithology of the Batholith and Its Related Dykes.

For convenience, we may refer to the quartz monzonite under three type forms although these types grade into each other and cannot be regarded as separate rocks (Plate XII). In the main mass at the headwaters of Beaver creek and from there westward to Arlington lakes, the rock is pinkish white, medium to coarse grained, and of granitoid texture. Measurements made upon a thin section from Maloney lake showed its mineral proportions by weight to be as follows. Orthoclase feldspar 34 per cent, oligoclase feldspar 32 per cent, quartz 27 per cent, biotite 6 per cent, and titanite, magnetite, zircon, and apatite together about 1 per cent. Orthoclase occurs in conspicuous pink individuals and quartz in dull greasy grains. Hornblende is absent.

In places within the main mass and in small stocks like the one at Beaverdell, the pink orthoclases are larger than the other minerals in the rock and it is then of the granitoid porphyritic type. This type is wholly crystalline, the orthoclases are pink, from ½ to 3 and 4 inches in length, very clean cut in outline, and nearly always twinned according to the Carlsbad law. Microscopic study shows that they are a microperthitic intergrowth of anorthoclase or soda orthoclase and albite in the proportions of 5 to 1, and that the mineral proportions are as follows: anorthoclase 34 per cent, oligoclase 46 per cent, quartz 14 per cent, biotite 5 per cent, and magnetite and titanite less than 1 per cent. An analysis of the specimen upon which these measurements were made and which comes from about one-quarter of a mile southeast of the Beaverdell post-office, is given below It was made by Mr. M. F. Connor, of the Department of Mines.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	MnO
70·20	15·40	1·00	1·02	0·60	2·00	4·58	4·67	0·30	0·25	0·03

—100·05

South of the Collier lakes, a portion of the fine-grained roof of the batholith has been exposed by erosion. This is a pink fine-grained holocrystalline, even-grained to porphyritic rock. The grains are quite small, the average being less than one-fiftieth of an inch in diameter. The mineral proportions of a thin section measured from near Collier lake are as follows: feldspar 79 per cent, quartz 18 per cent, biotite 2 per cent, magnetite 1 per cent, and hornblende and titanite together about one-third of one per cent. The feldspars are all a perthitic intergrowth of albite and orthoclase in nearly equal proportions. This rock is a quartz syenite-aplite and it grades through a rather sudden transition into the normal type of quartz monzonite. The following analysis of the specimen whose mineral proportions are given above, was made by Mr. M. F. Connor, of the Department of Mines.

SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	TiO_2	MnO
69·16	15·92	1·54	0·92	0·33	0·64	5·06	5·97	0·60	0·20	0·06

—100·40

Dykes with the Batholith. A few dykes of quartz latite porphyry radiate out from the main mass. They are porphyritic with phenocrysts of pink feldspar and quartz in a grey groundmass.

Sheets and dykes of quartz syenite-aplite and porphyry are intruded into the fine-grained roof of the batholith near Collier lakes. They are nearly the exact equivalents of the rocks which they intrude. Pegmatite dykes, the offshoots of the batholith, are often seen near its edges.

The Beaverdell batholith is unfoliated and in this regard it differs from the Wallace group and the Westkettle batholith. The metamorphism observed in it is that associated with surface weathering, although it has evidently been acted upon by hot waters locally and to a slight extent.

Structure.

The mass of quartz monzonite is unfoliated, and that is one of the criteria by which it may be separated from quartz diorite, which is generally foliated near the contacts of the two rocks. The batholith has been sheared and faulted. Evidence of shearing is seen in all three of the areas of quartz monzonite, and its direction is indicated by the direction of small parallel valleys which are quite commonly found all over the surfaces of the batholiths. Shearing does not appear to have extended intimately through the mass; that is, there are blocks nearly one-half mile across which are unsheared or at least not very evidently fractured. The direction of outcrop of the more prominent of the shear planes varies from north to about northeast, and these are accompanied in places, as they are in the neighbourhood of China buttes, by a set of fractures striking at about right angles from them. Occasionally, as in an outcrop at Arlington lake, the presence of a dyke in the quartz monzonite enables one to see that faulting, or off-set of the rock material, has actually taken place; but instances of that kind are rare, and the actual amount of disturbance can only be guessed at. The faulting and shearing are of the same character as the faulting and shearing which affected the quartz diorite except that the east-west system of shear zones which often carry ore minerals in the quartz diorite is apparently absent from the younger quartz monzonite.

Relation to Other Formations.

This intrusive is found in places to lie under certain members of the Wallace series, and pegmatitic and siliceous offshoots of the quartz monzonite penetrate the Wallace. In one instance it lay over a mass of green Wallace schist and carried inclusions of the schist. It includes fragments of quartz diorite, becomes fine-grained near their mutual contact, sends dykes into it, and seems to have produced foliation in it. Both Wallace and quartz diorite are, therefore, older than the quartz monzonite. The mass of augite syenite porphyry on Lake ridge contains inclusions of quartz monzonite, in which are dykelets of augite syenite porphyry. The augite syenite in turn has been intruded by aplite dykes related to the quartz monzonite. We can, therefore, consider quartz monzonite and augite syenite to be of very nearly the same age. Quartz monzonite pebbles are found in the Curry series and dykes related to the Tertiary lavas penetrate the batholith. The quartz monzonite is evidently older than both the conglomerates and the lavas.

Age and Correlation.

The Beaverdell quartz monzonite is older than the Oligocene sediments of the Curry Creek series and younger than the Westkettle batholith, which has been doubtfully referred to the Jurassic. Certain considerations make it probable that the quartz monzonite was intruded much later than the quartz diorite of the Westkettle batholith. The conglomerates of the Oligocene Curry Creek series carry many pebbles of quartz diorite but very few pebbles of the younger quartz monzonite. This means that a very large area of quartz diorite was exposed at the time the conglomerates were formed and a correspondingly small area of quartz monzonites, for a large mass of quartz monzonite lies near the conglomerates, and large numbers of its weathered fragments would have been incorporated in the conglomerate if the batholithic body had been exposed at the surface. The Beaverdell quartz monzonite was then either a much later intrusion or it solidified much farther from the surface. But its roof is finer grained than that of the quartz diorite and is more likely to have solidified at the same depth or nearer the surface. We, therefore, conclude that a period of erosion separated the two intrusives. Moreover, the Beaverdell batholith shows no signs of banding or foliation and we may presume that it was intruded after the profound crustal disturbances which took place at the end of the Cretaceous. On these grounds it is, therefore, placed in the Eocene, with the question mark that must be attached to correlations based on evidence other than fossils.

AUGITE SYENITE PORPHYRY.

A long dyke-like mass of augite syenite lies upon the east boundary of the map-area from Lake ridge northward for 5 miles; its exact extent is not known, but it is probably rather narrow.

Lithology.

The more common type of syenite is a dark, black to chocolate coloured rock, with greenish phenocrysts of augite and biotite lying in a dense groundmass. The coarse phase, which is occasionally met with, is grey, holocrystalline, and made up of feldspar, biotite, and augite. An occasional larger feldspar or augite crystal gives the rock a porphyritic appearance, but it does not resemble the fine-grained phase very much in the field. This fine-grained type very often intrudes the coarse, and they are, therefore, apt to be taken as distinct varieties. One can, however, find a gradation from the one into the other and an examination of such a gradation shows that the many apparent varieties are really one species of rock. Under the microscope, the coarse-grained variety is found to consist of iron ore, apatite, biotite, augite, andesine, orthoclase, and accessory quartz. The texture is granitoid and somewhat porphyritic, and the proportion of feldspar to augite and biotite is about 6 to 1. There is about five times as much orthoclase as andesine; iron ore, apatite, and quartz are accessory.

In the degree of metamorphism and also of faulting and shearing to which this rock has been subjected it resembles the Beaverdell batholith. It was apparently intruded at the same time (see page 51).

CURRY CREEK SERIES.

Distribution.

A series of sediments and tuffs is found upon the high southwestern portion of Wallace mountain, and a smaller patch lies on Kloof ridge south of Cañon creek. Together they occupy between 4 and 5 square miles of the map-area, and probably extend beyond the southern limits of the area. Small outliers of the same type were seen on the northern nose of Curry mountain and below outcrops of volcanic flows on the eastern slopes of Hall creek. The sediments and tuffs are best developed on the broad top of the Wallace Mountain block. They are well exposed at the headwaters of Curry creek on Wallace mountain and are here called the Curry Creek series.

Lithology.

The series consists of 200 feet of very fine-grained white tuff overlying about 2,500 feet of conglomerates. Within the conglomerates are occasional beds of arkosic sandstones and clastic material of volcanic origin. In certain places the series rests upon breccias. Dykes and sills of andesite cut across breccias, conglomerates, and tuffs at various angles.

The breccias lie under the conglomerates at the western edge of the area. They are grey or brown in colour, and are made up of angular fragments of the underlying Wallace series. The fragments are of all sizes, but generally not over 2 inches across; they lie packed together in a groundmass of finer material of the same kind, and are in most cases bound into a solid mass with iron oxide or some other type of cement. The composition of the fragments in the breccia varies with the particular type of the older series they overlie.

The conglomerates consist of rounded pebbles and boulders and of more angular fragments lying embedded in a matrix of finer material. The rock varies in colour from grey to brown, sometimes mottled by the differing colours of the pebbles. The pebbles consist of Westkettle quartz diorite; diorite, metamorphosed andesites, tuffs, and sediments of the Wallace series, and occasionally Beaverdell quartz monzonite. The pebbles of granitoid texture are generally well rounded and smoothly polished and vary in size from a coarse sand to boulders 3 feet through. Fragments of finer grained material, metamorphosed volcanic rocks and sediments, are more often angular than rounded; they are very seldom more than 4 or 5 inches in diameter. The larger pebbles and boulders lie in a matrix which is generally finer material than, and of the same type as the pebbles, although it occasionally resembles a fine mud. The matrix is generally grey or greenish-grey. The conglomerates are characteristically poorly sorted and occur in beds 15 to 50 feet thick.

Within the conglomerates well bedded sandstones are occasionally found which resemble them in their makeup, but are finer grained and more evenly bedded. They are of small extent, both laterally and in a vertical direction.

Certain beds which were referred to in the field as conglomerates and sandstones proved upon microscopic examination to be formed partly by volcanic agencies. Other agglomerates occurring in small patches north of the main mass were recognized as such in the field. An agglomerate found near the basalt body at Lassie lake contained fragments of basalt of the same type as that in the nearby flow, as well as pebbles of quartz diorite and quartz monzonite. Agglomerates found on Curry mountain and at the China buttes contained fragments of lava and ash several inches across, and were often largely made up of such fragments. The agglomerates probably form a very small portion of the series.

Overlying the conglomerates are beds of light coloured tuff. The tuffs are extremely fine-grained and generally dense, and somewhat resemble the commercial honestones. Their colour is white to yellowish grey. In the hand specimen one can get no idea of their composition. They occur in beds which are rarely over one inch in thickness, and break with a conchoidal fracture.

Metamorphism.

The conglomerates and tuffs are in places somewhat weathered, and have in certain instances been epidotized. Near certain contacts with intrusive dykes, the tuffs are baked to a flinty grey rock, but the series as a whole is unaltered.

Structure.

On Wallace mountain the series lies upon an uneven weathered surface. The breccia exposed in places below the conglomerate is evidently talus or badly disintegrated material and was traced in several instances to solid rock under it. The solid rock was andesite or tuff of the Wallace series and the breccia was of the same material and had evidently not moved far from its source near Curry creek. The talus lies at steep angles on the solid rock suggesting that the original surface was hilly, but folding has taken place since the series was deposited and one can draw no safe conclusions from the present attitude of the old floor.

The conglomerates consist of unsorted beds sometimes 50 feet thick with thinner and better sorted beds of fine material in between. The tuffs at the top of the series are conformable upon the conglomerates, they are thin bedded and well stratified. The conglomerates dip eastward at angles up to 45 degrees, but their dip diminishes as one ascends in the series and goes westward; the tuffs lie practically flat. To the west of them are a number of eastward dipping Wallace tuffs and they all together form an irregular synclinal fold with its axis striking north and south.

The series has been faulted in many places, the most noticeable fault being in the bottom of Crystal creek east of the conglomerate area, where there has been a relative downthrow on the west side of at least 500 feet.

Relations to Other Formations.

The Curry Creek conglomerates hold pebbles of all the members of the Wallace group, of the Westkettle quartz diorite, and in lesser degree of the Beaverdell quartz monzonite. The conglomerates are, therefore, younger than these three latter. The Nipple Mountain lavas overlie it and dykes and sills related to them are intruded into it. The Nipple Mountain series is the younger. Whether or not a period of erosion intervened between the formation of the Curry Creek series and the outpouring of the lavas is not clear, for their contacts were seen at a few places only and at those the evidence upon that point was conflicting.

Age and Correlation.

One fossil land plant was found in a lens of tuff lying in the conglomerate. This was referred to the Tertiary by Mr. W. J. Wilson[1] of the Geological Survey and by Dr. F. H. Knowlton of the United States Geological Survey, but as it is a new genus no closer determinations of the age could be arrived at. R. W. Brock[2] has described a series in the Boundary Creek district, about 35 miles southwest of Beaverdell, which consists of conglomerates overlain by "white gritty tuffs." The tuffs are widespread, and both conglomerate and tuff are succeeded by volcanic flows. They are of Tertiary age. With this series R. A. Daly[3] correlates his Kettle River formation, which contains abundant plant remains and is of Oligocene age. The Kettle River formation consists of 200 feet of arkosic breccia overlain by 900 feet of coarse conglomerate which is followed by 1,000 feet of sandstone; over these lie a series of volcanic flows of which certain members resemble the flows found in the Beaverdell area.

The Boundary Creek series corresponds closely to the Curry Creek series in its lithological character. It differs from the Kettle River series mainly in the presence of the fine tuffs which do not occur in the latter. The Kettle River series occurs near Rock creek, about 30 miles in a straight line south of Wallace mountain. The Boundary Creek conglomerate lies east of Rock creek and not far from it. The lithological successions within the series in the Boundary Creek, Rock Creek, and Beaverdell areas resemble each other closely enough to warrant the placing of the Curry Creek series in the Oligocene.

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[1] Wilson, W. J., "A new genus of dicotyledonous plant from the Tertiary of British Columbia": Bull. No. 1, Victoria Mem. Museum, Geol. Surv., Can., No. 1240, pp. 87-88, 1913.

[2] Brock, R. W., "Preliminary report on the Boundary Creek district, British Columbia. Ann. Rep., Geol. Surv., Can., Vol. XV, p. 102A, 1902-3.

[3] Daly, R. A., "Geology of the North American Cordillera at the 49th parallel": Pt. 1, Geol. Surv., Can., No. 1203, pp. 394-5, Ottawa, 1912.

NIPPLE MOUNTAIN SERIES.

Distribution.

The series is made up of lava flows and dykes of which six main types were encountered. These are olivine basalt, augite andesite, hornblende andesite, biotite andesite, dacite, and trachyte. Olivine basalt occurs in small areas in the block of country between the Westkettle river and Beaver creek, and two small knobs of olivine basalt lie on Curry mountain. The plug forming Goat peak is an olivine-free basalt. Basic volcanic flows lie northeast of Collier lake and may well be olivine basalt. Augite hornblende andesites, biotite andesites, and dacites occur together on Nipple mountain, and also on Wallace mountain; a light coloured flow which has, from its microscopic appearance, been called trachyte, occurs with the other four types on Wallace mountain. Crystal butte is made up of more than one type of volcanic flow, generally of andesitic character. Numerous dykes of Tertiary material resembling the flows cut the older rocks of the area; they are especially abundant on Crystal mountain. All but one of them, examined microscopically, proved to be augite-andesite.

Tertiary volcanic rocks are also found upon the western side of the Kettle River valley, just east of the map-area; they occupy the lower end of Copper creek at a point about 5 miles from the northeastern corner of the map. At this place they lie at the level of the present bottom of the Kettle River valley, and from there south they may be seen both near the valley and capping hills on the eastern side (Plate XIII).

Lithology.

The lavas range in colour from black through shades of brown and red to white. Olivine basalt is quite black, and so are certain outcrops of the augite andesites and hornblende andesites. Olivine basalt can be distinguished from the andesites in that it is never glassy, and phenocrysts of green olivine are generally visible through the rock. The black andesites generally have a glassy looking groundmass in which phenocrysts of white feldspar and augite or hornblende can be distinguished. The predominating colour of the lavas is red or brown. Most of the red coloured lavas proved upon microscopic examination to be andesites. Feldspar is the chief phenocryst and is accompanied by either biotite or hornblende. Of the red lavas, the biotite andesites, upon Red mountain west of the map-area, are the most conspicuous. In places on the cliffs near the top of the mountain the mass is split into narrow bands, sometimes only a few inches through. On a fresh surface the rock is buff coloured and one sees that the bands are thin and closely spaced, so that from 20 to 26 lie within the thickness of an inch. Flat vesicles lie within their longer directions parallel to the bands.

The augite andesites are sometimes brown as well as black and dark grey, a great many of the Tertiary rocks in the district are augite andesite, and they are usually porphyritic with somewhat irregularly shaped phenocrysts of feldspar and augite in a dense or semicrystalline groundmass.

The light coloured or white lavas are either biotite andesites, dacites, or trachytes. The dacites can be distinguished from biotite andesite and trachyte by the presence of quartz phenocrysts which are generally quite conspicuous. Trachyte was seen only on Wallace mountain. It is difficult to distinguish the white biotite andesite from trachyte, especially if the rocks are dense and phenocrysts are few. The total thickness of the series is between 4,000 and 5,000 feet; 4,300 feet are exposed on Nipple mountain.

Metamorphism.

The lavas have been very slightly altered and are noticeably fresh within a few inches of the surface. They are sometimes brecciated and in places partly altered to sericite, epidote, and quartz. The alteration was observed in older members of the series and is thought to have been caused by hot waters accompanying the intrusion or extrusion of younger lavas in the series.

Structure.

The surface upon which the lavas were extruded, appears from a study of the physiography to have been one of mature topography with some deep valleys. The hilltops were rounded, with fairly gentle slopes. The filling of such low valleys as that of the main Kettle river (Plate XIII) by lava flows proves that deep valleys like the Kettle existed at the time of their extrusion.

The lava flows were quite probably small in extent. We can infer this from the diversity of types met with in a small lava area like that on Wallace mountain, which indicates differentiation from a small magma chamber.[1] That basalt is found alone on China and St. John ridges, while four other types of lava, but no basalt, occur upon Nipple mountain 4 to 5 miles away, seems a conclusive proof of the small areas originally covered by the flows. It is doubtful whether all of the district was entirely covered by Tertiary lava at any one time.

Biotite andesite, dacite, hornblende andesite, and augite andesite were extruded in the order named beginning from the oldest. The relative positions of trachyte and basalt are uncertain, although basalt is believed to be the last product of volcanic activity.

The lavas upon Nipple mountain have been folded into a syncline pitching west of south; another such synclinal fold exists at Copper creek on the Kettle river. We have no direct evidence of faulting although it has probably taken place. Brecciated lavas occur at Goat peak and other places. Those found with the basalt contain scoria and are evidently related to the extrusion of the basalt, others may be due to faulting.

Columnar jointing is well developed in many outcrops of the more basic lavas such as in Goat peak and in the mesa west of Lassie lake. In other places the lavas are platy, that is separated into very fine plates parallel to the original surface of the flows.

Relations to Other Formations.

Dykes of material resembling the Tertiary lavas and in places radiating away from such lavas intrude the Wallace series, the Beaverdell quartz-monzonite, and the Curry Creek series.

[1] For an explanation of the reasons why a great degree of differentiation is to be expected from the products of a small body of magma, see Harker, Alfred, "The natural history of igneous rocks," p. 143, the Macmillan Co., New York, 1909.

The extrusives are also found lying on top of these formations, and on top of the quartz diorite batholith. The lavas are, therefore, younger than all these rocks, and are the youngest solid rocks found within the map area.

Age and Correlation.

The lowest part of the series of lavas described by Daly, at Midway, about 30 miles due south of the Beaverdell area, corresponds to this series in petrographic character. They are said to extend for 15 miles north of Midway, and patches of them are probably found between that point and the outcrop in the Beaverdell area. Both series consist of lavas ranging from olivine basalt to trachyte. At Midway analcite-bearing rocks are found on top of the series; they are made up of phenocrysts of augite, alkalic feldspar, olivine, and accessory biotite, in a glassy groundmass largely filled with analcite crystals and alkalic feldspar. Nothing of this type was seen in the Beaverdell series, but certain of the olivine basalts are analcite- bearing, and this mineral is rare enough to point to a consanguinity of the extensive series in the two areas. Geographically, they may be said to be practically coextensive, for the Midway series is found for 15 miles north of Midway,[1] that is, not over 15 miles south of the Beaverdell area. The intervening distance was not explored, but in all probability lavas of the same types are to be found there. The time of their extrusion was in both cases shortly after the formation of a series of breccias, conglomerates, sandstones, and tuffs. It is true that this clastic series is not absolutely identical in the two areas under discussion, but they correspond quite closely in their more marked characters, especially if compared to a similar series in the Boundary Creek district, and we have correlated them together. We may, therefore, correlate the Beaverdell series of extrusives in a broad way with those described by Daly.

The lavas at Beaverdell correspond most closely to what has been called by Daly, the "Middle group" at Midway. He placed the Middle group in the Oligocene on the score of con-

[1] Daly, R. A., Geol. Surv., Can., Memoir No. 38, p. 398.

formity with the Oligocene Kettle series below. The Nipple Mountain series are either Oligocene or, if unconformable with the Curry series, a point on which there is some doubt, they are Miocene.

GLACIAL DEPOSITS.

Two types of Quaternary deposits are found in the district. They are the irregular blanket of glacial drift which is spread over the greater part of the upland but varies greatly in thickness from one place to another, and river alluvium which is found in sheets upon the valley bottoms or in irregular terraces hanging on the valley sides.

Because the river alluvium is very largely composed of re-sorted glacial deposits, and some typical glacial deposits are found near the bottom of the valleys, the two types often blend into each other. In the mapping of this area no attempt was made to separate them, nor were either of them mapped where outcrops of bed-rock were plentiful. The areas denoted as recent deposits upon the map are those upon which unconsolidated materials were widespread and thick enough to cover the bed-rock over appreciable areas. Where such areas lie upon or near the valley bottoms they are in nearly all cases river deposit. Where they extend out of the valley bottoms they may be taken as more or less modified glacial deposit. A good deal of glacial drift lies upon certain parts of the upland, but very little of it has been mapped.

Distribution.

All of the upland within the map-area is covered to a greater or lesser extent with drift, which contains boulders foreign to the underlying rock and is, therefore, presumably of glacial origin. Thus on rocky points like Goat peak one may find a few such boulders and the higher ridges in the area are in places very thickly covered with unconsolidated glacial material.

An attempt to enumerate all such drift covered areas would be of no particular value. A thin blanket of drift is found everywhere upon the upland, but it is probably thicker in upland valleys than on ridges, and on the southeastern than on the northern slopes. What seems to be the remnant of an end moraine occurs in Wallace valley and that is the only undoubted glacial deposit found in a young valley below the upland surface.

Lithology.

The glacial material is composed of more or less rounded or elongated boulders mixed with sand, clay, and smaller pebbles. Its greatest thickness very seldom exceeds 100 feet but is very variable. The boulders and pebbles are of rock types found within the district and generally of igneous origin.

No especial search was made for striated boulders and only one or two were seen. The matrix in which the boulders lie is very generally sand. In a large number of outcrops clay is absent, and where present it does not seem to make up the bulk of the matrix.

Structure.

The glacial drift generally forms a blanket of irregular thickness over the upland, but in one or two places, like Wallace valley, a number of rounded hillocks and kettle holes occur, suggesting an end moraine; long narrow ridges resembling lateral moraines are seen in other places.

The direction of glacial striæ was taken at about a dozen points on the upland; they trend in a direction from south to southeast except in one outcrop on Arlington hill where the direction was west of south.

The striæ correspond in direction to those determined by Brock and Daly[1] along the International Boundary to the south. One may assume that they have been caused by the same continental ice sheet and that the deposits of glacial drift were, like them, formed in the Pleistocene.

RIVER DEPOSITS.

Distribution.

River deposits are to be found in practically all the larger valleys. They cover the valley floor and are found in terraces

[1] Daly, R. A., "Geology of the North American Cordillera": Part 1, pp. 589-590, 1913.

upon the nearby valley sides. These terraces lie from a few feet to nearly 300 feet in elevation above the beds of the present streams. Plate VI shows the valley floor and at least two distinct terraces at Carmi; one lies at the foot of the first line of timber, and the other can be seen in the snow covered strip which lies just over the tops of the first line of trees in the picture.

Lithology.

The character of the river deposits varies very much from place to place on the valley floor. In certain localities it consists of large rounded boulders in a matrix of finer pebbles and sand; in other localities the material is finer and in certain spots clayey. Its thickness is variable but must be nearly 100 feet in parts of the Westkettle River bottom.

Structure.

The river deposits are more or less tabular shaped bodies with their upper surfaces sloping slightly toward the present streams. They lie in terraces one above the other, the vertical distances between terraces varying from a few feet to nearly 100. They are very irregular in plan, as one may see by following any particular terrace either up or down stream. Stratification is at times well developed in the alluvium, but a great deal of the material is unstratified.

HISTORICAL GEOLOGY.

The following is an account of the origin of the various formations and their structures with a summation of the evidence upon which the conclusions given here are based. The formations and their members are considered in order beginning from the oldest.

WALLACE GROUP.

The limestones and hornfels of the Wallace were laid down in quiet waters either in a large lake or arm of the sea. They were followed by the tuffs of the Wallace, which were laid down in the same manner, immediately following them or after an interval of erosion. The tuffs were probably extruded in the Triassic, through volcanoes of the explosive type, and were blown out as fine ashes. They were followed by quiet flows of augite andesite lavas. Accompanying these lavas were intrusions of basic rocks, pyroxenite, hornblendite, saxonite, saxonite-porphyry, and olivine gabbro. The long period of erosion which started in the Mesozoic and has probably continued in certain parts of the cordillera until the present time, began in this region after the extrusion of either the lavas or the tuffs. Intrusions of hornblende diorite porphyries in the Jurassic were followed shortly after by the intrusion of the large Westkettle batholith and its later satellitic dykes.

The absence of conglomerates, the carbonaceous bands in the limestone, and the fine-grained and thin-bedded character of the hornfels indicate that the sediments of the Wallace were deposited in quiet waters far from shore or off the coast of a lowland. The texture of the hornblende andesite tuffs indicates that they were the products of volcanoes of the explosive type, while the texture and form of the augite andesite lavas which followed them prove that they flowed quietly out of fissures or through irregular cavities in the crust. Some of the basic intrusives appear to have formed from magma bodies whose upper portions broke through the crust to form augite andesite flows. Most of the schists were of igneous origin and some can be traced into unfoliated members of the Wallace group. The origin of the greater part of the schists is in doubt. The hornblende diorite porphyries occur near the Westkettle batholith and are akin to it in composition. They are the youngest member of the Wallace group and are believed to be satellites of the Westkettle batholith.

WESTKETTLE BATHOLITH.

The Westkettle batholith worked its way quietly up into the crust, making a cavern for itself by magmatic stoping, prying off crust blocks and letting them sink into the magma, and not exerting any very great mechanical thrust upon the surrounding rocks. Near its contact it recrystallized the limestones and hornfels and sent out feldspathic dykes and stringers of quartz into them. Certain of the limestones were not only recrystallized but many contact metamorphic minerals, garnet, epidote, certain sulphides, etc., were formed in them. It mashed certain of the rocks near its contact, but not extensively. As the batholith cooled its magma became differentiated by fractional crystallization, the process being modified by local assimilation or partial assimilation of crust blocks.

The Westkettle batholith is very irregular in shape with numerous knuckle-like masses projecting into the surrounding rocks. Within some of these projecting arms the products of the marginal assimilation of crust blocks by the magma are found. The basic phase of the quartz diorite, on Arlington mountain lying near outlying blocks of pyroxenites and other basic rocks of the Wallace group, is probably a product of such assimilation. Marginal assimilation has not played an important part in the intrusion of the batholith except within such finger-like projections as the one upon Arlington mountain. The absence of extensive faulting along the margin of the batholith or of foliation in the neighbouring rock formations, the absence of evidence of doming of the overlying rocks and the projection of numerous wedges of the crust down into the batholith prove that the quartz diorite body did not make a place for itself by mechanical thrust, such as would be exerted by a viscous body moving either upward or laterally through the upper earth crust. Local evidences of mechanical thrust are found such as the foliation planes in the Wallace group parallel to the quartz diorite contact on Crystal butte and small domes in the quartz diorite roof on Knob hill, but these merely emphasize the absence of such evidence around the remainder of the mass.

The hypothesis of magmatic stoping accounts best for the facts observed. Numerous fragments of the original crust lying in the roof of the batholith and wedge-like portions projecting down and laterally into the igneous mass from the older rocks outside, together with the general irregularity of outline of the quartz diorite mass, suggest that it made its way upward and laterally by prying off small sections of the crust at one time. A crust block found in the batholith near Beaverdell 1,000 feet below its roof, showed no sign of fusion but had a chilled edge of the quartz diorite developed next to it, proving that it has sunk very rapidly through the mass after being pried loose from the upper crust. The virtual absence of roof blocks in the batholith at a certain depth below the chilled roof, points to the same conclusion. The pried-off blocks then sunk rapidly through a fluid magma and except in the projecting arms of the batholith where they could not sink far, their fusion must have taken place at great depth. The fine-grained roof may be accounted for by the sudden foundering of a large section of the crust which brought the upper section of the magma into contact with much colder rocks causing a sudden chill, increase in viscosity, and rapid crystallization. The viscous upper layer would retain a number of the last blocks loosened from the roof, while such as passed through this viscous mass would sink rapidly to the bottom.

The hypothesis of magmatic stoping was first suggested by Daly[1] and was thoroughly proven by Barrell[2] working on independent lines at about the same time.

Below the chilled roof, the batholith varies from more acid through an average facies to more basic portions. These are apparently not arranged in a symmetrical manner either in respect to the margin of the batholithic mass or its roof. The two more commonly accepted hypotheses explaining the differentiation of magmas are that of "fractional crystallization" and that of "liquation." According to the former the less soluble minerals are supposed to crystallize out in the cooler portions of the magma that is near the edges and the loss of material by crystallization is supplied by movements of similar material in some manner from the interior. This is generally believed to be the manner in which so many large intrusives have been differentiated into a basic border and more acid interior. In "liquation" the magma is supposed to separate into two fluids before crystallization, these fluids being immiscible under the conditions obtaining at the time. The lighter fluid rises to the

[1] Daly, R.A., "The mechanics of igneous intrusion"; Amer. Jour. Sci., 4th. ser., Vol. 15, 1903, pp. 269-298.

[2] Barrell, Jos., "Geology of the Marysville Mining Region, Montana," U.S.G.S., Prof. Paper No. 57, pp. 151-174, Washington, 1907.

top of the magma chamber and the two crystallize in that position giving a symmetrical arrangement of the two varieties of the mass in a vertical direction, with a rather sharp contact between them.

There is no evidence of any kind to show that "liquation" took place in the magma of this batholith. The most probable explanation of the variations observed is that the mass differentiated by "fractional crystallization" and that this process was modified by the occasional sinking of crust blocks into the magma during the process, and the partial assimilation of such blocks in outlying arms of the magma chamber.

BEAVERDELL BATHOLITH.

Erosion continued after the intrusion of the Westkettle batholith and lasted throughout the Cretaceous. At the end of the Cretaceous there were orogenic disturbances throughout the cordillera, which, however, affected the rocks in this area only slightly. The forces acting on the crust probably came from the southwest, forming east-west shear zones and local foliation trending in a northwesterly direction. The period of disturbance was followed by the intrusion of the Beaverdell batholith, directly after which the intrusive body of augite syenite porphyry came into place. The Beaverdell batholith worked its way upward while still liquid, partly by prying the crust aside, partly by thrusting the older rocks upward, and partly by magmatic stoping. It split upon cooling into two liquids and the lighter, more alkalic and more fluid liquid, rose to the surface and solidified as a fine and even-grained roof. The intrusion of the batholith mashed and brecciated the older rocks near its contact and probably was responsible for the greater part of the metamorphism observed in the Wallace and quartz diorite. It may also have been the primary cause of the formation of the silver-lead orebodies.

The Beaverdell quartz monzonite batholith has comparatively smooth outlines and at Collier lakes a portion of its roof is dome-shaped. Very few crust blocks are found within the mass; but it has evidently caused foliation, brecciation, and alteration of the older rocks near its margin. These facts suggest that it was more viscous at the time of its intrusion than the Westkettle batholith and made a place for itself more largely by a thrusting aside or upward of the crust than was the case with the older batholith. There is no doubt, however, that magmatic stoping was also operating in this case for slabs of the Westkettle batholith less than 50 feet thick are found lying on top of the Beaverdell batholith and between it and the Wallace group. These slabs are the remnants of a massive rock body of great vertical extent which was removed by the intruding Beaverdell quartz monzonite. There is no evidence of its having been thrust aside and the greater part of the older batholith must, at such places, have foundered through the liquid intruding magma; that is, it was removed by magmatic stoping.

Three main variations in the composition of this batholith were observed (Plate XII). At Collier lakes and to the north of them there is a fine-grained roof facies consisting of 78 per cent of intergrown orthoclase and albite in nearly equal proportions, 2 per cent of biotite, and no oligoclase. Its specific gravity is 2·5. Below this roof and passing into it by a sharp transition lies a facies which represents a type seen in by far the greater number of outcrops exposed, and which may be taken to represent the main portion of the upper 1,000 feet of the batholith. It contains about 4 per cent less orthoclase than the fine-grained facies, 6 per cent of biotite, and in addition 32 per cent of oligoclase. Its specific gravity is 2·57. At the village of Beaverdell a small stock is exposed, its outcrops lie 1,000 feet in elevation below the fine-grained roof at Collier lakes and 10 miles away from it. It must represent an offshoot from the magma at least 1,500 feet below the roof. It contains the same amount of orthoclase and biotite as the main part of the batholith, but the amount of oligoclase has increased to 46 per cent. Its specific gravity is 2·66. The minerals in the roof facies have all crystallized together, the oligoclase and biotite in the other facies have crystallized before the rest of the rock. There are, therefore, three facies of the batholith lying one over the other. The lower carry the larger proportions of the minerals which are the heavier and which crystallize first from the magma, and the specific gravity of the rock variations themselves decrease from the bottom to the top.

It may be supposed that as the magma moved slowly upward the first minerals to form, oligoclase and some of the biotite, lagged behind and the lighter liquid residue moved upward past them and accumulated toward the top. The upper thin roof facies must have separated out before crystallization commenced, for its constituents all crystallized together and are sharply differentiated from the material below. The hypothesis is, therefore, practically that of liquation and gravitative adjustment, the greater part of the differentiation being supposed to have taken place while the magma was still fluid.

The difference in the manner of differentiation of the Westkettle and Beaverdell batholiths may be explained by the comparatively smooth-walled chamber of the latter which allowed of gravitative adjustment such as could not take place in the irregular cavity holding the magma of the Westkettle batholith.

CURRY CREEK SERIES.

In Oligocene time local deposits of coarse conglomerates were laid down at the foot of steep slopes, probably in the form of alluvial fans in mountain valleys. Later on volcanic eruptions took place and dense tuffs were laid down in small lakes on top of the coarse conglomerates; probably, therefore, in the bottom of mountain valleys choked with detritus. The Oligocene was followed by disturbances which faulted the conglomerates and older rocks and provided channels for the extrusion of the later lavas. The system of faults trending north to northeast was probably formed at this time.

The brecciated material lying in places below the conglomerates of this series is made up of angular fragments which in many instances grade down into solid rock of the same type as the fragments. The greater part of the breccia has not been formed by faulting and is believed to be a consolidated talus, that is a land deposit.

The breccias were seen in one case lying on the side of a steep canyon, where they appear to have been originally formed. This, together with the great total thickness of the series and the unsorted character of certain of the beds, suggests deposition upon or at the foot of steep slopes. The conglomerates were probably laid down as alluvial fans in mountain valleys or near the foot of mountain ranges. The tuffs on top of them were blown out of volcanic vents in the form of a fine glassy dust. Their thin-bedded character and the remains of land plants in them indicate that they were deposited in freshwater lakes such as might be formed in some valley choked with debris. A period of faulting followed, the faults trending from west of north to northeast. Along a fault line following the bed of Crystal creek, the conglomerates were downthrown at least 500 feet vertically and many other faults of smaller extent were seen displacing the series on Wallace mountain. Dykes of the later Nipple Mountain series have been intruded along fault planes which lie parallel and close to the ones displacing the Curry series, and which were presumably formed at the same time. Faulting, therefore, took place between the Oligocene and Miocene.

NIPPLE MOUNTAIN SERIES.

In the Miocene there were local extrusions of lavas partly through volcanic vents and partly through short fissures. They were in the main andesitic in character and were probably derived from shallow magma chambers.

A number of circular volcanic plugs lying nearly in line from Goat peak to China buttes are thought to mark the sites of volcanic vents. All are circular or elliptical in plan with precipitous sides. Goat peak, the largest, is oval in plan and is surrounded by sediments and tuffs which lie nearly flat or dip inward toward the igneous mass. The volcanic mass is steep, almost a sheer cliff on all sides, and the difference in elevation between its contacts with the sediments on the eastern and western side of the peak is about 500 feet and the top of the peak is nearly 300 feet higher than the higher contact. The geological map (in pocket) shows the contact line climbing up along the northern face of the peak and the sediments dipping in locally toward the basalt. The rock is everywhere porphyritic. On top and for 50 feet down it shows irregular and poorly developed columnar structure, the columns lying nearly flat and with no definite direction. For a hundred feet below well-defined vertical columns are seen, and below that the rock on the west side of the peak is banded, the bands dipping south. About 200 feet below this banded area on the other side of the mountain the basalt is badly brecciated.

That Goat peak is an intrusive of neck-like form is suggested by its lining up with three other bodies of the same shape. The fact that it is strongly brecciated in parts, its porphyritic texture, the form of its ground plan, and its sheer and precipitous sides lead to the same conclusion. The relations of the tuffs and sediments to the basalt body and their dipping toward it indicate that the basalt was intruded into them and that hot gaseous or lava emanations preceded the intrusion.

That the basalt occupies the site of a vent through which lavas came to the surface and is not merely an intrusive which cooled below the surface, is indicated by the arrangement of its columnar structure, flat columns above indicating an escape of heat upward to the surface and vertical columns below indicating lateral cooling, that is, the upper and lower parts of the rock body cooled under different conditions. Remnants of lavas on the neighbouring mesas, which approach the olivine free basalt on Goat peak in composition, tend to confirm the supposition that Goat peak is the site of a Miocene volcano. Some of the smaller necks in this area are probably also located in old volcanic vents.

The numerous dykes of this series, however, suggest that a very large portion of the lavas made their way to the surface through fissures rather than volcanic vents.

The distribution of the olivine basalts with respect to the other members of the series indicates that the flows were local in their extent. The small areas covered by the lavas and the diversity of types met within one area argue that they were derived from small magma chambers, and the short lateral extent of many of the fissures suggests that these small chambers were situated near the surface.

The series was, therefore, derived from small magma chambers situated near the surface. The lavas made their way upward through fissures and partly through volcanic vents and did not spread far from the point at which they came to the surface. A period of disturbance followed their extrusion and the series was thrown into a number of open folds trending north and south. These disturbances were accompanied by further faulting, the faults trending in the same direction as those formed previous to the formation of the series.

In the late Pliocene, erosion had carved the irregular accumulation of Miocene lavas and the older land surface under them into a surface with regional slopes of from 3 to 6 per cent. This surface was then in the stage of late maturity and no peneplain remnants existed in it.[1] In the late Pliocene the whole region was uplifted 1,000 to 2,000 feet and canyons were carved in the broad open valleys then in existence.

In Pleistocene time a glacial ice cap moved over the country, travelling in a southerly direction, and upon its retreat there were secondary invasions of valley glaciers which re-shaped the valleys and carved out lake basins. Upon the retreat of the glaciers a thin blanket of drift and occasional morainal deposits were left over the area. Afterwards erosion again became active and much of the glacial debris was eroded away and re-sorted by the rivers. Finally, as the rivers cut into their beds, terraces were formed near their bottoms. These terraces are probably the result of climatic changes and the wanderings of stream meanders; the formation of terraces is in operation to-day.

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[1] Museum Bulletin No. 11.

CHAPTER V.

ECONOMIC GEOLOGY. ORE DEPOSITS.

Three types of ore deposits are found within the Beaverdell area. Each of these can be distinguished from the others without much difficulty, partly because of their form, and largely because of their difference in the groups of minerals of which they are made up. They are, therefore, treated separately here and may conveniently be classed as

(1) Mineralized shear zones;
(2) Stocks;
(3) Contact metamorphic deposits.

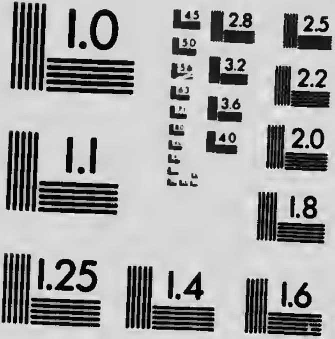
By "mineralized shear zones" are meant a series of more or less tabular bodies of brecciated rock, quartz, and ore minerals which lie between well-defined walls. They include the galena, sphalerite, pyrite, silver-bearing ores, and the chalcopyrite gold-bearing ores. Among the former are the only ore-bodies in the district which have up to the present time been worked at a profit.

By "stocks" are meant a number of ore-bodies of irregular form within which the shattered country rock has been impregnated with metallic minerals and sometimes with quartz. Although in places approaching a tabular form they do not have the two well-defined walls of the "mineralized shear zones." With the stocks have been included irregular bodies of ore occurring in quartz veins. These ore-bodies do not belong to the well-defined mineralized shear zone or the contact metamorphic types and, since in places they carry the same minerals as the stocks, they are for convenience classed with them. The "stocks," therefore, include more than one type of ore-body. The typical ore minerals of the stocks are pyrrhotite, chalcopyrite, and pyrite, but pyrrhotite does not occur in all of them. They carry values in gold.

By "contact metamorphic deposits" are usually meant mineral deposits formed in limestones or other calcareous

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



rocks by the intrusion of an igneous body. Such deposits are characterized by very definite associations of minerals. Only one contact metamorphic deposit is described here. It occurs largely but not entirely in limestone, and no intrusive igneous body was found nearby to which its origin could be reasonably ascribed; but because of the typical association of contact metamorphic minerals of which it is composed it is classed as a contact metamorphic deposit.

The minerals which are found in these three types of deposit are treated together at the beginning of this chapter. They are described together in order that the groups of minerals which form the different deposits may be more easily compared. The section on mineralogy is intended for reference rather than for general reading, since it is made up largely of detailed descriptions of minerals. It may, therefore, be found an advantage to omit this section and proceed at once to the description of the three types of ore deposits which follow; they are treated in the following sequence: (1) mineralized shear zones; (2) stocks; (3) contact metamorphic deposits.

After the general description of each of the three types there is a section devoted to the description of the individual mines and prospects.

MINERALOGY.

In this section all the minerals found in the ore deposits described in this chapter are treated together. They are first arranged in a table of zones of mineral formation, and later described in alphabetical order.

The minerals which occur with the ore-bodies in this area are conveniently divided into two groups: those which formed part of the original country rock, and those which were introduced later and form part of the ore-bodies. It is with the latter type that we are chiefly concerned. The minerals which together made up the country rock before the introduction of the ore will be only very briefly described.

In order to compare the association of minerals which go to form the three types of ore deposits, on the basis of the conditions of temperature and pressure under which they were formed, the minerals are arranged together in the following table. The table is based upon the study of ore deposits in many different localities by Lindgren,[1] W. H. Emmons,[2] and others.

Table of Minerals in the Beaverdell Area Arranged According to Zones of Deposition.

I Contact metamorphic deposits.	II Deposits of the deep vein zone.	III Deposits at moderate or shallow depths, igneous rocks nearby.	IV Secondary minerals in the zone of secondary sulphide enrichment.	V Secondary minerals in the oxidation zone.
Ankerite	Ankerite	Ankerite	Ankerite	....
Arsenopyrite	Arsenopyrite	Arsenopyrite	....	....
....	....	....	Azurite	Azurite
....	Barite (?)	Barite	....	....
Bornite	Bornite	Bornite	....	....
Calcite	Calcite	Calcite	Calcite	....
Chalcopyrite	Chalcopyrite	Chalcopyrite	Chalcopyrite	....
Chlorite (?)	Chlorite (?)	Chlorite	Chlorite	....
Epidote	Epidote	....	....	....
Galena	Galena	Galena	Galena (?)	......
....	....	Kaolin	....	Kaolin
....	....	....	....	....
....	....	....	Malachite	....
Molybdenite	Molybdenite	Molybdenite	....	....
Pyrrhotite	Pyrrhotite	....	....	....
Pyrite	Pyrite	Pyrite	Pyrite	....
....	....	Pyrargyrite	Pyrargyrite	....
Quartz	Quartz	Quartz	Quartz	....
....	Sericite	Sericite	....	....
....	....	....	....	Silver
Sphalerite	Sphalerite	Sphalerite	....	....
....	[3]	Tetrahedrite	Tetrahedrite ?	....
....	....	Turgite and	Turgite and	Turgite
....	....	Amorphous	Amorphous	
....	....	Hematite	Hematite	....
Wollastonite	....	....	....	....

[1] Lindgren, Waldemar, "The relations of ore deposits to physical conditions." Economic Geology, March-April, 1907, pp. 105-127.

[2] Emmons, W. H., "A genetic classification of minerals." Economic Geology, Vol. III, pp. 611-627.

[3] Tetrahedrite has in very rare instances been found in veins formed at great depth. It is found in the deep levels at Butte, Mont. (The enrichment of sulphide ores, W. H. Emmons, Bull. United States Geol. Surv., No. 529, p. 175), and in copper gold, tourmaline deposits (Lindgren, Waldemar, Mineral deposits, pp. 654-655.)

The table includes only those minerals which form part of the ore deposits.

The minerals of this area which are known, from studies in other places, to occur in contact metamorphic deposits are placed in column 1. Contact metamorphic deposits are generally found in limestones not far from an intrusive igneous mass. They are presumed to have been formed under conditions of high pressure and of especially high temperature, and certain minerals are found associated only in deposits of this kind.

Deposits of the deep vein zone are those formed under very high pressures and temperatures, but not necessarily close to, or immediately as the result of the intrusion of, an igneous body. They are supposed to have formed at 12,000 feet or more from the surface, but may in exceptional cases have been formed at much shallower depths. Lindgren[1] estimates that they were formed at temperatures between 300 and 575 degrees Centigrade. The amount of pressure is uncertain, but probably over 300 atmospheres.

Deposits formed at moderate or shallow depths grade in places into those of the deep vein zone, but have certain characteristics of their own, and certain minerals never found in the deep vein zone often occur in them. The temperatures and pressures under which they were formed are presumed to have been much lower than those which prevailed during the deposition of minerals of the deep vein zone or of the contact metamorphic deposits. Lindgren[1] has estimated these temperatures to be from 175 to 300 degrees Centigrade for intermediate, and about 100 to 300 degrees for shallow depths, and the pressures 140 to 400 atmospheres for intermediate, and less for shallow, depths.

Columns IV and V are devoted to secondary minerals which have been formed from the ores first deposited by the action of water solutions. They are generally formed by the action of percolating water near the surface of the ground. At a certain distance from the surface all the pores in the rocks are filled with water. This is known as the ground water, and its upper

[1] Lindgren, Waldemar, "Mineral deposits," pp. 444, 513-514, 613-614.

surface the ground water level. Above this level the ground water disintegrates and dissolves the minerals and forms oxides, hydroxides, and native metals; below the ground water level, with some minor exceptions, the action is one of deposition, and secondary sulphides as well as other minerals are formed. The temperatures and pressures at which these reactions occur are uniformly low.

It is evident from a glance at the table that a great many of the minerals are found in deposits which have formed under widely divergent conditions. Thus ankerite, calcite, chalcopyrite, pyrite, and quartz, are found in contact metamorphic deposits which have been formed under high temperatures and pressures and they are also in other places secondary minerals which have formed by the action of cold surface waters under quite low pressures. Other minerals, such as kaolin on the one hand, or pyrrhotite on the other, are restricted to certain zones only, and the presence of these restricted minerals helps to classify the deposits in one or another of these zones, and thus furnishes a clue to the conditions under which they were formed. The table will be referred to again in the discussion upon the genesis of the ores.

DETAILED DESCRIPTION OF MINERALS.

Ankerite, or ferruginous dolomite. Composition generally $2CaCO_3,MgCO_3,FeCO_3$. In rhombohedral crystals also crystalline massive, granular, compact. Colour, white, greyish, or reddish. Hardness about 4. Specific gravity about 3.

Well crystallized brown ankerite was seen at the Carmi mine where it occurs in a roughly banded fissure vein associated with sphalerite, pyrite, and quartz.

Arsenopyrite. FeAsS. Orthorhombic, crystals prismatic or flattened vertically, also massive. Metallic lustre. Colour, silver white inclined to steel grey, streak dark greyish-black. Hardness about 6. Specific gravity 6·0.

Arsenopyrite is occasionally seen in the "stocks" found in the Wallace series. It is said to occur in the silver-lead sh ones on Wallace mountain, but was not identified in any of the ores from that locality. A test upon partly decomposed, earthy, ore from the Rob Roy mine, however, revealed the presence of arsenic and sulphur together, in amounts which strongly indicate the presence of arsenopyrite. It is, therefore, probably also to be found within the unoxidized ore-bodies.

Azurite. $2CuCO_3.Cu(OH)_2$. Monoclinic. Crystals varied in habit, massive, and also earthy. Lustre vitreous. Colour, azure blue to berlin blue. Streak blue, lighter than the colour. Hardness 3·5 to 4. Specific gravity about 3·8.

Azurite is found in small amount as an alteration product of the contact metamorphic copper ores in the Lottie F. claim on Copper creek.

Barite or heavyspar. $BaSO_4$. Orthorhombic crystals generally tabular, also massive and earthy. Lustre vitreous to pearly. Colour, generally white, streak white. Hardness 2·5 to 3·5. Specific gravity about 4·5.

Barite was detected in one instance in an ore-bearing vein on the Gold Drop claim. It occurs associated with quartz, sphalerite, and galena, and was formed after part of the quartz and probably before sphalerite and galena.

Bornite or purple copper ore. Cu_5FeS_4. Isometric. Habit, cubic, with faces often roughly curved, and massive. Lustre metallic. Colour, copper red to brownish on a fresh surface, tarnished quickly to an iridescent colour. Streak greyish-black. Hardness 3. Specific gravity about 4·9-5·4.

Bornite was seen only in the contact metamorphic deposits at the Lottie F. claim on Copper creek where it apparently forms the principal ore mineral. It is in some instances intergrown with chalcopyrite.

Calcite. $CaCO_3$. Rhombohedral, crystal habit varied, also fibrous, granular, compact, or earthy. Cleavage perfect in three directions. Lustre vitreous to earthy. Colour, white or colourless, sometimes coloured in various shades. Streak white or greyish. Hardness 3. Specific gravity 2·7.

Calcite is found in nearly all the shear zones on Wallace mountain; it occurs there as an alteration product of the labradorite in the quartz diorite constituting the country rock, and as veinlets in the ore-bearing shear zones and the faults cutting the shear zones. The veinlets of calcite appear to have been formed after the rock had been partly altered to sericite and chlorite, and after the formation of the ore minerals galena, etc. Calcite occurs in the disseminated deposits in the Wallace series where it is again a later product than chlorite or sericite. When ores are found in or near limestones it occurs as part of the original country rock in greater or less amount. Calcite is not an important gangue mineral in any of the ores occurring in fissure veins.

Chalcopyrite or yellow copper ore. $CuFeS_2$. Tetragonal sphenoidal, often massive. Metallic lustre. Colour, brass yellow often tarnished, streak greenish-black.

Chalcopyrite is a constituent of the ores at Carmi, and of veins upon Arlington mountain. It is occasionally seen upon Wallace mountain; a vein on the Wabash claim for instance, carries chalcopyrite with pyrite, but it is not a common mineral on the mountain. It occurs with pyrrhotite at the Big Strike and in others of the disseminated deposits, and with bornite in the contact metamorphic deposit at the Lottie F. mine on Copper creek. No large bodies of chalcopyrite were seen at any place in this area, nor does chalcopyrite appear to be a prominent constituent of any of the ores. At the Lottie F. mine on Copper creek it is apparently intergrown with bornite.

Chlorite. The chlorites are silicates of aluminum with ferrous iron, magnesium, and chemically combined water; they are monoclinic and generally in scales, thin leaves, or fibres. Lustre somewhat pearly, colour deep grass green or a paler green, seldom white or red. Hardness about 2. Specific gravity about 2·7.

Chlorite is found in small flakes as an alteration product of the crushed quartz-diorite in the shear zones in which the fissure veins of Wallace and Arlington mountains occur. The green colour of the crushed and altered material is probably largely due to finely disseminated chlorite.

Epidote. A hydrous orthosilicate of calcium, aluminum, and iron, with varying proportions of aluminum and iron, often $HCa_2\ (Al,Fe_3)\ Si_3O_{12}$. Monoclinic. Lustre vitreous. Colour, yellowish-green to black, streak uncoloured. Hardness 6 to 7. Specific gravity about 3·5.

Epidote is an alteration product of biotite and hornblende and to a lesser extent of the feldspars in the country rock near the shear zones on Wallace mountain and at other places. It is never an important gangue mineral and cannot be said to form an integral part of the ore deposit on Wallace mountain, because it is equally as well developed away from the shear zones as it is near or in them.

Feldspar. Feldspar forms a large percentage of the original minerals of the country rock of the shear zones veins and of some of the stocks. The feldspars in the shear zones on Wallace mountain are labradorite and orthoclase, the latter carrying about 10 per cent of albite in microperthitic intergrowth and occurring in smaller amounts than the labradorite; at Carmi and Arlington mountain the rock carries feldspars of the same types except that orthoclase is not always present. Those found near the stocks are in general basic plagioclases.

Galena. PbS. Isometric. Massive or in cubes and combinations of cubes and octahedrons. Perfect cubic cleavage. Metallic lustre, colour and streak lead-grey. Hardness 2·5. Specific gravity 7·5.

This is the most important ore of silver in the lodes upon Wallace mountain. It has also been found in small amount at the Carmi mine and perhaps in other prospects within the area. It is sometimes massive, very often in rather large cubic crystals, and upon one or two occasions well developed crystals were seen with a combination of cubic and octahedral faces. A qualitative test made upon about 3 grams of galena from the Bounty claim by solution in nitric acid, precipitation in hydrochloric acid, and thorough washing in hot water, yielded a strong curdy precipitate of silver chloride, thus proving a fairly high content of silver in the galena. Probably all galena occurrences on this mountain are argentiferous. Just how the silver occurs in the galena is not known, the specimen tested appeared to be fresh and the silver content is probably not due to any secondary process.

Kaolin or Kaolinite. $H_4Al_2Si_2O_9$. Monoclinic, generally in thin scales forming clay-like masses. Lustre pearly to earthy;

colour white, grey, or brownish. Hardness 2 to 2·5. Specific gravity about 2·6.

In certain of the cross faults which cut across the ore-bodies a mass of soft, grey, clayey, decomposed rock is often found associated with greenish material, fragments of ore, quartz, native silver, and calcite. It is probable that this soft, clayey material is partly composed of kaolin formed by ordinary weathering, for these "slips" are often wet and the ground water is percolating through them.

Malachite. $CuCO_3Cu(OH)_2$. Monoclinic. Rarely crystalline, often massive, earthy. Colour, bright green, streak paler green. Hardness 3·5-4. Specific gravity 3·9-4·03.

Malachite is an alteration product of the copper ores at the Lottie F. claim on Copper creek. It is to be expected in the altered portion of any chalcopyrite or bornite ore.

Molybdenite. MoS_2. Crystals hexagonal in form, commonly foliated, massive or in scales. Lustre metallic; colour, pure lead-grey, gives a bluish-grey trace on paper, greasy feel. Hardness 1 to 1·5. Specific gravity 4·8.

Molybdenite occurs in a quartz vein outcropping on Captain Gordon's claim on Arlington mountain, and in a number of other places. It is of no value as an ore of molybdenite unless found in large amount.

Pyrargyrite or ruby silver. Ag_3SbS_3. Rhombohedral, hemimorphic, crystalline or massive. Colour, black; by transmitted light deep red. Streak purplish-red. Transparent in very thin splinters, anisotropic. Hardness 2·5. Specific gravity about [illegible]

[illegible] f ruby silver were seen at the Sally, Rob Roy, and [illegible] mines; it is to be looked for in any of the galena lodes [illegible] mountain. The specimens seen occurred with galena [illegible] some pyrite; in certain places it occurs with perfectly fresh galena and pyrite and is, in all probability, a primary mineral. Sometimes, however, the ore is crumbly suggesting that disintegration had taken place. A specimen from the Rob Roy was tested to detect the possible presence of proustite or of argentiferous tetrahedrite (freibergite). The test proved the absence of copper and arsenic, and the presence of silver, antimony, and sulphur; it was, therefore, pyrargyrite. The mineral was found to be anisotropic, but no interference figure could be obtained in it. It had a deep red colour and very high index of refraction. Pyrargyrite carries very nearly 60 per cent of silver and is, therefore, a most valuable silver ore.

Pyrite. FeS_2. Isometric in cubes and pyritohedrons, faces often striated, often twinned, frequently massive. Lustre metallic. Colour, pale brass yellow, streak greenish-black or brownish-black. Hardness 6-6·5. Specific gravity 5.

Pyrite is a constant constituent of the ores upon Wallace mountain. It is found in the shear zones at Carmi, and upon Arlington mountain, and in the stocks of the St. John and Triple Lakes region. The pyrite varies in colour from very light yellow to a much deeper shade; the lighter variety when massive may be mistaken for arsenopyrite.

Pyrrhotite. $Fe_{11}S_{12}$. Hexagonal, rarely crystalline, commonly massive. Metallic lustre. Colour bronze yellow to reddish, easily tarnished, streak dark grey to black. Hardness 3·5 to 4·5. Specific gravity about 4·6. Generally somewhat magnetic.

Pyrrhotite is found only in the stocks which occur in the Wallace series, It was seen at the Big Strike claim on St. John ridge, on one of the Larsen and Burns' claims on Kloof ridge, and on the O.K. and Silver Dollar claims in the Triple Lakes region.

Quartz. SiO_2. Hexagonal in prismatic crystals terminated by rhombohedrons, or massive. Colour generally white or colourless, lustre vitreous, streak white. Hardness 7. Specific gravity 2·6.

Quartz forms the principal gangue mineral in the fissure veins on Wallace mountain, at Carmi, or upon Arlington mountain. It is a prominent primary constituent of the quartz-diorite which forms the country rock for these fissure veins, but is found in much larger amount as a secondary mineral within the veins, either as a fissure filling or replacing fragments of altered quartz diorite. It quite often constitutes the outside band in fissure veins and was evidently one of the first of the secondary minerals to crystalline. The quartz of the fissure veins is generally white, seldom colourless or glassy, the crystals often arranged with their longer dimensions perpendicular to the wall of the vein, and in such cases the ends projecting toward the interior of the vein sometines terminate in rhombohedrons or pyramids, giving rise to comb texture. Sometimes the quartzes project into a cavity or druse in the vein, in one case at the Sally mine the first generation of vein quartz had been corroded, and secondary quartz grown over it, the two generations having the same optical orientation.

Sericite. Scaly or fibrous muscovite. An orthosilicate of aluminum and potassium of varying composition, often H_2K, Al_3 $(SiO_4)_3$. Lustre vitreous to pearly or silky. Colourless to light shades of brown, green, violet, and yellow. Streak uncoloured. Hardness 2·2 to 5. Specific gravity about 3.

Sericite occurs as an alteration product in the fissure veins on Wallace mountain, at Carmi, and on Arlington mountain. It replaces both feldspar and primary quartz in the crushed quartz-diorite and in later fine-grained dykes intruded into the east and west fissures. In a thin section of altered quartz diorite from the lodes of the Sally mine, needle shaped crystals of sericite may be seen cutting into and across grains of primary quartz and feldspar. In certain thin sections practically all the original material has been replaced by sericite.

Silver. Ag. Isometric, in a circular or net-like form, also massive, and in plates. Ductile and malleable. Colour and streak silver white, grey to black when tarnished. Hardness 2·5 to 3. Specific gravity 10·5.

Native silver is found in a number of mines on Wallace mountain chiefly in or near the later fault planes, where it is associated with calcite fragments, decomposed rock, or "gouge," and green material which is probably largely chlorite. It is generally in thin leaves hackly scales and they often lie on a smooth surface of the rock, probably in most cases the edge of a break. Native silver was not seen except in the later cross faults or very close to them. It was in places evidently deposited in these fault planes and its formation, therefore, took place after the primary ore had been formed and faulted. It is a secondary product and was probably formed by the cold surface waters which now percolate through the fault planes.

Sphalerite or zincblende. ZnS. Isometric. In tetrahedrons or massive. Perfect dodecahedral cleavage. Lustre resinous to adamantine. Colour yellow, various shades of brown to black, sometimes white or green. Streak brownish to light yellow and white. Hardness 3·5 to 4. Specific gravity 4.

Sphalerite in greater or less amount generally accompanies the galena on Wallace mountain; it is found well developed in a tunnel on the bank of the river at Carmi. The sphalerite on Wallace mountain is not mined for zinc, and a large percentage of it in the ores is considered a distinct disadvantage. Specimens of sphalerite from the Bounty mine on Wallace mountain and from the Carmi mine were tested for iron and manganese. Iron was present and manganese absent from both specimens.

Tetrahedrite or grey copper ore. $Cu(Ag)_8 \cdot Sb(As)_2S_7$. Isometric tetrahedral, often granular or massive. Lustre metallic. Colour, flint grey to iron black with the same streak. In silver-bearing tetrahedrite the streak is often reddish. Hardness 3·4. Specific gravity 4·4—5·1.

Tetrahedrite was identified in ore from the Buster shaft and is reported from a number of mines on Wallace mountain. At the Buster shaft tetrahedrite is intergrown with galena, and to a larger extent with sphalerite. It is undoubtedly a primary mineral there and was formed with galena immediately after the first generation of quartz in the vein. A small portion of this mineral, which is fine grained and dull grey in the hand specimen, was segregated and tested by Doctor W. M. Bradley of the Mineralogical Department at Yale university. Satisfactory tests were obtained from the same carefully segregated sample for silver, antimony, copper, and sulphur. Arsenic was not present. The mineral is, therefore, argentiferous tetrahedrite.

Turgite or amorphous hematite. Deposits of very fine grains of iron oxide were detected under the microscope, lying in veinlets with quartz, chlorite, and calcite in material from the Sally mine. Very small veins of iron oxide were also seen in a number of specimens from other mines on Wallace mountain, and a reddish deposit of iron oxide is being deposited on the walls of the mine workings to-day. Only a very small amount of the material was obtained for testing; this had a light red streak and when tested with chemical reagents definitely proved the presence of iron. This is probably an oxide of iron with the composition of hematite or turgite.

Unknown Species. An aluminous silicate of calcium, manganese, iron, and sodium. It contains no potash or combined water. Isometric. Lustre non-metallic, colour, pinkish-white, in transmitted light colourless. Isotropic. Index of refraction about 1·59. Fuses to a shiny brown, blebby glass; fusibility about 4, and the fused mass is slightly magnetic. It gives an orange flame. Hardness about 5·5 or over. Fracture conchoidal.

This material occurs in the contact metamorphic deposits on Copper creek; it is found lining ellipsoidal cavities and appears to have formed after the ore sulphides (see Plate IX). Tests made in the mineralogical laboratory of Yale university by Doctor W. M. Bradley proved the presence of silica, alumina, iron, calcium, manganese, and sodium, but no potassium or combined water. The index of refraction was measured by Professor W. E. Ford and found to be 1·59. This mineral does not agree with any description seen in Dana's Manual of Mineralogy or other standard books, but because of the small amount available, and the fact that it carries inclusions of bornite, and is hard to obtain pure, no quantitative analysis could be made of it. This may be what has been called edelforsite, an impure, noncrystalline, wollastonite.[1]

Wollastonite. $CaSiO_3$. Monoclinic, commonly tabular, usually cleavable; massive to fibrous, also compact, cleavage perfect, parallel to the axis *a*. Lustre vitreous, colour white inclined to yellow, red, or brown. Streak white, optically negative.

Wollastonite was detected in thin section among the ore minerals from the contact metamorphic deposit on Copper creek. It is possible that the unknown silicate mentioned above is the compact, noncrystalline variety of wollastonite.

[1] Dana, E. S., "A system of mineralogy," p. 373, 6th edition, 1909.

THE MINERALIZED SHEAR ZONES.

DESCRIPTION.

Definition.

In order to clearly indicate the types of ore-bodies which are described under this heading, the term "mineralized shear zones" will be again defined. The particular kind of "mineralized shear zone" in which the ores treated of in this section occur consists of a roughly tabular body of brecciated and partly altered country rock, quartz, ore minerals, and in places, intruded and altered dyke rock. These lie between comparatively solid, unaltered, and well-defined walls of country rock. The amount of broken up country rock within the shear zones varies; in places there is not much brecciated rock and the material between the walls is nearly all quartz; and at other localities altered dyke rock takes up most of the space between the walls. The "stocks" in which the second type of ore-bodies occur are in places also found in shear zones, but they are seldom well defined, and since they carry a different type of ore, they are called "stocks" in this report.

Distribution.

Mineralized shear zones carrying values in silver are found over an area of about 3 square miles on Wallace mountain, and at the town of Carmi they carry values in gold and small quantities of silver. Ore showings have also been obtained from shear zones on Arlington and King Solomon mountains; those on Arlington mountain are said to carry values in gold and copper.

Mineralogy.

The ore deposits on Wallace mountain consist of pyrite, galena, sphalerite, tetrahedrite, pyrargyrite, native silver, and perhaps argentite, in a gangue made of sericite, quartz, barite, iron oxide, and calcite. Of the ore sulphides pyrite, galena, and sphalerite are more commonly found, and argentite was not seen in specimens collected by us, and is probably not very common. Sericite and quartz form the principal gangue minerals and barite was seen in one place only. Native silver, iron oxide, calcite, and chlorite are in general later than the sulphides.

The ores at Carmi are made up of sphalerite, pyrite, chalcopyrite, galena, molybdenite, sericite, quartz, and ankerite. Galena and molybdenite occur in comparatively small amount and ankerite was seen in one place only.

On Arlington mountain the shear zones carry chalcopyrite, pyrite, and occasionally molybdenite in a gangue of quartz, sericite, and calcite. Magnetite is present in certain altered brecciated fragments of pyroxenite, but this may be a product of the original pyroxenite magma and not a part of the later mineral deposit which formed the ores.

The Country Rock.

The typical "mineralized shear zones" are found only in the Westkettle quartz diorite which is a grey rock resembling a granite and made up of feldspar, quartz, biotite, and hornblende. A description of this rock body and its variations is to be found in the chapter on general geology. The silver-bearing galena ores occurring in the mineralized shear zones were seen in older rocks of the Wallace group in two instances only, and were then poorly developed; they have never been found in the Beaverdell quartz monzonite. The gold-bearing pyrite chalcopyrite ores such as occur in the mineralized shear zones in quartz diorite at Carmi, are, however, also seen in the Wallace group at that place, on Arlington mountain, and in other places.

The practical restriction of the galena ore-bodies to the Westkettle quartz diorite is a matter of great economic importance if true, and the evidence upon that point is, therefore, given at some length here.

Restriction of the Shear Zones and Galena Ores to Quartz Diorite. The shear zones, which in their typical development strike east-west and dip south, are found in the greatest number in the quartz diorite upon Wallace mountain; but although the area of rocks of the Wallace group which lies to the east of the quartz diorite upon the mountain contains a great deal of shattered rock, and occasionally the shattering lies in zones or belts, the well-defined shear zones with clean cut walls which are found in the quartz diorite appear to be absent. In one place at the Buster shaft a shear zone crosses from quartz diorite to a porphyry of the Wallace group. In the quartz diorite it has well-defined walls, but not in the Wallace. Although partly covered it could be traced in the quartz diorite area, by means of test pits sunk in it, nearly up to the contact, and if continued along its strike it should have crossed the contact, at about right angles. On the other side of the contact, however, in the Wallace porphyry it was slightly offset to the north and appeared as an indefinite zone of shattered rock. Some galena, sphalerite ore was found in this zone, but it did not appear to be present in any quantity.

Galena ores were seen in one other place in a shear zone of the Wallace group; that is, at the Washington and Idaho shafts, but the ore does not have the coarse texture of that found in the quartz diorite, and occurs in small amount. It is possible that there are other silver-bearing galena deposits in the Wallace group, but careful prospecting all over Wallace mountain and other parts of the district has failed to bring them to light. The clean cut shear zones in the quartz diorite appear to have furnished more space for the deposition of the galena ores than the shattered areas in the Wallace group.

The shear zones appear to be absent also from the Beaverdell quartz monzonite, although they were looked for in the area at Beaverdell and in the larger areas elsewhere. In like manner the ores which occur in these shear zones are, as far as we know, absent from the Beaverdell quartz monzonite, although the quartz monzonite rock bodies have been thoroughly prospected and, because of their light colour, ore would be easily seen in them.

The reasons for the absence of the ores from the quartz monzonite, and their small development, in the Wallace group, is discussed more fully in the section dealing with the genesis of the ores.

Variations in the Country Rock. Within the quartz diorite batholith itself there are a number of variations in the character of the rock, but as far as we know these variations have not affected the character or value of the ores. The quartz diorite varies from medium-grained to fine, and from light coloured, acid, rock, to a dark, basic variety. At Carmi and on Arlington mountain it is generally gneissic; on Wallace mountain massive. The difference in character between Carmi and Wallace Mountain ore (see pages 86, 87) is explained, however, as due not to a change in country rock but to a difference in the depth of formation. In other words, the ores at Carmi are thought to represent the deeper parts of the shear zones, while the ores so far found on Wallace mountain represent the shallower. If true, that would mean that at a certain depth below the present surface the ore-bearing shear zones on Wallace mountain carry ores similar in character to those found near the surface at Carmi. The evidence on which this supposition is based is presented under the discussion of variations of the ore in depth (pages 108, 109).

Dykes In or Near the Shear Zones. At an open-cut on the Sally No. 2 vein, a fine-grained grey dyke has been intruded along the east-west shear zone. Dykes of similar appearance occur in the east-west shear zones at the Carmi mine on the Bounty Fraction claim. They occur near the ore-bodies on the Rambler and Buster properties. In the hand specimens these rocks are grey to greenish-grey, very dense, and generally somewhat brecciated; they weather to a rusty brown colour. The dyke on the Bounty claim proved on microscopic examination to be an andesite with trachytic texture, nine-tenths of it being made up of andesine feldspar, and the remainder of biotite, orthoclase, and possibly a few grains of quartz. The dykes at the Sally mine, and also at Carmi, were almost completely altered to sericite, but appeared to have formerly been fine-grained and probably largely feldspathic. Because of the resemblance of hand specimens of all these dykes to the andesite dyke on the Bounty Fraction, and their almost universal occurrence within east-west shear zones, they are taken to be contemporaneous intrusions of the same type. Ore is found developed within these dykes at the Sally and Carmi mines and they were, therefore, intruded after the formation of the east-west shear zones and before the formation of the ore. Since they were formed long after the intrusion of the Westkettle batholith, occur near but not in the Beaverdell batholith, and are more highly altered than that body they are believed to be satellites of the Beaverdell batholith preceding its intrusion.

Pink dykes of aplite are found in the tunnels of the Rob Roy and Homestake claims, both of which lie east and uphill from the outcrop of Beaverdell quartz monzonite (Figure 1). The Homestake tunnels are close to the quartz monzonite, and the Rob Roy about one-half mile away. A dyke of quartz porphyry in the quartz diorite near one of the Homestake tunnels, an undoubted offshoot of the mass of quartz monzonite below it, resembles the pink aplite dykes found in the mine tunnels very closely in composition and general appearance. Both are made up almost entirely of quartz and orthoclase feldspar with a subordinate amount of plagioclase and a little biotite. The granite aplite dykes may, therefore, both because of their composition and their position, be regarded as offshoots from the intrusive body of Beaverdell quartz monzonite. They have been slightly, but not entirely sericitized and are believed to have been intruded at the time of the deposition of the ores.

Structural Features of the Shear Zones.

On Wallace mountain, at Carmi, and on Arlington mountain the typical mineralized shear zones are from 1 to 10 feet wide and with minor exceptions they strike east and west, and dip to the south. At the Rob Roy and Kokomo workings on Wallace mountain the strike is southeast, while at the Bell it is west of south. The zones are, however, often displaced by cross faults, and the strike of blocks of the same zone is not always the same. The dip is generally to the south and varies from about 50 degrees to the vertical; occasionally it is to the north, but on Wallace mountain northerly dips are in most places very evidently the result of tilting incident to later faulting, or otherwise the amount of dip is nearly 90 degrees.

The smooth walls of the zones and the large amount of brecciated material found in them indicates that their formation must have caused a considerable displacement of the quartz diorite; but the amount of displacement cannot be determined because of lack of datum planes.

List of mi

1 Tunnel on

2 Sally No4

3 Wellington

4 Rob Roy N

5 Rob Roy tu

6 Sally No1

7 Sally No2

8 Outcrop of

9 Workings

10 Shaft on

11 Shaft on

12, 13, 14 Workings
and Bound

15 Shaft on th

16 Shafts on

17 Shafts on

18 Shaft on th

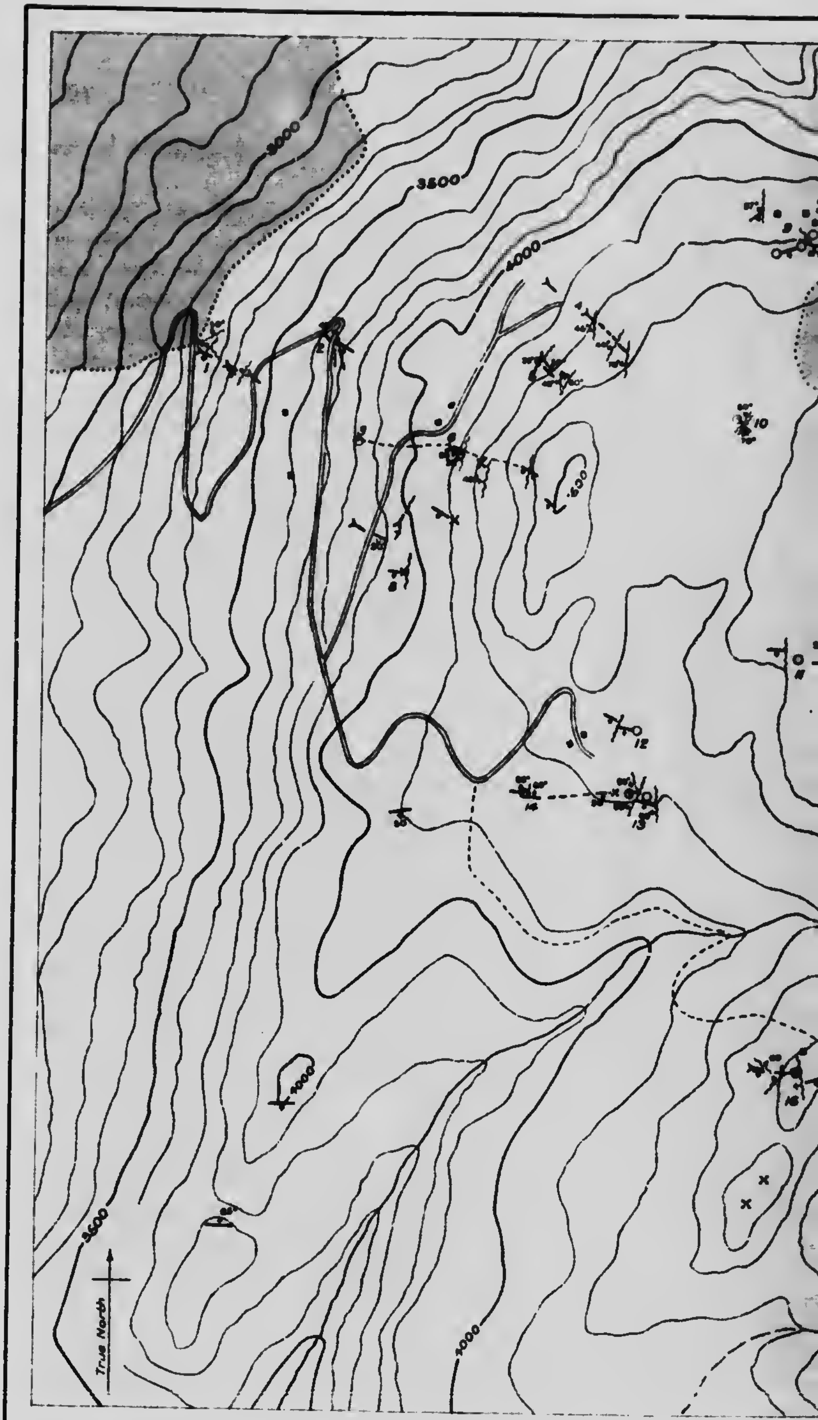
19 Shaft on th

20 Shaft on th

21 Shaft on th

List of mine workings

1 Tunnel on the Homestake claim
2 Sally No. 4 tunnel
3 Wellington shaft
4 Rob Roy No. 7 Tunnel
5 Rob Roy tunnel
6 Sally No. 1 tunnel
7 Sally No. 2 tunnel
8 Outcrop of Excelsior vein
9 Workings on the Bell claim
10 Shaft on the Kokomo claim
11 Shaft on the Wabash claim
12, 13, 14 Workings on the Duncan and Bounty Fraction claims
15 Shaft on the Bounty claim
16 Shafts on the Rambler claim
17 Shafts on the Standard claim
18 Shaft on the Buster claim
19 Shaft on the Washington claim
20 Shaft on the Idaho claim
21 Shaft on the Nepanee claim

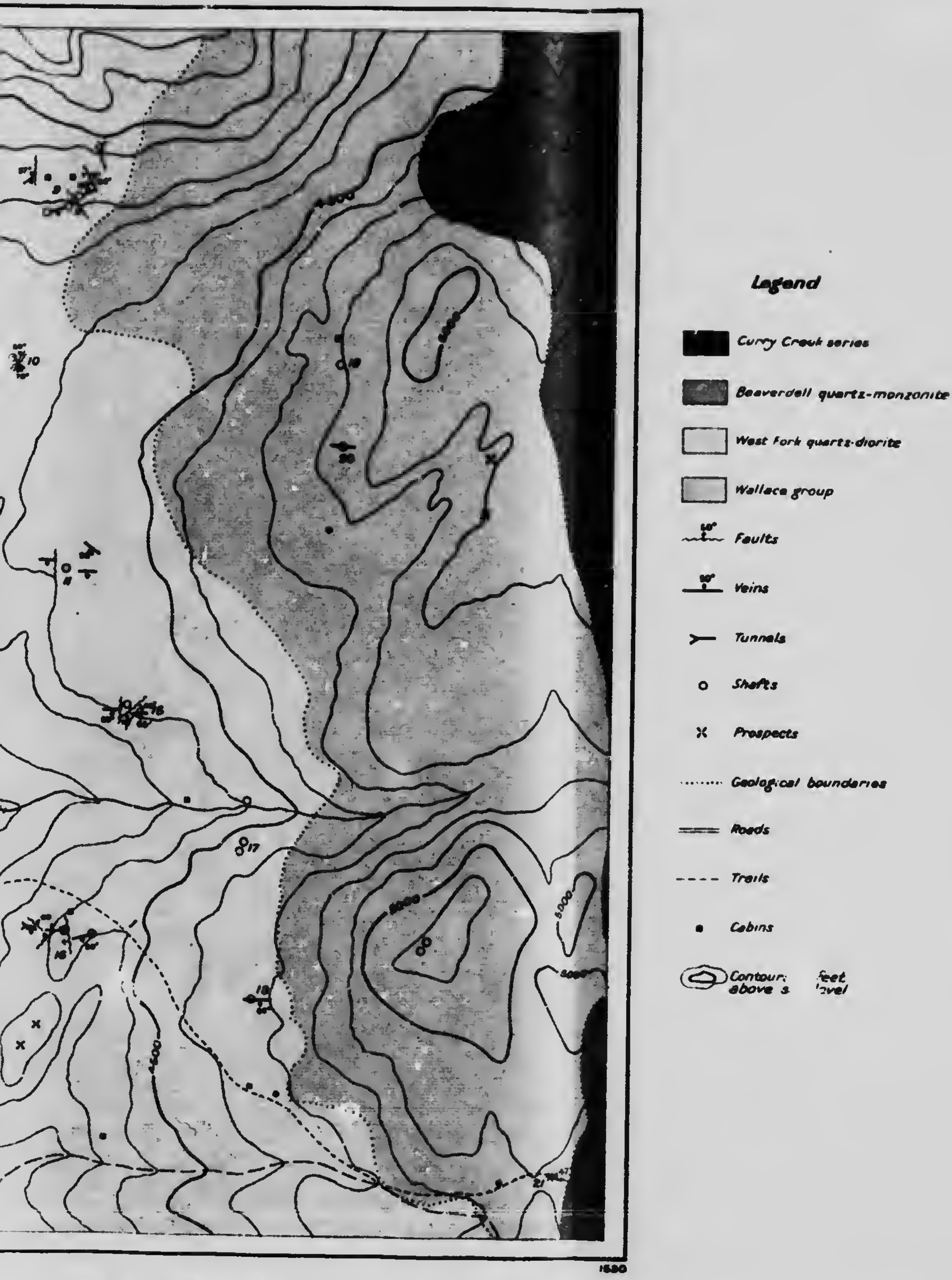


Geological Survey, Canada

Fig. 1 Silver-Lead mines on W

Scale of Feet
0 500 1000

To accompany memoir by L. Reinecke



s on **Wallace Mountain**

of Feet

Textural Features of the Deposits.

The material in the zones is either vein filling or altered and replaced country rock and dyke matter. The filling may be in distinct single, parallel, or linked veins within the shear zone, but it is often an irregular filling between brecciated fragments with occasional veinlets into the walls of the shear zone. In like manner, one occasionally finds well banded veins in which successive bands succeed each other with some regularity, and in which there is a definite sequence of minerals from the margin toward the centre; but more often the banding is very irregular or absent, and the veins are made up of aggregates of coarse interlocking crystals which appear to have crystallized together. In the better banded veins good crystal faces are often developed on that part of the minerals projecting toward the centre of the vein, and this is especially true of the quartz, and gives rise to what is known as comb structure (Plate VII). Occasionally the ends of the crystals project into a cavity and form druses in which all the free crystal faces are well developed.

The altered rock within the shear zones consists of fragments of quartz diorite which have been more or less intensely altered by the ore-bearing solutions. The quartz diorite of the walls is comparatively fresh. When alteration of the fragments has not been intense the original texture of the quartz diorite may be recognized, but the more highly altered pieces are a mass of greenish white, rather soft material, traversed by veinlets and irregular areas of quartz and chlorite, more rarely of the sulphide ore minerals pyrite, galena, and sphalerite.

The texture of the deposits at Carmi is similar to that of the deposits on Wallace mountain, although in the few outcrops which are exposed there is more quartz filling and less brecciated quartz diorite. In Carmi also, an altered aplitic dyke in places occupied nearly the whole width of the shear zone. The texture of the zones on Arlington mountain does not seem to have any striking peculiarities which differentiate it from the texture of the zones on Wallace mountain.

Paragenesis. The principal ore and gangue minerals in the shear zones on Wallace mountain were probably formed in the following chronological sequence: sericite, quartz, barite, pyrite; then sphalerite, galena, and tetrahedrite, accompanied by more quartz and pyrite; pyrargyrite; and, lastly, native silver accompanied by chlorite, iron oxide, and calcite. Sericite has in places replaced both feldspar and quartz of the original rock, but it is seldom seen in vein quartz and then only in one or two flakes near the outer edges of the veins. Although quartz may have begun to form in these veins before sericitization ceased it is evident that most of the sericite was formed before the quartz, for secondary quartz sometimes cuts across flakes of sericite. Barite was seen in one vein only; it lies there inside quartz on the outside of a vein of quartz, sphalerite, and galena. It is possible that barite is the filling of a secondary opening in the outside quartz band of this vein and may, therefore, be later than galena and sphalerite; but since its occurrence is very rare its relative age is not of great importance.

Pyrite was seen in many instances replacing not only altered quartz diorite including flakes of the secondary sericite, but also vein quartz, for the smooth face of one pyrite crystal was seen to cut cleanly across more than one crystal of vein quartz; in a great many instances also it was formed on top of the quartz crystals in banded veins. It was, therefore, formed later than the first generation of quartz. In banded veins on the Wellington, Bounty, Buster, Rambler, and Gold Drop claims bands of quartz form the outside of the veins; they are succeeded in one or two cases by bands of pyrite, and sometimes by sphalerite or galena and tetrahedrite. The relative succession of the pyrite, sphalerite, and galena is not clear. It is probable that pyrite was formed in some cases ahead of sphalerite and galena. Sphalerite and galena were probably formed at about the same time and were accompanied in very many instances by more pyrite and quartz. Tetrahedrite was found at the Buster shaft intimately intergrown with galena in a vein in which the bulk of the tetrahedrite and galena formed ahead of the sphalerite. It is here undoubtedly a primary ore and one of the first to form in the vein. In several cases quartz and galena are clearly the last minerals to crystallize, for they form drusy linings to cavities in the veins. In one specimen pyrargyrite appears in a banded vein; it is accompanied by sphalerite, pyrite, and galena all of which appear fresh and unaltered. Pyrargyrite is believed to be primary in this vein, and one of the last minerals to form. In a vein in the Sally No. 2 tunnel the following succession was seen: (1), quartz; (2), iron oxide, probably hydrous, deposited on the corroded ends of the quartz crystals; (3), a second generation of quartz followed in places by a deposit of iron oxide; (4), chlorite; (5), calcite. Pyrite appears in this vein after the first generation of quartz; its relation to the chlorite and calcite was not seen, but the formation of iron oxide before chlorite and calcite indicates that the pyrite crystallized before they did.

Veinlets of calcite cut the altered rock and the other vein minerals, and are found traversing individual crystals of galena and sphalerite; where seen in the same vein with chlorite they were the younger. Calcite was probably the last mineral to form in the veins. In certain fault planes which cut across the veins and displace them, native silver is found accompanied by clayey gouge chlorite and calcite. Native silver was evidently the last ore mineral to form.

The paragenesis of the minerals at Carmi and on Arlington mountain was not studied; it is probable, however, that sericite preceded quartz and the ore minerals. From what could be learned from one banded vein it seemed that ankerite and sphalerite preceded in that place the formation of pyrite and quartz, but the evidence is not very clear.

Localization of Ore Masses Within the Shear Zones.

Very little has been learned in the course of this work regarding the shape of the bodies of paying ore within the shear zones. The lack of extensive underground work, the absence of definite records, and the fact that no mines were being worked in 1911 prevented the obtaining of data on that point. Since the shear zones are roughly tabular bodies it is to be presumed that the ore-bodies were also more or less tabular or slab-like; their thickness does not appear to exceed 10 feet and is in most cases one foot. Their original lateral extent is hard to estimate for the shear zones and the ore-bodies in them have been cut across and displaced by a large number of faults. A glance at the vertical projection of the stopes in the Sally No. 1 tunnel, Figure 4, indicates that many ore-bodies are now bounded on more than one side by fault planes. Although no returns are available on that point, it may be taken for granted that stoping in the Sally No. 1 tunnel did not proceed far beyond the limits of rich ore and, on the other hand, the backs of the stopes show that little or no rich ore was left in them. The shape of the stopes in Figure 4, may, therefore, be taken as the approximate shape of the ore-bodies as they existed before mining commenced. That is, they were tabular bodies generally bounded on two or more sides by fault planes. Since the structural conditions are the same in the other mines on Wallace mountain, and in the one at Carmi, that is, the ores are in tabular shear zones which have been displaced by a large number of closely spaced fault planes, one may look for ore-bodies of the same shape in the other mines; that is, roughly triangular or four or more sided slabs bounded by fault planes.

Variations of Values in Depth. It is locally reported that particular ore-bodies vary very greatly and rapidly in value in a lateral direction, but we have no definite data on that point. The variations in depth of any one ore-body are also still problematic, for no one shear zone has been mined through a depth of even 200 feet, and in most of them the depth attained has been less than 100 feet. Such variations would not be easy to trace very far, even if underground work had opened up the ore-bodies to greater depths, because of the faulting and displacement of ore-bodies which have occurred.

It is probable, however, that the ores at Carmi represent the type of ore which is to be found in depth below the Wallace ores, and in that case the ore-bodies will vary from rather rich silver-lead ores to somewhat low grade gold-bearing ones. Since the evidence upon which this assumption is grounded is of a somewhat theoretical nature it is given in the section devoted to the genesis of the ores, under the heading, "variations of the ore in depth" (pages 108, 109).

Faults.

A large number of faults offset the ore-bearing shear zones. They are found in every mine where the ore-bodies have been developed to any extent, not only on Wallace mountain but also at Carmi. They have been the greatest sing obstacle to the development and mining of these ore-bodies and their study is, therefore, of importance. In Figure 2 the strikes of all the faults encountered in the Beaverdell area have been plotted on a projector chart, the zero of which indicates true north. Those marked with arrows were not found upon Wallace mountain; many of those not so marked indicate the strike of more than one fault plane, some of them not on Wallace mountain. Four or five fault planes were sometimes found to strike in the same direction and have then been indicated by one line only; five out of every six lines on the chart represent fault planes cutting across the ore-bearing shear zones on Wallace mountain. In Figure 1, those faults are indicated which were actually seen on the surface; and of the faults seen underground only those were plotted which, from their dip and strike, were believed to have reached the surface. The large number of faults which have broken across the ore-bodies is indicated by Figures 3 and 4. Figure 3 is a perspective view of the underground workings of the Sally No. 1 tunnel, and Figure 4 is a vertical projection of the stopes in a plane lying in a direction parallel to the general direction of the tunnel; that is, south of east. The major faults on Wallace mountain trend from a direction slightly west of north to northeast. Figure 2, indicates that they fall roughly into four groups which lie within about 10 degrees of each other and which include a great many smaller faults. What the relations between these groups are is not known, for the homogeneity of the body of quartz diorite prevents the tracing of fault lines from one mine tunnel to another.

There seems to be no general relation between the direction of fault planes in any particular mine and the amount of displacement they have occasioned. There is, however, a relation between their dip and the displacement along them. In the Sally No. 1 tunnel for instance, Figures 3 and 4, faults dipping

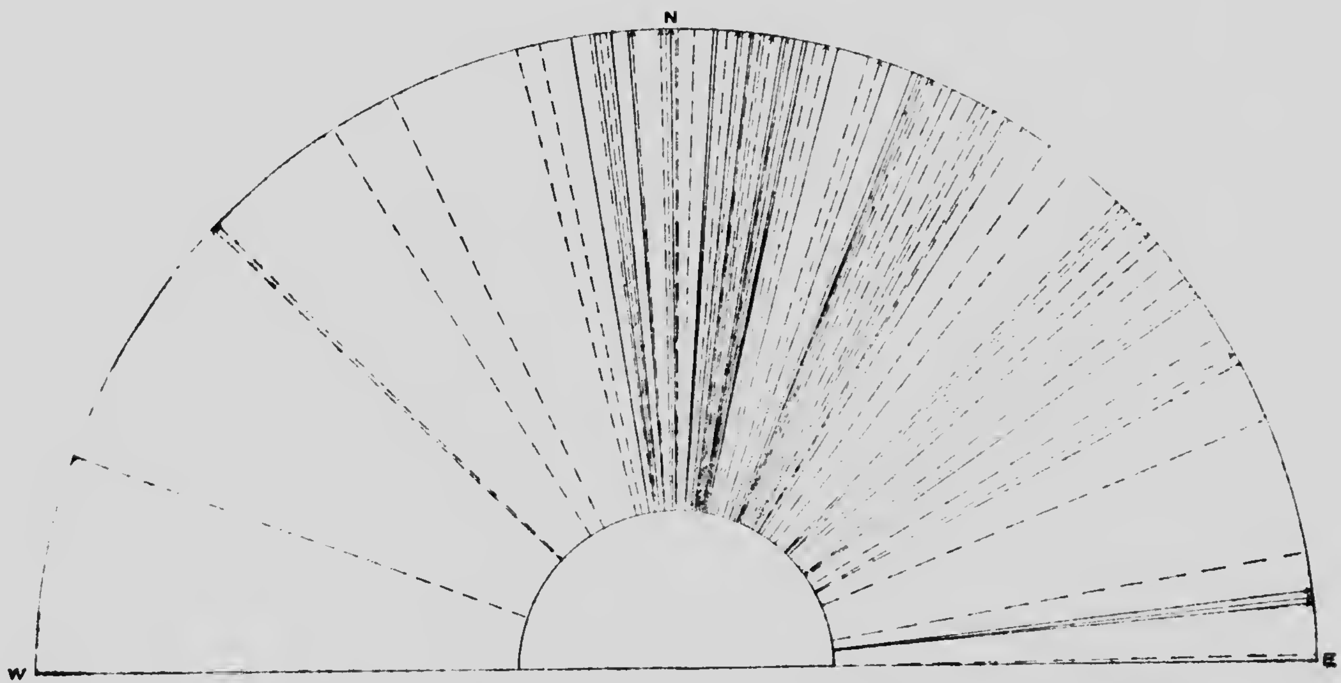


Fig.2. Chart showing the directions of strike of faultplanes in the Beaverdell area
All but those marked with arrows cut the ore bearing shearzones on Wallace Mountain
Major faults in solid lines   Minor faults in broken lines

at angles of from 30 to 40 degrees to the west have caused the larger displacements, and the blocks between them have been broken up by a large number of minor faults, most of which are nearly vertical or dip steeply to the west or east. In the Rob Roy No. 7 tunnel, Figure 5, the major fault planes dip about 40 degrees to the west but vary at least 30 degrees in strike. Although the larger and flatter fault planes generally cut across the steeper ones, the reverse is often the case (Figures 3 and 4).

The amount of displacement along the faults could be measured with accuracy in one or two instances only. The direction of lateral displacement is generally a relative offset of the eastern part of the shear zone to the south. In the Sally No. 1 tunnel an ore-bearing shear zone dipping south at an angle of from 50 to 60 degrees has had its eastern end offset about 50 feet to the south along the fault plane (Figure 3). An offset of the same character and magnitude occurs in the Rob Roy tunnel. Numerous small offsets of from 1 to 10 feet can be measured in nearly all the mine workings, and larger offsets are indicated in many of them(Figure 1), but variations in the character of the same shear zones from point to point make their identification along these faults and the measurement of their displacement, a matter of guesswork.

Some indication of the probable amount of throw or vertical displacement which has obtained along the faults is given in Figure 4. In order to make such measurement we must assume that the upper limits of the stopes shown in the figure indicate the upper limit of an ore-body which, before faulting had taken place, formed a continuous tabular body with its upper surfaces roughly parallel to that of the ground water and, therefore, to the surface of the ground. We must further assume that the surface of the ground, and consequently of the ore, sloped to the west toward a probable ancient stream course rather than eastward. If such an assumption is justifiable the part of the ore-body east of fault B, Figures 3 and 4, was not only offset 50 feet to the south, but also thrown down at least 100 feet. Fault B is, therefore, a reverse fault, while the flat fault between it and fault C appears to have been a normal fault. The same condition appears to have held in the Rob Roy (Figure 5).

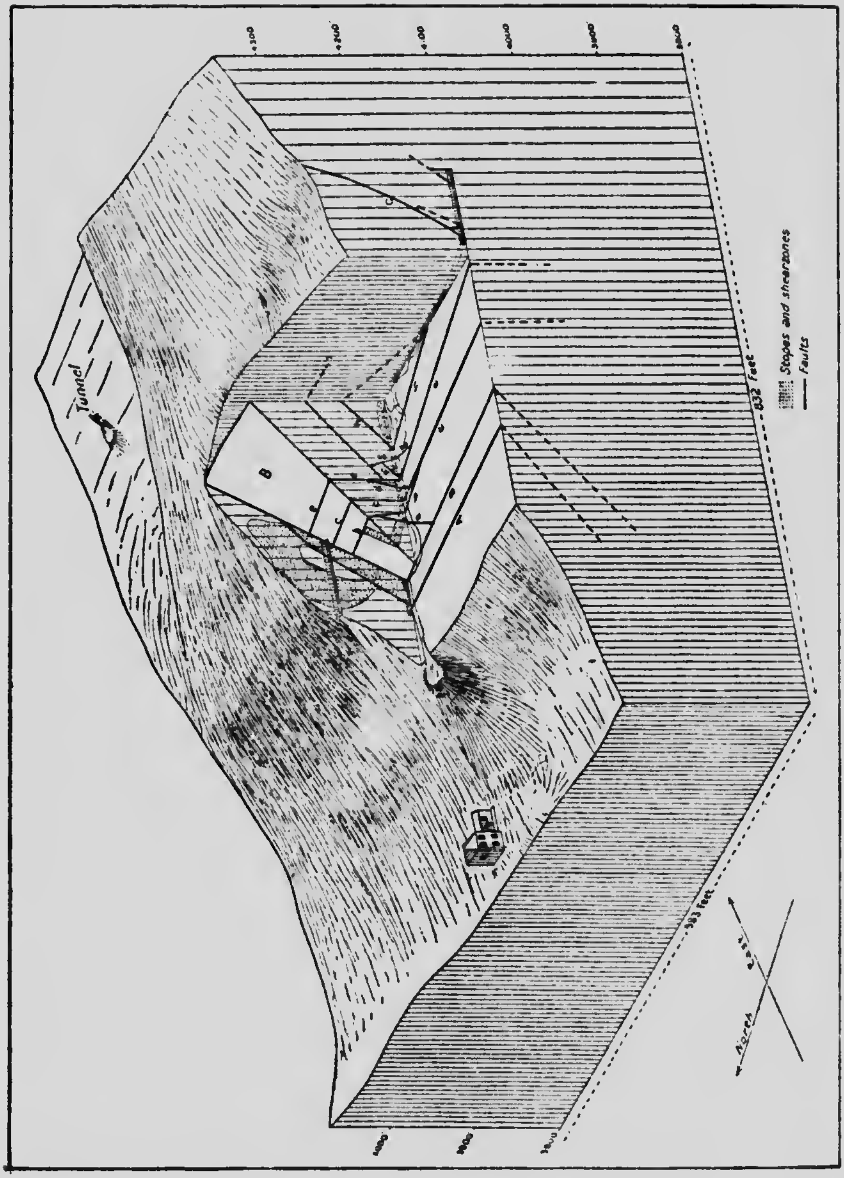


Fig. 3. Stereogram of Sally No. 1 Tunnel

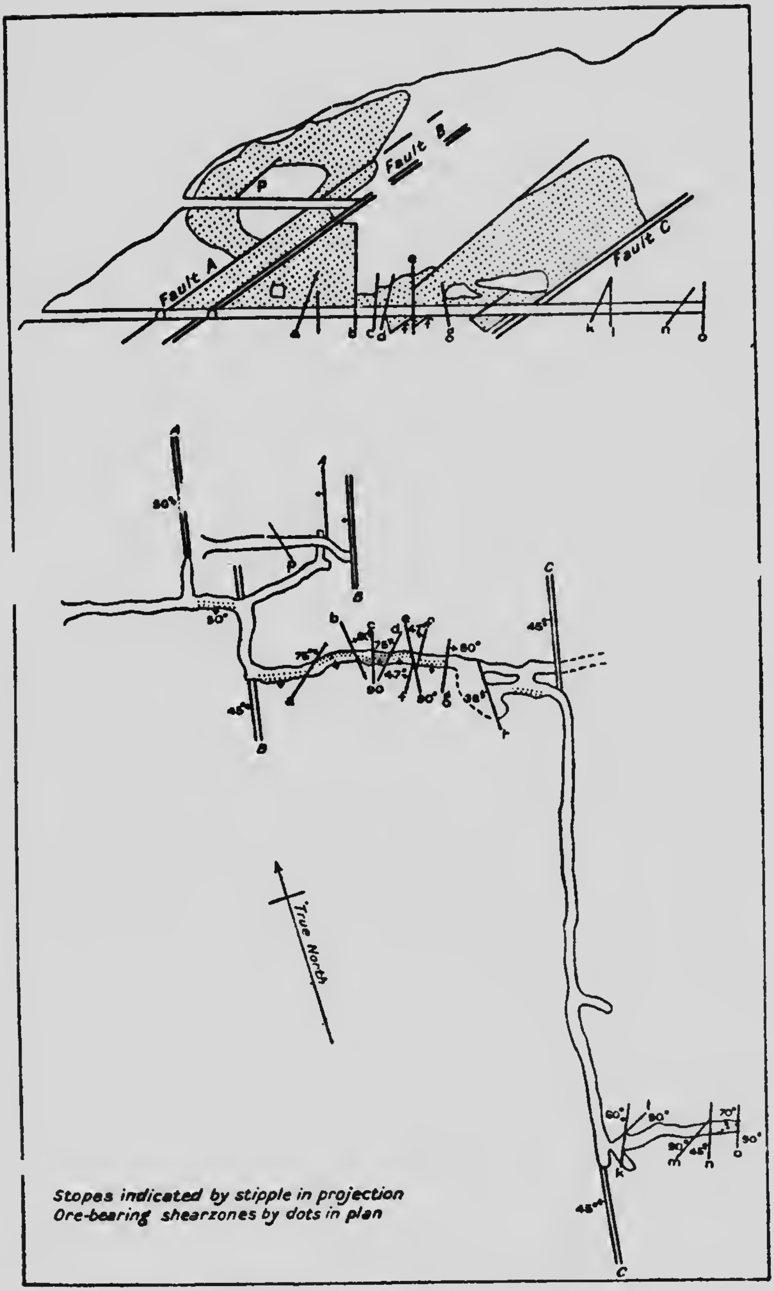


Fig. 4. Vertical projection and plan of the Sally No. 1 tunnel and stopes.

Scale of Feet

Based on a compass-and-paced survey by G. M. Turnbull.

To sum up: a series of east-west shear zones upon Wallace mountain with a generally southerly dip has been displaced by numerous faults, the majority of which trend in directions varying from west of north to northeast, and dip to the west. The larger of these faults generally have flat dips of from 20 to 60 degrees and the blocks between them have been broken by steeper fault planes; occasionally, however, a steeper fault plane cuts across a flat one. The displacement along the faults is generally a lateral offset of the eastern end of the vein to the south, and sometimes but not always a downthrow of that side along the fault plane.

No relation was discovered between the direction of fault lines and their time of formation, and it is possible that they were all formed at the same time. The detailed relations which obtain in the Sally and Rob Roy mines seem to hold for all the other mines on Wallace mountain and also at Carmi. At Carmi the ore-bearing shear zone striking east and dipping south is offset at frequent intervals by cross breaks. In most cases the east side of the shear zone is relatively displaced to the south. The shear zones on Arlington mountain and those on King Solomon mountain, in which indications of ore have been found, are of the same general character as those upon Wallace mountain; cross faulting has probably affected them in the same way.

Surficial Alteration and Secondary Deposition.

Very little leached and oxidized surface material or gossan is found with these ores. The zone of intense surface alteration is seldom more than a few feet thick, and unaltered ore is found very close to the surface. The depth of the ground water level upon Wallace mountain varies from about 15 to 40 feet from the surface; that is, in disused shafts from which there was no outlet, water stands at about that level. It probably varies from place to place as the topography changes and would also vary from one season to another. Surficial alteration by means of the dissolving, oxidizing, and hydrating action of surface waters may be expected down to the ground water level, and it may extend below that level in and near breaks in the rocks. Such alteration has, in many other silver deposits, caused the formation of native silver, silver chlorides, and silver bromides in the zone above, and the deposition of secondary sulphides below the ground water level, but in this area its effects have evidently been very slight.

Some of the oxidized material which is said to occur to depths of 70 feet from the surface at the Rob Roy No. 7 tunnel and to contain silver chlorides was tested in the laboratory, but gave no tests for silver or chloride and appeared, in fact, to be made up nearly entirely of silica and iron oxide. The ore has in some cases altered to a crumbly greenish mass and such masses are often very rich in silver, perhaps because of the leaching away of pyrite in the ore. Along the fault planes a great deal of clayey gouge, chlorite, and calcite, accompanied by some native silver and partly altered ore, are to be seen, and these are probably products of surficial alteration and secondary deposition. It is possible that some of the pyrargyrite is due to secondary deposition, but some of it is believed to be primary. The reason for the small amount of oxidized ore present is discussed under "processes of secondary deposition," page 110.

The only suggestion of extensive secondary enrichment is the shape of the upper limits of the stopes in Figure 4, which as stated on page 97 may be due to the control of the upper limits of the ore-bodies by the ground water, or in other words, their upper limits were affected by surficial alteration. With no independent evidence to prove such alteration or enrichment. not much weight can be given the suggestion.

GENESIS OF THE ORES.

The following hypothesis is put forward to account for the formation of the ores on Wallace mountain and at Carmi. The ores upon Wallace mountain were deposited in the shear zones in which they are found, by hot ascending solutions which partly replaced the brecciated country rock and partly filled cavities between the broken fragments. The depth at which they were formed is less than 2,000 feet. The hot waters were probably derived from the intrusion of the stock-like mass of Beaverdell quartz monzonite which crops out on both sides of the town of Beaverdell. The ores at Carmi were probably formed in the same way, but at greater depth from the surface.

Agent of Deposition.

That the deposits were formed from aqueous solutions is proven by the fact that the greater part of them exist as fissure fillings, the veins being in many cases well banded, and sometimes exhibiting comb and druse texture (Plate VII). The mineral sericite occurs abundantly with the ore minerals, and appears to have been formed in the same general process. The formation of sericite in ore-bodies is in nearly all cases due to hot ascending waters[1]. In the only instance in which sericite has been ascribed to the action of cold solutions, it is described as a product of the decomposition of potash feldspar. In the ore deposits described here the potash feldspars are very often less badly altered to sericite than the plagioclases, and the process of alteration is evidently not dependent on them. Primary tetrahedrite such as occurs in this deposit is also never found except in deposits where igneous rocks are nearby to furnish hot solutions for its formation. The association of a number of minerals, all of which may be formed by hot ascending solutions, with primary tetrahedrite and sericite, which are practically always formed by hot solutions only, proves that the ore-bodies were formed by hot ascending solutions. Since sericite occurs with the Carmi ores also, which at the time of deposition were at least 1,000 feet farther from the surface than some of the Wallace ores, we may say that they were formed by the same agency; and the same reasoning applies to the sericite-bearing ore-bodies on Arlington mountain.

Temperature and Pressure of the Solutions. Some idea of the conditions of temperature and pressure which obtained during the formations of the minerals may be gained from the association of minerals in the lodes, and also from the probable depth of tne ores from the surface at the time of their formation. And here there is a marked difference between the ore-bodies on

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[1] Emmons, W. H., "The enrichment of sulphide ores," Bull. U.S.G.S., No. 529, pp. 152-153.

Wallace mountain and those at Carmi; the latter were formed at decidedly greater depth and, therefore, under higher temperatures and pressures. The presence of tetrahedrite as a primary constituent in the Wallace Mountain ores indicates that they were formed at moderate or shallow depths (see the table on page 75). Tetrahedrite has, however, in rare instances been found at great depths. Barite also, although occasionally found in deep veins, is more commonly formed at shallow depths. Pyrargyrite, which was found at the Rob Roy tunnel intergrown with perfectly fresh galena and pyrite, is apparently there a primary mineral and as such has never been found in the deep vein zone. The presence of these minerals points to the formation of the ores at moderate or shallow depths. The other minerals present in the ore-bodies teach us nothing, for most of them may be formed at all depths from the surface. Epidote is formed in the deep vein zone or near igneous contacts only, but epidote is not a part of these deposits, for it is formed in almost any portion of the quartz diorite batholith, and quite probably before the ores. From the minerals present there we may, therefore, infer that the ores on Wallace mountain were formed at moderate or shallow depths.

At Carmi the mineral associations are somewhat different; tetrahedrite, pyrargyrite, and barite are missing; chalcopyrite and molybdenite are present at Carmi but not on Wallace mountain, and galena, the principal ore mineral on Wallace mountain, is present in small amount only. None of the minerals in the deposit at Carmi unmistakably indicate that the formations were formed at shallow or moderate depths; on the other hand, all the minerals present may have been formed either at great or moderate depths. The absence of minerals deposited at shallow depth in the Carmi ores and their presence in the nearby Wallace mountain ores, which have apparently been formed under the same geological and structural conditions, indicates that the Carmi ores were deposited at greater depth from the surface. This supposition is proved by their relative topographic position.

A detailed study[1] of the topography of this district has shown that in early Pliocene times this region was a rolling,

[1] Bulletin No. 11, Geol. Surv., Can.

hilly country with comparatively gentle slopes, and that a broad valley with gently sloping sides existed where the Westkettle is to-day; moreover, areas like the top of Wallace mountain and other places back of the deep valleys have been comparatively unchanged since then, and exist to-day as an upland representing the remnants of the old land surface. The deep trough of the Westkettle has been dug out since late Pliocene times, and one can, by projecting the upland surface to meet the trough, see that at Carmi it has been deepened at least 700 feet. Now the ores on Wallace mountain crop out on the old upland surface and, therefore, Carmi ores were in early Pliocene times at least 700 feet deeper than those on Wallace mountain. The ores were formed in late Eocene or early Oligocene times, however (pages 111, 112) and we know less regarding topographic conditions in those times. It is certain that the ore-bodies both on Wallace mountain and at Carmi were much more deeply buried then than in the Pliocene, and the marked difference in the mineralogy of the ores at the two localities indicates that the present site of Carmi was very much farther from the surface than the present top of Wallace mountain. The actual difference in depth was probably comparable to their present difference in elevation, namely: between 1,300 and 2,000 feet.

The floor of the Curry Creek series of Oligocene age, which outcrops to the east of the Wallace Mountain ores (Figure 1) probably represents the surface of the land at the time the ores were formed. Unfortunately, folding has warped this floor and faults have displaced blocks of the conglomerates and of all the other rocks to a very large extent, and hence measurements of the depth of the ore at deposition cannot be made. The amount of downthrow of the conglomerates is in one case at least 500 feet, and may be much greater. Part of the old floor near Curry creek is to-day at least 600 feet below the ore-body at the Buster shaft on Wallace mountain. The conglomerates directly east of the Buster lie about 350 feet above it, and the topography there indicates that faulting has not been very intense. If a throw of about 1,000 feet has accompanied faulting at this point the ores on Wallace mountain were formed at about 1,400 feet beneath the old surface. The ores at Carmi were at least

700 and probably 1,000 feet deeper. Lindgren's[1] description of the mineralogy and form of ore-bodies which have originated at intermediate depths fits the ore-bodies on Wallace mountain and Carmi very closely. Lindgren, however, states that such deposits are formed from 4,000 to 12,000 feet from the surface. If that were the case on Wallace mountain, we must either assume that a long erosion interval existed between the formation of the ores and the deposition of the Oligocene conglomerates, which is not likely, as will be shown in the discussion of the age of the ores; or that faulting must have displaced the floor, on which the conglomerates lie, about 5,000 feet, a supposition for which there is no foundation. The ores on Wallace mountain although characteristic of the intermediate zone must be assumed to have formed at a depth much less than 4,000 feet, probably less than 2,000 feet. Lindgren suggests temperatures of from 175 degrees to 300 degrees Centigrade, and pressures of from 140 to 400 atmospheres for ore-bodies formed at intermediate depths. These high temperatures and pressures at such shallow depths may be accounted for by supposing that the Wallace series formerly overlay the silver-bearing, quartz diorite shear zones and that by preventing the upward escape of the hot, rising solutions, caused an abnormal increase of pressure and heat in the shear zones.

Process of Deposition.

The chemical changes involved in the deposition of the ores were probably large additions of potash and silica, and the loss of calcium and sodium. This is indicated by the alteration of the labradorite feldspar in the country rock to sericite, and further not only by partial replacement of breccia pebbles by quartz, but also by the large quantity of quartz which exists as cavity filling in the shear zones. Sulphur and the metallic metals have been added in lesser amounts.

Cavity Filling and Replacement. The process of deposition was apparently partly a simple filling of cavities; but this was accompanied by a replacement of fragments of the country rock.

[1] Lindgren, Waldemar, "Mineral deposits," pp. 513-515.

Banded veins, often showing comb structure (Plate VII) and druses or cavities left unfilled in the veins, are the proofs of cavity filling. The evidences of replacement are best seen in thin section. In a section from the Sally No. 1 tunnel narrow, needle-shaped blades of sericite were seen to replace not only the primary feldspar but also the quartz. The needle-shaped sericites extend from one mineral of the original rock into the other, without the slightest change in the outside faces of the sericite blades. The clean cut way in which the sericite blades "pierced" the primary quartz without a sign of a break in either side of them, was especially noticeable. Perfectly formed crystals of pyrite were seen cutting across feldspar, quartz, and biotite in fragments of the quartz diorite. The sides of the pyrite crystals were perfectly straight, and cut from one replaced mineral to another without deviation. The pyrite was in this case secondary, for it occurred close by in large quantity as a vein filling, while it was absent from the country rock at a short distance away from the shear zones. In other places crystals of pyrite were seen to cut across blades of sericite and well crystallized individuals of vein quartz; it was, therefore, also replacing sericite and quartz.

Quartz is probably also partly a replacement product; it was seen in hand specimens forming irregular areas with wavy boundaries in the altered country rock, but proof of metasomatic replacement is not so evident in thin sections. No cases of replacement of the country rock by galena, sphalerite, or tetrahedrite were recognized in thin sections nor in the hand specimens. Since, therefore, sericite, quartz, and pyrite were in a great many cases the first minerals to form it is possible that the solutions at the time of their deposition were under greater pressure and higher temperature than when the later minerals were formed and that metasomatic replacement took place, which was not possible later.

Replacement appears to be confined nearly entirely to the shear zones, for although sericitization extends beyond them, the rock in the walls is decidedly more fresh than the brecciated fragments between them, and replacement by pyrite is not known to have taken place far from the shear zones. Detailed studies may prove that this statement is not entirely correct, but the impression that was gathered from examining nearly all the shear zones on Wallace mountain was that there is a sharp line of division between rather intensely altered rock fragments in the shear zones and comparatively fresh rock in the walls.

Influence of the Country Rock. The effect of the country rock on the ores has already been described. The different facies of quartz diorite do not appear to have caused any variation in the character of the ores, and if they exerted any chemical influence upon the deposition of the sulphides it is not very apparent. The formation of the ore-bodies in quartz diorite and not in the Wallace group must be ascribed rather to the different way in which the rock bodies sheared than to differences in their chemical character. The shearing which affected the quartz diorite batholith must also have affected the older Wallace series; but while well marked shear zones with clean cut walls formed in the quartz diorite these zones upon entering the Wallace group resulted in masses of broken rock with indefinite boundaries. The more distinct shear zones in the quartz diorite formed easy and effective passages for the ore-bearing solutions, and the greater part of the ore was deposited as cavity fillings within them. The indefinite shear zones in the Wallace group overlying the quartz diorite, seem to have stopped the ascending solutions, and the valuable ore minerals, which appear to have formed rather by fissure filling than replacement, are not present in that series to any great extent. This seems to be proven where a shear zone was actually traced from quartz diorite into the Wallace group, as in the case of the shear zone on the Buster claim. These considerations make it seem probable that the upper limit of the larger ore-bodies was the original roof of the quartz diorite batholith; that is, its upper contact with the Wallace group which has now been largely eroded away. This probably holds true for that part of the roof which originally lay over Wallace mountain.

Whether the reasons given here for the presence of the ore in quartz diorite rather than in the Wallace group are correct or not, the fact remains that the ores are almost exclusively in the quartz diorite batholith. In prospecting for galena ores, therefore, areas underlain by quartz diorite should be examined before and more carefully than those underlain by other types of rock, and when shear zones of the type seen on Wallace mountain are discovered they should be carefully examined for signs of ore.

Variations of the Ore in Depth. The variations of ores in a vertical direction on any shear zone is a matter of great practical importance, and since it is largely governed by the manner or process of ore deposition it may be further discussed here. Unfortunately, no mines on Wallace mountain have uncovered any one ore-body over a vertical range of more than 200 feet; it is, therefore, necessary to compare shear zones which outcrop at different levels, and draw conclusions from them. We propose to show that the deeper and still uncovered parts of the silver-bearing shear zones on Wallace mountain resemble the gold-bearing ores at Carmi.

It has been shown that the Carmi ores, which occur in the same types of east-west shear zones as those on Wallace mountain, and were formed at a greater depth from the surface, probably from 700 to 2,000 feet farther down, are made up of a different group of minerals. Although the ore-bodies at both places carry a great deal of quartz and sericite, the ores on Wallace mountain are typically silver-bearing and carry large quantities of galena, sphalerite, and pyrite, with subordinate tetrahedrite, pyrargyrite, and native silver; the ores at Carmi carry gold, with a very little silver, and the sulphides sphalerite, pyrite, chalcopyrite, with a little molybdenite and very little galena. Chalcopyrite is very rare, and molybdenite is absent from the Wallace Mountain deposits; tetrahedrite and pyrargyrite from those at Carmi. Since chalcopyrite and molybdenite are often found in deep veins, tetrahedrite very seldom, and pyrargyrite never, and since the ores at Carmi were formed under the same geological and structural conditions as those on Wallace mountain, it is believed that the Carmi ores represent the deeper parts of ore-bodies whose upper parts have been eroded away; or in other words, that the deeper parts of the shear zones on Wallace mountain carry ores which resemble those at Carmi. Sericite, quartz, and pyrite were the first minerals to form in the deposits on Wallace mountain, and they are common to the ores both localities. The fact that they formed first proves that they were capable of crystallizing with more ease from the solutions than the galena, tetrahedrite, etc. They could, therefore, be precipitated under fairly high temperatures and pressures in the lower parts of the shear zones, while the other minerals did not crystallize until they reached the higher portions of the veins or shear zones where temperatures and pressures were lower. This accounts for the difference in mineralogical makeup between the Carmi and Wallace Mountain ores.

The exact depth at which the change from the silver-lead ores to the gold-bearing pyrite ores would take place is, of course, hard to estimate. The change will in all probability be a gradual one, and it may take place at considerable depth. Judging from the difference in elevation between the Carmi mine and the Sally on Wallace mountain, the change should come within 1,300 feet below the level of the Sally, but it may, and probably does, take place much nearer the surface.

Processes of Secondary Deposition.

It has been established, chiefly through a consideration of the mineralogical associations in the ores, that the metallic sulphides were deposited by hot ascending solutions. We come now to a class of minerals that were deposited later than the sulphides and that were formed largely by the action of cold surface waters. Calcite and native silver and soft clayey material, which is probably largely kaolin and chlorite, often appear in the cross faults which offset the ore-bodies, and veinlets of calcite and chlorite are found cutting across the ore-bodies. Calcite, chlorite, and iron oxide were seen in veinlets in the sericitized country rock, and the rock immediately next to these veinlets seems to have been subjected to further alteration of a type different from the original sericitization and silicification. In one instance where chlorite and calcite appeared in the same vein with pyrite and quartz they were formed after the quartz and pyrite. The occurrence of calcite, chlorite, kaolin, and native silver in the cross faults proves that they are of later origin than the ores. They were in all probability formed by cold surface waters. Pyrargyrite may in some instances have been deposited by cold descending waters, but evidence on this point is not clear. Since quartz is sometimes found deposited upon a coating of iron oxide in the veins it is quite probable that some of the quartz has been deposited by surface waters.

Secondary alteration and deposition are suggested by the shape of the stopes as illustrated in Figure 4 (see also page 101), but no independent evidence is available to support this suggestion.

Shallowness of the Zone of Secondary Deposition. Except in the fault planes secondary alteration by surface waters is seldom seen more than a few feet from the surface and one may find fresh ore sulphides in places right at the surface. The shallowness of the zone of oxidation or weathering is interesting, for it holds not only for the ore deposits, but for the rocks themselves and is wide-spread phenomenon in southern British Columbia. One finds, for instance, that except where they are badly brecciated the rocks are not very deeply weathered; and if a block of rock be broken from an outcrop at the surface it will be coated with a thin weathered film on the surface and along the joint planes, but this film will seldom be more than an inch or a few inches thick, and inside the rock will be fresh and unaltered. Residual soil, that is, rotten rock which has formed in place by weathering, is absent or very sparingly developed in this district.

Since this phenomenon is very wide-spread and is true of a great many different rock types, it cannot be ascribed to the density, or any other characteristic, of the rocks themselves; nor can it be ascribed to the topography of the district, for it is common to regions in which the topographic forms are very different. The wide-spread action of the glaciers which covered all except the highest peaks in British Columbia in recent geological time does, however, furnish an explanation which appears to fit the facts. There is evidence to prove that glaciers cut out the rock basins now occupied by lakes on the uplands and remoulded the beds of the deeper valleys. It is, therefore, reasonable to suppose that the moving glaciers which were powerful enough to cut out basins in the solid rock would remove any partly disintegrated material overlying the rock, with comparative ease. The lack of weathered material overlying the ores is, therefore, ascribed to recent glacial action and the small amount of altered material which is found is believed to have formed largely since glacial times. The period which has elapsed since glacial times is comparatively short, if figured in the geological time scale, and the amount of alteration which has taken place in that period is, therefore, also comparatively small.

Source of the Metals and Age of the Deposits.

It has been shown that the deposits on Wallace mountain were formed by hot ascending solutions; it is believed that these solutions were magmatic waters derived from the stock of quartz monzonite which outcrops at Beaverdell, nearby, and west of the ore deposits. The reasons for ascribing the ores to this intrusion are its position in respect to the ore-bodies, and the relative age of the ores. The mines which have produced most of the ore on Wallace mountain lie directly over the body of quartz monzonite and it is likely that the other ores on Wallace mountain are underlain by it, for it outcrops again to the southeast, south, and southwest of them, and not far away. No outcrop of quartz monzonite was found near the ore-bodies at Carmi, but a body of quartz monzonite lies close to the smaller occurrences on Arlington mountain, which resemble those at Carmi mineralogically.

The shear zones in which the ores are found have never been seen either in the quartz monzonite body at Beaverdell or in other quartz monzonite bodies in the map-area, notwithstanding the fact that such shear zones were looked for in them; moreover, ore of the type discussed here is, so far as we know, absent from that rock body. The shear zones were, therefore, formed after the intrusion of the Westkettle quartz diorite and before or during that of the Beaverdell quartz monzonite; that is, between the Jurassic and the Eocene. It is possible that they were formed during the Post Laramie revolution, at the end of the Cretaceous. The ores were, however, formed just after the intrusion of quartz monzonite, for they occur after intense sericitization in the shear zones, an alteration which has affected the quartz monzonite to a very slight extent, if at all. The ore is found, moreover, in dykes which follow along the shear zones and which are, therefore, very probably satellites of the quartz monzonite intruded before the main mass came to place, see page 89. In addition to this evidence we find that aplite dykes, which are undoubtedly offshoots of the quartz monzonite, occur near the ore-bodies and have been partly but not completely sericitized, proving that the ore came after their intrusion. It has been proven, moreover, that north-south faulting of the type which has offset the ores began not later than the end of the Oligocene and the ores must, therefore, have been formed either in the Eocene or Oligocene. The only large intrusive which came to place within that time was the Beaverdell quartz monzonite, and since the metamorphism it induced in the older rocks was very marked, and since the latter are generally more intensely sericitized than the quartz monzonite, which is practically unaffected by sericitization, we may safely assume that sericitization and, therefore, ore deposition was caused by magmatic waters emanating from the quartz monzonite shortly after it had been intruded and had cooled.

To sum up: the ore-bodies in the shear zones on Wallace mountain, at Carmi, and on Arlington mountain were formed by ascending solutions of hot waters and at depths of probably not over 2,000 feet on Wallace mountain, and 1,000 feet farther from the surface at Carmi. Their mineralogical make-up and mode of occurrence, however, resemble that of deposits formed at much greater depths, 4,000 to 12,000 feet. This anomaly is ascribed to the influence of the Wallace group which probably overlay the quartz diorite at the time the ores were formed, and because the clean cut shear zones in the quartz diorite died out in the Wallace, that rock series acted as a tight blanket which prevented the hot solutions from rising to the surface and increased their pressures and temperatures very greatly. The temperature and pressure at which they were formed probably compares with that of ores formed at depths of from

4,000 to 12,000 feet; that is, temperatures of from 175 degrees to 300 degrees Centigrade, and pressures of from 140 to 400 atmospheres. The process of deposition appears to have involved the addition of a great deal of potassium and silica to the rock, and of lesser amounts of the metals, and of sulphur. The country rock had apparently no chemical effect upon ore deposition, but the quartz diorite, by permitting the formation of distinct fissures, enabled large and continuous ore-bodies to form within itself. In the Wallace group on the other hand, circulation was retarded by the irregular shattering of the rocks, and no large ore-bodies are found.

The ores have been formed partly by replacement, more largely by cavity filling. Replacement has been confined to a large degree to fragments of broken quartz diorite within the shear zones, and sericite, quartz, and to a lesser degree pyrite, have replaced the rock much more actively than the other minerals which seem to have been formed nearly entirely as cavity fillings. The hot metal-bearing solutions were derived from the magma of Beaverdell quartz monzonite. The chronological sequence of intrusion and ore formation is approximately as follows:

(1.) The formation of east-west shear zones in the Westkettle quartz diorite;

(2.) The intrusion of the Beaverdell quartz monzonite preceded by the intrusion of d[illegible]ndesite, and accompanied by intrusions of aplite dykes;

(3.) The formation of sericite in the shear zones during the intrusion of the quartz monzonite;

(4.) The formation of quartz and pyrite, and the other metallic sulphides;

(5.) Faulting and offsetting of the ores;

(6.) The formation of native silver, iron oxide, chlorite, calcite, and kaolin.

DEVELOPMENT AND MINING.

The work done upon the various ore-bodies on Wallace mountain consisted in 1911 of open-cuts and a few shallow shafts, and tunnels. From the shafts drifts were run along the shear zones and the ore above the drifts stoped out. In a few cases the ore was taken out by underhand stoping. The amount of development work is very small and in no case have the workings reached a depth of more than 200 feet. The details of the development in each case may be obtained in the descriptions of mines which follow. The plan has been to follow the ore-bodies as closely as possible and to mine all the ore in sight. The process is known as "gophering" and was probably justified in view of the pockety nature of the ores, and the lack of sufficient capital for development work. Drilling was done by hand, the broken ore transported to the mouths of the tunnels by hand-cars or wheelbarrows, and out of the shafts by bucket and windlass. It was hand sorted on the surface and rich ore, that is, ore running over $90 to the ton, shipped by rawhide trail to the nearest wagon road, and from there by wagon or sleigh to Midway. Wagon roads are built up to the principal producing mines. The low grade ore was stored in open bins near the mine openings.

At the Carmi a steam hoisting plant and Cameron pump were installed in 1901, and a ten stamp mill erected in 1904. Some low grade ore was treated in this mill by amalgam plates and the cyanide process. The sheds which covered the equipment at the Carmi were in poor repair in 1911 and the equipment was consequently exposed and in danger of being ruined.

Production.

The total value of the ores shipped from the district at the end of the year 1911 was about $100,000. Nearly $99,000 worth was sent from the mines on Wallace mountain between 1900 and 1909, and between $1,000 and $2,000 worth from the low grade ores at Carmi in 1901.

FUTURE POSSIBILITIES.

Small bodies of rich ore have been found on Wallace mountain, and there is reason to believe that there are other ore-bodies of the same kind which have not been discovered. The problem of finding these bodies is a difficult one because of the faulting and displacement which the shear zones have undergone, and the cost of exploratory work is apt to be greater than the profits derived from the ores. If mining on a large scale is to be carried on exploration by diamond drilling may prove economical, but in drilling from the surface blocks of ore with steep dips are apt to be missed.

The continuation and character of the ores in depth is best proven by exploration or actual mining. The length of outcrop of the shear zones on Wallace mountain, however, indicates that they may continue for several hundred and even a thousand feet in depth. It is probable that in the deeper part of such shear zones the silver-lead ores found upon the mountain change in character to the low grade gold ores as seen at Carmi (see page 108).

If the question of exploration for displaced ore-bodies can be satisfactorily solved there should be no insurmountable difficulties in the actual mining of the ores. Timber is plentiful and the rough topography should permit of adequate drainage of the mines and economical extraction by tunnelling. The problem of transportation is solved by the presence of the Kettle Valley railway in the Westkettle valley. The Westkettle valley is from 1,500 to 2,000 feet below and 1 to perhaps 3 miles in a horizontal distance, from the silver mines on Wallace mountain.

The mine at Carmi is a low grade property, but the length of outcrop of the shear zone in which its ores lie indicates that the shear zone may continue to a depth of 1,000 feet or more. Whether the ore continues to that depth is, of course, another question. It is also possible that exploration by diamond drilling may prove successful at this mine. The Kettle Valley railway crosses over this property within a few hundred feet of the shaft.

DETAILED DESCRIPTION OF MINES.

Introduction.

The description of the mines and prospects in this district applies to conditions which obtained up to the end of the year 1911. Further work has been done on some of the claims since then and the records of development and production are, therefore, not complete in every case. Many mines also were abandoned when the field work was done, and as the shafts were then filled with water no examination of their underground workings could be made. Records of assays of abandoned prospects are difficult to get, and in this work no special attempt was made to secure complete records of production of any but one or two of the larger mines.

The mines on Wallace mountain are described together here; they are followed by a description of the Carmi mine, of two claims on Arlington mountain, and of the Butcher Boy; other prospects in the district are described after the general description of the stocks and contact metamorphic deposits.

Sally Group.

Location. The Sally group of mines comprises eleven claims upon the eastern face of Wallace mountain. The principal ore-bodies have been found upon the Sally and Rob Roy claims. The property was operated until the beginning of the year 1910 by the Vancouver and Boundary Creek Development and Mining Company, Limited, and most of the actual mining was done under the supervision of Mr. Robert Wood of Greenwood.

History and Production. The first claims in this group were probably staked between 1896 and 1900, and from that year until February 1910 mining work was more or less continuously done on the veins of these properties. The mines were shut down in 1910 and had not re-opened in the autumn of 1911. About 644 tons of ore were shipped from the Sally group, presumably all to the smelter at Trail. The gross value of the ore shipped was $71,818.56, or an average of about $111 to the ton; the charges for railway freight and smelting were $8,887.09, and the net returns $62,933.47. Besides the ore shipped there is something over 2,000 tons of second-class ore separately stacked outside the Sally and Rob Roy tunnels. Some of this is shown within the cribbing in Plate I. This ore is thought to average about $25 to the ton.

Development and Mining Methods. The ore-bodies on this property have been explored by drifts run along the veins

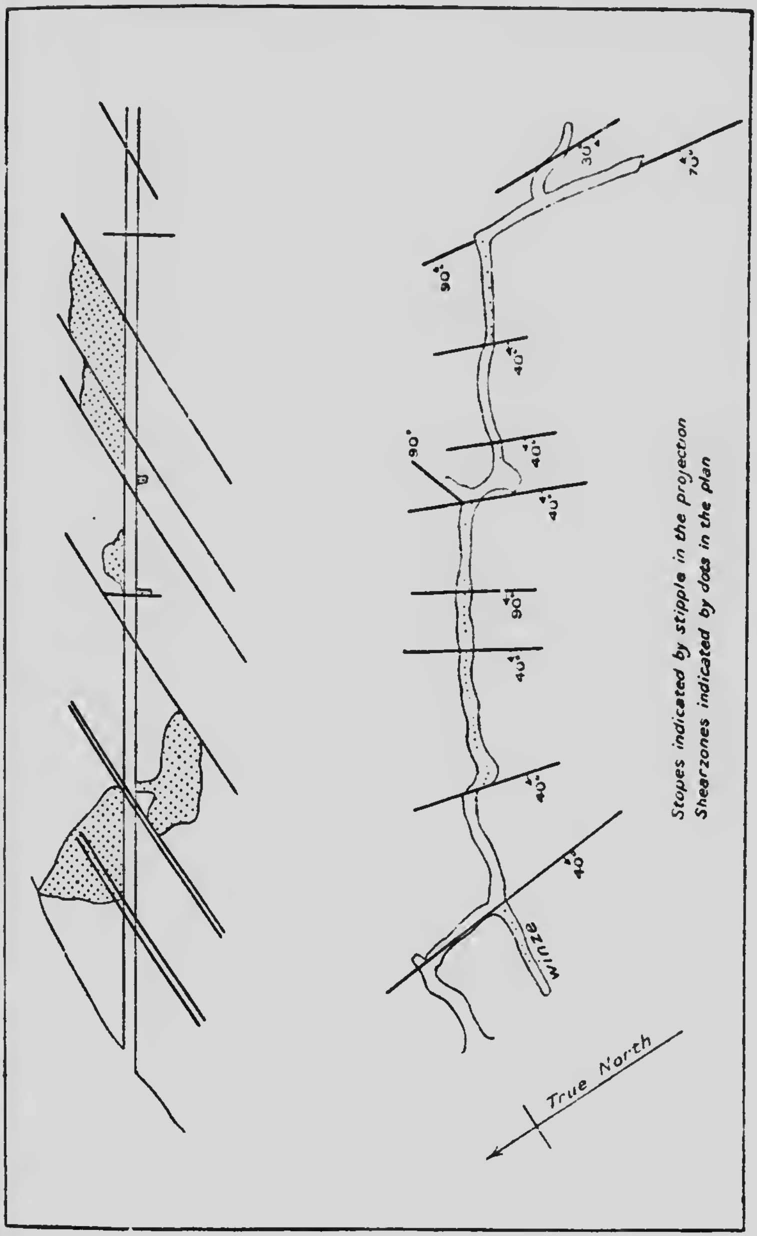

Fig. 5. Vertical projection and plan of the Rob Roy No 7 Tunnel

Scale of Feet

100 50 0 100

Based on a compass-and-pace survey by G.M Turnbull.

and by cross-cuts along the fault planes cutting the veins. They have also been prospected by a number of open-cuts, and by a shaft in one instance. The frequency with which the veins are displaced by fault planes has given these drifts a correspondingly crooked course (Figures 4, 5, and 6). The largest amount of development and mining has been done upon the Sally No. 1 and the Rob Roy Nos. 6 and 7 tunnels. The ore has been mined by overhead stoping from the tunnel levels and occasionally by winzes and small underhand stopes. The total amount of tunnelling on these properties is said to have been about 2,000 feet. Practically no ore was seen in the backs of the overhead stopes in the Sally No. 1 tunnel, but some ore was evidently left in the Rob Roy tunnels.

The ore was conveyed on small trams operated by hand to the mouth of the tunnel, where it was hand sorted and shipped by sleighs and wagons to Midway 48 miles away; from there it was transported by rail to the smelter. As long as the ore had to be shipped to Midway, freight and smelter charges amounted to the large total of about $30 to the ton; the cartage to Midway alone being about $16 per ton. This has prevented the shipping of any but very rich ore, averaging about $100 to the ton, from these or any other mines in the district. The only case in which low grade ore was shipped from the district proved, according to local report, a financial failure.

A large, well constructed bunk house and some outhouses, as well as ore sheds, have been constructed on the Sally and Rob Roy claims (Plate I, Frontispiece).

Geological Relations. The ores occur in shear zones in rather acid quartz diorite. The shear zones dip in general about 60 degrees to the south on the Sally and Wellington claims, and generally to the south on the Rob Roy. Ore has been shipped from three veins, the Rob Roy Nos. 6 and 7, and the Sally No. 1. The shaft on the Wellington claim is possibly on the same vein as the Sally No. 1 tunnel. The shear zones are displaced by numerous faults striking from north to northeast and dipping west. The relation of the faults to each other, and the character and amount of displacement they have caused are described in the general discussion of the geological relations of the ores on Wallace mountain, pages 95 to 100. An idea of the character may be obtained from Figures 1, 2, 3, 4, and 5.

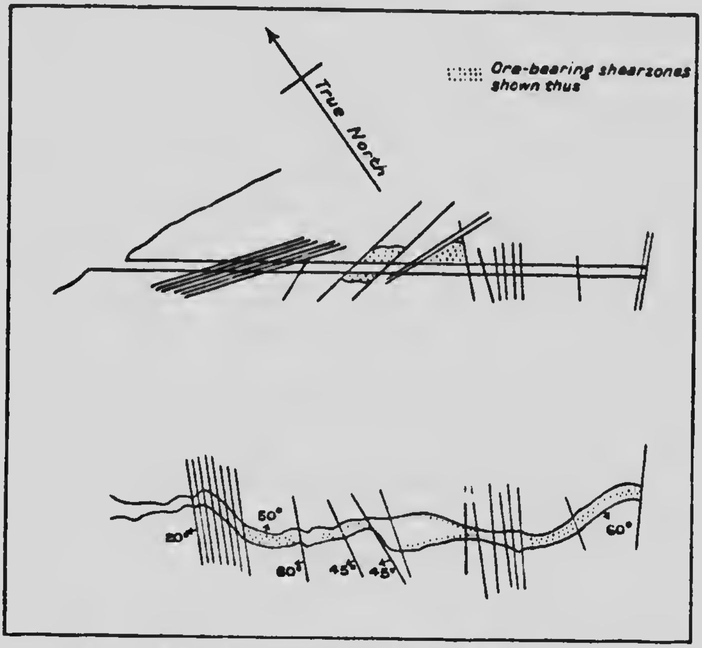

Fig. 6. Vertical projection and plan of the Rob Roy No. 6 tunnel

Character of the Ores. The ores in the Sally and Rob Roy tunnels consist of galena, pyrite, sphalerite, tetrahedrite, and pyrargyrite in a gangue of sericite, quartz, and altered rock. Native silver is found near the fault planes and occurs in a gangue of chlorite, kaolin, calcite, altered rock, and iron oxide. The ore at the Wellington shaft several hundred feet below these tunnels contains more sphalerite and much less galena. Very little was learned about variations of the ore-bodies, either laterally or vertically, except that they are reported to vary greatly in value from place to place. The oxidized zone where it exists is very thin, probably a few feet thick, but surface alteration has penetrated to greater distances along fault planes and has probably caused the formation of native silver. Pyrargyrite may in certain cases be a product of secondary sulphide enrichment, but if such a process obtained here it was not a very general one.

Commercial Possibilities. The success of mining here and elsewhere upon Wallace mountain will depend largely upon an understanding of the systems of faulting which have offset the ore-bodies, for the cost of exploring for displaced ore-bodies is apt to be very great. Rich ore has been taken out of the tunnels on the Rob Roy and Sally claims, and there are probably other ore-bodies of the same type which have not yet been discovered. If exploratory work should uncover enough of these blocks of ore there should be no great difficulty in the actual mining of them. Timber is plentiful and the steep topography, with the outcrops of the shear zones running down hill, should permit of driving adits along the shear zones and ensuring good drainage as well as economical extraction. Transportation of the ore to the railway near Beaverdell should present no great difficulties. The question of the continuation of the ores in depth is discussed on page 108.

Rambler Claim.

The Rambler claim lies on the southern slope of Wallace mountain south of the upper part of Dry creek (Figure 1). The claim has been worked for a number of years by Mr. W. H. Rambo, who is a part owner; it is mentioned in the report of the provincial mineralogist in 1901, and is said to have had ore ready for shipment at the time.[1]

About 75 tons of ore have been shipped from the Rambler, with a gross value of between $9,000 and $10,000. The workings consist of two shafts, one of them 35 feet and the other about 95 feet deep, a cross tunnel about 240 feet long, and about 100

[1] Robertson, W. F., Annual Report of the Minister of Mines of British Columbia for the year 1901, pp. 1058 and 1144, Victoria, B.C., 1902.

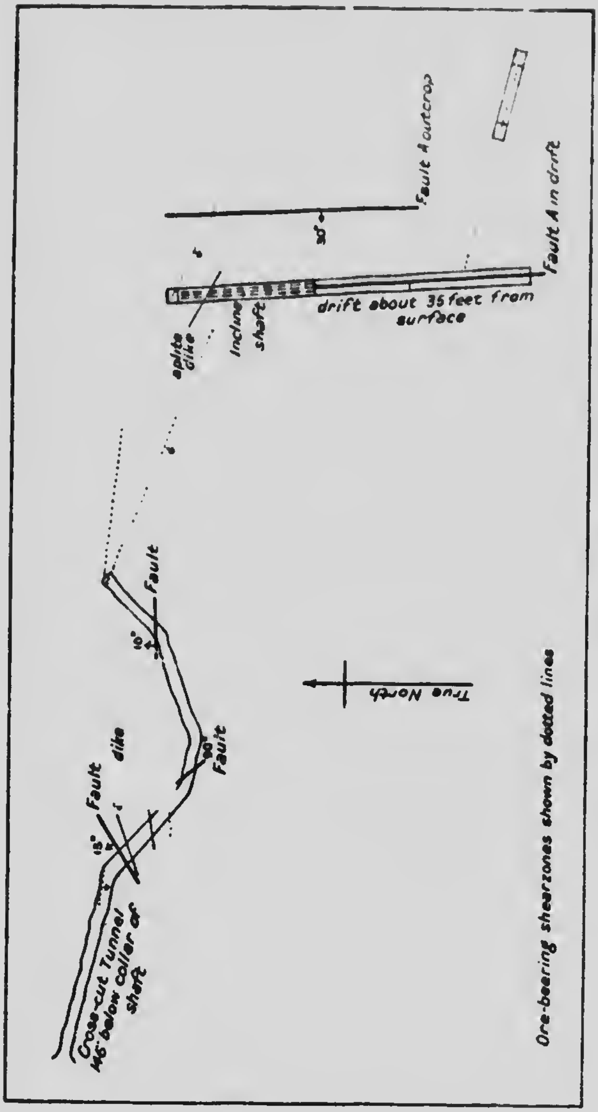

Fig. 7. Plan of workings on the Rambler claim

feet of drifts. An excellent cabin, two shafts, and a stable are on this claim (Plate VIII). The ore occurs in two veins with nearly vertical dip, which are offset by several faults (Figure 7). It is possible that the two main veins were originally one and were displaced by the strong fault A, striking in a northerly direction as shown on Figure 7. The country rock is the usual quartz diorite accompanied by aplite dykes. The fault is marked on the surface by a little escarpment which is shown beyond the cabin on Plate VIII. The ore was obtained from the westerly shaft whose shaft house is shown in the plate. The chute from which it was taken extended from near the surface down for about 65 feet, and the ore was taken from a triangular area in the vein lying between the southerly inclined shaft and the westerly dipping fault plane. The upper side of the chute was perhaps 40 feet wide. More ore with high silver content occurs across the fault plane from this chute and immediately at the surface.

This is a promising claim.

Duncan and Bounty Fraction Claims.

The Duncan and Bounty Fraction claims lie on the north side of Dry creek between the Sally mines and the Rambler; they were acquired by the Wallace Mountain Mining Company in 1904. The property was shut down in 1911. The greater part of the development on this claim has been done by that company. In 1909 the property was managed by Mr. Tom Henderson, and according to him 160 tons of ore had then been shipped from the two claims, with a gross value of from $15,000 to $16,000. Some second-class ore has also been produced.

Five small shafts were seen on the Duncan and Bounty Fraction claims, the deepest of them 100 feet. Two of them were filled with water. The dry workings are situated together on the upper northern edge of Dry Creek canyon. About 340 feet of drifting, and some stoping, had been done in these workings and a total of 600 feet is said to have been done on the property. The drifts are extremely irregular in plan and profile and here, as in a good many of the other small mines on the mountain, the plan has been to follow the ore as closely as possible. Two cabins, and a shaft house in good repair are built on the claims.

Geological Relations. All but one of the shafts seen lie in a more or less east-west direction from each other, and it is probable that they are on the same vein, but cross faulting has offset this vein repeatedly (Figure 8) and the ore-bodies are as usual limited by fault planes. Veins or shear zones are from 1

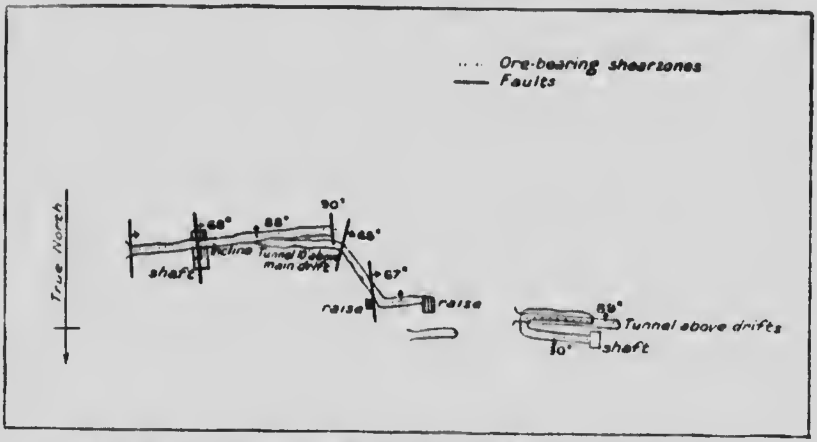

Fig 8 Main workings on the Duncan and Bounty Fraction claims

Scale of Feet

50 25 0 100

to 4 feet wide; they sometimes branch into two, and in one case two parallel veins lie within 16 feet of each other. Their position may, however, have been brought about by cross faulting. Their dips are nearly vertical on the eastern side of the property, and in one case 60 degrees to the north. A plan of the main workings is shown in Figure 8, which also shows the position of the veins and faults. Some faulting has occurred near the shaft lying a few hundred feet north of the main workings, and near the one which is about 800 feet west of them. The main shear zone on this property is nearly in line with one about 2,000 feet to the west, on top of the ridge overlooking Beaverdell, and they may be parts of the same original shear zone. If that is the case veins on this property may continue in depth to nearly 2,000 feet. From a commercial point of view not much dependence can be placed on such a possibility, for it is based on the unproved assumption that the veins on the two ridges are the same, and, moreover, the intense faulting which has taken place through this mountain makes all underground conditions more than usually uncertain.

Bell Claim.

The Bell claim is situated to the northwest of the Rob Roy. Ore is said to have been shipped from it in the spring of 1909. It was abandoned in 1910 and 1911. The workings seen were three shafts, two filled with water, several prospects, and a cross-cut tunnel about 390 feet long. Whether further work was done from the shatts is not known. There are two cabins on the property. A mineralized shear zone was seen in only one place in the cross-cut, but several outcrops of ore-bearing zones were seen on the surface. The relations of the shear zones and the larger faults are shown in Figure 1.

Buster Claim.

The Buster claim lies to the east of the Rambler. It is said to have been located about 1899, and was acquired by the Alaska Mining Company in 1909, which issued 250,000 shares of stock. Some development was done on this property in 1909 and 1910. The workings consist of an incline shaft and a number of prospects on an east-west lead. There is a very excellent cabin, and also a stable on this property. The lead extends from quartz diorite at the shaft to the Wallace series several hundred feet east of the shaft. It is about 1 to 4 feet wide in the quartz diorite, dips about 60 degrees to the south, and strikes about 10 degrees north of west; in the Wallace it has apparently become a rather indefinite zone of shattered rock. The ore is of the usual Wallace Mountain type, and contains tetrahedrite intergrown with galena and sphalerite, and also pyrite and native silver in the usual quartz-sericite gangue. Six tons, averaging over $90 a ton, had been taken out in 1909. More ore was sacked and ready for shipment in 1910.

Standard Claim.

The Standard claim lies on Dry creek north of the Buster. The Standard had been operated for a number of years by Mr. Patrick Kennedy of Beaverdell. Three inclined shafts were seen on the property; how much drifting has been done was not ascertained. A good cabin is situated near one of the shafts. Ore is said to have been ready for shipment from this claim in 1903. The country rock is a rather fine-grained quartz diorite.

Bounty Claim.

The Bounty claim lies to the east of the Bounty Fraction. The claim was not being worked at the time of our visit; it had been located at least 10 years before. The workings consist of a tunnel about 100 feet long, from the end of which there is a 90-foot inclined raise to the surface. Ore occurs in a narrow vein near the foot of the shaft, and again in the tunnel. It has been displaced by three faults (Figure 1). The country rock is a rather fine-grained quartz diorite.

Wabash Claim.

The Wabash claim lies north of the Bounty. The workings consist of several prospect holes and a shaft. The shaft is said to be 25 feet deep and to have a 60-foot drift at its bottom. It was filled with water to within 15 feet of the surface in the autumn of 1911. Ore is said to have come from the end of the shaft. Galena and pyrite ore were in one of the prospects northwest of the shaft; another vein carried chalcopyrite and pyrite.

Kokomo Claim.

The Kokomo lies north of the Wabash (Figure 1). Mr. George Barrett of Beaverdell is part owner of this claim. According to Mr. Barrett the shaft on the claim is 80 feet deep and 75 feet of drifting has been done from it. Two branching veins striking south of east and dipping steeply to the southwest are cut by two parallel northeast trending faults, and offset as shown in Figure 1.

Gold Drop Claim.

The Gold Drop claim lies to the south of the Buster and not far south of the southern border of the map-area. The workings consist of a tunnel 37 feet long, a shaft perhaps 50 feet deep 400 feet from the tunnel, and several open-cuts. The mouth of the tunnel is about 130 feet below the collar of the shaft. The shaft, tunnel, and one of the open-cuts lie on an east-west shear zone which dips at a little less than 90 degrees to the south. The ore occurs in rather acid quartz diorite, in places in an aplite or quartz porphyry which is intruded into the east-west shear zone. It shows fine banded texture (Plate VII) and consists of the usual Wallace mountain ore minerals in a gangue of quartz, barite, and chlorite. This is the only place where barite was seen on Wallace mountain in the course of this work.

Homestake Claim.

The Homestake claim lies to the west of north of the Sally group (Figure 1). A good deal of tunnelling has been done on this claim, and a shear zone with quartz veins was seen near the portal of two of the tunnels. The tunnels are very crooked, with branches in many places. They follow fault planes more often than such parts of the shear zone as are crossed in the tunnels. There does not appear to have been any very definite plan in their development.

Carmi Mine.

History and Development. The Carmi mine is situated directly south of and close to the town of Carmi. The claim was located in 1896 by Mr. J. C. Dale, who is also the founder of the town of Carmi. The property was sold in 1900 to the Carmi Mining Company of London, England, and was then managed by Mr. E. H. Throuston. The mine was worked between 1899 and

1900 and again in 1904. It has been shut down since then. In 1901, 885 tons of ore were shipped to the smelter at Greenwood. It averaged over $20 to the ton in gold, and carried about 4 ounces of silver.[1]

An incline shaft 183 feet deep has been sunk on the level, and over 250 feet of drifting done from it. There is also a tunnel 85 feet long with a winze in it near the bank of the Westkettle river; the depth of the winze is not known. In 1901 the equipment consisted of a steam hoisting plant and a Cameron pump, and in 1904 a ten stamp mill was added. Four hundred tons of waste were treated in the [illegible]amation and the cyanide process: it did not stay in operation long. When seen in 1911 the board sheds covering the equipment near the shaft were in sad disrepair, some of them fallen down, and the machinery was in danger of being ruined by exposure.

Geological Relations. Since the shaft was filled with water at the time of our visit, the information given here is such as could be learned from the surface. The ore consists of sphalerite, chalcopyrite, pyrite, galena, and some molybdenite, in a gangue of quartz, ankerite, and in places intensely sericitized dyke material. The ores lie in an east-west quartz vein which dips from 45 to 60 degrees to the south and is in places accompanied by a dense grey dyke, probably of andesite. The country rock at the shaft is a fine-grained somewhat gneissic quartz diorite. At the mouth of the tunnel on the river it is a dense banded rock of the Wallace group, probably a tuff or sediment. The vein has been frequently offset between the shaft and tunnel by cross faults. It seems to be the same vein as that found in the shaft of the Butcher Boy, which is about 500 feet to the west of the Carmi shaft; but between these also there are frequent offsets of the vein; at least so it appears from the openings where pits have bared the lead.

Commercial Possibilities. If the numerous fragments of the east-west shear zone between the tunnel on the Westkettle and the Butcher Boy shaft are parts of what was one lead before faulting took place, as there is good reason to believe, the shear zone

[1] Robertson, W. F., Annual Report, Minister of Mines of British Columbia for 1907, pp. 1058-1140.

must have been over 1,800 feet long at the level of the present surface of the ground. It is generally assumed, that a fissure may extend in depth for the same distance as it outcrops on the surface, although it does not by any means always do so. There is, therefore, reason to believe that the shear zone will continue in depth for a good many hundred feet, although it probably does not go down to 1,800 feet. Faulting does not, moreover, appear to have displaced it to so large or irregular an extent as was the case in many of the shear zones on Wallace mountain and it should, therefore, be rather easier to find the faulted ore-bodies underground. There is a possibility, therefore, of making a mine out of the Carmi if enough ore exists in the shear zone. On the latter point no opinion can be expressed, for the shaft and drifts from it were inaccessible at the time of our visit, and no idea could be obtained of the character of the ore-bodies nor their size. It is not, however, very probable that the ore will prove richer in depth. Since the shear zones in which the ore is found may be located at frequent intervals on the flat which extends from the river to the present shaft, and its dip is in places not very steep, it should be possible to carry on exploration for ore-bodies with the diamond drill, a method by which the presence or absence of ore-bodies can be proven in a fairly satisfactory manner if the dip of the shear zone does not become too steep, and which is more economical if used extensively than tunnelling or shaft sinking.

An item of cost at Carmi, which a number of the mines on Wallace mountain will not have to face, is that of drainage. It is evident from the map (in pocket) that the level of the river is not over 140 feet or so below the collar of the shaft, and since it is one-quarter mile away, it is not probable that any effective drainage can be obtained from cross-cut tunnels. The cost of pumping will, therefore, have to be reckoned on, all through the life of the mine.

Butcher Boy Claim.

The Butcher Boy was mined at one time by Mr. J. C. Dale of Carmi; it is not known who the present owner is. There is an incline shaft on the property which lies 500 feet west of the Carmi shaft and is probably on the same shear zone, although this shear zone has been frequently displaced by cross faults between the two. The shear zone carries values in gold, silver, and copper. It contains quartz, pyrite, and the same type of aplite dyke material as is found on the Carmi property. The shear zones strike roughly east-west and dip to the south.

Claims on Arlington Mountain.

Certain prospects on Arlington mountain occur in somewhat the same type of shear zones as those at Carmi. On what is known as Captain Gordon's claim on the top of Arlington mountain a 70-foot trench has exposed an east-west vein of quartz which occurs with altered quartz diorite in what seems to be a shear zone in gneissic quartz diorite. The veins cut across the planes of foliation. The ore consists of pyrite, chalcopyrite, and some molybdenite in a gangue of quartz, sericite, calcite, chlorite, and partly altered quartz diorite.

The Arlington claim is said to belong to the Bank of Montreal. A shaft 30 feet deep, a trench 40 feet ... and numerous prospect holes are found on this claim. The ore ... said to carry values in silver and copper. About 10 tons of ore were lying near the shaft in 1911. Ore minerals are found in an east-west shear zone in pyroxenite of the Wallace series and a north-south quartz vein is found to the east of the shaft. Chalcopyrite, pyrite, calcite, and quartz were seen lying in brecciated pyroxenite on the claim.

Prospects have also been located on shear zones of this type on King Solomon mountain and several small shafts and tunnels driven.

STOCKS.

DESCRIPTION.

Definition. The term "stocks" is applied in this report to a number of ore-bodies of irregular form, within which the shattered country rock has been impregnated with metallic minerals and sometimes with quartz. Although in places approaching a tabular form, they do not have the two well-defined walls of the shear zones. With the stocks are included irregular bodies of ore occurring in quartz veins. These ore-bodies do not belong to the well-defined "mineralized shear zone" or to the contact metamorphic types, and since in place they carry the same minerals as the stocks, they are for convenience classed with them. The stocks, therefore, include more than one type of ore deposit.

Distribution. Prospects which carry ores of this type have been examined upon the eastern side of Wallace mountain, in Curry creek, on St. John ridge, and in the region near the Triple lakes. They are probably to be found in many other places within the Wallace group.

Mineralogy. The minerals associated in the stocks vary from place to place. Pyrite is found in nearly all of them, and pyrrhotite is associated with pyrite in most places. Chalcopyrite, arsenopyrite, and molybdenite are the other sulphides. The gangue is generally quartz, sometimes calcite, and epidote. In places the sulphides are finely disseminated through the rock and appear to replace it, and in such cases the gangue is country rock.

The Country Rock. The country rock is generally some member of the Wallace group, but not always the same rock type. In the greater number of cases it is composed of dense grey Wallace rock, probably a tuff or sediment, and this often has some limestone associated with it. This is the country rock on the Ellsworth and St. John claims on St. John ridge, in several claims near the Triple lakes, and a number of others. At the Nepanee shaft the ore is in diorite porphyry of the Wallace group, and in the claims of Larson and Burns it is sometimes found in a white porphyry, and in one instance at a contact of quartz diorite and Wallace, it was found in both. Tertiary volcanic dykes sometimes cut across the country rocks near the ore-bodies and since they were never found carrying metallic sulphides it is presumed that they were later than the ores.

Structure of the Stocks. The stocks very often occur in belts of shattered rock which have on occasions a well-defined wall, but two clean cut walls are as a rule not present. Their dip and strike vary from place to place; some of the stocks occur as large masses or veins of quartz; these may be very wide and persistent for a considerable distance, as in the Ellsworth claim, but they are generally irregular in outline and rather short.

Textural Features. Sometimes the ore minerals occur in quartz veins, as in some of the prospects on Burns' and Larson's claims; more often they are irregularly disseminated through broken up country rock; in such cases the pyrite is generally well crystallized with well formed crystal faces which cut across the grain of the rock, and seem to be replacing it. Pyrrhotite and pyrite are in places developed in nearly solid masses of sulphide.

Secondary Oxidation. The processes of oxidation have affected a number of these masses and formed a conspicuous iron cap or gossan of leached rock. This cap is probably not very deep and the products of the leaching are doubtless deposited below the leached zone.

GENESIS OF THE STOCKS.

The stocks vary in their mineral makeup and to some extent in their geological occurrence; it is, therefore, possible that they may not all have been deposited in the same way or by the same agencies. The pyrrhotite-pyrite bodies are, however, distinctive; they occur in the same rock types and the presence of pyrrhotite argues conditions of great pressure and heat at the time of their formation (see table on page 75). Certain of the stocks, on the other hand, which carry chalcopyrite and pyrite, but no pyrrhotite, resemble the shear zone deposits at Carmi in their mineral makeup and may, therefore, have been formed under conditions of moderate temperatures and pressures. They have probably been formed by agencies entirely different from those which formed the bodies of pyrrhotite.

The Pyrrhotite-bearing Stocks. The genesis of the pyrrhotite stocks as well as of the other ore-bodies included under the heading of stocks cannot be proven with satisfaction until more of the deposits are opened up by underground work and further studies have been made. The pyrrhotite ores which were studied in the field were all in rocks of the Wallace group although some of the stocks which did not carry pyrrhotite were seen in Westkettle quartz diorite. The pyrrhotite ores may, therefore, be assumed to have formed either before or during the intrusion of the Westkettle quartz diorite. At the Silver Dollar claim pyrrhotite was found in a white porphyritic rock which is probably a late member of the Wallace group, or a dyke connected with the intrusion of the Westkettle batholith. It is therefore, probable that the time of their formation was very close to the intrusion of the batholith. Since the mineralogy of the pyrrhotite stocks indicates that they were formed under great pressures and temperatures, such pressures and temperatures as would obtain at depths great r than 12,000 feet, we may assume that they were formed either at great depth or at shallower depths where the pressures and temperatures had been abnormally increased by an igneous intrusion. They were evidently formed by hot rising solutions which were possibly derived from the quartz diorite magma.

Others of the stocks, such as that at the Mogul claim, which occurs in quartz diorite, may have been formed by waters rising from an underlying body of Beaverdell quartz monzonite; but since in the case of the Mogul the nearest outcrop of the quartz monzonite is about a mile away, we have no good means of proving the supposition.

FUTURE POSSIBILITIES.

No ore-bodies large or rich enough for extensive mining have been opened up in these stocks. Their future depends upon the discovery of large bodies of ore, for they are situated at some distance from the new railway and are as a rule low-grade properties.

PROSPECTS LOCATED ON THE STOCKS.

The following claims which are located on stocks are described here: the Nepanee claim, Tuzo's claim, the Ellsworth or Big Strike, the St. John, Burn's, and Larson's claims. the O.K. Silver Dollar, and Mogul claims.

Nepanee Claim.

The Nepanee claim lies toward the southeastern part of Wallace mountain and southeast of the Buster (Figure 1). Mr. M. J. Cummings of Beaverdell is a part owner of this property. The workings consist of an incline shaft 70 feet deep; 300 feet to the northwest is a 30-foot shaft and two prospect holes with some drifting. Assays from the incline averaged about $14 in gold, silver, and copper, and carried about 3·3 per cent of copper. A sample from the northern workings ran $16 per ton in gold and $2 in silver. The shaft is in a zone of shattered hornblende diorite porphyry of the Wallace group; it has a well defined hanging-wall, but not a marked foot-wall; the direction of the lead is about 20 degrees south of east, and it dips about 45 degrees to the north. The northern workings are in a somewhat indefinite zone of brecciated Wallace rock. The ores consist of pyrite, and arsenopyrite, disseminated through the broken Wallace group. It is accompanied by veins of quartz.

Tuzo's Claim.

A claim owned by Mr. J. Tuzo of Midway lies about one mile up Curry creek from the mouth of the canyon. A tunnel on the claim is situated about 200 feet in elevation above and north of the creek bed. There is a trail up the canyon to the claim. The ore consists of pyrite disseminated through dense fine-grained rock of the Wallace group, and it is accompanied by stringers of quartz.

Ellsworth or Big Strike Claim.

This claim lies on top of St. John ridge between Spout and St. John creeks at an elevation of over 4,600 feet, and is marked on the map by three prospect holes. It was probably first staked in the year 1900 by Doare and Harris[1] and was restaked in 1911 by Mr. P. J. Kennedy. Assays made in 1901

[1] Robertson W. F., Ann. Report Minister of Mines of British Columbia for 1907, pp. 1058-1140.

gave 50 cents in gold and 3 ounces of silver to the ton. The workings consist of two prospects and one shaft lying within 50 feet of each other; the shaft was filled with water to within 15 feet of the surface in 1911. The ore consists of pyrite, pyrrhotite, and a little chalcopyrite, in a gangue of quartz, epidote, and calcite. The epidote and calcite are sometimes in veinlets through the sulphides. The sulphides lie in a wide vein of quartz which apparently outcrops again 300 feet from the prospects; it apparently strikes south 10 degrees west and dips to the west. The country rock is limestone in the eastern prospect; dense Wallace rock, probably a quartzite, is found in the western prospect, and under the limestone in the eastern prospect. It is possible that the vein on the Ellsworth continues to the St. John to the south, for the strike is in that direction, but the intervening country is drift covered, and this supposition has not been verified.

St. John Claim.

The workings of the St. John lie a little more than one-half mile south of the Ellsworth at an elevation of about 4,500 feet on St. John ridge. The St. John belonged at one time to Collier, Thompson, and Sterling; the present owners are unknown. There are three prospects on a north-south line on this claim. There appears to be a vein of quartz in dense Wallace rock, probably a sediment. The northern hole has an exposure of 15 feet of quartz in it; the southern is in a shear zone with not much quartz showing.

Burns' and Larson's Claims.

Mose Burns and John Larson own and operate four claims on the side hill overlooking Beaver creek, one-half mile east of Larsen creek. Larsen creek is named after John Larson, but the name was misspelt on the map. The four claims are in succession from northwest to southeast the Gateway, Golden Dawn, Moonlight, and Alameda. These claims were worked practically every summer from 1903 to 1911, and a great many prospect holes have been opened up. The workings on the Gateway claim are a short tunnel, a prospect, and a shallow shaft;

on the Golden Dawn a shaft 30 feet deep and a tunnel 30 feet long; on the Moonlight five or more prospect holes; on the Alameda one shaft and two prospect holes. The ore in the Gateway, Golden Dawn, and Moonlight claims carries values in copper which vary from low up to, occasionally, 5 per cent. The values in the Alameda are in gold, and are said in one case to have run over $14 per ton.

The ores in the Gateway, Moonlight, and Golden Dawn consist of pyrite and chalcopyrite in a gangue largely of quartz. The country rock is metamorphosed limestone, argillite, and diorite porphyry of the Wallace group; this has been intruded by acid binary granitic dykes which are porphyritic and aplitic in character, and seem to have been accompanied by the injection of a great deal of quartz into the surrounding sediments. A number of Tertiary, rather basic, dark dykes also cut the rocks near the ore-bodies. The granitic dykes are thought to be offshoots from the large mass of quartz diorite which lies down hill and close below the claims; its contact is seen in the lower tunnel of the Gateway. The position of the claims and of the quartz diorite is shown on the map (in pocket). The ore is most often found in quartz veins near the white porphyritic dykes, and its character does not seem to have been greatly influenced by the presence of either the limestones or the Tertiary dykes.

The sulphides on the Alameda are pyrrhotite and pyrite, which are in stringers or finely disseminated through dense Wallace rock, probably an altered sediment. Arsenopyrite is also said to be found on this claim, and it was seen on top of the hill to the east of it. Hornblende diorite porphyry was seen near the ores, but no sulphides were found in it, although they are said to be present.

Very little can be said regarding the possible occurrence of paying ore-bodies on these claims. At the time of our visit no large bodies of ore had been opened up, and until fairly large bodies are found the cost of transporting the ore to the nearest railway station, which will probably be near Beaverdell, about 8 miles away, will prevent the mining of the rather low-grade ores.

O. K. Group.[1]

The O. K. group, which consists of the Oro Fino, O. K., Ivanhoe, Liberty, and Tip Top Fraction, was located in 1897 by H. B. Thorn and C. Matheson. [illegible]is group lies in the Triple Lakes region, east of B[illegible]rns and [illegible]rson's claims. Selected samples from certain of the prospect holes in the group gave $11 of gold to the ton, the average, however, being nearer $5 to the ton.[1]

Three prospects presumably on the O. K. claim are situated near the summit of Kloof ridge, somewhat over one-quarter of a mile west of the lower of the Triple lakes. There is a sheared zone in one of the holes [illegible] degrees west of south. The ore consists of py[illegible]pyrite disseminated through dense Wallace rock. Several hundred feet to the east there is a tunnel and prospect 10 feet [illegible] with Wallace limestone and, probably, argillaceous sediment forming the country rock. These claims have evidently not been worked for years.

Mogul Claim.

The Mogul claim lies on Lake ridge about one-half mile east of the upper of the Triple lakes. It is said that this claim is, or was at one time, owned by R. Roberts of Greenwood, and others. Assays of ore from the dump on the surface gave $20.40 in gold and 10 ounces of silver to the ton.[2] The country rock is a fine-grained quartz diorite which has been sheared in a number of places and intruded by dykes of aplite and basic Tertiary volcanic dykes. Quartz and pyrite stringers occur in the aplite, and pyrite is found in drusy cavities in the quartz veins.

This occurrence has features which ally it with the mineralized shear zone deposits at Carmi and on Arlington mountain.

Silver Dollar Claim.

The Silver Dollar lies on the northern end of Lake ridge about one-half mile south of the divide between Deer creek and

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[1] Ibid. p. 1137.
[2] Ibid. p. 1137.

the Triple Lakes valley. It is marked by a shaft on the map. The claim was at one time owned by C. Newman and Josep Peterson. Ore fron a dump near the workings carried $16.40 in gold and 6 ounces of silver to the ton.[1] The workings consist of a shaft about 40 feet deep with a cross-cut tunnel coming into it 20 feet from the surface; the shaft was filled with water up to about 35 feet from the surface. The country rock is a dense tuff, or sediment, of the Wallace group and an acid granitic dyke cutting the tuff. The shaft has been sunk in a shear zone about 5 feet wide, striking nearly due north and dipping nearly 90 degrees. A break near the mouth of the tunnel strikes slightly east of north and dips 45 degrees to the southwest. The ore, which consists of pyrite, pyrrhotite, and arsenopyrite, was seen in both the dense tuff-like rock and the light coloured granitic rock. It appears to be disseminated through the shattered country rock in an irregular manner.

THE CONTACT METAMORPHIC DEPOSIT.

DESCRIPTION.

Definition.

By "contact metamorphic deposits" is meant here mineral deposits which have been formed in intruded limestones close to the contact of the intrusive body, and directly as the result of the intrusion. Such deposits are characterized by very definite associations of minerals.

Location.

A contact metamorphic deposit carrying values in copper has been opened up on the Lottie F. claim on Copper creek a few miles north of the area. The workings lie on the west side of the creek about 300 feet above its bed, and 2 miles from where it joins the Kettle river. Its junction with the Kettle river is about 40 miles north of Westbridge.

This is the only ore deposit of the contact metamorphic type found in the district.

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[1] Ibid. p. 1138.

Mineralogy.

The minerals in the deposit on Copper creek are chalcopyrite, bornite, malachite, azurite, and pyrite, and with them garnet, an unknown silicate, epidote, wollastonite, quartz, and probably calcite. These do not include the minerals which made up the original country rocks. Bornite and chalcopyrite are the principal ore minerals, and garnet forms the greater part of the gangue. A pinkish calcium, manganese, iron silicate, which is described in detail in the section on mineralogy, occurred as a lining of certain cavities in the ore.

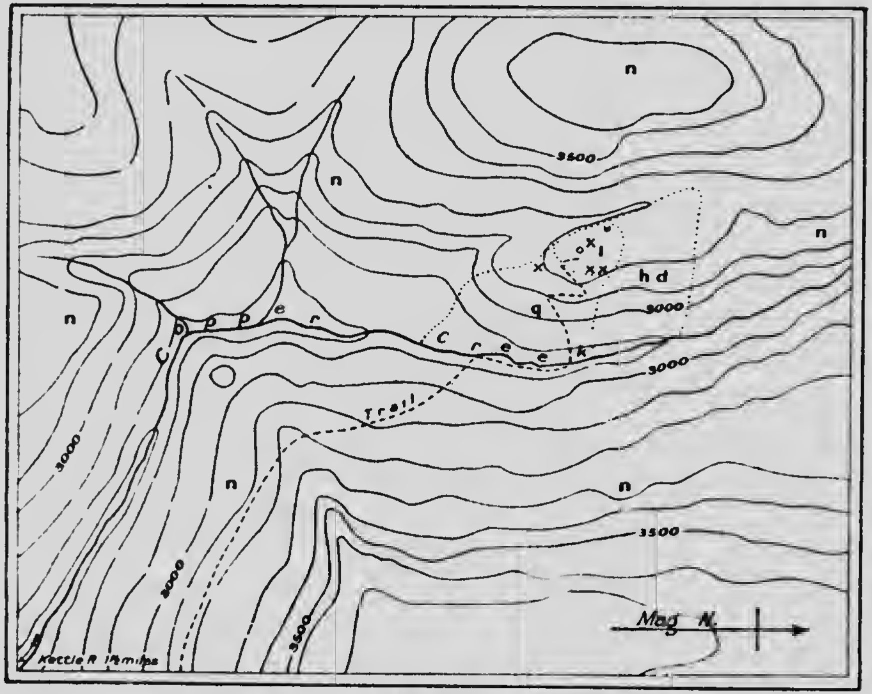
Geological Relations.

The country rock in which the ores are found is limestone and hornblende diorite of the Wallace group. The limestone outcrops over a somewhat circular area about 500 feet across and in places hornblende diorite lies close to the surface under it. Most of the ore is in the limestone, but some ore was seen in diorite. The diorite outcrops to the north of the limestone area, and a quartzitic member of the Wallace to the east (Figure 9). The quartzite seems to underlie the limestone. The area occupied by these three members of the Wallace group is somewhat oval and about 1,500 feet across. It is completely surrounded by Tertiary lava flows. Dykes of the same material as the lavas cut through the rocks of the Wallace group. Both limestone and diorite of the Wallace series are badly brecciated at their contacts.

The Ore-Body.

Very little could be learned regarding the structural relations of the ore-body, for the workings were abandoned and filled with water. It appeared to be of irregular shape and confined largely to the limestone, although found in the underlying diorite.

Texture. The ores seemed to be massive in places. In certain specimens collected from the dump of one of the shafts they contained peculiar ellipsoidal cavities (Plate IX) and around



Legend

- l Wallace limestone
- q Wallace quartzite or tuff
- hd Wallace hornblende-diorite
- n Nipple Mountain lavas
- o Shaft
- x Prospects
- ······ Geological boundaries

Position of trail approximate only

All distances estimated

Fig. 9. Sketch of topography and geology on and near the Lottie F claim on Copper Creek

Scale of Feet

500 0 1000 2000

these cavities the ore and gangue minerals were in concentric bands; the cavities were about 1 inch across. The succession which held from the outside to the centre was, in one case, bornite, an unknown silicate perhaps wollastonite, quartz, and a light coloured weathering product. In another instance it seemed to be chalcopyrite, bornite, the silicate mentioned above, and quartz. Bornite occurs in places lying in fine veinlets through chalcopyrite, suggesting that it is later. Garnet was found in skeletal crystals intergrown with bornite and was, therefore, formed at the same time. Wollastonite occurs in well shaped crystals within masses of bornite, and is thought to be older than bornite. The relative time of crystallization of the epidote is not known. The order of crystallization is probably somewhat as follows: chalcopyrite, wollastonite, bornite, and garnet, and perhaps epidote, the unknown calcium silicate, quartz, and later calcite, malachite, and azurite.

Secondary Alteration. The only signs of secondary alteration which were observed were a slight alteration of bornite to azurite and malachite in the ellipsoidal cavities which occur in the ore, and a change of the calcium silicate to what appeared to be kaolin. There were also veinlets of calcite which were probably of secondary origin.

GENESIS.

The mineral associations of the sulphide ores with garnet, wollastonite, and epidote are typical of contact metamorphic deposits. The association has in so many other regions been proven to be typical of the deposits which have been distinctly formed by contact metamorphism that it is only necessary to decide in this case as to the intrusive which caused the metamorphism. Three possibilities may be discussed here: first, that the deposits were due to the access of heat and mineralizers brought about by the Tertiary lavas; second, that they were due to the intrusion of the Wallace diorite; or, third, that they are the result of the intrusion of a large batholithic mass which is covered and was, therefore, not seen. The first hypothesis may be dismissed as contrary to general observation,[1] for ef-

[1] Lindgren, Waldemar, "Mineral deposits," p. 664.

fusive rocks very seldom exert any very great metamorphic effect upon the surrounding rocks. The hornblende diorite of the Wallace group is the only intrusive seen near the ores, but it is not very likely that its intrusion caused their formation, for the hornblende diorite itself contains ore which was introduced after it had solidified. The ores were, therefore, formed after the diorite had cooled and not at the time of its intrusion. Since in contact metamorphic deposits the formation of the ores seems to have taken place during intrusion and while the intrusive was hot, it is evident that the ores must have been caused by an intrusive later than the hornblende diorite. The last hypothesis is that contact metamorphism is due to a large igneous body intruded below the deposit but not outcropping on the surface. It seems quite probable that such an igneous body, or part of one, actually exists below Copper creek, for the Beaverdell quartz-monzonite batholith outcrops 3 miles to the east, and a few miles to the west, of this place and covers large areas in both cases. It seems quite possible then, that the ores were formed by contact metamorphism induced by a large mass of Beaverdell quartz monzonite intruded below them. It is presumed that this mass is not far below, but its actual depth is a matter of surmise.

LOTTIE F. CLAIM.

The contact metamorphic deposit described above, lies on the Lottie F. claim. The workings on the claim consist of a shaft perhaps 50 feet deep and a number of prospect holes. The shaft was filled with water to about 35 feet from the surface at the time of our visit. About 20 tons of ore were lying on the dump of the shaft at the time, and from its general appearance it was estimated to carry between 5 and 10 per cent of copper to the ton. The geological relations at this claim have been described in the general section on contact metamorphic deposits.

The commercial possibilities of the claim will depend on finding a large body of ore. The limestone, which probably carries the greater part of the ore-body or bodies, occupies a small area on the surface and although it may underlie the surrounding younger volcanics that is still unproven. The problem of transportation will be the most difficult to solve. The most convenient railway station should be Westbridge on the Kettle Valley railway. Westbridge is between 35 and 40 miles from the mouth of Copper creek. In 1911 there was a wagon road from Westbridge for about 20 miles up the river, and a survey had just been made for a road which was to go the rest of the way. From the mouth of Copper creek to the mine is about 2 miles up the creek, and the creek bed rises over 300 feet in that distance. The collar of the shaft lies about 700 feet in elevation above the floor of the Kettle River valley and the end of the proposed wagon road. There is enough timber and water for mining purposes and it is probable that the rough topography can be utilized in the draining of the mine workings and in general development, if sufficient ore is found to make development work feasible.

SCHEELITE.

Scheelite, the tungstate of calcium, occurs in a prospect hole near the western side of the broad top of Arlington mountain. The prospect, which is not marked on the map, lies from 300 to 400 feet west of the trail to Arlington lakes, between the 3,500 and 3,600-foot contour lines on the map, and near the boundary between the Wallace group and quartz diorite.

Scheelite is an ore of tungsten and as such is valuable if found in quantity. The mineral was only seen in thin section under the microscope. It lay in veinlets about one-twenty-fifth of an inch wide, within a limestone altered to garnet and epidote. None of it could be detected in the hand specimen brought from the field, and its presence was not suspected until revealed by the microscopic work.

The rock in which this mineral is found is a reddish-white garnetiferous limestone with numerous veinlets of quartz through it. Fifty feet to the north is the contact of the quartz diorite batholith and the Wallace group of which the limestone forms a member. Petrographic study of the scheelite bearing rock indicates that it was originally a siliceous limestone; that it had been partly replaced by garnet and epidote, and that scheelite, calcite, and quartz lie in veinlets which cut through the replaced rock and penetrate the garnets. Under the microscope (Plate X) the scheelite is grey, uniaxial, positive, birefringence approximately 0·015 and refraction higher than grossular garnet.

From the occurrence of the scheelite it may be inferred that it was formed after the garnet and epidote. Garnet and epidote are undoubtedly products of the intrusion of the quartz diorite, and the fissures in which the scheelite occurs were probably formed upon the cooling of the replaced limestone which had been heated to a high temperature by the intrusion. The simplest explanation for the origin of the mineral is that it was formed by liquids and vapours given off by the quartz diorite magma after the magma had come to rest and partially cooled.

Concentrates carrying 60 per cent tungsten trioxide, that is, the equivalent of about 75 per cent of scheelite, sold in 1910 at from $400 to $500 to the ton.[1] It is probable that there is more scheelite in the quartz veins in this prospect hole and that there are other occurrences in the garnetiferous limestone near the contact of the quartz diorite batholith. Such a garnetiferous limestone lies east of the Westkettle river and south of Trapper creek, quite close to the old Kelowna pack trail, and there are a number of other outcrops of the same type of rock. However, at present the occurrence of scheelite is of more mineralogical interest than of commercial importance.

SERPENTINE AND ASBESTOS.

Serpentine and asbestos were seen on the west side of Hall Creek canyon south of the lower end of the long swamp and just below an escarpment of white andesite. They occur in the lower 10 feet of a flat sill-like mass of black saxonite porphyry which is about 60 feet thick and which lies immediately under the cliff of white andesite. The serpentine lies in green bands through the black rock and the asbestos in little veinlets through the serpentine.

The bands and veinlets lie more or less parallel to the lower contact of the sill and the asbestos veins appear to be larger

[1] Lindgren, Waldemar, "Mineral deposits," p. 584.

near the surface of the ground than away from it. It is thought that the asbestos and serpentine were formed from the saxonite porphyry by waters percolating downward through the sill, and that the growth of the flat veins of asbestos was hastened by the removal of the rock cover over the sill by erosion.

Probably not one-half of the lower 10 feet of the sill is changed to serpentine and the asbestos veins are seldom over an inch thick. The occurrence described here is not, therefore, of commercial importance, but it indicates that asbestos is present and that it may be expected to occur in many of the black basic intrusive rocks which are found in various places in the district. The profitable mining of asbestos, like that of a number of other non-metallic minerals, requires that the material exist in large amount and that transportation charges should not be very high.

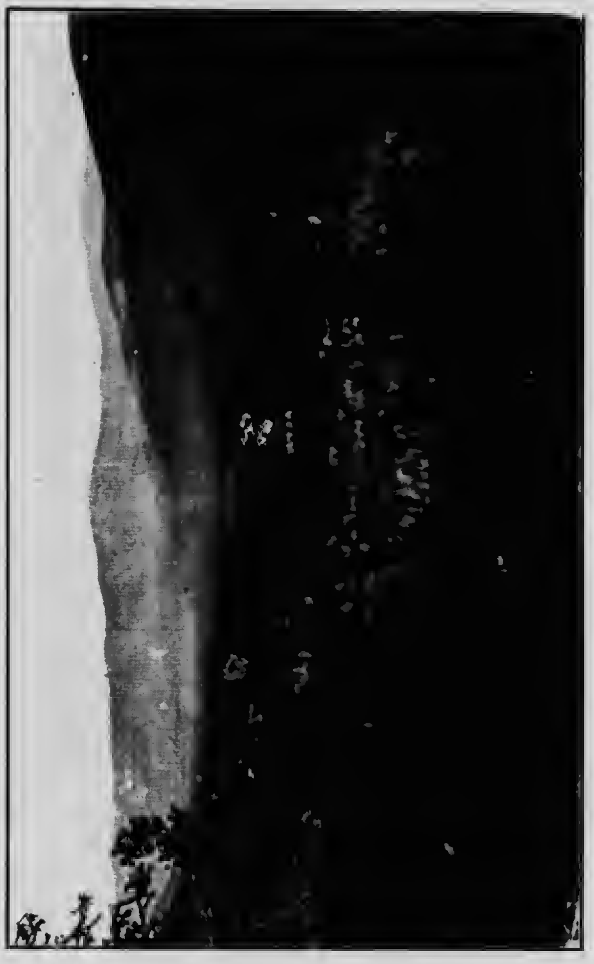
ROAD MATERIALS.

The altered andesites of the Wallace group should make very excellent material for surfacing wagon roads, and so should any of the Nipple Mountain lavas. Any dense or porphyritic igneous rock which is rather dark coloured will generally make good road metal. Such material should be looked for where areas of the Wallace group cross the valleys. Quartz diorite, quartz monzonite, and all coarse-grained rocks resembling granite are inferior to the denser and darker igneous rocks for use on roads. The limestones and schistose rocks which are found in this district should not be used at all.

Explanation of Plate II.

The forest-covered, flat bottom of the Westkettle valley, and Beaverdell village (Pages 21, 24).

PLATE II.



EXPLANATION OF PLATE III.

Recently burned area with thick growth of underbrush (Page 26)

PLATE III.

Explanation of Plate IV.

Banded tuffs of the Wallace group (Page 34).

PLATE IV.

Explanation of Plate V.

Variations in the Westkettle batholith ([illegible] natural size). (Page 42).

a. Fine-grained roof facies (quartz monzonite).
b. Average medium-grained facies (quartz diorite).
c. Acidic facies from the Sally mine (granodiorite).

PLATE V.

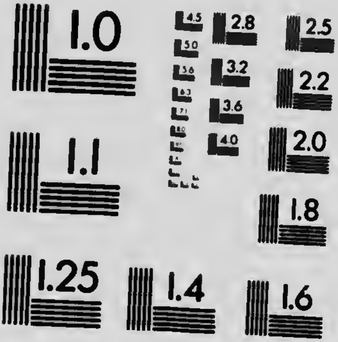
Explanation of Plate VI.

Terraces in the Westkettle valley at Carmi (Page 63).

PLATE VI.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



Explanation of Plate VII.

Banded ore from the Gold Drop claim (Pages [illegible]1, 12[illegible]).

Plate VII.

EXPLANATION OF PLATE VIII.

Shaft house and cabin on the Rambler claim (Page 122).

Plate VIII.

Explanation of Plate IX.

Ellipsoidal cavities in the contact metamorphic ores on Copper creek (enlarged $1\frac{1}{4}$ times). (Pages 138, 140).

g. Garnet.
b. Bornite.
x. Unknown silicate.
q. Quartz and alteration products.

PLATE IX.

Explanation of Plate X.

Microphotograph of a vein of scheelite quartz and calcite in an altered limestone (enlarged 20 times). (Pages 142, 143).

c. Calcite.
q. Quartz.
s. Scheelite.
g. Garnet.
e. Epidote.
i. Aggregate of fine grains of calcite and quartz, probably a remnant of the original limestone.

PLATE X.

EXPLANATION OF PLATE XI.

Boulder of brecciated augite andesite, Wallace group; outcrops on the hill above (Photo by O. E. LeRoy). (Page 39).

Plate XI.

Explanation of Plate XII.

Variations in the Beaverdell batholith (⅔ natural size). (Page 48).

a. Fine-grained roof facies (quartz-syenite-aplite).

b. Medium to coarse-grained facies forming the greater part of the batholith (quartz monzonite).

c. Coarse-grained porphyritic facies forming the stock at Beaverdell (quartz-monzonite porphyry).

PLATE XII.

a

b

c

Explanation of Plate XIII.

Nipple Mountain lavas at the mouth of Copper creek, Kettle river. The lavas lie on the floor of the river valley at an elevation of about 2,800 feet. (Pages 57, 59).

Plate XIII.

INDEX.

A.

	PAGE
Acknowledgments	2
Agriculture	22
Alaska Mining Company	124
Albite	68
Analysis of Beaverdell quartz monzonite	49
" " Weskettle quartz diorite	43
Anarchist series	40
Andesites	36
Animal life	23
Ankerite	77
Antimony	81, 84
Area	3
Argentite	86
Arlington claim	129
" lakes	48, 50
" mountain	5, 14, 17, 65, 86, 142
" " claims on	129
Arsenic	77
Arsenopyrite	77
Asbestos	17, 143
Attwood series	40
Augite syenite porphyry	12, 52
" " " lithology	52
Azurite	78

B.

Bank of Montreal	129
Barite	78, 86
Barrell, Jos	66
Barrett, George	125
Bartlett, Ernest	2
Basic intrusives	35
Beaver creek	21, 48
" valley	11
Beaverdell	68
" batholith	67, 69
" " composition of	68
" quartz monzonite	12, 15, 16, 31, 48, 88, 113
" " " age and correlation	51
" " " lithology of	48
" " " relation to other formations	50
" " " structure	50
Beaverton camp	6
Bell claim	124
Berry, L. W	2
Bibliography	7
Big Strike claim	82
Biotite	68, 69
Blewett mining district	41
Bornite	78
Boundary Creek series	56

PAGE
89
Bounty Fraction claim.........80, 84, 92, 125
" mine.........3, 84, 85
Bradley, W. M.........56, 62
Brock, R. W.........82, 134
Burns and Larson's claims.........134
" Mose.........84, 88, 89, 92, 124
Buster claim.........128
Butcher Boy claim.........

C.

30
Cache Creek series.........78, 86
Calcite.........6
Cañon city.........39
" creek.........129
Captain Gordon's claim.........40
Carboniferous.........3, 5, 14, 15, 63, 86
Carmi.........6, 84, 89, 115, 126
" mine.........126
" Mining Company.........105
Cavity filling.........79
Chalcopyrite.........50, 54, 70
China buttes.........5, 39
" creek.........59
" ridge.........79
Chlorite.........2
Clark, Karl, M.........22
Climate.........12, 49, 67, 68
Collier lakes.........27
Commercial possibilities.........3
Communication.........69
Conglomerates.........49
Connor, M. F.........16, 73
Contact metamorphic deposit.........137
" " deposits, description of.........140
" " " genesis of.........78, 79, 81, 84
Copper.........16, 57, 59
" creek.........118
Costs, Sally mine.........30, 67
Cretaceous.........55, 70
Crystal creek.........12, 48, 57, 65
" mountain.........66, 67
Crystallization, fractional.........133
Cummings, M. J.........13, 31, 51, 53, 69, 70
Curry Creek series.........56
" " " age and correlation.........53
" " " distribution.........53
" " " lithology.........54
" " " metamorphism.........55
" " " relation to other formations.........55
" " " structure.........33, 54, 57
" mountain.........

D.

126, 128
Dale, J. C.........30, 41, 47, 56, 60, 62, 66
Daly, R. A.........30, 31, 41
Dawson, G. M.........

PAGE
Dry creek.......... 120
" Creek canyon.......... 122
Duncan and Bounty Fraction claims.......... 122
Dykes.......... 70
" in or near the shear zones.......... 89

E.

Ellsworth.......... 130
" or Big Strike claim.......... 133
Emmons, W. H.......... 75
Eocene.......... 12
Epidote.......... 65, 79
Evans, Horace F.......... 7

F.

Fans, alluvial.......... 21, 69, 70
Faults.......... 70, 72, 95
" system of.......... 69
Fauna. See animal life.
Feldspar.......... 80
Ferroux mountain.......... 13
Field work.......... 2
Fissures.......... 70, 71
Ford, W. E.......... 85
Formations, description of.......... 9
Fossil land plant, Curry Creek series.......... 56
Future of the district.......... 17
" possibilities.......... 114

G.

Galena..........
" ores, restriction of, to quartz diorite..........
Galloway, Charles.......... .
Garnet.......... 65
Genesis of contact metamorphic deposits.......... 140
" " ores.......... 101
" " the stocks.......... 131
Geology, economic.......... 14, 73
" general.......... 9, 29
" historical.......... 63
Glacial deposits.......... 61
" " distribution.......... 61
" " lithology.......... 62
" " structure.......... 62
" striæ.......... 62
Goat peak..........11, 20, 57, 59, 61, 70, 71
Gold.......... 86
Gold Drop claim..........78, 92, 126

H.

Hall creek.......... 17
Henderson, Tom.......... 122
Historical geology.......... 63

PAGE
History 4
Homestake claims 90, 126
Hornblende diorite porphyry 37
Hornfels 34
Hughson, William 2

I.

Idaho shaft 88
Inhabitants 26
Interior plateaus 18
Irving, J. D 3

J.

Jurassic 11, 31, 47, 64

K.

Kaolin 80
Kelowna 22
Kennedy, P. J 133
Kettle holes 21
" river 9, 20, 59
" River formation 56
" Valley railway 4, 6
King Solomon mountain 14, 25, 86
Kloof ridge 53, 136
Knob hill 25, 65
Knowlton, F. H 56
Kokomo claim 90, 125

L.

Lake ridge 51
Larson and Burns 130
" " " claims 82, 134
" John 134
Lassie lake 13, 54
Lava 71
Lavas, extrusions of 70
Lead 80
Limestone 34
Lindgren, W 75, 105
Liquation 66, 67
Location 3
Lottie F. claim, described 141
" mine 16, 78, 79, 81

M.

McCullough, F. H 2
Magmatic stoping, hypothesis of 65, 66
Malachite 81
Maloney lake 48
" valley 25

PAGE
Mesas.... 71
Mesozoic.... 30, 31, 41
Midway.... 3, 22
" series.... 60
Mineralized shear zone, country rock.... 87
" " zones.... 14, 73
" " " definition.... 86
" " " description.... 86
" " " distribution.... 86
" " " faults.... 95
" " " genesis of the ores.... 101
" " " localization of orc masses.... 93
" " " mineralogy.... 86
" " " process of deposition.... 105
" " " processes of secondary deposition.... 109
" " " source of the metals and age of the deposits.... 111
" " " structural features.... 90
" " " surficial alteration and secondary deposition.... 100
" " " textural features.... 91
Mineralogy.... 74
" of contact metamorphic deposits.... 138
" " shear zones.... 86
" " stocks.... 130
Minerals, description of.... 77, 115, 132
Mining.... 113
Miocene.... 13, 30, 61, 70
" lavas.... 20, 72
" volcano.... 71
Mogul claim.... 132, 136
Molybdenite.... 81
Morainal deposits.... 21, 72
Mosher ridge.... 33

N.

Nepanee claim.... 130, 133
Newman, C.... 137
Nicola formation.... 9, 30, 41
Nipple mountain.... 13, 20, 57, 59
" Mountain lavas.... 17
" " series.... 13, 57, 70
" " " age and correlation.... 60
" " " distribution.... 57
" " " lithology.... 57
" " " metamorphism.... 58
" " " relation to other formations.... 59
" " " structure.... 58

O.

O. K. claims.... 82, 136
Okanagan batholith.... 46
Oligocene.... 13, 30, 31, 56, 61, 69, 70
Oligoclase.... 68, 69

PAGE
Ore deposits 73
" " types of. 14
" variations of, in depth 108
Oroville-Nighthawk mining district 41
Orthoclase 68
Osoyoos batholith 47

P.

Palæozoic 30
Paragenesis 91
Pennsylvanian 29
Penticton 22
Peterson, Joseph 137
Phoenix volcanic series 9, 41
Pirsson, L. V. 3
Plants, land 70
Pleistocene 72
Pliocene 72
Pre-Cambrian 29
Previous work 7
Production 114
Pyrargyrite 81, 86
Pyrite 82, 86
Pyrrhotite 82
Pyrrhotite-bearing stocks 131

Q.

Quartz 82, 86
" diorite. See Westkettle quartz diorite batholith.
" monzonite. See Beaverdell quartz monzonite.
Quaternary deposits 61

R.

Rambler mine 81, 89, 92, 120
Rambo, W. H. 120
Red mountain 58
Remnel batholith 47
Rendell camp 6
Replacement 105
River deposits 62
" " lithology of 63
" " structure of 63
Road material 17, 144
Rob Roy mine 78, 81, 90, 97, 116
Roberts, R. 136
Robertson, William Fleet 7
Rossland group 40

S.

St. John 130
" claim 134
" ridge 9, 16, 33, 59
Sally group 6, 45, 116

PAGE
Sally mine.... 81, 89
" No. 1.... 94, 95
" No. 2.... 89, 93
Scheelite.... 17, 142
Schists.... 37
Sericite.... 83, 86
Serpentine.... 143
Shuswap series.... 29
Silver.... 80, 81, 83, 84, 86
" Dollar claim.... 82, 132, 136
" -lead ore-bodies.... 67
Smith, Ed. G.... 3
Sphalerite.... 84, 86
Stansfield, John.... 2
Stocks.... 16, 73
" description of.... 129
" future possibilities.... 132
" genesis of.... 131
" prospects located on.... 132
Structure, columnar.... 71
Sulphur.... 77, 82
Sutherland schists.... 40

T.

Table of formations.... 32
" " minerals in the Beaverdell area.... 75
Talus, consolidated.... 69
Terraces.... 21, 62, 72
" elevation of.... 63
Tertiary.... 13, 30, 56, 57
Tetrahedrite.... 84, 86
Thompson river.... 30
Throuston, E. H.... 126
Timber.... 24
Topographic map.... 2
Topography.... 9, 18
" local.... 19
" regional.... 18
Transportation.... 3
Trapper creek.... 41
Triassic.... 64
Triple lakes.... 5, 16, 48, 136
Tuffs.... 34, 69
Tungsten.... 142
Turgite.... 84
Turnbull, G. M.... 3
Tuzo's claim.... 133
Tuzo, J.... 133

U.

Uplands.... 20

V.

PAGE
Valleys 21
Values, Burns and Larson's claims 135
" Buster claim 125
" Carmi mine 127
" Duncan and Bounty Fraction claim 122
" Ellsworth claim 134
" Mogul claim 136
" Nepanee " 133
" O. K. group 136
" Sally mine 116
" Scheelite 143
" Silver Dollar claim 137
Vancouver and Boundary Creek Development and Mining Company .. 116
Vegetation 24
Vents, volcanic 70, 72
Volcanoes, extinct 20

W.

Wabash claim 79, 125
Wallace group 9, 17, 31, 33, 63, 64, 65, 68, 88
" " age and correlation 40
" " distribution 33
" " lithology and metamorphism 34
" " relations to other formations 39
" " structure 38
" lake 42
" mountain 5, 6, 13, 14, 15, 33, 53, 57, 70, 86, 87
" Mountain Mining Company 122
" schist 51
Washington shaft 88
Wellington claim 92
Westkettle batholith 64, 68, 69
" diorite 16
" quartz diorite 11, 31, 41, 87, 113
" " " age and correlation 46
" " " distribution 42
" " " dykes related to 43
" " " lithology of 42
" " " metamorphism 44
" " " relation to other formations 46
" " " structure 45
" river 1, 5, 9, 20, 21, 63
" valley 9, 33
Wilson, W. J 56
Wollastonite 85
Wood, Robert 116
Wookey, S. I 2
Wright, W. J 3

Z.

Zinc 84

LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY

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

Memoirs and Reports Published During 1910.

REPORTS.

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

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

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

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

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

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

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of new Brunswick—by Lawrence M. Lambe.

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

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

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

MEMOIRS—TOPOGRAPHICAL SERIES.

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

Memoirs and Reports Published During 1911.

REPORTS.

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

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

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

Summary Report for the calendar year 1910. No. 1170.

MEMOIRS—GEOLOGICAL SERIES.

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

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

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

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

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

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

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

MEMOIRS—BIOLOGICAL SERIES.

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

Memoirs and Reports Published During 1912.

REPORTS.

Summary Report for the calendar year 1911. No. 1218.

MEMOIRS—GEOLOGICAL SERIES.

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

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

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

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

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

Memoirs and Reports Published During 1913.

REPORTS, ETC.

Museum Bulletin No. 1: contains articles Nos. 1 to 12 of the Geological Series of Museum Bulletins, articles Nos. 1 to 3 of the Biological Series of Museum Bulletins, and article No. 1 of the Anthropological Series of Museum Bulletins.

Guide Book No. 1. Excursions in eastern Quebec and the Maritime Provinces, parts 1 and 2.

Guide Book No. 2. Excursions in the Eastern Townships of Quebec and the eastern part of Ontario.

Guide Book No. 3. Excursions in the neighbourhood of Montreal and Ottawa.

Guide Book No. 4. Excursions in southwestern Ontario.

Guide Book No. 5. Excursions in the western peninsula of Ontario and Manitoulin island.

Guide Book No. 8. Toronto to Victoria and return *via* Canadian Pacific and Canadian Northern railways; parts 1, 2, and 3.

Guide Book No. 9. Toronto to Victoria and return *via* Canadian Pacific, Grand Trunk Pacific, and National Transcontinental railways.

Guide Book No. 10. Excursions in Northern British Columbia and Yukon Territory and along the north Pacific coast.

MEMOIRS—GEOLOGICAL SERIES.

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

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

MEMOIR 26. *No. 34, Geological Series.* Geology and mineral deposits of the Tulameen district, B.C.—by C. Camsell.

MEMOIR 29. *No. 32, Geological Series.* Oil and gas prospects of the northwest provinces of Canada—by W. Malcolm.

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

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

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

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

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

Memoirs and Reports Published During 1914.

REPORTS, ETC.

Summary Report for the calendar year 1912. No. 1305.

Museum Bulletins Nos. 2, 3, 4, 5, 7, and 8 contain articles Nos. 13 to 22 of the Geological Series of Museum Bulletins, article No. 2 of the Anthropological Series, and article No. 4 of the Biological Series of Museum Bulletins.

Prospector's Handbook No. 1: Notes on radium-bearing minerals—by Wyatt Malcolm.

MUSEUM GUIDE BOOKS.

The archæological collection from the southern interior of British Columbia—by Harlan I. Smith. No. 1290.

MEMOIRS—GEOLOGICAL SERIES.

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

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

MEMOIR 30. *No. 40, Geological Series.* The basins of Nelson and Churchill rivers—by William McInnes.

MEMOIR 20. *No. 41, Geological Series.* Gold fields of Nova Scotia—by W. Malcolm.

MEMOIR 36. *No. 33, Geological Series.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C.—by C. H. Clapp.

MEMOIR 52. *No. 42, Geological Series.* Geological notes to accompany map of Sheep River gas and oil field, Alberta—by D. B. Dowling.

MEMOIR 43. *No. 36, Geological Series.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec—by J. J. O'Neill.

MEMOIR 44. *No. 37, Geological Series.* Clay and shale deposits of New Brunswick—by J. Keele.

MEMOIR 22. *No. 27, Geological Series.* Preliminary report on the serpentines and associated rocks, in southern Quebec—by J. A. Dresser.

MEMOIR 32. *No. 25, Geological Series.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C.—by R. G. McConnell.

MEMOIR 47. *No. 39, Geological Series.* Clay and shale deposits of the western provinces, Part III—by Heinrich Ries.

MEMOIR 40. *No. 24, Geological Series.* The Archæan geology of Rainy lake—by Andrew C. Lawson.

MEMOIR 19. *No. 26, Geological Series.* Geology of Mother Lode and Sunset mines, Boundary district, B.C.—by O. Le Roy.

MEMOIR 39. *No. 35, Geological Series.* Kewagama Lake map-area, Quebec—by M. E. Wilson.

MEMOIR 51. *No. 43, Geological Series.* Geology of the Nanaimo map-area—by C. H. Clapp.

MEMOIR 61. *No. 45, Geological Series.* Moose Mountain district, southern Alberta (second edition)—by D. D. Cairnes.

MEMOIR 41. *No. 38, Geological Series.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick—by Marie C. Stopes.

MEMOIR 53. *No. 44, Geological Series.* Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia (revised edition)—by D. B. Dowling.

MEMOIR 55. *No. 46, Geological Series.* Geology of Field map-area, Alberta and British Columbia—by John A. Allan.

MEMOIRS—ANTHROPOLOGICAL SERIES.

MEMOIR 48. *No. 2, Anthropological Series.* Some myths and tales of the Ojibwa of southeastern Ontario—collected by Paul Radin.

MEMOIR 45. *No. 3. Anthropological Series.* The inviting-in feast of the Alaska Eskimo—by E. W. Hawkes.

MEMOIR 49. *No. 4, Anthropological Series.* Malecite tales—by W. H. Mechling.

MEMOIR 42. *No. 1, Anthropological Series.* The double curve motive in northeastern Algonkian art—by Frank G. Speck.

MEMOIRS—BIOLOGICAL SERIES.

MEMOIR 54. *No. 2, Biological Series.* Annotated list of flowering plants and ferns of Point Pelee, Ont., and neighbouring districts—by C. K. Dodge.

Memoirs and Reports Published During 1915.

REPORTS, ETC.

Summary Report for the calendar year 1913, No. 1359.

Summary Report for the calendar year 1914, No. 1503.

Report from the Anthropological Division. Separate from Summary Report 1913.

Report from the Topographical Division. Separate from Summary Report 1913.

Report from the Biological Division: Zoology. Separate from Summary Report 1914.

Museum Bulletin No. 11. *No. 23, Geological Series.* Physiography of the Beaverdell map-area and the southern part of the Interior plateaus, B.C.—by Leopold Reinecke.

Museum Bulletin No. 12. *No 24, Geological Series.* On Eoceratops canadensis, gen. nov., with remarks on other genera of Cretaceous horned dinosaurs—by L. M. Lambe.

Museum Bulletin No. 14. *No. 25, Geological Series.* The occurrence of Glacial drift on the Magdalen islands—by J. W. Goldthwait.

Museum Bulletin No. 15. *No. 26, Geological Series.* Gay Gulch and Skookum meteorites—by R. A. A. Johnston.

Museum Bulletin No. 17. *No. 27, Geological Series.* The Ordovician rocks of Lake Timiskaming—by M. Y. Williams.

Museum Bulletin No. 6. *No. 3, Anthropological Series.* Pre-historic and present commerce among the Arctic Coast Eskimo—by N. Stefansson.

Museum Bulletin No. 9. *No. 4, Anthropological Series.* The glenoid fossa in the skull of the Eskimo—by F. H. S. Knowles.

Museum Bulletin No. 10. *No. 5 Anthropological Series.* The social organization of the Winnebago Indians—by P. Radin.

Museum Bulletin No. 16. *No. 6, Anthropological Series.* Literary aspects of North American mythology—by P. Radin.

Museum Bulletin No. 13. *No. 5, Biological Series.* The double crested cormorant (Phalacrocorax auritus). Its relation to the salmon industries on the Gulf of St. Lawrence—by P. A. Taverner.

MEMOIRS—GEOLOGICAL SERIES.

Memoir 58. *No. 48, Geological Series.* Texada island—by R. G. McConnell.

Memoir 60. *No. 47, Geological Series.* Arisaig-Antigonish district—by M. Y. Williams.

Memoir 67. *No. 49, Geological Series.* The Yukon-Alaska Boundary between Porcupine and Yukon rivers—by D. D. Cairnes.

Memoir 59. *No. 55, Geological Series.* Coal fields and coal resources of Canada—by D. B. Dowling.

Memoir 50. *No. 51, Geological Series.* Upper White River District, Yukon—by D. D. Cairnes.

Memoir 65. *No. 53, Geological Series.* Clay and shale deposits of the western provinces, Part IV—by H. Ries.

Memoir 66. *No. 54, Geological Series.* Clay and shale deposits of the western provinces, Part V—by J. Keele.

Memoir 56. *No. 56, Geological Series.* Geology of Franklin mining camp, B.C.—by Chas. W. Drysdale.

Memoir 64. *No. 52, Geological Series.* Preliminary report on the clay and shale deposits of the Province of Quebec—by J. Keele.

MEMOIR 57. *No. 50, Geological Series.* Corundum, its occurrence, distribution, exploitation, and uses—by A. E. Barlow.

MEMOIR 68. *No. 59, Geological Series.* A geological reconnaissance between Golden and Kamloops, B.C., along the line of the Canadian Pacific railway—by R. A. Daly.

MEMOIR 69. *No. 57, Geological Series.* Coal fields of British Columbia—by D. B. Dowling.

MEMOIR 72. *No. 60, Geological Series.* The artesian wells of Montreal—by C. L. Cumming.

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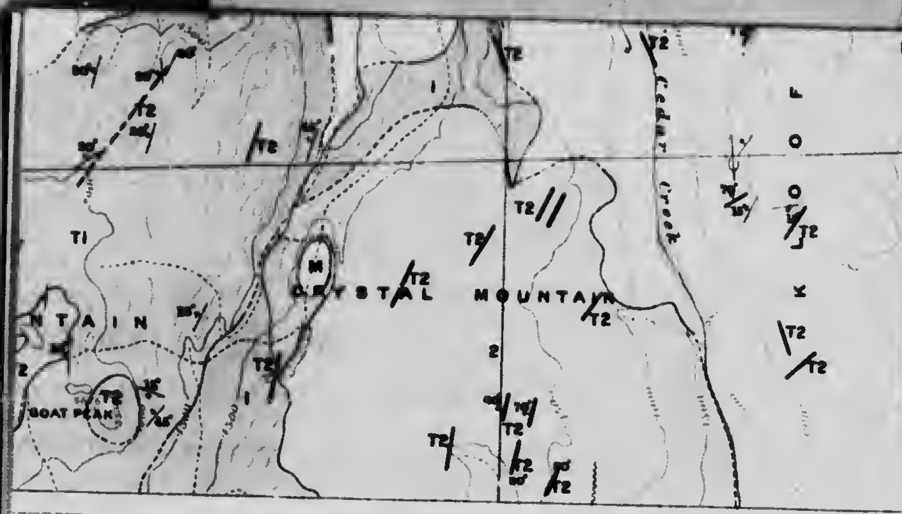
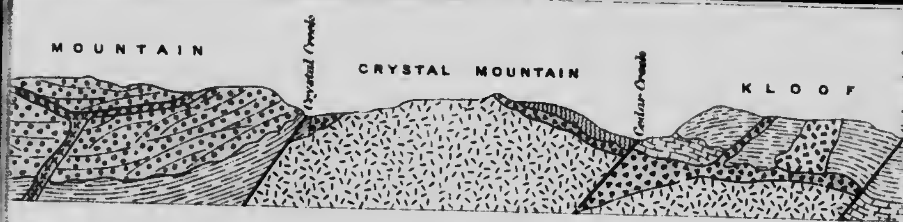


gitude West from Greenwich 119°00'



ttle batholith (quartz diorite) — hornblende diorite porphyry — augite andesite dykes and flows — hornblende andesite tuff — hornblende dacite schists

ullace group

ctural section along line E-F
orizontal and vertical scale, 1/62,500

MAP 37 A
(Issued 1915)

EAVERDELL

YALE DISTRICT

BRITISH COLUMBIA

GEO

L.REINECKE,

TOPOG

L.REINECKE, (IN CHA

Scale, 1/62,500

Miles 1 2 3

Kilometres 1 2 3 4 5

te. For practical purposes assume
1 MILE TO 1 INCH

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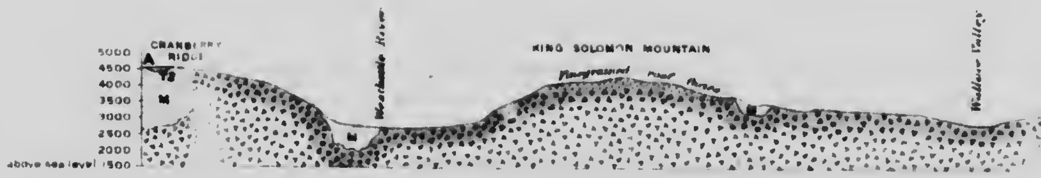
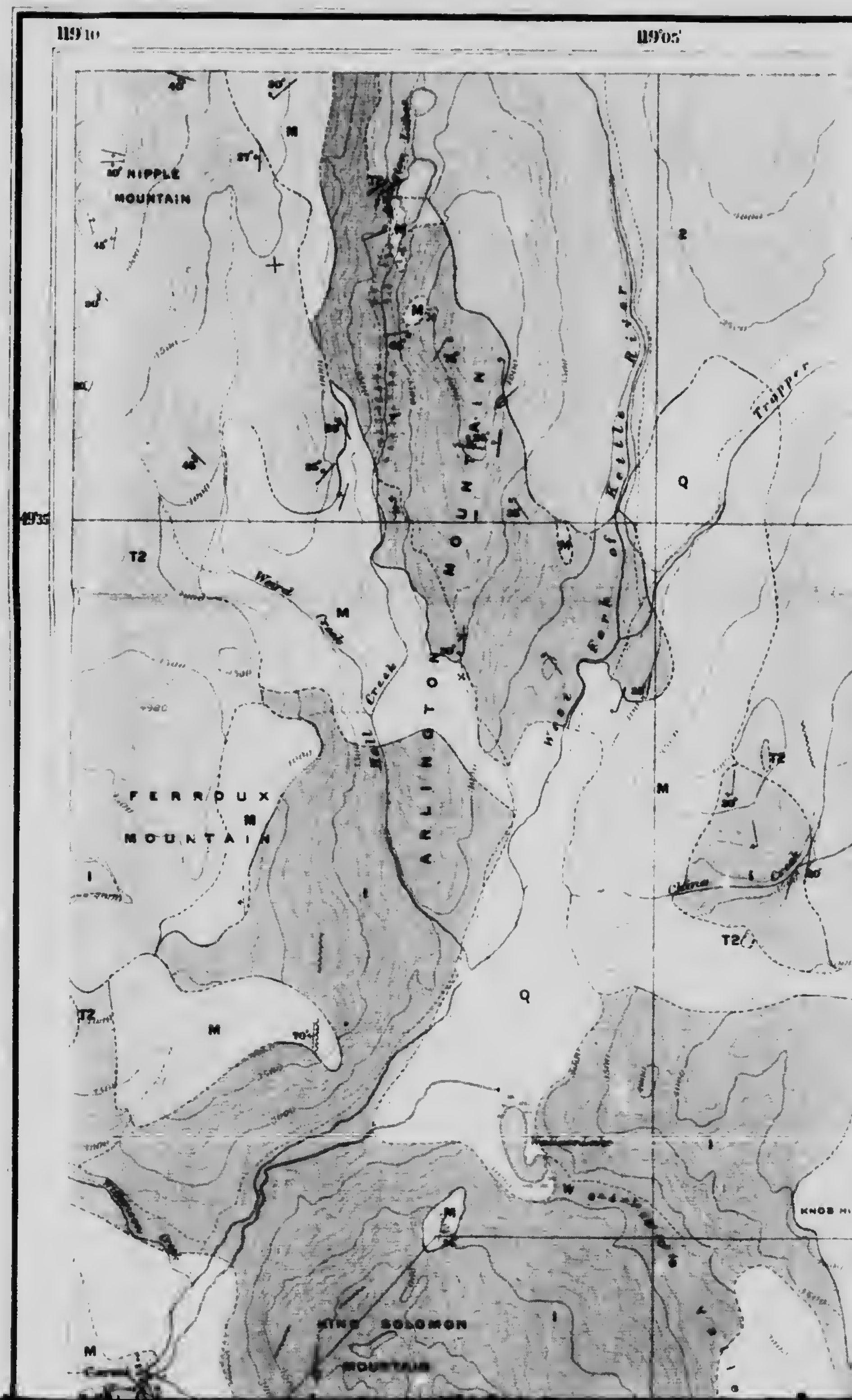
HON L CODERRE, V

GE



Structural
Horiz



LEGEND

QUATERNARY		Q	River alluvium; glacial drift
TERTIARY	MIOCENE ?	T2	Nipple Mountain series *unaltered lava flows and dykes*
	OLIGOCENE	T1	Curry Creek series *dacite tuffs, conglomerates*
	EOCENE	3	Augite syenite porphyry
		2	Beaverdell batholith *quartz monzonite and dykes*
MESOZOIC	JURASSIC ?	1	Westkettle batholith *quartz diorite and dykes*
		M	Wallace group *metamorphosed igneous rocks, largely lavas and tuffs, with sediments at base; basal portion possibly carboniferous*

Symbols

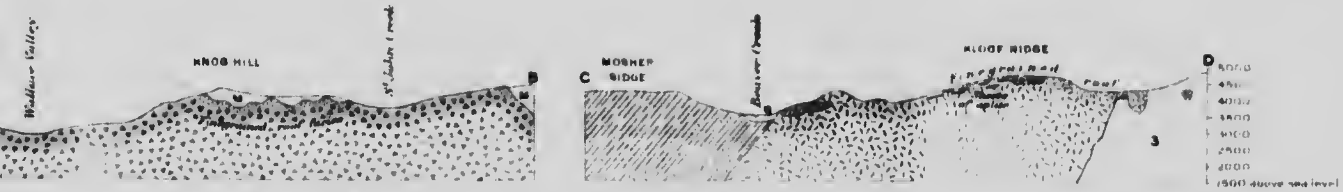
Geological boundary *clearly located*

Geological boundary *located with a possible error of 500 1200 feet*

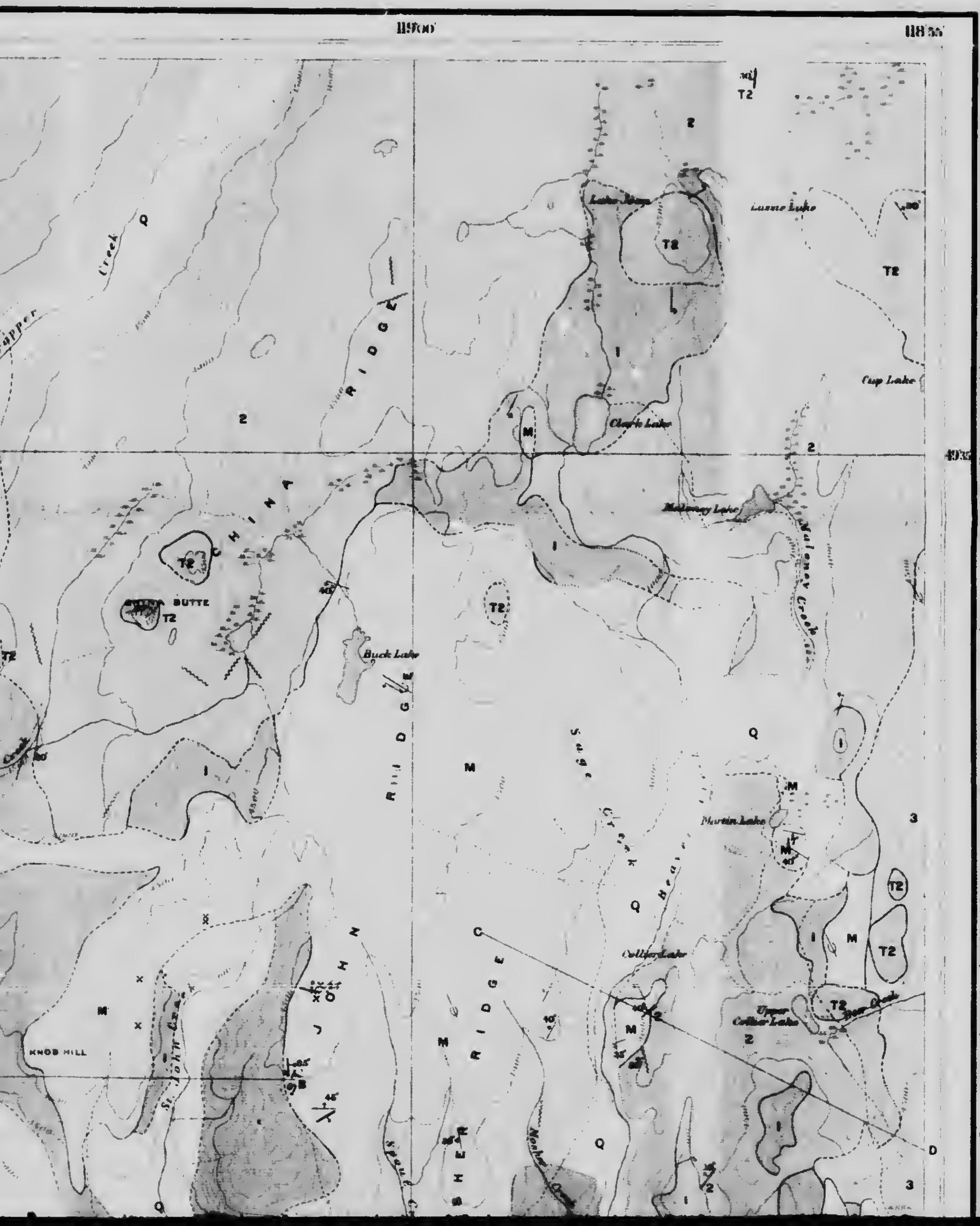
Canada
Department of Mines

...DERRE, MINISTER, R.G. McCONNELL, DEPUTY MINISTER

GEOLOGICAL SURVEY



...tructural sections along lines A B, C D
Horizontal and vertical scale, 62500



LEGEND

Culture

Roads and buildings

Trails

Bridges

Post offices

Shafts

Tunnels

Prospects

Bench marks

Water

Rivers and lakes

Streams, flow disappearing

Geological boundary
closely located

Geological boundary
located with a possible error of 500-1200 feet

Geological boundary
position assumed

Horizontal strata

Dip and strike of strata and flows

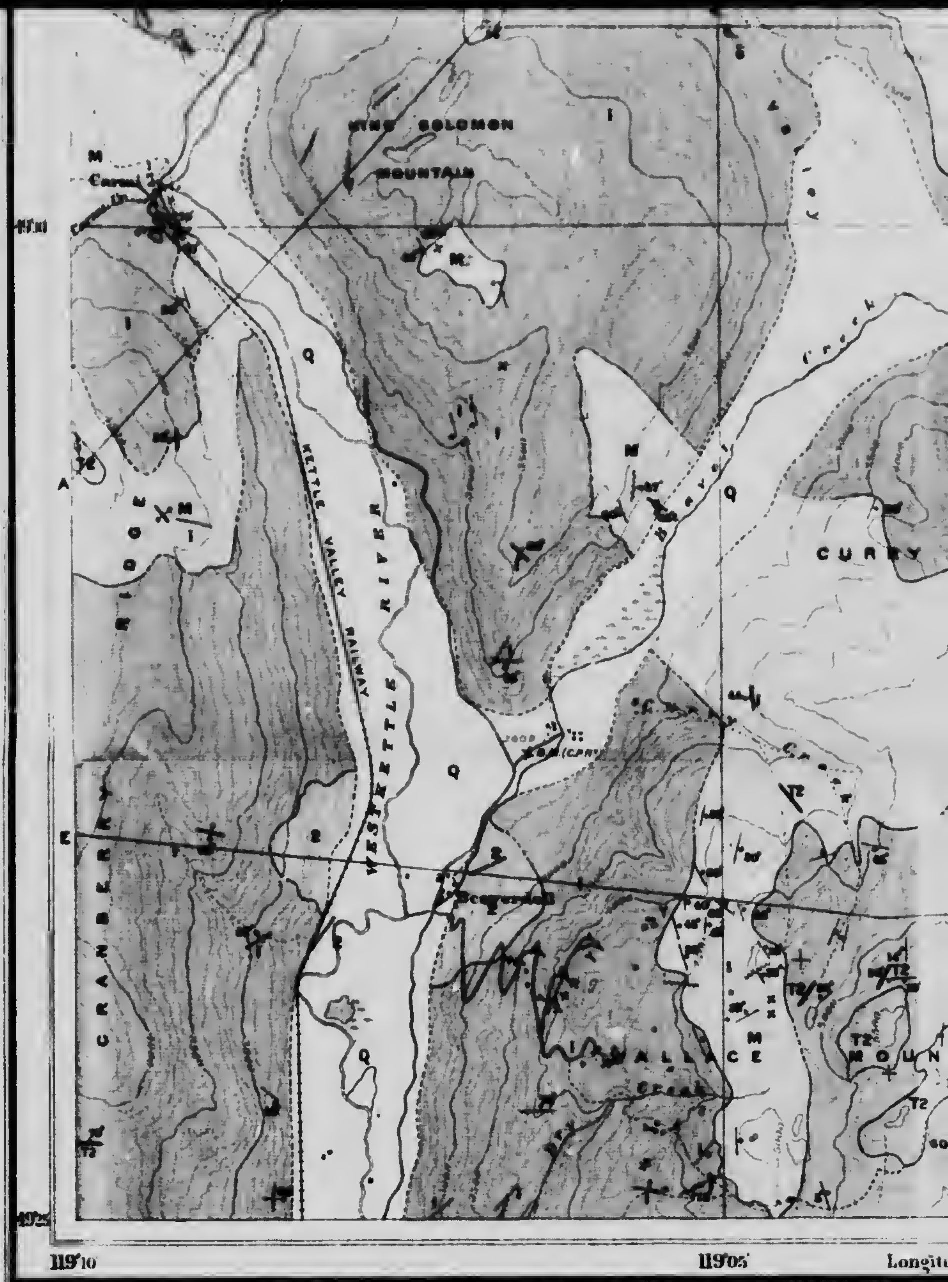
Dip and strike of dykes, veins, and fractures

Dip and strike of planes of foliation

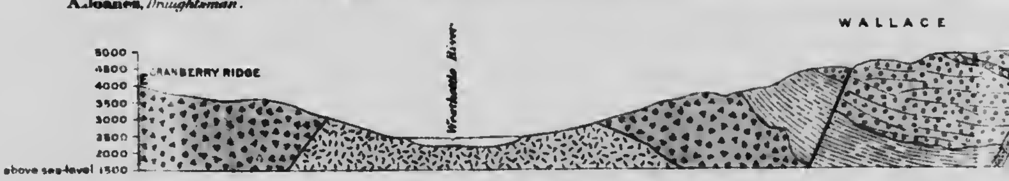
Veins

Fractures
zones of brecciation; faults

Glacial striæ



C.O.Senécal, *Geographer and Chief Draughtsman.*
A.Joanes, *Draughtsman.*



River alluvium | Nipple Mountain series *(dyke)* | Curry Creek series *conglomerates* | Beaverdell batholith *quartz monzonite)* | Westkettl...

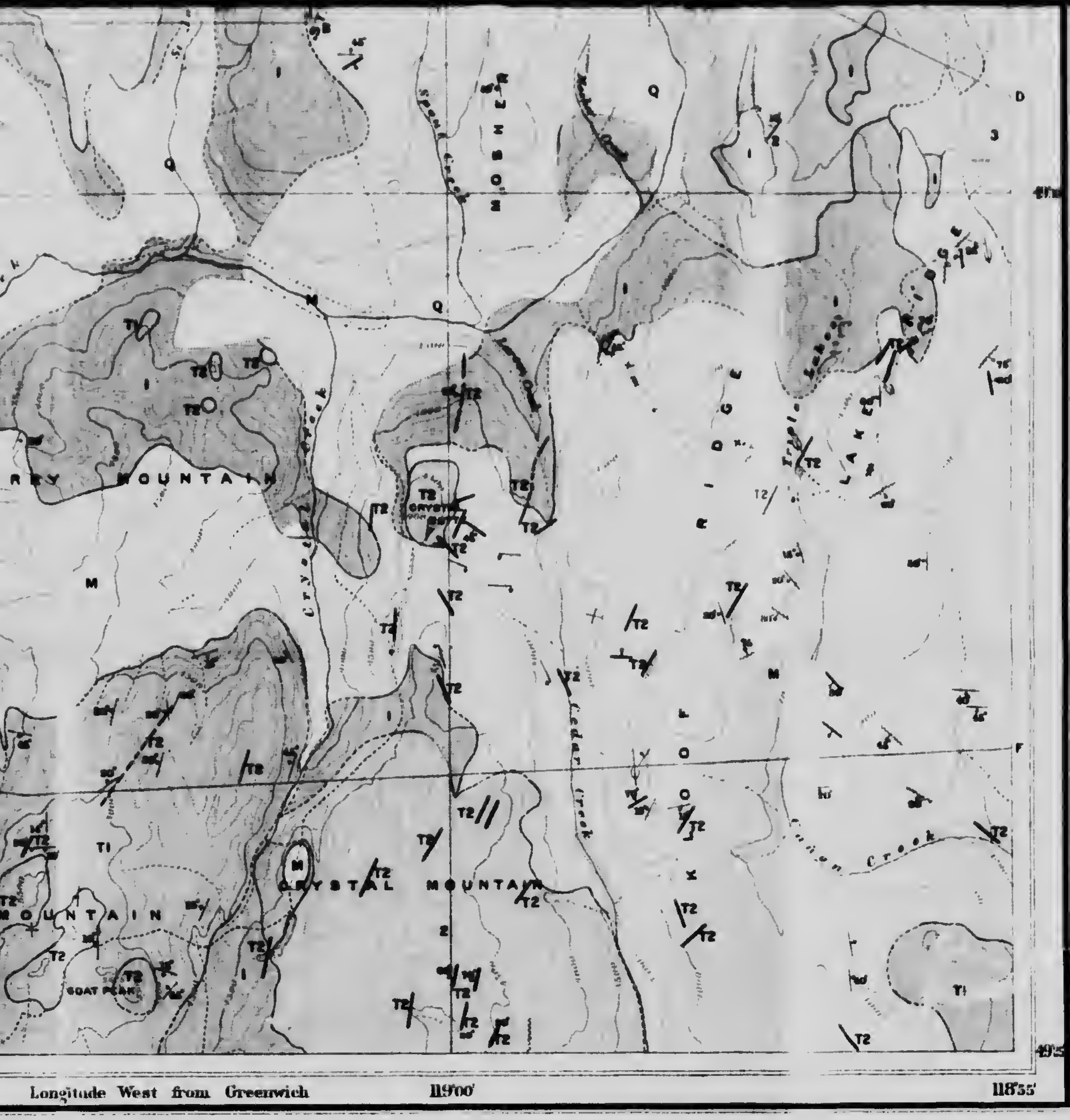
Structu...

Scale, 100 Miles to 1 Inch

BE...
YA...
B...

Note ...

To accompany Memoir by L. Reinecke



Rivers and lakes

Streams, flow disappearing in places

Watercourses with intermittent flow

Marshes

Relief

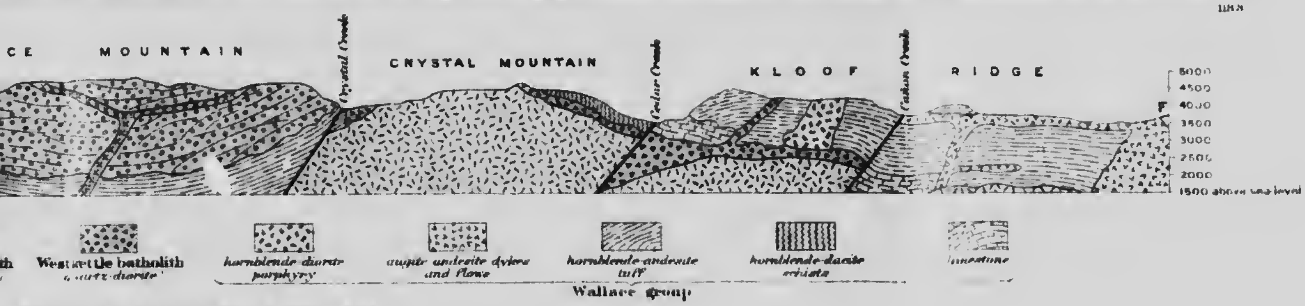
Contours showing land forms and elevations above sea level. Interval, 100 feet

Figures showing heights in feet above sea level

Geographical position subject to revision

Magnetic declination about 24°10' East

Determination of contours based on elevation of C.P.R. bench mark



Structural section along line E-F

Horizontal and vertical scale, 1/62,500

MAP 37 A

(Issued 1915)

BEAVERDELL

YALE DISTRICT

BRITISH COLUMBIA

Scale, 1/62,500

Miles 0 1 2 3

Kilometres 1 2 3 4 5

Note For practical purposes assume **1 MILE TO 1 INCH**

GEOLOGY

L. REINECKE. 1911.

TOPOGRAPHY

L. REINECKE, IN CHARGE 1909, 1910.