CANADA

DEPARTMENT OF MINES

Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister

GEOLOGICAL SURVEY

W. H. Collins, Director

Summary Report, 1924, Part A

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OTTAWA

F. A. ACLAND

PRINTER TO THE KING'S MOST EXCELLENT MAJESTY

1925

No. 2066

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SUMMARY REPORT, 1924, PART A

UPPER BEAVER RIVER AREA, MAYO DISTRICT, YUKON

By W. E. Cockfield

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Illustrations

INTRODUCTION

Silver-lead deposits were discovered in 1922 on McKay hill, in the vicinity of Upper Beaver river, and as the discovery followed so closely that of Keno hill, a stampede to the area occurred, and numerous claims were staked. Subsequent prospecting, however, showed that the deposits were low grade, and many of the claims were abandoned. In 1923, prospecting of the area continued and resulted in the discovery of the deposits on Silver hill, and also of high-grade float on Grey Copper hill. These discoveries did not become known until midwinter when a second stampede to the area took place and some fifty claims were staked around the discovery claims of Grey Copper hill. As the staking took place in the winter it was not until the spring of 1924 that any development could be undertaken, and on account of the retarded summer very little effective work could be done on most of the claims until June or July. Many of the claims, therefore, had no showings of mineral in place on them.

In 1923 the writer made a hurried trip to McKay hill, and a report on the properties there was published.[1] In 1924 about two months were spent in the area. The work included the mapping, on a scale of 2 miles to the inch, of an area including all the known deposits, and the preparation of more detailed plans of some of the deposits. The writer was assisted in this work by Messrs. C. H. Stockwell, B. B. Brock, and S. Gibson, all of whom performed their duties in a highly satisfactory manner. Thanks are also due to the prospectors met in the district, who assisted in many ways in forwarding the work.

[1] Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1923, pt. A, pp. 22-30.

LOCATION AND MEANS OF ACCESS

Upper Beaver River area as mapped comprises that part of the watershed of Beaver river lying to the west of Braine creek. The area is best reached by means of the stampeders' trail from Keno hill to McKay hill. This trail, although designed as a winter route and swampy in part, nevertheless affords a fair summer route to the area, and offers no insuperable difficulties to the use of pack animals. It follows the valley of the south fork of McQuesten river to McQuesten lake, and thence crosses the hills to the valley of the north fork of McQuesten river, which is followed nearly to its head, where a low pass leads to Beaver River valley. From this point two routes are available to the different properties; the trail which follows up Falls creek, passing McKay hill, and crossing a high summit to Police creek where it terminates, is most used in summer. From Police creek to the various properties on Carpenter creek, trails are scarcely necessary as the country is open and the gravel bars of the creeks afford good travelling. The northern descent of the pass from McKay hill is somewhat steep and during the early part of the summer is blocked by deep snow-drifts. The second route follows Beaver valley to the mouth of Carpenter creek and thence up Carpenter creek to the various properties. This is a good route in winter, but in summer that part of Beaver valley which it traverses is swampy. The distances of McKay hill, Grey Copper hill, and Silver hill from Mayo, following the Keno Hill road and the stampeders' trail, are approximately 87, 99, and 107 miles, respectively.

It may also be pointed out that a canoe route to the area is available. In 1905 Camsell and Keele, of the Geological Survey, ascended Stewart and Beaver rivers as far as the mouth of Braine creek, and it seems probable that gasoline launches might ascend Stewart and Beaver rivers from Frazer falls to the mouth of Rackla river. This, however, would require portaging around Frazer falls some 50 miles above Mayo in order to establish communication with lower Stewart river.

TOPOGRAPHY

Upper Beaver River area lies within the Ogilvie range, a spur of the Mackenzie Mountain system. The Ogilvie range at this point forms the height of land between Yukon and Mackenzie Rivers basins, and separates the waters of the Stewart on the one hand from those of the Peel on the other. The range is rather rugged; the higher peaks attain elevations of 6,500 to 6,700 feet above sea-level. Few peaks exceed this elevation. The floors of the larger valleys stand at elevations of from 2,500 to 3,000 feet. The maximum vertical relief is, therefore, around 4,000 feet.

The hills are long, branching ridges with knife-edged crests, surmounted by small, ragged peaks mostly composed of the more resistant rocks. Towards the height of land the presence of a somewhat flat-lying limestone has a marked effect upon the topography, as, owing to differential erosion, it weathers into castellated forms with numerous cliff faces, giving to the hills an extremely rugged appearance.

The main valleys are longitudinal, following in a general way the trend of the strata. Only one of these valleys occurs in the area mapped, namely Beaver River valley; but Camsell[1] notes the parallelism of the valley of Nash creek and upper Wind river with that of Beaver river. The valley of Beaver river upstream from the mouth of Braine creek has a general northwest trend, with a width of 2 to 3 miles. The main branch of Beaver river enters this valley from the southwest at the mouth of Carpenter creek; the main valley, however, continues to the northwest and is occupied in turn by parts of Carpenter, Police, and McLean creeks, and, across the divide, by a stream tributary either to Wind river or Hart river. The divide between Police creek and this stream is formed by a low, gravel ridge.

Beaver valley is joined by shorter and narrower transverse valleys. The two principal valleys of this type are those of Braine and Carpenter creeks; that of Braine creek has been described by Camsell[2] in detail, and the valley of Carpenter creek so closely corresponds to the description that it need not be described at length. In general, it may be said that these valleys have each several parts with steep grades, or even canyons, between which the stream bed spreads out over the entire valley floor in a network of ever-changing channels, forming typical braided watercourses. These broad gravel flats, having a width of half a mile or more, in the spring are occupied by large sheets of ice 8 to 10 feet thick, caused by the overflowing of the water in cold weather. In the upper parts of the valleys it is doubtful whether these ice-sheets entirely disappear during the summer, as in August one several acres in extent and having a thickness of from 6 to 20 inches was noted on Carpenter creek.

The larger valleys afford good proof that they were glaciated during the Pleistocene period, On the upper part of Carpenter creek, the level of the ice did not extend much above the present-day timber-line, that is about 4,500 feet above sea-level. Below that level the valley exhibits the scouring typical of a glaciated valley, with numerous glacial forms and striæ. Above it the hills rise in bold, rocky faces totally devoid of any signs of glaciation. In the lower reaches of the valleys the elevation attained by the ice was somewhat lower. The direction of ice movement, where determined, was apparently outward from the crest of the range.

GEOLOGY

GENERAL STATEMENT

The rocks exposed in this part of the Ogilvie range comprise both sedimentary and igneous types; the former, however, predominate and underlie by far the greater part of the area. The sediments have been divided into three main groups and the igneous rocks into two groups. The following table gives the general subdivisions of the rocks, and the age relations will be discussed in connexion with each group.

[1] Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, pp. 17 CC.
[2] Camsell, C., Idem., pp. 11 CC–14 CC.

Era	——	Lithology
Quaternary....................	Superficial deposits.............	Chiefly valley accumulations; gravel, sand, muck, and glacial deposits
		Augite diorite
		Augite andesite with tuffs and breccias
Palæozoic	Devonian to Ordovician.........	Limestone and shaly limestone
		Volcanic agglomerate, shale, and sandstone
Precambrian (?)..............	Tindir group (?)................	Calcareous sandstone, slate, argillite, and limestone
		Quartzite, slate, limestone, and conglomerate

PRECAMBRIAN (?)

The Precambrian (?) group, consisting of quartzite, slate, limestone, and conglomerate, occurs only to the south of the main depression forming the valleys of Beaver river and Police creek. On account of the fact that wherever found the rock assemblage was separated by this wide valley from the other rocks of the district, its age relations were not obtained. From a study of the lithology it seems probable that this group, together with the second Precambrian? group formed of calcareous sandstone, slate, argillite, and limestone, represents the Tindir group described by Cairnes[1] from the International Boundary section. On the boundary the age of the Tindir group was determined as pre-Middle Cambrian, with a strong probability that the rocks are Precambrian. In Beaver River area, the second of the two groups mentioned is known to be pre-Ordovician. The lithological characters of the rocks in Beaver River area and on the boundary 200 miles away are in many respects identical, but as similar rocks have been described only from one intervening point[2] and where also their age was not determined, any correlation must remain entirely tentative until further work be done.

The quartzites are white, light grey, or blue, and at a distance may easily be mistaken for limestone. They are metamorphosed to a certain extent, but have not suffered nearly so much in this respect as the quartzites of the Yukon group. Under the microscope they are seen to consist of interlocking grains of quartz and feldspar with a small amount of sericite and, in some specimens, calcite or dolomite. Occasional beds contain a certain amount of mica and chlorite arranged in streaks between layers of purer quartzite. The quartzites occur mainly to the south of Beaver river, and interbedded with them are beds and bands of white crystalline limestone, and red and green slates. The latter occur as narrow beds between more massive beds of quartzites. The limestone on the other

[1] Cairnes, D. D., "The Yukon-Alaska International Boundary," Geol. Surv., Can., Mem. 67, 1914, pp. 44-57.
[2] Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1918, pt. B, p. 16.

Canada
Department of Mines

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GEOLOGICAL SURVEY

W. H. COLLINS, DIRECTOR.

Issued 1925

LEGEND

Superficial deposits
(glacial and stream deposits, soil and muck)

Augite diorite

Greenstone: chiefly hornblende and augite andesites, with associated tuffs and breccias

DEVONIAN TO ORDOVICIAN

3 Limestone and shaly limestone

4 Shale, tufaceous agglomerate with intercalated greenstone

Unconformity

5 Calcareous sandstone, slate, argillite and limestone

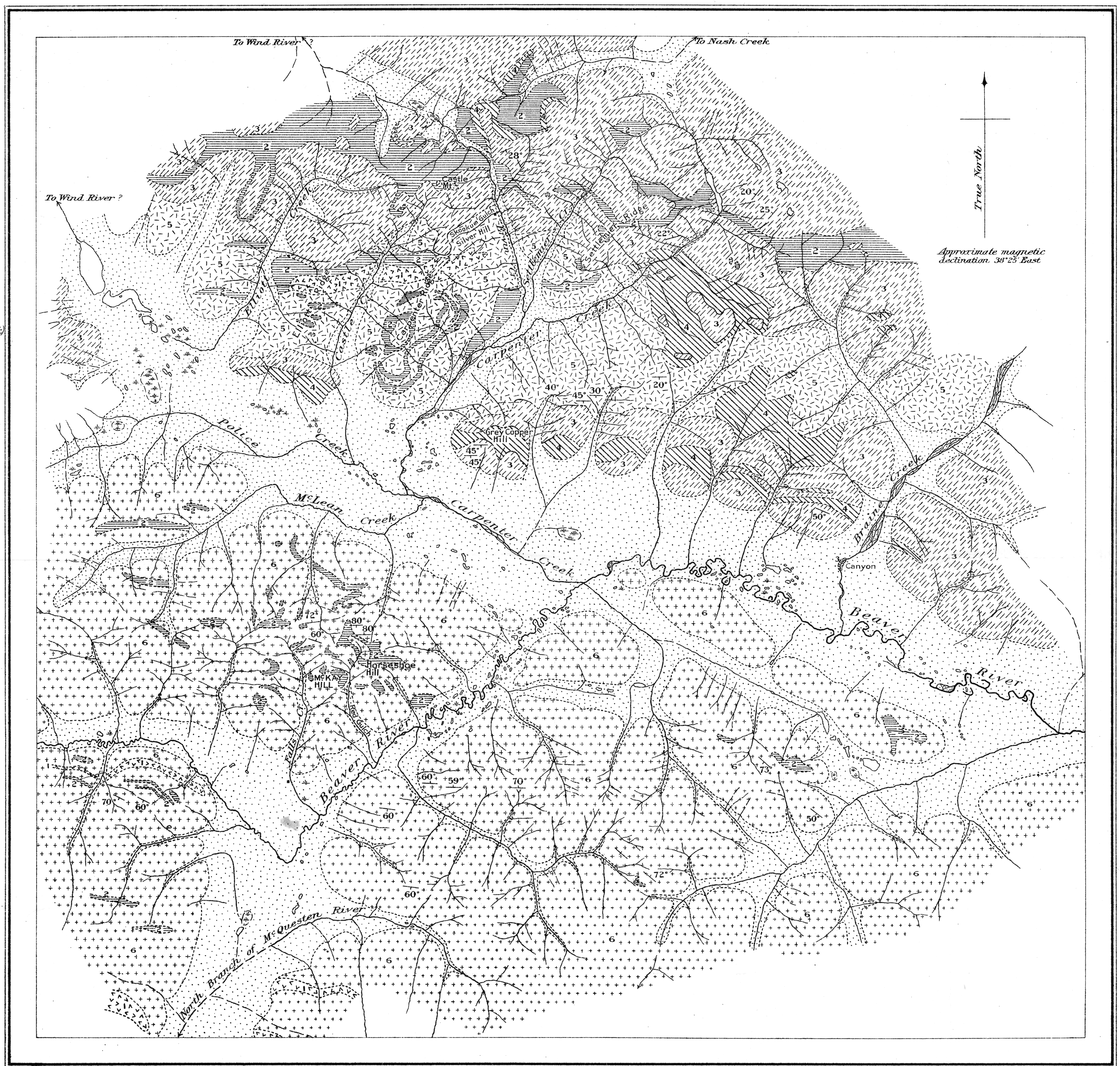
6 Quartzites and vari-coloured slates

Symbols

Geological boundary

Dip and strike

Glacial striæ



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

Publication No. 2064

UPPER BEAVER RIVER AREA, MAYO DISTRICT, YUKON.

To accompany Report by W. E. Cockfield, in Summary Report, Part A, 1924.

Scale of Miles
1 0 1 2 3 4

Geography and geology by W. E. Cockfield, *1924.*

hand in many places attains thicknesses of 50 feet or more, but the beds apparently die out along their strike to be replaced by others at different horizons.

Between Beaver river (west of the mouth of Carpenter creek) and Police creek, slates predominate. These are red, green, grey, or black and included in them are thin beds of quartzite and conglomerate, and more massive beds of white or grey crystalline limestone.

The quartzite-slate group is closely folded and in many places faulted. Between Police creek and Beaver river the dip is prevailingly to the north, but changes rapidly from place to place indicating an extremely complex structure. To the south of the Beaver the dips are prevailingly to the south and mostly at from 50 to 85 degrees.

The pre-Ordovician sediments to the north of the main depression forming the valleys of Beaver river and Police creek, are calcareous or dolomitic sandstones and limestone, with slates and argillites. These rocks weather a dull red to brown and viewed from a distance give the hills a bright red appearance perceptible at distances of 50 miles or more. As these form the country rock of some of the ore deposits this feature is of some importance, for the areas where such rocks occur may be discerned from a distance.

The calcareous or dolomitic sandstones are composed of varying proportions of calcite or dolomite, and quartz. Viewed under the microscope the rocks are seen to be extremely fine in grain, with calcite or dolomite, and quartz, arranged in layers, giving to the rock a laminated appearance; this lamination is accentuated in weathering by the solution of the more readily soluble material. Associated with these are smaller amounts of sandy, white limestone. The slates are red to brown, and break readily into plates 1 to 2 feet in diameter. Associated with the slates are dark-coloured or black argillites. These rocks are everywhere closely folded and, in many places, faulted.

VOLCANIC AGGLOMERATE, SHALE, AND SANDSTONE

The principal exposures of these rocks are found near the base of the Ordovician-Devonian limestone. Outcrops at other localities, however, suggest that they may occur also at higher horizons. The thickness varies rapidly from place to place. On the upper part of Carpenter creek these rocks are exposed on the eastern side of the creek, on a steep hillside, where they attain a thickness of considerably over 1,000 feet. To the west of Carpenter creek they thin rapidly and finally disappear. They are again developed, but apparently at a higher horizon, to the north of Castle mountain; along the hills facing Beaver valley these rocks appear in a narrow, yet continuous, band close to the base of the limestone.

The major part of the material is volcanic in origin, and is probably related to the augite andesites, but differs from the agglomerates directly associated with the andesites in that rounded pebbles and boulders of rocks other than greenstone are also present. Lithologically the bulk of the rock is composed of augite-mica andesite, and is dark green to dark purple. Microscopically the rocks consist mostly of secondary minerals chiefly chlorite and calcite. Occasional crystals of biotite and augite occur, and in some specimens patches of brown volcanic glass. The feldspars are turbid and altered. The groundmass is largely altered to calcite, but where preserved is microcrystalline. Pebbles and boulders of the Tindir and other rocks, quartzite, slate, limestone, calcareous sandstone, and greenstone were observed. The number of pebbles varies greatly from place to place. In certain parts, however, they are fairly abundant. Associated with the agglomerate are beds of dark-coloured shales and sandstones.

ORDOVICIAN-DEVONIAN LIMESTONE

This limestone is almost invariably white or slate-coloured, and as a whole is somewhat massive-bedded over the greater part of the area, though shaly and sandy members are present.

The limestone occurs in two areas or bands; one of these outcrops along the hills bordering Beaver valley on the north, and the other occupies the larger part of the northern part of the area. These two bands are thought to represent the limbs of an anticline, the central part of which has been removed by erosion. The southern band has a dip of 25 to 50 degrees to the south and the northern band a gentle dip to the north. To the north and west, beyond the area surveyed, the limestone apparently flattens, and, farther away, assumes a southern dip, forming a broad, shallow syncline.

Fossils are present, but are by no means abundant. Corals are extremely plentiful at various localities, and form coral reefs, but large areas of the limestone appeared unfossiliferous. The following fossils were collected during the summer and determined by E. M. Kindle of the Geological Survey.

Lot No. 7662: Horizon, Devonian
- *Favosites* cf. *digitatus*
- *Favosites* cf. *radiatus*
- *Cyrtina* cf. *umbonata*

Lot No. 7956: Horizon, Silurian
- *Favosites* cf. *favosus*
- *Stromatopora* cf. *antiquua*

Lot No. 7960: Horizon, Silurian
- *Bryozoa* (undeterminable)
- *Megalomus* cf. *canadensis*

Lot No. 7961: Horizon, Silurian
- *Cladopora* cf. *cervicornis*
- *Orthis flabellites*
- *Whitfieldella nitida*

Lot No. 7964[1]: Horizon, Silurian or Ordovician
- *Actinoceras* sp. allied to *A. richardsoni*

Lot No. 7963: Horizon, Silurian or Ordovician
- *Strombodes* sp.
- *Zaphrentis* vel *Streptelasma* sp.
- *Eridophyllum* sp.

Lot No. 7958: Horizon, Silurian and Ordovician
- *Favosites* cf. *favosus*
- *Columnaria alveolata*
- Bryozoa ? not determinable
- *Cornulites* n. sp.
- *Lophospira* sp.

Lot No. 7959: Horizon, Ordovician
- *Columnaria alveolata*
- *Zaphrentis* ? sp.
- *Eridophyllum* cf. *rugosum*
- *Halysites* n. sp.

[1] Donated by J. McLean, Keno hill, Yukon.

Lot No. 7957, consisting of graptolites, was determined by Dr. Ruedemann who reports as follows: "The faunule from the Beaver River district of Yukon Territory is not very good material, but I could make out the following forms, apparently all that there are.

Didymograptus sp. two forms, fragments
Dicranograptus sp. nov. cf. *ramosus* Hall
Climacograptus cf. *antiquus* group
Glyptograptus cf. *teretiusculus euglyphus* (Lapworth)

This faunule would indicate a late Normanskill age for the beds. In *Climacograptus antiquus, Glyptograptus euglyphus,* and the coarser of the *Didymograpti,* it suggests the fauna described by Lapworth from Dease river, and Kicking Horse pass, British Columbia, but the faunule is too small for definite correlation."

Mr. Kindle in reporting on the collection says "The Halysites in lot 7959 represents a type which we generally consider to be confined to Ordovician faunas, and which appears to be identical with a new Richmond species or variety in the Lake Windermere district of British Columbia. Lot 7958 appears to include both Ordovician and Silurian species.

The Ordovician fauna collected by D. D. Cairnes from the Alaska Boundary section[1] (XI K 46) appears to be the same as that represented by faunule 7960 in the above list. The Silurian elements in the collection show Niagaran affinities. The Devonian collection is too small both in individuals and species to offer more than the observation that it probably represents a Middle Devonian horizon."

Lots No. 7956 and 7963 were obtained from the southern limestone area, and the balance of the fossils from the northern area. The Devonian fossils were obtained from one locality only, namely at the head of Carpenter creek, close to the height of land. It seems probable that within the area mapped the Devonian is represented only to a slight extent and that practically all the limestone mapped belongs to the Ordovician or Silurian. No definite break was recognized between these two systems.

The limestone overlies unconformably the calcareous or dolomitic sandstones, slates, and argillites classed as pre-Ordovician. The relations were best determined in the vicinity of Silver hill (Figure 1, section) where the pre-Ordovician rocks dip at 50 to 85 degrees to the west and the limestone 15 degrees to the west. The unconformity is indicated in a similar way on Grey Copper hill and at other points in the area.

As the Ordovician-Devonian does not occur with the Tindir rocks found to the south of Beaver valley, it must be assumed that this area was a landmass during these periods, or that the limestone, if deposited, has since been removed by erosion. In the latter case one would expect to find patches of limestone on the higher summits, as in the area of Tindir rocks immediately to the north of Beaver valley, but no such outcrops of limestone were observed. It, therefore, seems reasonable to assume that this area was a landmass in Ordovician to Devonian times.

AUGITE ANDESITES

Rocks of this type are abundantly developed in the area. They are most numerous in the hills between Beaver river and Police creek, but also

[1] Geol. Surv., Can., Mem. 67, p. 67.

(over)

occur in both the pre-Ordovician rocks and the limestone north of Beaver River valley. In the quartzites to the south of Beaver river they are scarce. Both intrusive and extrusive types are present. Due to better outcrops they are best seen in the limestone areas where they occur chiefly as sills, in some cases persistent over considerable distances. None was noted in the higher parts of the limestone series.

In the area to the south of Beaver valley both intrusive and extrusive types occur. Both are later than the pre-Ordovician sediments, and lacking definite evidence to the contrary are assigned to the same period as the intrusives cutting the limestone farther north.

They are dark green, fine-textured to aphanitic rocks which under the microscope show advanced alteration to secondary minerals. The main constituents are augite and feldspar in a groundmass that is in many places almost completely altered to chlorite and calcite. Associated with them are tuffs and breccias, the latter being composed of angular fragments of the intruded rock and angular and rounded fragments of greenstone. Many of the breccias on examination show angular fragments of greenstone cemented by calcite. Vugs and amygdules occurring in the rock are filled with calcite, which has also replaced neighbouring parts of the rock to form large masses of this mineral. The breccias or agglomerates differ from those previously described in that in addition to greenstone they carry fragments only of the rock intruded, whereas the previously described agglomerates contained rounded fragments of other sedimentary rocks.

No definite data as to the age of the greenstones of Beaver river are available, other than that they are later than the rocks they cut or overlie. In the lack of definite evidence to the contrary, however, the augite andesites may all be considered to belong to one period of igneous activity not older than the Silurian and perhaps Devonian, though the greenstones were not noted cutting the uppermost limestones.

AUGITE DIORITE

The intrusions of augite diorite are of small areal extent. One sill-like mass was noted to the west of Carpenter creek and several sills south of Beaver river. They vary considerably in grain, from coarse to fine, but are holocrystalline and characteristically of a granitic habit. The principal minerals are pyroxene (augite) and plagioclase feldspar (andesine). These are accompanied by secondary minerals, chiefly chlorite and calcite.

The age relations of the augite diorites to the limestone were not definitely determined. At the only point where they were observed in juxtaposition the contact was obscured by talus. The data on the age relations of the diorites and andesites are inconclusive, but it is thought that they belong to the same general period of vulcanism and that cooling under different conditions gave rise to different types.

SUPERFICIAL DEPOSITS

The areas of superficial deposits outlined on the map are the occurrences in the larger valleys where their thickness is probably so great as to preclude the possibility of prospecting bedrock. The areas thus indicate the positions of the major valleys. The superficial deposits represent accumulations of an unknown thickness of gravel, sand, soil, muck, and glacial deposits of Pleistocene and Recent age.

ECONOMIC GEOLOGY

GENERAL STATEMENT

The staking of McKay hill in 1922 led to further prospecting in the district, with the result that deposits were discovered on the south end of Carpenter hill the same summer, followed by the finding of ores on Silver hill and Grey Copper hill in 1923. The only known deposits of mineral in upper Beaver River area occur on these hills and consist of silver-lead and silver-copper ores. Of these, the former are the more plentiful.

The silver-lead ores consist of galena with subordinate tetrahedrite and zinc blende in a gangue of quartz or calcite. A number of samples taken of the veins indicate a relatively low content of silver, and this is confirmed by a larger number of samples of vein float taken the previous summer (1923). Where tetrahedrite is present the silver content increases, but samples of fairly pure tetrahedrite show in most cases less than 70 ounces of silver to the ton. In one case, namely Grey Copper hill, tetrahedrite float assaying 900 ounces of silver to the ton has been reported, but none of this was available on the ground at the time of the writer's visit.

DESCRIPTION OF PROPERTIES

Silver Hill

Silver hill is situated near the head of Ervin creek, a tributary of Carpenter creek. It is a knife-edged ridge forming a northern spur of Carpenter ridge. Eight claims and two fractions, staked two deep across the ridge, as shown in Figure 1, have been located by J. Carpenter, E. Ervin, and J. McLean, of Keno Hill. Several claims have been staked at either end of the group by other parties.

The rocks outcropping along the ridge consist of calcareous or dolomitic sandstones, intercalated with which are beds and thin layers of impure sandy limestone. The strata strike in a general way along the ridge and dip at angles of 50 to 85 degrees to the west. Both strike and dip, however, vary rapidly from place to place. The western slope of the ridge forming the dip slope is steep, and exhibits numerous outcrops, particularly above the talus slope at the base. It is on this steep hillside that all the deposits located to date have been found. The eastern slope of the ridge is gentler and is covered with a thick layer of soil, moss, and vegetation (Plate I). Intrusive in the sandstone are several bodies of greenstone. The largest of these outcrops on the ridge to the east of Silver hill, in such a position that the beds of sandstone carrying the ore deposits lie above its upper contact (section, Figure 1). On the ridge to the west of Silver hill the Ordovician-Devonian limestone overlies unconformably the calcareous sandstones.

The calcareous sandstones of Silver hill have been faulted to some extent. Many of the faults are transverse to the strike of the strata, but several strike faults were noted. The fissures as a rule are short. There is no direct evidence as to the age of these fissures; they have not been traced from one formation to another. It may be stated, however, that the Ordovician-Devonian limestone has also been faulted in many places, though this faulting may have taken place at an entirely different period.

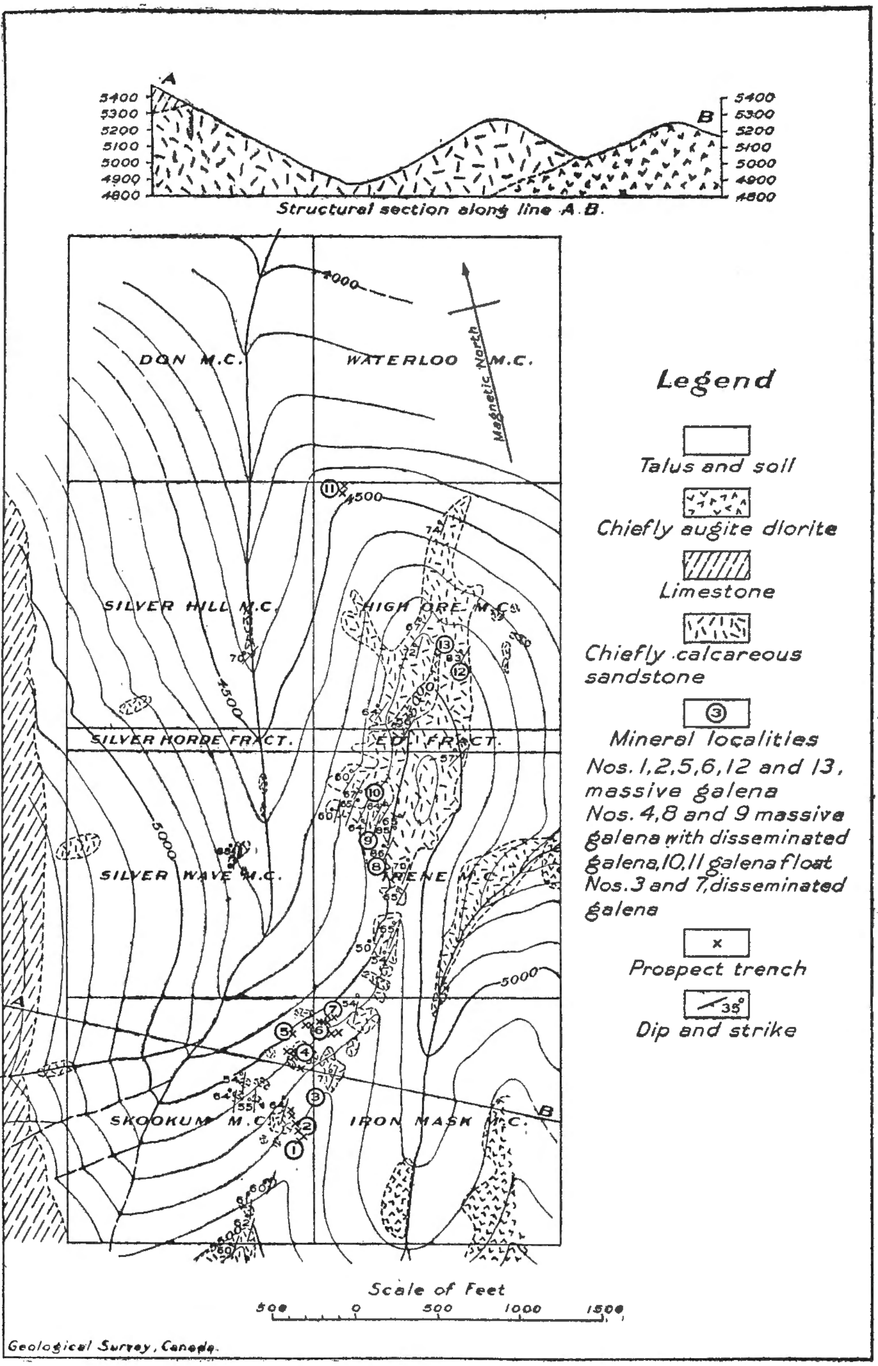


FIGURE 1. Silver hill, Mayo district, Yukon.

It is possible that the short, transverse faults are due to minor crustal adjustment accompanying the intrusion of the greenstone masses.

The ore deposits have formed along the short, transverse fissures which served as channels for the mineralizing solutions. Mineralization apparently took place by replacement of the wall-rock along these fissures; the replacement was apparently of a selective character, the impure limestone beds offering the most favourable spots for the formation of ore-bodies. The minerals are not confined to the fissures, but in many cases extend out to varying distances as disseminated ore. The mineralization consists of galena with subordinate zinc blende and a little pyrite in a gangue of calcite and siderite. Quartz is present only in minor amounts. The galena observed at the surface is quite fresh, being coated only with a thin film of carbonate, but in some places an iron capping composed chiefly of limonite occurs to a depth of a few feet. The position of the ore-bodies near to the underlying greenstone, and the lack of other igneous rocks in the neighbourhood, suggest that the mineralizing solutions may have had their origin in the magma which formed this greenstone mass.

The workings consist of a number of prospect pits or trenches. On the accompanying plan (Figure 1) numbers have been placed at different localities for purposes of reference, and these locality numbers are employed in the following descriptions.

At locality No. 1 a vein or lens of ore has been traced for 50 feet on the hillside by means of three trenches. In the lower trenches the ore-body is 2 feet thick and in the upper or eastern trench 6 feet. Probably it will extend considerably farther in both directions. As exposed it consists almost entirely of massive galena, fairly free from gangue, with pyrite, zinc blende, calcite, and siderite. Another vein lying 50 feet to the north and roughly parallel occurs at locality 2. It has been traced by trenches for 175 feet, has a thickness of 4 to 6 feet, and where exposed is bounded by definite unmineralized walls of contorted calcareous sandstone. The mineralization is identical with the body at locality No. 1, save that no siderite was noted. A sample was cut across the maximum exposed width of 6 feet, and the assay returns showed 9·00 ounces of silver to the ton and 69·38 per cent lead.

At locality No. 3 a vein has been partly exposed in an open-cut. The vein consists of disseminated galena and has a width of 4 feet. This vein may possibly represent a continuation, along the strike, of the deposit at locality No. 4, where an outcrop of country rock carries irregular bodies of massive galena over a total width of 100 feet. The distribution of the sulphide is highly irregular, although very few pieces of the rock can be obtained which do not show specks of galena or pyrite. The largest mass of galena noted was exposed for 30 feet and had a thickness of 6 inches to 1 foot. At locality No. 5, a little to the north of this zone, a vein of 3 feet carrying some disseminated galena is partly exposed in a trench. This may represent an extension of the larger deposit described above.

At locality No. 6 is one of the largest of the deposits on the property. It is not well exposed, but appears to be a tabular body 26 feet thick where it is crossed by a trench, and strikes north 30 degrees east with a dip of 68 degrees to the northwest. This ore-body is exposed only in the single cross-trench and consequently its length is unknown. It is composed mostly of galena, but carries a little pyrite and zinc blende. Near the hanging-wall there is a horse of unreplaced country rock. The walls at either side of the deposit are not well exposed. The foot-wall where seen is sharply defined, but on the hanging-wall side the country rock shows disseminated galena a short distance from the deposit. A sample was cut along the face of the trench, excluding, however, material from the horse of country rock and the assay results showed 4·5 ounces of silver per ton and 65·46 per cent lead. Forty feet to the north is another showing (locality No. 7) with 5 to 6 feet of galena disseminated through country rock. It has not been prospected.

Locality No. 8 is on the Irene claim 1,100 feet northeast of locality No. 7. Here two or more faults of different strike intersect limestone and form a fault breccia a few yards in diameter which has been partly cemented with galena and pyrite. The sulphides also occur in the country rock for distances of at least 100 feet from the fault breccia, but nowhere is any large body of ore visible.

Locality No. 9 shows a small seam of massive galena exposed for a few feet along its strike. At localities Nos. 10 and 11 galena float is present and apparently indicates the existence of one or more concealed deposits, for it occurs in such a position that it could not have come from any of the known deposits.

At localities Nos. 12 and 13 at the northern end of the hill several showings of massive galena in place are partly exposed. Work on these showings had not been commenced at the time of the writer's visit, but they may represent parts of the same lode. A large quantity of float in the slide rock below suggests the occurrence of an ore-body of considerable size.

Grey Copper Hill

Grey Copper hill is situated 4 miles north of the mouth of Carpenter creek. The discovery, by R. Fisher, in the autumn of 1923, of rich tetrahedrite float on this ridge, led to a stampede to the district during the winter of 1923-24. About fifty claims were staked, most of them being located on the snow. Only the assessment work required to hold them was done during the summer of 1924.

Only one mineral vein was noted, but float from one or more other veins was observed. The available evidence indicates that the deposits are tetrahedrite-pyrite-siderite veins somewhat similar in type to those occurring on Keno hill, except that galena is an important constituent of the veins on Keno hill, whereas no galena was noted on Grey Copper hill.

The only visible vein noted occurs on the discovery claim—the Grey Copper King. This vein outcrops in a small canyon in a gulch on the western face of the hill, a few hundred feet above timber-line. It is partly exposed in a small open-cut on the northern side of the canyon. Along the strike of the veins, rock exposures are wanting on the opposite side of the gulch and no attempt has been made to discover if the vein continues in this direction. The vein occupies a fault fissure striking north 10 degrees west and dipping 78 degrees to the southwest. It is not exposed for its full width, which is estimated to be 24 to 30 inches. The vein-filling consists of siderite, tetrahedrite, and pyrite with some quartz, azurite, and malachite. The siderite makes up by far the greater part of the deposits and is coarsely crystalline and of a light brown colour. Tetrahedrite and pyrite are scattered through the siderite in small specks and bunches. A sample of the 16 inches of the vein exposed was taken, and assayed 52·0 ounces of silver to the ton.

The second discovery on Grey Copper hill consists of float only and was also made by R. Fisher. It lies on the King Tut claim, toward the head of the gulch already referred to. On this claim, owned by R. Fisher, and the adjoining Silver Queen, owned by L. B. Erickson, siderite float has been found. Occasional lumps of fairly pure tetrahedrite carrying up to 1,100 ounces of silver to the ton have been picked from this float, but none was observed by the writer although a careful search was made. The bedrock of the gulch at this point is wholly covered by a thick accumulation of frozen talus, and this, in addition to a large snow-drift which remained most of the summer, prevented the prospectors from sinking their trenches to bedrock during the past season. A body of siderite about 20 feet long and of unknown thickness was noted in place on the southern side of the gulch. There can be little doubt that a concealed siderite-pyrite-tetrahedrite vein crosses these properties, and that the tetrahedrite carries high values in silver, but the position and course of the vein, its width, and the character and value of its ore-shoots, must remain unknown until further prospecting has been done.

On some of the other claims, quartz and siderite float have been discovered, but to date the veins from which this came have not been located.

McKay Hill and Neighbouring Hills

McKay hill is situated between Beaver river and Police creek. The chief claims with mineral showings are: the Carrie and Whiterock, owned by L. B. Erickson; the Snowdrift, owned by W. F. McKay; and the Black Hawk, owned by C. Beck.

The mineral deposits occur in and at the borders of small masses of largely amygdaloidal andesites and andesitic breccias in which calcite fills the amygdules and replaces the original constituents of the rocks. No deposits are known in the Tindir slates which occur at this point. The deposits are exposed only in a few instances; in most cases their presence is indicated only by float.

The positions of the exposed bodies and the distribution of the float indicate that one mineralized zone crosses the southern face of McKay hill (Figure 2) with a general strike of north 30 degrees east magnetic, and that it passes close to the common corner of the four claims. It cannot be stated definitely whether this zone is a continuous vein with ore-shoots at intervals, or whether it consists merely of a number of distinct lenses of mineral arranged along a single line. The latter alternative seems the most likely explanation, since the float occurs at isolated points. Other deposits, some of them roughly parallel to this zone, also occur at different points on the claims.

The main showing lies on the Carrie claim about 400 feet southwest of the common corner of the four claims. At this point an open-cut has exposed a mass of galena, 12 feet 6 inches wide. The strike on the hanging-wall side is north 30 degrees east and on the foot-wall side it is north, both walls being approximately vertical. In a second cut 30 feet to the north-

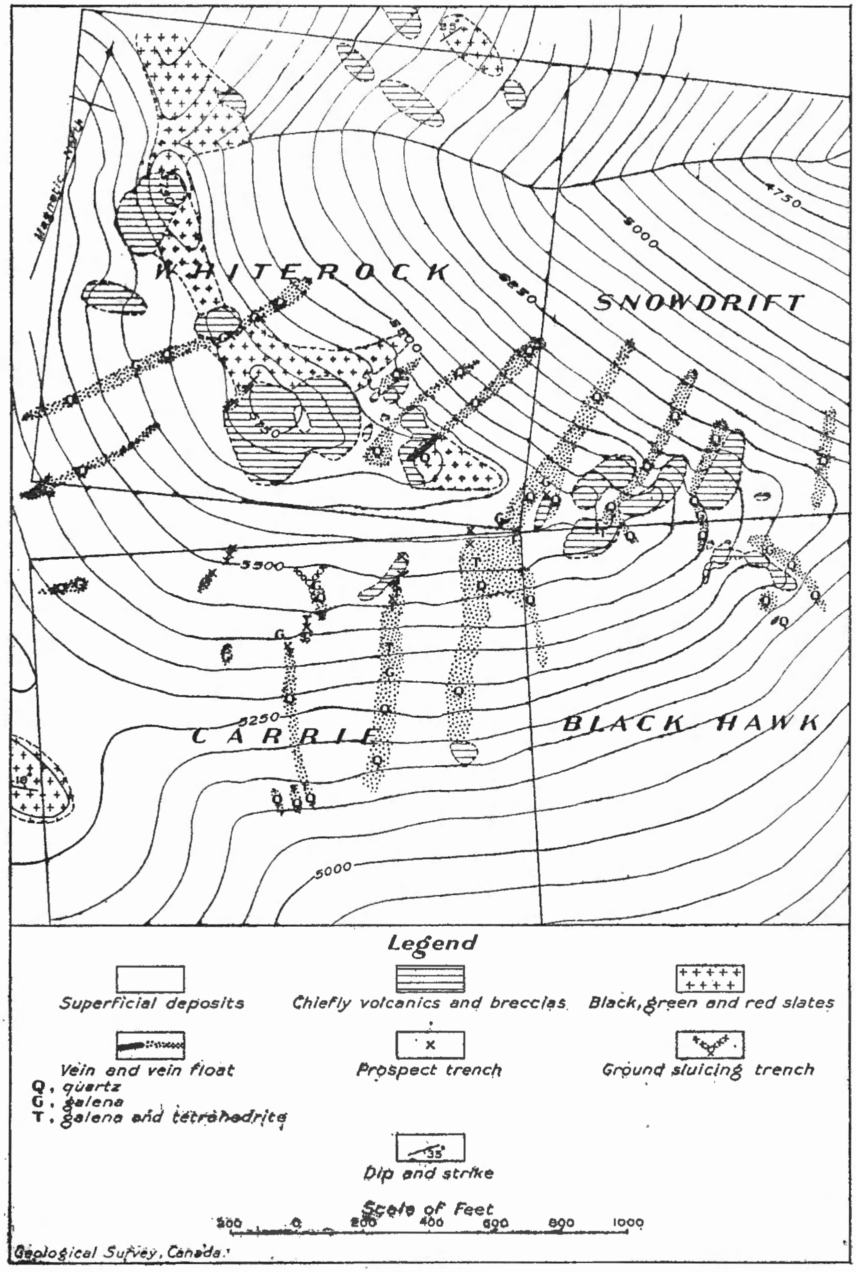


FIGURE 2. Principal claims on McKay hill, Mayo district, Yukon.

east, the ore-body is 4 feet wide and in a third cut some 50 feet northeast of the second, no ore was found. A section across the large showing from the hanging-wall to the foot-wall shows:

	Feet	Inches
Disseminated galena in quartz		6 to 10
Crushed quartz		12
Massive galena, with tetrahedrite and blende	5	
Quartz with disseminated galena	4	6
Massive galena	2	6

The galena in these cuts has a laminated or gneissoid texture, such as is common in other deposits in Mayo district. The laminæ pass around crystals of tetrahedrite, giving the appearance of an augen gneiss.

A sample, No. 4, was cut across the face of this body in the southwestern trench, from wall to wall over the full width of 12 feet 6 inches, and assayed 3·25 ounces of silver to the ton and 56·45 per cent lead. For the sake of comparison two assays, Nos. 18 and 19, of samples of the float from this vein taken during the summer of 1923, are added. These assayed respectively 45·0 and 14·0 ounces of silver to the ton and 59·45 and 78·20 per cent lead.

At the common corner of the four claims the most northeasterly outcrop of this zone occurs. Though only partly exposed, it apparently consists of a sheeted zone with the following approximate section from east to west.

	Feet
Quartz with disseminated galena	10
Leached and iron-stained greenstone	8
Quartz with some disseminated galena	4
Leached greenstone	10
Quartz with disseminated galena	3

Three samples were taken: No. 13 of the 3-foot vein; No. 14 of the central vein; and No. 15 of the 10-foot vein; of which the assay results are 4·00, 10·00, and 5·50 ounces of silver to the ton and 22·83, 44·00, and 39·38 per cent lead.

No outcrops other than those described above occur along the zone, but streams of float descending the hillside indicate where other mineralized portions occur, and by tracing the float upward to where it ceases the positions of the ore-bodies may be readily located. Two samples, No. 16 a picked sample carrying tetrahedrite, and No. 17 an average of the float, were taken the previous summer and the assays of these gave 62·1 and 17·80 ounces of silver to the ton and 9·57 and 63·40 per cent lead, respectively.

Veins or ore-bodies other than those belonging to the zone described occur as follows. Two large quartz veins, apparently barren, occur near the summit of McKay hill. To the north of the summit the existence of two veins is indicated by float. One of them occurs about 100 feet and the other 300 feet northwest of the summit. The first of these probably occurs at or near the contact of the greenstone mass forming the summit of McKay hill, with black slates. The vein has not been found in place, but apparently consists mainly of quartz, galena, and tetrahedrite. A sample, No. 11, taken of the float in 1923, assayed 13·20 ounces of silver to the ton and 54·00 per cent lead. The second vein presumably occurs in a small saddle at the contact of a smaller greenstone mass. Two trenches have been dug across the saddle, but neither of these reaches bedrock. The float, however, cannot be far from its point of origin. It consists chiefly of galena with a little tetrahedrite. A sample of the float, No. 12, taken the previous summer, assayed 11·00 ounces of silver to the ton and 44·95 per cent lead.

On the eastern end of the hill one vein outcrops on the Snowdrift claim about 200 feet to the east of the common corner of the four claims. It is only partly exposed, with the hanging-wall and 18 inches of the vein showing. Judging by the float, however, a streak of galena lies adjacent to the exposed part. The strike of the vein is north 5 degrees west magnetic and the dip 70 degrees to the southwest. The quartz lying along the hanging-wall is barren for a width of about a foot and carries vugs lined with large crystals; the remaining 4 to 6 inches exposed is well mineralized with tetrahedrite, azurite, and malachite. The covered part of the vein probably consists of quartz with galena. Two samples were taken; of these No. 9 is a picked sample of the tetrahedrite, and No. 10 is intended to represent the average of the vein material, both float and that in place. These showed 38·00 and 26·00 ounces of silver to the ton and 4·58 and 19·76 per cent lead.

Quartz float containing galena occurs in two places at the eastern end of the ridge around small greenstone masses, and probably indicates the occurrence of two other veins or lenses of ore, but no trenching has been done on these. Quartz float, apparently barren, crosses the eastern slope of the hill.

Adjoining the four claims described above are the Snowball, Big Windy, Wild Goose, and Eagle claims on the south, the Wild Duck and Bessie claims on the north, and the Tiger and Red Rock claims on the west. These claims may be considered as part of a group to which the four described belong. On the east and north of this group is the Yellow Rock group of six claims owned by A. N. Martin, O. Dahl, E. Anderson, and C. Williamsen. Mineral float has been found at several localities on this group, but the deposits from which it comes have not yet been located.

Horseshoe hill lies east of McKay hill, across from which it is separated by a small gulch known as Red gulch. The rocks exposed are similar to those of McKay hill, and the mineralization may be an extension of that of the McKay Hill area. In the saddle at the head of the right fork of Red gulch a large amount of vein float occurs, and a group of four claims, the Independence group, has been staked by A. N. Martin, O. Dahl, E. Anderson, and C. Williamsen. The float consists of quartz, galena, and tetrahedrite, but the deposit from which it comes has not been located. The assays of three samples, Nos. 6, 7, and 8, taken of this float in 1923, showed 1·00, 0·60, and 1·00 ounces of silver to the ton and 62·30, 42·36, and 29·15 per cent lead.

On the other hills surrounding McKay hill there is considerable evidence of mineralization. Large quartz veins occur on the hills on both sides of the head of Falls creek. The quartz outcrops where examined usually proved to be barren, but similar barren veins occur in the vicinity of the McKay Hill deposits. In one instance, on the Crystal claim of F. Envoldsen, on the western side of Falls creek and about 2,500 feet above the level of the creek, the quartz carries galena, chalcopyrite, and zinc blende, with limonite, probably derived from pyrite. The deposit has not been prospected to any extent.

The deposits of McKay hill and the surrounding hills are not sufficiently well exposed to permit of obtaining a good idea of their nature and genesis. As a general rule the deposits occur in, or at, the margins of the greenstone masses. The conditions on the southern face of McKay hill, where most work has been done, suggest the presence of a series of lenses of ore arranged along a line striking approximately north 30 degrees east, but it is impossible to say whether there is a continuous vein with ore-shoots localized at the points where mineral has been found in place or as float, or whether there is a series of lenses entirely independent of one another. The discovery of particles of galena and tetrahedrite in the greenstone suggests the existence of a genetic connexion between this rock and the ore deposits. This conception is somewhat strengthened by the fact that calcite has been deposited in the amygdules of the greenstone, and has also replaced parts of the greenstone to form large masses of calcite. As far as is known the ore-bodies are confined to the greenstones and to their contacts with the Tindir slates, a fact that would further support the idea of a genetic relationship between the greenstones and the ore-bodies. If this theory be correct the individual ore-bodies cannot be of great size, as the greenstone bodies are themselves small.

Other Localities

A considerable amount of float consisting of galena, calcite, and siderite was observed on the southern end of Carpenter ridge, but no deposits were seen in place. The prospect pits made here in 1922 and 1923 have largely been filled in by slide rock. It is doubtful if any veins were uncovered by the pits. A grab sample, No. 5, was taken of the float and the assay gave 8·75 ounces of silver and 56·0 per cent lead.

On Elliott hill, on the Apex claim, staked by J. McCluskey in 1922, a quartz vein about a foot thick crosses the ridge a quarter of a mile north of the summit. The vein is exposed along the strike for a few feet only. Quartz forms the bulk of the vein-filling. Associated with it is some chalcopyrite and a little galena. The chief values would appear to be in copper. No sample was taken.

Galena has been reported to occur in the continuation of Beaver valley to the northwest 30 miles beyond the height of land.

CONCLUSIONS

None of the ores which to date have been located in place in Beaver River district are rich enough to permit of mining at a profit under existing conditions of transportation. At present the ores would have to be hauled overland to Stewart river a distance of 85 to 100 miles and shipped from there to smelters on the Pacific coast, distant some 3,000 miles by the route followed. When it is considered that the mining costs of the Keno Hill ores aggregate upwards of $100 a ton, and that these are situated 45 to 60 miles nearer to the shipping point than the Beaver River ores, and that the latter, on account of their remoteness, would have to bear correspondingly higher mining and shipping charges, it will be readily seen that mining of the Beaver River ores, if dependent upon shipping to outside smelters, is out of the question. If a railway to the coast were constructed mining might be carried on successfully, particularly if reduction works were erected in the district. These improvements could be justified only if a sufficient tonnage of ore were proved, a condition which does not yet obtain.

On the other hand galena has been found at many points over an area of several hundred square miles, and this with comparatively little prospecting. It is almost certain that with further work other deposits will be discovered, both within and beyond the area described. High-grade ore has not yet been found in place, but occurs as float, and it is quite possible that within the near future deposits of high-grade ore may be found such as would permit of profitable mining.

DRIFTWOOD CREEK MAP-AREA, BABINE MOUNTAINS, BRITISH COLUMBIA

By George Hanson

CONTENTS

Illustrations

INTRODUCTION

The numerous mineral deposits of Skeena River district have for many years attracted the attention of the mining public. As early as 1884 many individuals and several small companies were engaged in washing placer gold from creeks flowing into Skeena river. Since then prospecting has been directed successfully toward the discovery of commercially valuable lode deposits. Babine[1] mountains, situated within the mineralized area, contain a number of mineral deposits and in 1924 the writer geologically mapped an area of 175 square miles, here designated Driftwood Creek map-area. A topographic map prepared by W. H. Miller, of the Topographical Division, Geological Survey, was used as a base for geological mapping. Previously, the Geological Survey had carried out work along Telkwa, Bulkley, and Skeena rivers, and in the vicinity of Hazelton, but practically the only published references to the mineral deposits of Driftwood Creek area are contained in the Annual Reports of the Minister of Mines, British Columbia, for the years 1905 and 1911 to 1923.

H. C. Gunning, J. L. Ramsell, and C. F. Barton rendered able service in the field. The writer wishes to acknowledge his indebtedness to mining engineers and prospectors encountered during the course of the work, for many courtesies and helpful suggestions.

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"Bulkley Valley and Vicinity," Geol. Surv., Can., Sum. Rept., 1908.
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"Skeena River District," Geol. Surv., Can., Sum. Rept., 1910.

[1] Babine (French meaning "hanging lip") was a name applied by voyageurs of the Northwest Trading Company to a river, large lake, and neighbouring mountains, in central British Columbia, from the fact that the Indians of the district wore ornaments in the lower lip.

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LOCATION

Driftwood Creek map-area is located in Babine mountains and lies between latitudes 54° 45′ and 55°, and between longitudes 126° 45′ and 127°. Some years ago an Indian trail leading from Moricetown eastward to the head of Long Meadow creek was used as the means of access. Now, several good trails extending from the roads near Smithers and Telkwa penetrate the area. By these trails, the western edge of the map-area is about 10 miles east of the Canadian National railway at Smithers.

PHYSICAL FEATURES

Babine mountains lie between Babine lake and river on the northeast, and Bulkley and Skeena rivers on the southwest. The axis of the range trends northwesterly. The highest peaks, some of which exceed 8,500 feet, are in the northern part of the range. Towards the south they become lower, and in Driftwood Creek map-area, which occupies a medial position in the range, the highest peaks rise to 7,800 feet above sea-level. Farther south they rarely exceed 7,000 feet. The eastern side, in the map-area, has a slope of 1,000 to 1,500 feet a mile down to an elevation of approximately 3,500 feet; farther east, to Babine lake (25 miles to the east and at an elevation of 2,222 feet) and for 15 miles east of the lake, the surface is undulating and no mountains rise above 5,000 feet. The slope on the western side of the map-area down to an elevation of 3,000 feet is about the same as that on the eastern side; from that elevation the surface is interrupted only by occasional low rock ridges and inclines gently eastward to Bulkley river 1,800 feet above sea-level at Smithers.

The highest point in the map-area is 7,800 feet and the lowest 2,500 feet. Babine range passes diagonally across the area, so that the base of the mountains lies within the northeast and southwest corners of the area, which contain practically all of the surface below 4,000 feet in elevation. The mountains are not dissected by deep valleys. The higher peaks are sharp and precipitous. Relatively flat surfaces are present on mountain tops rising even above 7,000 feet, are seen also at elevations of 5,000 to 5,500 feet, but are more common at 6,000 feet. The flat areas between the elevations of 5,000 and 7,000 feet do not form a single undulating surface, but are separated by abrupt slopes.

The drainage of the area is eastward and westward from the axis of Babine range. The main streams flowing westward are Reiseter, Driftwood, Lyon, Ganokwa, and Carr creeks. The chief streams flowing east are Debenture, Cronin, Little Joe, and McKendrick creeks. Most of the

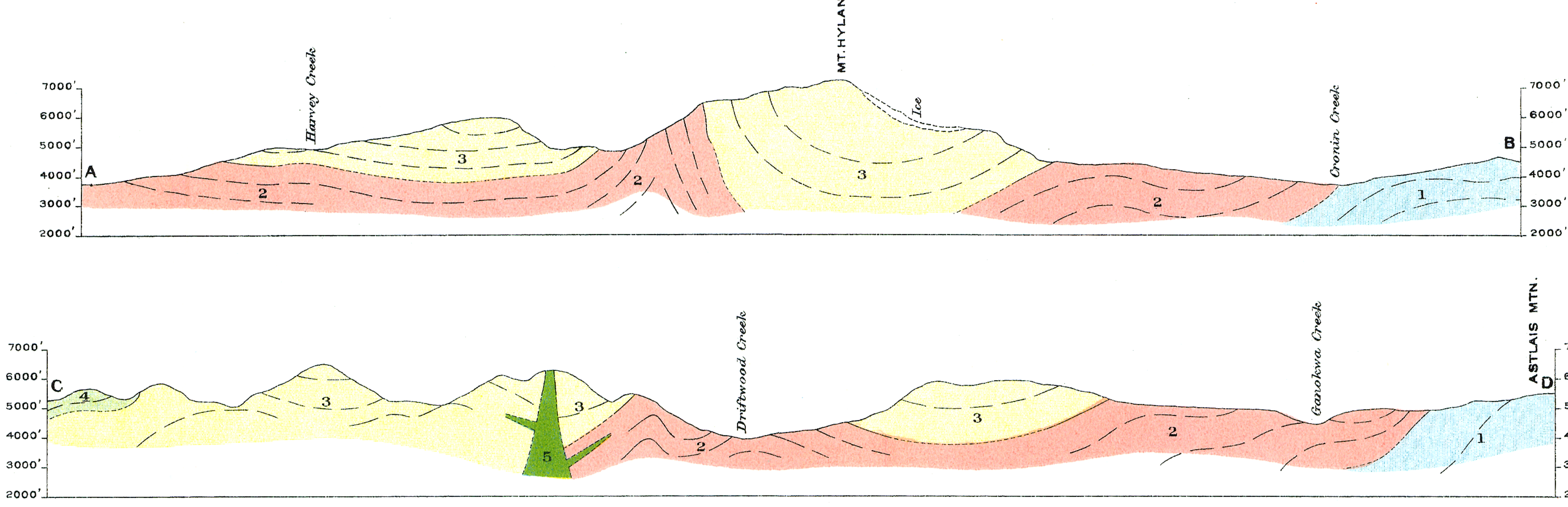
Canada
Department of Mines

HON. CHARLES STEWART, MINISTER, CHARLES CAMSELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

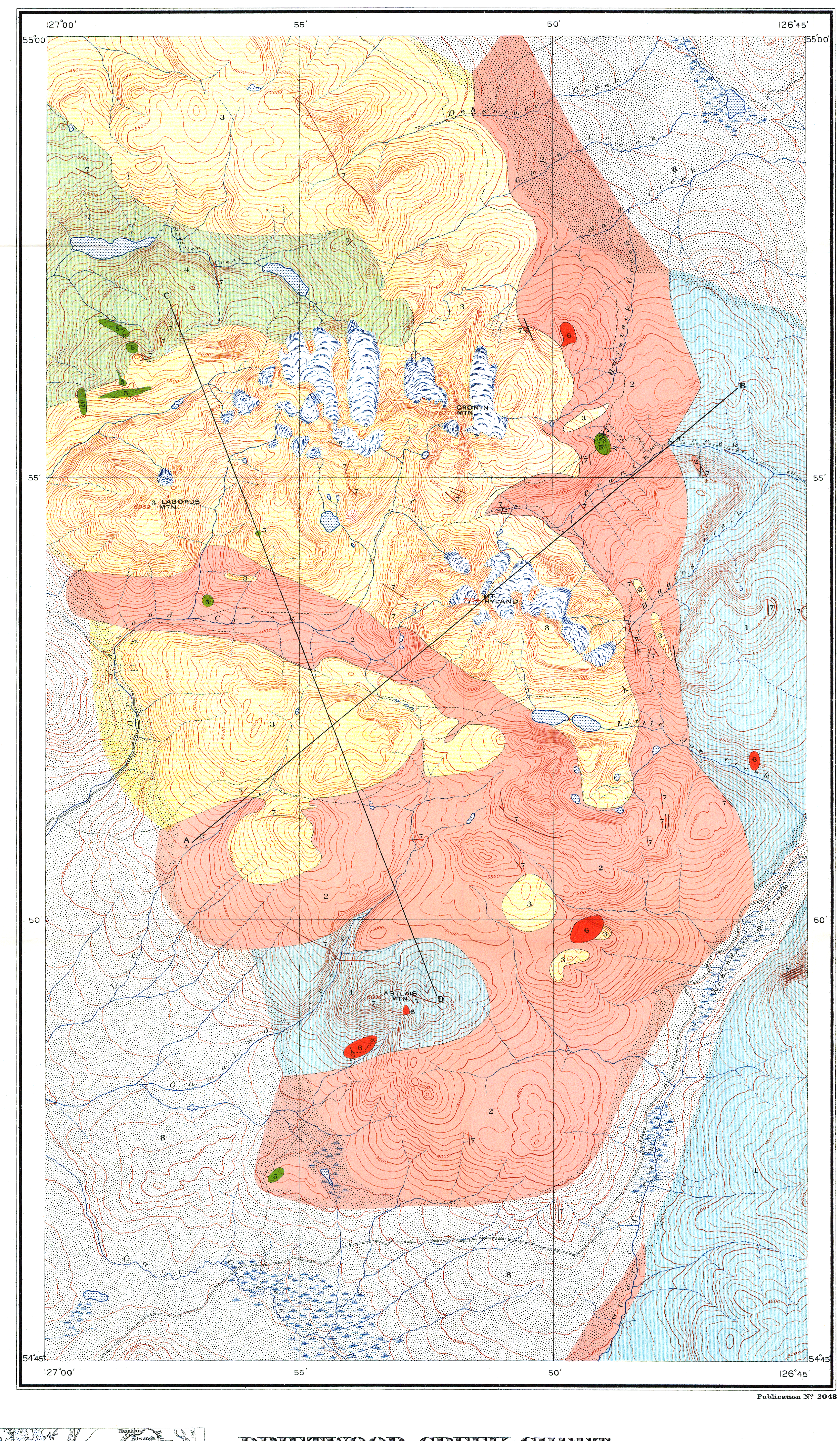
W. H. COLLINS, DIRECTOR.

Issued 1925



Structural sections along lines A B and C D

Scale, horizontal and vertical, $\frac{1}{63,360}$



LEGEND

QUATERNARY — RECENT

8 — *Drift covered area*

7 — *Dykes of quartz diorite, quartz porphyry, lamprophyre, and rhyolite*

6 — *Diorite and quartz diorite stocks*

MESOZOIC — JURASSIC

5 — *Quartz porphyry and rhyolite (intrusive)*

HAZELTON GROUP

4 — *Interbedded tuffs, argillites, and quartzites*

3 — *Andesite, rhyolite, porphyrite, and related tuffs and breccias*

2 — *Argillite, quartzite*

1 — *Tuff, breccia, andesite*

Symbols

Geological boundary *(defined)*

Geological boundary *(approximate)*

Fault

LEGEND

Roads and buildings

Road not well travelled

Trail

Mine tunnel

Prospect

Intermittent stream

Marsh

Glacier

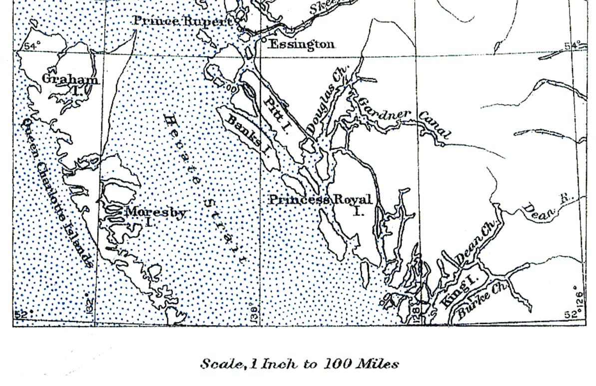
Contours

6952 — Height in feet

Elevations referred to Mean sea-level

Magnetic declination, 1923.

Publication Nº 2048



Scale, 1 Inch to 100 Miles

DRIFTWOOD CREEK SHEET

(WEST HALF)

COAST DISTRICT

BRITISH COLUMBIA

Scale, $\frac{1}{63,360}$ or 1 Inch to 1 Mile

Miles: 1 ¾ ½ ¼ 0 1 2 3

Kilometres: 1 0 1 2 3 4 5

Contour interval 100 Feet

GEOLOGY

Geology by G. Hanson, 1924.

TOPOGRAPHY

W. H. Boyd, *Chief Topographical Engineer.*

Surveys and topography by W. H. Miller, 1923.

To accompany report by G. Hanson, in Summary Report, Part A, 1924.

creek valleys are steep-sided and U-shaped for part of their extent. A steep, narrow canyon 700 feet deep is present on Ganokwa creek. McKendrick and Carr creeks flowing northeast and southwest respectively, head in a low pass through Babine mountains. The pass is less than 3,400 feet above sea-level, and the Carr-McKendrick valley is a relatively large valley extending across the range. Numerous small lakes occupying rock basins are present at the heads of most of the creeks.

Ganokwa Creek canyon is much narrower in proportion to its depth than the other glaciated valleys and was probably carved in part in Recent time, but other evidences of pronounced post-glacial erosion are lacking. The melting of ice and snow at the close of the Pleistocene probably supplied much more water to Ganokwa creek than it now carries. Furthermore, the basin at the head of the creek is more extensive than the basins at the heads of the other creeks, and consequently more water would be supplied to Ganokwa creek than to the others, both during the melting of the Pleistocene ice fields and in more recent time.

Glacial erosion has played a part in shaping many of the creek valleys, but has been more effective in altering the topographic features at greater altitudes. No evidence was found to show that the map-area had been abraded by a continental ice-sheet. Alpine glaciers exist on the northerly slopes of the higher mountains. Numerous glacial cirques and occasional U-shaped valleys prove the former presence of glaciers which have now disappeared. The valleys of Cronin, Higgins, Little Joe, and Reiseter creeks are U-shaped and have been eroded in part by glacial action. It has been stated that the continuity of the relatively flat areas at altitudes varying from 5,000 to 7,000 feet is broken by abrupt slopes. Almost all the abrupt slopes have been produced by glacial erosion near the heads of the glaciers.

If the material eroded by the glaciers were replaced, the physical features of the map-area would be quite different. The relatively flat-lying surface in the mountainous part of the area would be continuous along the axis of Babine mountains and would also extend eastward and westward along the interstream ridges where the mountain range slopes to the lower bordering country. The thus restored flat-topped part of Babine range in the map-area would be about 7 miles wide and would range in height from 5,500 to 8,000 feet. The higher parts of this undulating, pre-Pleistocene surface are underlain by hard rocks and the lower parts by softer rocks.

It is believed that the stream valleys in the map-area were eroded in part during the Tertiary period. This belief is based on certain observations made in connexion with Driftwood Creek valley. Where this valley enters Bulkley valley, at the base of Babine mountains, there is a small area of sedimentary rocks which, judged from their state of consolidation, are probably Tertiary. These rocks are so situated as to indicate that they must have been formed from the erosion of Driftwood valley.

The slope from the upper, partly destroyed, surface of the area to the lower country east and west of Babine mountains may have been accentuated by glacial erosion during the Pleistocene period, but it is improbable that the two levels merged into one another before Pleistocene erosion. It does not seem probable that glacial erosion was extensive enough to produce the two distinct surfaces. It is believed that the comparatively low and even surface east of Babine mountains resulted from long-continued erosion in Tertiary time, and that it originated later than the higher surface of the map-area. Probably, also, the broad valley of the Bulkley was eroded in part during the same second cycle of erosion, which produced the low surface east of Babine mountain.

The date of the commencement of the first cycle of erosion which produced the still partly preserved, elevated, undulatory surface of Babine mountains, is not definitely known. It possibly commenced with the mountain-building accompanying the intrusion of the Coast Range batholith in late Jurassic or early Cretaceous time and presumably ended during the Cretaceous before the Laramide revolution. The second cycle of erosion probably commenced with the uplift accompanying the Laramide revolution at or near the end of the Cretaceous. If the materials subsequently eroded were restored, there would result a great undulating plateau which probably had formed at or near sea-level.

The post-Cretaceous erosion surface represented at Smithers by Bulkley valley inclines gently up the valley to Rose lake, 50 miles east. From Rose lake eastward to Prince George this surface descends from 2,400 feet to 1,900 feet. A large part of the area extending many miles north and south of the Canadian National railway between Rose lake and Prince George, lies at elevations ranging from 1,900 to 2,500 feet. This surface was probably formed in the main during the second cycle of erosion. Bulkley river, however, may have occupied approximately its present geographical position during Cretaceous time and may have maintained its course during the uplift accompanying the Laramide revolution. The date of formation of the lower erosion surface may be indicated by certain sedimentary rocks noted at François lake, which lies 25 miles south of Rose lake. Horizontal beds on the north shore of the lake at an elevation of 2,400 feet hold fossil leaves which have been identified as of Upper Eocene age by W. A. Bell, of the Division of Palæontology. The fossil-bearing sediments may have been deposited in downwarped basins formed in late Eocene time, but more probably they repose on a surface produced by the second cycle of erosion before Upper Eocene time.

Counterparts of both the upper and lower erosion surfaces exist in several parts of British Columbia, but have been noted particularly along North Thompson river and in Cariboo district.[1]

GENERAL GEOLOGY

Driftwood Creek map-area lies near the centre of a belt of Jurassic, extrusive volcanic and sedimentary rocks that borders the Coast Range batholith on the east. The belt has a length in a northwest-southeast direction of 250 miles and a breadth of 60 to 100 miles. It is interrupted in several places by relatively small intrusions of granitic rocks, by isolated basins of Cretaceous sedimentary rocks, and by areas of sedimentary and volcanic rocks of Tertiary age.

Leach stated that in the south, near François lake, the Jurassic rocks consist of massive flows and porphyrites, but that to the north the flows

[1] Johnston, W. A., "Placer Mining in Barkerville area, B.C.," Geol. Surv., Can., Sum. Rept., 1921, pt. A, p. 61. Uglow, W. L., "Cretaceous Age and Early Eocene Uplift of a Peneplain in Southern British Columbia," Bull. Geol. Soc. Am., vol. 34, 1923, pp. 561-572.

thin out and disappear, and tuffs, tuffaceous sediments, and sediments, become prominent.[1] Malloch found that still farther north the flows, tuffs, and tuffaceous sediments gave place to tuffaceous and normal sediments.[2] Dawson believed that along Skeena river there might be a gradation from porphyrite and coarse-textured volcanic rocks on the west to sediments on the east, but also stated that the finer-grained rocks seen on the eastern edge of the belt might be younger beds.[3] Porphyrites and coarse breccias are now known to be plentiful in the north, in the western part of the belt, around Portland canal and Alice arm. Combining the results of these various observations, it becomes evident that the coarser-grained, volcanic rocks are present in an interrupted band that follows closely the eastern contact of the Coast Range batholith and that northeastward from this contact sedimentary rocks become prominent. That is, there seems to be a gradation from coarse-textured volcanic rocks on the southwest to sediments on the northeast. This general condition renders it probable that in Jurassic time volcanic centres were more numerous near the present eastern edge of the Coast Range batholith than farther northeast. The sediments are clastics, are in part at least marine, and include comparatively coarse types such as conglomerate. It is concluded, therefore, that they were deposited comparatively near a body of land. The volcanic rocks themselves indicate that the volcanic centres lay to the west, possibly in a land area from which the clastic materials were derived.

Driftwood Creek map-area lies towards the centre of the large belt of Jurassic rocks and about 35 miles northeast of the eastern contact of the Coast Range batholith. The greater part of the rocks of the area are of Jurassic age and are chiefly of volcanic origin. The name Hazelton group, proposed by Leach[4] and recently used by the writer to embrace a group of formations lying below the Skeena series[5], is applied to these rocks which in this field fall readily into four divisions based on age and mode of occurrence.

Table of Formations

Period	Formation	Lithology
Recent	Stream deposits, etc	Gravel, sand
Pleistocene	Glacial deposits	Morainal debris
Upper Jurassic or Post Jurassic	Stocks and dykes	Lamprophyre and quartz diorite dykes Granodiorite, quartz diorite, and diorite stocks Rhyolite and quartz porphyry intrusives
Jurassic	Hazelton group	Upper Volcanic Division: tuffs, breccias, and lava flows, of andesitic and rhyolitic composition. Dykes, stocks, sediments, and tuffaceous sediments Sedimentary Division: argillites, quartzites, conglomerates Lower Volcanic Division: andesitic tuffs and lava flows

[1] Geol. Surv., Can., Sum. Rert., 1911, pp. 77-78.
[2] Geol. Surv., Can., Sum. Rept., 1910, pp. 93-94.
[3] Geol. Surv., Can., Sum. Rept., 1909, p. 63.
[4] Geo. Surv., Can. Rept. of Prog. 1879-80, p. 103 B.
[5] Geol. Surv., Can., Sum. Rept., 1923, pt. A, pp. 34-35.

HAZELTON GROUP

Lower Volcanic Division. Rocks of this division are present along the whole eastern edge of the map-area and also form Astlaig mountain. They are chiefly interbedded andesitic tuffs and lavas and are mostly reddish or purplish. The lava flows, noted especially along the northern rim of Ganokwa Creek canyon, are andesites and have scoriaceous surfaces. They are amygdaloidal in a few places and contain much light green epidote. Dull greyish-green and brick-red tuffs are common in several places. No rhyolite flows were observed in this division. The base of the division is not exposed, but the rocks exposed have an estimated thickness of 3,000 feet.

Strikes and dips were noted, but not sufficiently distributed to furnish conclusive evidence of the structure of these rocks. Between Higgins and Little Joe creeks the rocks are horizontal over an area of a square mile, but westward to the contact with the argillite division they have steep westerly dips and give the impression that they underlie the sediments conformably. Similar relations were observed on the ridge north of Cronin creek, but there the dips are not so steep. The volcanic rocks of Astlaig mountain also appear to be overlain by sediments.

A few metalliferous deposits are known to occur in these rocks, but were not examined. The apparent scarcity of mineral deposits may be due to the fact that the rocks are not well exposed and are consequently difficult to prospect.

Sedimentary Division. Rocks of this division outcrop over one-half of the map-area. They consist of black or very dark argillites, quartzites, argillaceous quartzite, hard sandstone, and conglomerates. On Driftwood creek and at the head of Ganokwa creek, argillites predominate. Fossiliferous, argillaceous quartzites are plentiful on the north and south sides of Cronin creek and also on Ganokwa creek. Conglomerate is not plentiful and occurs generally as lenses in argillite. Narrow bands of tuffaceous sediments are present, but coarse-grained tuffs were not seen. The strata have been subjected to regional shearing and the soft sedimentary rocks have been, in many places, extensively sheared. Graphite and ottrelite schist are not uncommon. The base of the series is not well exposed, but the basal members are, in the main, argillaceous quartzites. The uppermost beds consist, in most places, of argillite. The division underlies the upper volcanic division conformably.

The sediments have been severely folded and vertical dips and small reverse folds are common. They are too much folded and sheared for the thickness to be measured readily or accurately, but they are estimated to be 1,000 feet thick.

Several mineral deposits are present in the rocks of this division. The most notable of these are the Hyland Basin property, Higgins' property, and part of the veins at the Babine Bonanza.

A collection of fossils from a series of sedimentary rocks on Hudson Bay mountain, believed to be of the same age as the sedimentary series in Driftwood Creek map-area, and fossils from this division in Driftwood Creek district have been examined by F. H. McLearn, of the Division of Palæontology, whose report follows.

"Lot I. Hazelton group, upper part of sedimentary series, Hudson Bay mountain, between Silver lake and Schufer's mining property.

Entolium sp.
Gryphaea sp.
Homomya ? sp.
Lima gikshanensis McLearn
Lima tizglensis McLearn
Lima sp.
Modiolus sp.
Oxytoma sp.
Alectryonia weegeti McLearn
Perna weelaupensis McLearn
Pholadomya
Trigonia guhsani McLearn
Trigonia sp.
Nerinea sp.
"*Terebratula*" sp.
"*Rhynchonella*" sp.
corals, 2 specimens
Belemnites sp.
poor ammonite specimens

"Lot II. Hazelton group, upper part of sedimentary series, Hudson Bay mountain, ½ mile east approximately of Rico-Aspen mining property.

Belemnites sp.

"Lot III. Hazelton group, limestone bed probably a higher horizon than sedimentary series, Hudson Bay mountain, B.C., in Schufer's mining property.

Pecten sp.
"*Terebratula*" sp.

"Lot IV. Hazelton group, upper part sedimentary series, Babine Mountain area, at Cronin mining property.

Gryphaea sp.
Oxytoma sp.
Pecten sp.
"*Rhynchonella*" sp.
"*Nerinea*" sp.
Belemnites sp.

"Lot V. Hazelton group, upper part sedimentary series, Babine Mountain area, near head of Ganokwa creek.

"*Sonninia*" sp.
Pleuromya sp.
Lima or *Pecten*
Modiolis sp.
Trigonia sp.
Belemnites sp.

"*Correlation Note*

Lot I, from Hudson Bay mountain, contains *Lima* and *Trigonia* of Jurassic affinities and is dated Jurassic. Lots II and III, also from Hudson Bay mountain, contain only poorly preserved fossils, but may be of Jurassic age.

Lot V, from Babine mountain, contains an ammonite that is none too well preserved and a better specimen would be a prerequisite to an accurate correlation. It appears to be similar to *Sonninia* and *Witchellia;* if this be so, the age is Bajocian or lowest Middle Jurassic and the nearest Canadian fauna in age is that collected by McConnell from the Fernie (?) formation of lake Minnewanka, east of Banff, Alberta. Lot IV, also from Babine mountain, may be of Jurassic age."

The fragmental ammonite "*Sonninia*" sp., from Lot V, Babine mountain, was later submitted to S. S. Buckman who identified it as *Sonninia propinquans* Bayle, which occurs in the *sauzei* zone of the English Bajocian. He also identified a belemnite, *Megatenthis elliptiens* Miller, in the same fossil lot.

Upper Volcanic Division. This division underlies one-quarter of the map-area. It includes lava flows, tuffs, breccias, tuffaceous sediments, argillaceous quartzites, and argillite. Flows of andesite, usually of a reddish colour, are very common. In some places the flows are amygdaloidal and have scoriaceous surfaces. At the head of Ganokwa creek, andesite flows making up a thickness of 500 feet directly overlie the sedimentary rocks of the previously described division. Lava flows of this type form the base of the division in most of the southern part of the map-area; elsewhere, tuffs or tuffaceous sediments are the lowest members.

Brick-red and greyish-green tuffs associated with beds of coarser breccia are very common. The tuffs and tuffaceous sediments immediately overlying the sedimentary division in several parts of the area are impregnated with pyrite and outcrop as irregular rusty bands. These rusty bands do not strictly conform to the bedding, but follow the shear planes which make a small angle with the bedding. Apparently the pyrite was introduced after the shearing. In this volcanic series in the eastern part of the field are crystalline, feldspathic porphyries several hundred feet thick. These rocks appear to lie parallel to the bedding of surrounding rocks, but are much coarser than the ordinary lava flows. It is probable, therefore, that they are sills. Rhyolite flows are fairly common, especially on the mountains at the head of Driftwood creek directly west of mount Hyland and in the northwestern part of the map-area. Flow structure was readily discernible in several places. It is noteworthy that rhyolite flows were not seen in the lower volcanic division, and were found only in the uppermost part of the upper volcanic division. Tuffaceous sediments and sedimentary rocks were observed only in the northwest part of the area of this group of rocks.

Some of the finer-grained, softer rocks such as the lava flows, sills, and the coarser breccias, were more competent and escaped deformation. Between Reiseter and Debenture creeks the thickness of this division is estimated at 3,000 feet, but on Driftwood creek it is at least 4,000 feet.

Most of the mineral deposits of the district are located in the rocks of this division and chiefly within a thousand feet of the base of the series.

In the northwestern part of the map-area, a small area is occupied mostly by sedimentary rocks with interbeds of tuffs, numerous sills, and perhaps some flows of rhyolite. This area has been separately indicated on the map. Apparently in this locality sedimentary material was accumulating while volcanic activity prevailed elsewhere. The sediments exposed here appear to be the youngest members of the division.

The rocks of this part of the division could not be studied in any great detail, as they are poorly exposed. Black argillite, argillaceous quartzite, reddish, brick-coloured tuffs, and perhaps some rhyolite flows, make up the series, and this has been intruded by sills and dykes of rhyolite. Mud-cracks seen in the argillites show that the sediments and stratified tuffs were deposited in shallow water.

Intrusive Rocks of the Hazelton Group. In this division are grouped stocks, dykes, and sills which consist chiefly of rhyolite. A few consist of granodiorite porphyry and andesite porphyry. In the upper part of the upper volcanic division dykes and sills of andesite are not so plentiful as those consisting of rhyolite. It is believed, therefore, that the andesite lavas and related tuffs which make up the bulk of the Hazelton Group volcanic rocks were succeeded in the later stages of Jurassic volcanism by rhyolite flows and intrusives.

Around Reiseter creek dykes of rhyolite can be traced along their strike into stocks and sills. These larger bodies in some places are quartz-porphyry, feldspar-porphyry, and granite porphyry. A notable feature of the larger, tabular, intrusive bodies of rhyolite and porphyry is the presence of quartz veins. The veins have the same strike as the intrusives, but dip at right angles. These veins are mostly small, but where the parent rock body is large, as in a few instances on Reiseter creek, they are as much as 5 feet in width. The veins wedge out at the borders of the intrusive rock. They evidently represent cooling or shrinkage cracks filled with quartz derived from the enclosing rock.

Stock-like bodies of rhyolite are present but are not common. One of these on Cronin creek is 1,500 feet across. Some parts of this stock are feldspar-porphyry, but in most places the rock is very fine grained and is essentially a rhyolite. Several large inclusions of sedimentary rock in the stock probably aided rapid cooling and fine crystallization.

A few small areas of intrusive rock appear to be plugs occupying former volcanic craters. One of the smallest of these, located a short distance east of Lagopus mountain and crossed by the vertical section line C-D (*See* Map 2048), is oval, with diameters of 200 feet and 150 feet. Its boundaries are smooth. The rock resembles a diorite, but a thin section shows that it was originally a granodiorite although now composed almost entirely of secondary minerals.

The rhyolites and coarser rocks of similar composition had an important bearing upon mineral deposition. The veins of a property on Reiseter creek lie in a country rock of this type, from which the ore and quartz were evidently derived. The Babine Bonanza veins lie partly in a rhyolite stock and appear to be genetically related to the rhyolite. The quartz veins of the Hyland Basin and Higgins' properties are also very closely related to rhyolite and quartz-porphyry dykes. Many dykes of this kind contain disseminated pyrite.

UPPER OR POST-JURASSIC INTRUSIVE ROCKS

In this group are placed several small stocks of diorite, and dykes of granodiorite, quartz diorite, and lamprophyre. The stocks are small, the largest being about one-half mile in diameter. They intrude the rocks of the Hazelton group and, therefore, are Jurassic or younger. They may be allied to the Coast Range batholith. The dykes of granodiorite and quartz diorite resemble the diorite stocks in composition and texture, and all these intrusives may have a common origin.

Several lamprophyre dykes were seen. Their age could not be ascertained, but they are thought to be Post-Jurassic, for in nearby areas dykes of this type cut Coast Range granitic rocks and associated dykes.

The larger stock on the southern slope of Astlaig mountain contains disseminated copper sulphides, and claims have been staked there. The long, curving dyke south of the divide between Little Joe and Ganokwa creeks contains numerous gashes of quartz and a great deal of disseminated iron carbonate. Because of oxidation of the iron carbonate the dyke appears as a rusty band traversing the country.

PLEISTOCENE AND RECENT

Pleistocene accumulations are rare in the map-area. Morainal matter is present only around the base of glaciers. Recent rocks consist of rock-slide material along the valleys, of talus at the base of cliffs, and of the products of rock decay and erosion on the mountain slopes and in the valleys.

STRUCTURE

The general geological structure of the area appears to be that of a northerly plunging syncline, but this may be true only for the northern part of the map-area. As previously mentioned the evidence for placing the rocks of Astlaig mountain and those along the eastern side of the area in a lower volcanic division beneath the sedimentary division is not conclusive. The dips of the volcanic and sedimentary rocks, however, support the view that the volcanic rocks underlie the sediments. If this view be correct, the southern part of the field is a northerly-trending syncline. In the central part of the area the trend changes to northwest and the single syncline becomes gradually two synclines separated by a sharp, narrow anticline.

The volcanic rocks, especially the lava flows, intrusive rocks, and coarser breccias, have not been sheared nor sharply folded. The finer-grained tuffs have been sheared and contorted to nearly the same extent as the argillites of the sedimentary series. Small, overturned folds are visible in several places in these softer rocks. The sedimentary rocks as a whole have been severely folded and sheared as compared with the overlying volcanic division. During folding the assemblages of volcanic rock acted in the main as hard, unyielding masses, and the compression was taken up by the intervening sediments. In several places the sediments have been squeezed upward and folded back over the resistant bodies of volcanic rock, so that in a few places the sedimentary division now overlies the upper volcanic division, whereas originally it lay beneath. This process of "back-folding" of the sediments may have affected the relations between the sedimentary and the so-called lower volcanic division, which originally, perhaps, overlay the sediments, but this does not seem to have been the case.

The strike of the shearing is east-southeast. Shearing is not uniform over the whole district and is prominent only in a relatively narrow belt. The sheared zones are probably not related entirely to local folding, but have resulted from more widespread regional movements.

Faults, though numerous, are small. Only a few were seen in which the horizontal offset was greater than 100 feet.

ECONOMIC GEOLOGY

All the mineral deposits occur as veins, mostly narrow and comparatively short quartz veins. Their silver content, however, is in some instances very high, and several of the veins could no doubt be mined on a small scale with profit. The gold content is never high in any of the deposits. Copper, lead, and zinc are present in considerable proportion in some of the veins, but values in these base metals merely supplement the value in silver. With the present means of transportation only high-grade ore can be mined at a profit; consequently, it is not surprising to find properties idle which would have considerable merit were they more favourably located. All the mineral properties were examined except a few which were difficult to locate and on which little development work had been done. Systematic samples were not taken from any of the

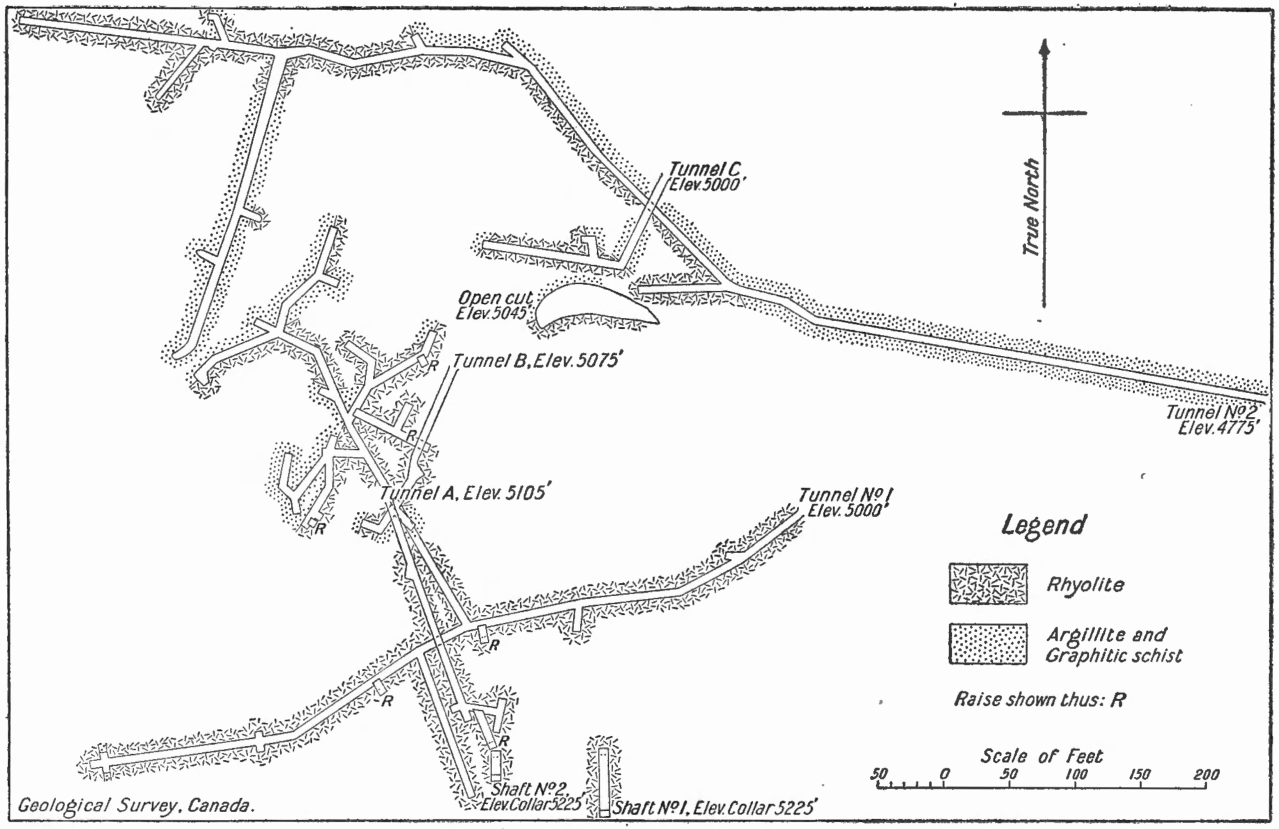


FIGURE 3. Plan of workings, Bonanza claim, Driftwood Creek area.

properties. Some of the descriptions of individual properties given below may seem brief and incomplete, but except where the development work had been extensive, the information obtainable was usually meagre.

DESCRIPTION OF PROPERTIES

Babine Bonanza Mining and Milling Company

This company's property is situated north of Cronin creek on the eastern slope of Cronin mountain, 5,000 feet above sea-level. Plans of the workings published in the Report of the Minister of Mines of British Columbia, 1920, are here reproduced (*See* Figure 3). A great deal of development work has been done, the tunnels, crosscuts, drifts, raises, etc., totalling about three-quarters of a mile in length.

The country rock is argillite and graphitic schist of the sedimentary division of the Hazelton group, intruded by a small stock of rhyolite and quartz-porphyry. The intrusive rock contains several large, irregular inclusions of sedimentary rock. The geology is further complicated by the presence of quartz-porphyry, quartz diorite, and lamprophyre dykes.

Two main veins have been explored by tunnels, raises, and shafts. A shaft has been sunk on what is perhaps a third vein. Many other smaller veins were encountered in the tunnels, but were not drifted on to any extent. Two inclined shafts, their mouths about 450 feet vertically above the lowest tunnel, have been sunk on what appear to be two distinct veins, but which, possibly, are one and the same. No. 1 vein, exposed in No. 2 shaft, has an easterly course and dips north. Adit A, 120 feet below shaft No. 2, crosscuts No. 1 vein near the face of the adit, and an inclined raise has been driven on the vein. This adit also crosscuts, 120 feet north of No. 1, another vein. Adit B, 150 feet below shaft No. 2, encounters No. 2 vein and continues as a drift along it. A large surface cut, about 180 feet below shaft No. 2, exposes No. 2 vein. Adit C, 225 feet below shaft No. 2, crosscuts No. 2 vein at the face of the adit. Adit No. 1, 225 feet below shaft No. 2, begins as a drift on No. 1 vein on which two raises have been driven. At the westerly end of this adit, some quartz which may represent No. 2 vein was encountered. From a point midway in this adit a long crosscut to the north encountered No. 2 vein about 160 feet northwest of No. 1 vein. The vein was drifted on to the northeast and southwest and inclined raises were put up. Adit No. 2, 450 feet below shaft No. 2, encounters No. 2 vein, 675 feet from the portal. The vein has been drifted on for some distance. Seven other smaller veins containing sulphides were crosscut by this adit.

The vein appearing in shaft No. 1 varies in width from 6 inches to 3 feet, being widest at the bottom of the shaft. Further development might prove this to be the same as No. 1 vein. It contains much sulphide in a quartz gangue. Galena, sphalerite, and tetrahedrite are the principal sulphides.

No. 1 vein is exposed for a depth of 50 feet along the dip of the vein in shaft No. 2. It varies from 1 to 6 feet in width and consists of quartz, galena, sphalerite, and tetrahedrite. The vein is narrowest at the bottom of the shaft. In adit A it is exposed for a length of 20 feet and has a width of 1½ feet. At the top of a raise driven from adit A the vein is 6 feet wide. Finally, in adit No. 1, the vein is exposed for a length of 360 feet.

For the first 240 feet from the portal it contains very little visible sulphide and varies in width from 6 inches to 2 feet. It then widens and for the next 75 feet of length varies from 4 to 6 feet and consists almost entirely of galena and sphalerite. For the next 45 feet the vein is again less than 2 feet wide and consists chiefly of quartz. A raise driven on the sulphide lens shows that the vein narrows rapidly with height. Evidently it pinches and swells within short distances along its strike and dip. The lenses may pinch out entirely and be succeeded along the strike or dip by other lenses. Tetrahedrite is more plentiful near the surface of the vein than it is at the depth of adit No. 1. This vein, where exposed by the mine workings, lies entirely in rhyolite, where splintery and irregular discontinuous fractures might be expected.

No. 2 vein is crosscut by adit A, 50 feet from the portal. At this point it varies from 1½ to 2½ feet in width within a length of 4 feet. The foot-wall here is a hard, fine-grained, grey, quartz-porphyry dyke, and the hanging-wall is rhyolite. In adit B the vein is 3 feet wide and is exposed for a length of 40 feet. Here it has a hanging-wall of rhyolite and a foot-wall consisting in part of argillite. Adit C crosscuts this vein, which is 3 feet wide on one side of the adit and 8 feet wide on the other. The hanging-wall is argillite and the foot-wall rhyolite. The vein is not very strong on No. 1 adit level. For a distance of 50 feet it is a mere stringer and for a further distance of 50 feet it varies in width from 4 inches to 3 feet. In a raise, along the vein driven from this adit, it varies from 1 to 3 feet. The hanging-wall is argillite in some places and rhyolite in others. The foot-wall is rhyolite. In adit No. 2 the vein is first encountered 670 feet from the portal. For 120 feet the vein varies in width from a few inches to 2 feet. For the next 50 feet the width varies from 3 to 7 feet. Here the vein appears to make an abrupt turn and continues in a drift to the southwest for a distance of 190 feet, the width varying from 1½ to 4 feet. At the southwestern end of this drift it divides into two branches, one of which pinches out. Almost the whole of the vein striking southwest has argillite on both walls. Most of the westerly striking part of the vein has rhyolite on both walls. The part striking southwest appears to be the downward extension of No. 2 vein from upper adits. The westerly striking part appears to have been deposited in a pre-mineral fault. The wider parts of the vein on this level consist of practically solid sulphide. In many places zinc blende is very common and there is also a notable amount of tetrahedrite. The westerly extension of the adit crosscuts five other quartz sulphide veins.

Vein No. 2, like vein No. 1, pinches and swells abruptly, but it is further complicated and its continuity is made less certain because the line of fracture in which the ore was deposited passes not only through rhyolite but also through relatively large inclusions of argillite and graphitic schist. The presence of dykes also tends to make the continuity less certain. For these reasons estimation of the quantity of probable ore in this vein is even less certain than in No. 1 vein, but more and wider individual shoots of ore are to be expected.

The workings described above are on the Bonanza claim. On the Homestake claim, adjoining the Bonanza on the southwest, are other veins. One of these, 4 feet wide in some places, has been developed by several short adits, shafts, winzes, and open-cuts. The vein strikes northeast and dips north, and has been traced almost to the shafts on the Bonanza claim. One-quarter mile from the Bonanza shafts the vein consists chiefly of quartz, but farther northeast it contains a good deal of galena, zinc blende, and tetrahedrite. The vein passes from sedimentary rock on the west into rhyolite on the east.

Debenture

The mineral showings on this group are located on Debenture creek. The owners are H. Bretzins and partner. Development work consists of a 400-foot crosscut adit, a short drift adit, and surface strippings. The country rock is stratified tuff and rhyolite, of the upper volcanic division. The rocks are severely sheared and weathered. A narrow, steep, rock shoulder projects from the mountain south of the property, and the ore zone or vein crosses this shoulder, is exposed on the summit and down the two opposite slopes, thus being exposed on two sides of a triangle. The mineral deposit contains galena in a gangue of quartz and country rock and is as much as 6 feet wide in a few places. The long crosscut adit has been driven into the shoulder of the mountain, but although it has penetrated beyond the point where the vein should have been intersected, the vein was not found. Probably it is cut off by an horizontal fault, and the adit was driven below this fault.

Hyland Basin Group

This property, owned by Messrs. Cain and King, is situated near the head of Cronin creek. Development consists of numerous open-cuts and two adits 190 and 25 feet long. The country rock is sheared argillite of the upper part of the sedimentary series, intruded by several dykes and perhaps sills of rhyolite parallel to the shearing of the sediments. The vein consists of galena and some tetrahedrite in a quartz gangue. It follows closely the contact between the argillites and a dyke of rhyolite. The open-cuts were caved at the time of the writer's visit, so the actual dip of the vein was not ascertained, but the strike is south 80 degrees west and is parallel to the shearing in the sediments. The long adit has been driven parallel to the vein at a distance of 20 feet to the north of it, and no attempt has been made to crosscut the vein from the adit. Small shipments have been made of selected ore containing a high silver content.

Victoria Group

This property, owned by P. Higgins, is situated near the head of Higgins creek. Development consists of adits, shafts, numerous trenches, and open-cuts. The country rock is argillite of the sedimentary division of the Hazelton group, intruded by rhyolite and quartz porphyry dykes. At the time of the writer's visit, most of the trenches and open-cuts had caved, and the shafts were full of water, consequently little was to be seen. During the past summer work was being concentrated on the upper adit. Here the vein is closely associated with a rhyolite dyke which contains numerous gashes of quartz and a good deal of disseminated pyrite. The vein lies between this dyke and one of quartz porphyry. Several veins are present on the property and veins are exposed in a zone fully half a mile long, but no single vein has been shown to have this length. The main vein is 3 feet wide in the upper adit, and contains galena and sphalerite in a gangue of quartz, ankerite, and slate. Tetrahedrite and pyrite are present in small amounts. Several tons of selected ore containing a good deal of silver have been shipped.

Little Joe

This property, owned by Messrs. Cain and King, is situated near the head of Little Joe creek. Development consists of a few open-cuts and two adits. The country rock is a sheared, stratified, grey tuff of the lower part of the upper volcanic division. Quartz veins similar to those on this property are found in the same stratigraphic horizon farther north, and it would appear that the lower part of the upper volcanic division was favourable for the formation of quartz sulphide veins. The ore-bodies on the Little Joe are narrow quartz veins containing tetrahedrite and some galena and sphalerite. The longer adit exposed a flat-lying vein for a length of 130 feet. The vein is from 1 inch to 1 foot thick. Numerous small stringers of quartz branch from the main or trunk vein. The best ore is found where the vein is less than 1 foot wide. A shipment of 5 tons of ore a few years ago netted approximately $500 a ton in silver.

Haig's Property

This property is located on the southern slope of Astlaig mountain. Development consists of open-cuts and two adits 120 and 40 feet long. The country rock is a diorite stock. Where the adits have been driven, the rock contains disseminated pyrite and chalcopyrite and small gash veinlets half an inch wide containing quartz, pyrite, chalcopyrite, and specularite. Certain areas in the diorite contain disseminated copper minerals and a low percentage of gold. The value of the mineralized rock exposed in the open-cuts and adits will depend almost entirely on the value of the gold content.

Social Group

This property lies between the head of Ganokwa creek and the head of the east branch of Driftwood creek. Development consists of open-cuts. The country rock is andesite lava dipping gently southwest of the base of the upper volcanic division. The rock is amygdaloidal and individual flows have scoriaceous surfaces. The vein occupies an easterly-striking vertical fault fissure and consists of quartz, bornite, chalcopyrite, and a little calcite and specularite. The main vein varies in width from a few inches to $1\frac{1}{2}$ feet and has been traced for 300 feet. Where it has been developed by surface cuts the volcanic rocks are only 100 feet thick and are underlain by sediments. The vein has not been found in the latter rock. Numerous gashes of quartz containing bornite and chalcopyrite are present in the wall-rocks of the vein. In small shipments of the ore the chief values were in copper and silver.

Iroquois Group

This group, owned by P. McPhee, is located on the mountain between the head of Ganokwa creek and the east branch of Driftwood creek. Development work consists of several open-cuts and two adits 65 feet and 45 feet long. Lava flows and tuffs of the upper volcanic division make up the country rock. The vein is over 5 feet wide in a few places and has been traced for several hundred feet. It strikes south 20 degrees east and dips 70 degrees northeast in the vicinity of the adits, but lower down on the hill swings to the east. The vein lies between fault walls and may be the same as that exposed on the Social group. The vein matter in the upper cuts and adits consists almost entirely of copper carbonates. In the lower adit the vein contains a little tetrahedrite. The structure of the mountain on which this property is located is that of a basin, that is the rocks on all sides of the mountain dip toward its centre. Some of the beds of tuff have been slightly mineralized, consequently, in addition to the fault vein, there are mineralized bands of tuff following the contour of the mountain.

Harvey Group

This group, owned by C. G. Harvey, is situated on the western slope of the mountain lying between Driftwood and Lyon creeks. The country rock consists of breccias, tuffs, and lava flows, of the upper volcanic division. The rocks dip toward the centre of the mountain on all sides. The ore-bearing zones are three or more and consist of mineralized, greyish volcanic rocks lying parallel to the enclosing strata. The development work has been concentrated chiefly on the two lower zones, which lie about 40 feet apart. The mineralized beds vary in width from a few inches to over 8 feet. Usually the whole band is mineralized, but the ore-shoots are restricted to quartz-sulphide lenses and veins lying in the mineralized band or zone.

Some years ago a long crosscut adit was driven eastward into the hill with the hope of crosscutting the ore zones exposed on the surface. The adit is 233 feet long, but would have to be extended an additional 150 feet in order to crosscut the two lower ore zones. Above this adit an incline shaft has been sunk along the lower zone to a depth of 25 feet. Another incline shaft about 60 feet deep along the slope has been sunk on the next zone, which here had a dip of 33 degrees. The lower zone has also been opened up 200 feet farther north by an incline shaft and short adit. Farther up the hill a good deal of work has been done on a third zone. The metallic minerals in the ore zones are chiefly chalcopyrite, tetrahedrite, and occasional galena, and the chief values are in copper and silver. It is noteworthy that ore has been shipped with profit from practically all of the shafts and open-cuts on the various veins. From shipments totalling 25 tons, the gross value obtained was $200 a ton.

Wright's Property

A number of claims have been staked on the northwestern and northern slope of the mountain lying between Driftwood and Lyon creeks. Wright, Driscoll, Kelly, and Orchard are the principal claim owners. The country rock is andesite and tuff of the upper volcanic division. Development on these claims consists of numerous open-cuts and several short adits. On the more westerly claims, owned by Wright and Driscoll, work has been directed toward opening up narrow quartz veins containing tetrahedrite, chalcopyrite, and pyrite. Six or more of these veins are known, each striking east and having vertical or steep dips. Late during the summer of 1924 these prospectors discovered another vein, but had not exposed it for more than 20 feet at the time of the writer's visit. This vein is 1 foot wide, and where exposed consists almost entirely of tetrahedrite which, according to a single assay, contained 22 per cent copper, 40 ounces silver, and $4 in gold a ton. In other veins tetrahedrite is present in smaller amounts, but contains in general much more silver. Veins of this type are present on the Wright and Driscoll claims and also on Mr. Orchard's claims. The country rock is hidden in most places by drift, making prospecting and the deciphering of structure difficult.

Adjoining claims to the northeast, owned by Mr. Kelly, exhibit a different type of mineralization. Here, the mineral is concentrated along siliceous zones paralleling beds of tuff and in this respect the veins or mineral zones are similar to those of the Harvey group. On the Kelly claims the mineralization is in two bands, confined to a bed of purple breccia lying between beds of fine-grained, reddish tuffs. The metallic minerals are pyrite, chalcopyrite, bornite, and tetrahedrite.

Silver King

This property, owned by P. Higgins, is situated near the head of Driftwood creek. The country rock is sheared tuff. The development work consists of several adits making a total length of 370 feet. Two of the longer adits are crosscuts which have not penetrated the veins. Here a zone of quartz veins extends over an horizontal distance of 1,500 feet. Individual veins are lens-shaped and discontinuous, varying from an inch to 8 feet in width, and are usually less than 200 feet long, but although individual veins pinch out and disappear other similar veins come in along the strike. The veins contain variable amounts of galena, tetrahedrite, chalcopyrite, and sphalerite, in a gangue of quartz. The tetrahedrite contains a good deal of silver.

Reiseter Creek Group

This property, owned by Messrs. Cain and King, is located in the northwestern part of the area on a tributary of Reiseter creek. The country rock is argillite intruded by dykes and sills of rhyolite and related igneous rocks. The quartz veins of this property lie in a large dyke-like body of fine-grained granite which consists chiefly of orthoclase with some plagioclase and quartz.

The quartz veins are large-scale examples of gashes of quartz that occur in many places in the area in numerous dykes and sills of rhyolite and are evidently the result of shrinkage in the igneous material. Such veins are confined solely to the dykes or sills.

On Reiseter creek several parallel veins are present in the dyke-like igneous rocks. They wedge out sharply at both contacts of the igneous body and apparently have resulted from the filling of shrinkage cracks.

The vein matter is quartz in the form of intergrown crystals which project inward toward the centre of the vein. In two of these veins, crystalline galena and chalcopyrite were found between quartz crystals. It is likely that the sulphides were derived from the same source as the quartz. The sulphides are confined to a narrow band, usually not more than 1 foot wide, within each of the two veins, which are 5 feet in width.

Genesis of the Ore Deposits

In Driftwood Creek district numerous dykes and sills of rhyolite, fine-grained granodiorite, and related types of rock individually contain many transverse gash veins of quartz. These veins are confined to the intrusive rocks and this relation suggests that the fractures in which the quartz is found are shrinkage or cooling cracks, and that the quartz filling was formerly part of the molten matter which formed the dyke or sill. Most of these veins exhibit drusy cavities. In a few veins which seemed to be of this type, crystalline galena occurs grown around well-formed crystals of quartz. It seems logical to believe that the quartz and galena have a common source, and that they were part of the intrusive body. It may be difficult to understand just how a rock could consolidate sufficiently to fracture and yet later supply enough fluid constituents to fill or nearly fill the fracture, but perhaps this is not more difficult than to understand how small, discontinuous veins could have been formed from material derived from a distant source.

Veins of this type are small where the parent rock is of little volume, but may be large where the parent rock is of great volume, and in such instances there is some likelihood that veins have formed in adjacent rocks as well as in the source itself. In some instances it might not have been possible for shrinkage cracks to form and all the mineral constituents normally forming the gash veins might have escaped into cracks in adjacent rocks.

In concrete instances, as at the Reiseter Creek property, Haig property, and the Babine Bonanza, the mineral deposits seem to be of local derivation. In several instances veins found in the upper volcanic division do not, seemingly, penetrate the underlying sedimentary rocks. The mineral deposits found on the mountain lying between Lyon and Driftwood creeks do not appear to penetrate the underlying sediments and are characterized by minerals common to all of them, but not common elsewhere in the district, and it is probable that these deposits have a common local source. Other deposits in the area may have been derived from more deep-seated sources.

Future of the District

The mineral deposits in the district are of small size and of various shapes. The writer believes that their size has been determined largely by the amount of mineral matter available in the source or sources. It is further believed that many of the mineral deposits are essentially local in origin, and that the metal-contributing sources were of small volume. It is expected, therefore, that small mineral deposits will be the rule. The sporadic distribution exemplified here by lens-shaped, discontinuous veins, is probably due largely to the diverse physical natures of the rocks, which belong to a volcanic series consisting of separate and different parts that fracture in different ways when subjected to stress and strain. The veins penetrating different members of the volcanic series thus naturally vary greatly in size and structure. A few deposits appear to be related to more deep-seated and perhaps more prolific sources of ore. These have more promise of permanency. A number of narrow veins in the district contain ore of high grade and in some instances may yield substantial profits on ore shipped. Deposits suitable for concentration have small tonnages, but probably sufficient for low profits.

PRINCE RUPERT TO BURNS LAKE, BRITISH COLUMBIA

By George Hanson

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INTRODUCTION

The Canadian National railway, from its terminus at Prince Rupert on the Pacific coast, crosses the Coast range by way of Skeena River valley. Leaving this valley at Hazelton, the railway runs southeastward up Bulkley River valley to its head and turning eastward descends Endako River valley past Burns lake, reaching Nechako river, which it follows downwards to its junction with Fraser river at Fort George. The railway route furnishes a geological section through the Coast Range batholith from the large area of schistose rocks of the Prince Rupert formation on its western margin to the volcanic and sedimentary rocks of the Hazelton and Skeena groups on its eastern border. The rocks of the Hazelton group continue southward and eastward along the railway until overlapped by Tertiary beds in the vicinity of Burns lake. The geology of the district traversed by the railway from Prince Rupert eastward has already been dealt with in various reports.[1] The present writer in 1924 re-examined the strata along the railway between Prince Rupert and Hazelton and visited several areas to the southeast. The following account presents some of the information gained during the course of this field work.

Tides travel up Skeena river to Kwinitsa, 46 miles from Prince Rupert. Between Kwinitsa and Kitwanga, a distance of 107 miles, the Skeena rises 5 feet a mile. Between Kitwanga and Hazelton, at the junction of Skeena and Bulkley rivers, a distance of 23 miles, the river rises approximately 8 feet per mile. Along Bulkley river from its mouth at Hazelton to its head at Rose lake, a distance of 123 miles, the grade is about 13 feet per mile.

The valley of the Skeena below Terrace, where it cuts through the main part of the Coast range, resembles a fiord. It is fairly straight and mountains rise steeply on both sides. At Essington, at the mouth of the river, the bottom of the valley is 2 miles wide, and just below the mouth of Lakelse river at the eastern edge of the main range of Coast mountains, it is $1\frac{3}{4}$ miles wide. This part of Skeena valley has been strongly glaciated, but may not have been greatly deepened by glacial erosion, as the larger tributaries of the Skeena, e.g. Ecstall, Khyex, Scotia, Exchamsiks, and Exstew rivers, not only enter the valley with a normal grade but have on

[1] McConnell, R. G., "Geological Section along the Grand Trunk Pacific Railway from Prince Rupert to Aldermere," Geol. Surv., Can., Sum. Rept., 1912.
O'Neill, J. J., "Preliminary Report on the Economic Geology of the Hazelton District, B.C.," Geol. Surv., Can., Mem. 110, 1917.
Leach, W. W., "Skeena River District," Geol. Surv., Can., Sum. Rept., 1910.

their lower reaches flood-plains of Recent silts perhaps 200 feet thick. If the silts in lower Skeena valley are thicker than this and the rock bottom valleys of the tributary streams enter the rock bottom valley of the Skeena as hanging valleys, the height of the hanging valleys may represent glacial deepening of the Skeena.

Lakelse river marks the western edge of a great valley crossing the Skeena at right angles. On the south side of the Skeena this valley is at first 12 miles wide, but narrows rapidly to 4 miles. The valley continues southward to Kitimat arm. North of Skeena river to Nass river the bottom of the valley is from 1 to 6 miles wide. At Nass river the valley is continued northward by the upper Nass. The Skeena east of its intersection with this north-south valley, which may be called the Kitsumgallum-Lakelse valley, occupies a normal stream valley which is wide or narrow as it cuts through soft or hard rocks, and which is crooked rather than straight. Truncated spurs along this part of the valley give evidence of glaciation. The valley of the Bulkley has also been somewhat modified by glaciation, but it is apparent that the valley has not been deepened to any great extent as tributary streams enter at grade.

In 1912, a bore-hole was put down in Skeena valley near Kwinitsa to a depth of about 200 feet below sea-level. The hole penetrated 200 feet of bluish clay with some rock salt at the base. A few years ago another bore-hole was put down at the junction of the Kitsumgallum-Lakelse and the Skeena valleys at Terrace. This hole is reported to have penetrated gravels and other unconsolidated material to a depth of 230 feet below sea-level. It is not likely that this depth below sea-level represents glacial erosion entirely, but rather preglacial stream erosion at a time when the land stood higher relative to sea-level than it does today. The bore-holes did not reach bedrock. The depth of the bedrock below the bottom of the bore-holes might be approximately the extent of glacial deepening. The valley was filled with boulder clay and silt in the Pleistocene after the land had subsided. During Recent times the land had been re-elevated about 500 feet[1], and the Pleistocene deposits have been eroded to some extent, but the re-elevation has not been of sufficient magnitude to bring the land back to its preglacial height. Rock canyons exist in several places along Skeena and Bulkley rivers. It is not likely that these canyons are located on the preglacial channel, but are new river channels dating from the close of the Pleistocene.

The Kitsumgallum-Lakelse valley apparently represents part of an old drainage system robbed by the lower Skeena. But the Skeena drainage system may have antedated the Kitsumgallum-Lakelse system, may have been robbed by the latter system in perhaps Cretaceous time, and later still perhaps in Tertiary or Pleistocene time, the Lower Skeena may have recaptured its former water.

The Lower Skeena is bordered by granitic mountains of the Coast range. These mountains rise fairly steeply from the Skeena trough, but rarely do they exceed 6,000 feet in height. Above Terrace, east of the main part of the Coast range, the mountains on either side of the Skeena are built of upturned quartzites and allied sedimentary rocks and rise to more than

[1] McConnell, R. G., "Portions of Portland Canal and Skeena Mining Divisions, Skeena District, B.C.," Geol. Surv., Can., Mem. 32, 1913, p 22.

8,000 feet. Here lie Seven Sisters and Kitsumgallum mountains. South of Hazelton are the rugged Rocher Déboulé mountains. West of the Bulkley at Smithers stands Hudson Bay mountain, 8,700 feet above sea-level. Across the valley to the east is the lofty Babine range. East of the mouth of Morice river none of the mountains along the railway to Burns lake are very high and the country becomes subdued and plateau-like.

GEOLOGY

PRINCE RUPERT TO HAZELTON

The rocks along the railway between Prince Rupert and Hazelton have been classified under the following headings.

Pleistocene and Recent	Boulder clay and gravel
Cretaceous	Skeena formation
Post Hazelton group	Stocks of granodiorite Coast Range batholith
Jurassic	Hazelton group
Triassic or Carboniferous	Prince Rupert formation

Prince Rupert Formation

Schistose sedimentary rocks of the Prince Rupert formation extend from Prince Rupert to Sockeye, a distance of 17 miles. Quartzites and argillaceous quartzites partly converted to quartz-mica schists make up the bulk of these rocks. They strike parallel to the shore-line on the west side of Kaien island and on the southwest side of Tsimpsian peninsula. The dip is 30 to 60 degrees east.

The contact between the Coast Range batholith and the Prince Rupert formation north of the railway at Sockeye has a northeasterly trend and cuts across the sedimentary rocks at right angles to their strike. No pronounced change takes place in the degree of crystallinity of the schists near the contact. Dykes of granodiorite are present, however, and narrow aplite dykes are numerous.

The age of the Prince Rupert formation has not been established and it is here classified as Triassic or Carboniferous in accordance with former practice.[1]

Hazelton Group

Two bands of volcanic rocks, each 7 miles wide, are crossed by the railway at Amsbury and Usk, respectively. Between Dorreen and Hazelton, sedimentary rocks of the Hazelton group predominate. The volcanic rocks noted at Amsbury and Usk were mapped by McConnell as being probably of Triassic age.[2] The writer, however, has given reasons for placing these rocks in the lower part of the Hazelton group.[3] They are fragmental and massive volcanics. Between Dorreen and Hazelton the rocks are sedimentary, have moderate angles of dip, and strike in general parallel to Skeena valley. Argillites and quartzites are the common types seen. Near the contact with the Coast Range batholith at Dorreen, the sediments are hard and cherty. Dykes are not common except at

[1] Dolmage, V., "Coast and Islands of British Columbia between Douglas Channel and the Alaskan Boundary," Geol. Surv., Can., Sum. Rept., 1922, pt. A.
[2] Geol. Surv., Can., Sum. Rept., 1912, p. 59.
[3] Geol. Surv., Can., Sum. Rept., pt. A, 1923, pp. 34-36.

Andimaul, where a few sills or dykes of granodiorite porphyry occur. The sediments along this part of the valley are continuous from Ritchie westward into Kitsumgallum district, and they also form the country rock of Seven Sisters mountains rising 8 or 10 miles east of Ritchie.

Most of the Hazelton group as indicated by marine fossils is of Jurassic age, but this series of rocks is of widespread extent and may reach upward into early Cretaceous and downward into the Triassic. In Skeena and Bulkley districts, however, no fossils of Triassic or of Cretaceous age have been found in the rocks of the group.

Intrusive Rocks

The Coast Range batholith is practically uninterrupted by other rocks between Sockeye and Amsbury, a distance of 68 miles. To the east two bands of granodiorite, each about 8 miles wide, are crossed by the railway at Vanarsdol and Pacific respectively. The rock in the band at Vanarsdol is similar to that of the Coast Range batholith farther west and is probably a tongue of the batholith joining the main body of the batholith south of Skeena valley. The band at Pacific consists of grey granodiorite and is somewhat different from the rocks of the Coast Range batholith proper. This body may be a tongue joining the main batholith south of Skeena valley, or it may be a separate stock. A small stock of granodiorite is crossed by the railway 3 miles south of Hazelton.

The intrusive rocks are chiefly granodiorite, but at the western contact of the batholith the rock is diorite. Several bands of diorite are present between Sockeye and Amsbury, which are evidently the result of assimilation of basic rocks by the batholith, as gradations are present from partly to completely absorbed basic schists. Several roof-pendants or bands of schist striking north to northwest are seen in the main batholith.

The batholith and stocks are intrusive in rocks of the Hazelton group, but are not known to cut any rocks of the Skeena formation.

Skeena Formation

Rocks of this formation are present in Bulkley valley southeast of Hazelton, but have not been previously noted along Skeena valley west of Hazelton. Argillites and sandstones outcrop at Skeena Crossing and though severely folded are yet much softer than the usual rocks of the Hazelton group and may belong to the Skeena formation. Several small areas of similar rocks exist between Cedarvale and Kitwanga, and the writer believes that these small areas represent remnants of a Cretaceous formation which formerly was more extensive. The rocks consist of shales, argillites, and sandstones, with occasional bands of conglomerate. It is interesting to note that a 6-foot bed of conglomerate seen in these rocks midway between Cedarvale and Woodcock contains pebbles of granodiorite. No fossils were found, but these rocks resemble those of the Skeena formation far more than they do those of the Hazelton group, and consequently are placed in the Skeena formation. The Skeena formation is believed to be of Kootenay age.[1]

[1]Malloch, G. S., "The Groundhog Coal-Field, B.C.," Geol. Surv., Can., Sum. Rept., 1912, p. 86.

Pleistocene and Recent

Banks of boulder clay 200 feet high occur near Hazelton. To the west, nearer Prince Rupert, boulder clay is not plentiful but may be covered by later sediments. Post-Pleistocene stream gravels are present at Hazelton and also in many places between Hazelton and Prince Rupert. At Hazelton the gravels were deposited by a westward-flowing stream. At the mouth of Sedan creek near Woodcock a recent gravel delta has been built up.

SMITHERS AND VICINITY

The railway line between Hazelton and Smithers was not traversed, but a few days were spent on Hudson Bay mountain. The rocks of this mountain are chiefly of the Hazelton group and occur in three main divisions. The lowest division consists of fragmental and massive volcanic rocks of andesitic composition. The middle division consists of argillites, quartzites, and related sedimentary rocks. The upper division consists of fragmental and massive volcanic rocks, and in this division flows of rhyolite are very common. The divisions appear to be conformable. These rocks have been intruded by dykes, sills, and small stocks of granodiorite.

No very clear idea of the structure of the mountain was obtained, but the prevailing dips are southerly and the mountain appears to be in the main a monocline dipping gently south. The structure is not simple nor easy to decipher, as overturned folds appear to be present on the western side of the mountain.

Fossils were collected from the sedimentary rock of the middle division of the Hazelton group at Silver lake and near the Rico-Aspen mining property. The fossils indicate that the rocks are of Jurassic age.[1]

BURNS LAKE AND VICINITY

In the vicinity of Burns and François lakes, the predominant rocks are again fragmental and massive volcanic rocks of the Hazelton group. The Jurassic rocks here, however, were not studied, and no subdivision was attempted. A few outcrops of hard sandstone, argillite, and conglomerate were observed, but no data were obtained to show whether these sediments are Jurassic or Cretaceous. Unconformably on this older basement rest isolated patches of Tertiary sediments and lava flows. The Tertiary rocks were noted especially in the vicinity of François Lake post office, where basaltic lava flows, 100 feet thick, apparently overlie conformably soft sedimentary rocks. Fossiliferous sediments are present along the northern shore of François lake. The Tertiary rocks do not appear to occupy extensive areas, and the formation is probably only rarely over 200 feet thick.

Fossils were collected from these rocks on the northern shore of François lake and have been examined by W. A. Bell, Palæontological Division, Geological Survey, who has furnished the following report:

[1] Hanson, George, "Driftwood Creek Map-area, Babine Mountain, B.C.," Geol. Surv., Can., Sum. Rept., 1924, pt. A.

"In the small collection, Accession No. 576 of fossil leaves from north shore of François lake, B.C., the following species were identified:

Sequoia langsdorfii (Brongniart)
Taxodium occidentalis Newberry
Ulmus? sp., single leaf
Fruits (*Samara* cf. *Ulmus*)

Sequoia langsdorfii and *Taxodium occidentalis* are common members of a western early Tertiary flora recently determined by Berry to be Upper Eocene in age, and the conclusion is that the formation containing the above species is likewise of Upper Ecoene age."

ECONOMIC POSSIBILITIES

A large body of pyrite with associated chalcopyrite, occurs some distance up Ecstall river, but except for this occurrence very few mineral deposits of importance are known between Prince Rupert and Terrace. North and south of Terrace along the eastern border of the main body of the Coast Range batholith, mineral-bearing veins are numerous. No large ore-bodies are known, but the veins though narrow are commonly very rich. They are quartz-sulphide veins containing free gold, and the value in most instances is almost entirely in gold. A short distance east of Terrace, bornite-free gold quartz veins occur, as well as other deposits of a more complex nature. East and west of Skeena river, in the neighbourhood of Fiddler and Lorne creeks, gold-quartz veins are again the rule. In the vicinity of Hazelton are numerous small to moderate-sized veins containing a great variety of minerals, among which may be mentioned gold, jamesonite, wolframite, scheelite, molybdenite, safflorite, and the common minerals of copper, lead, zinc, silver, iron, and arsenic.

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

A vein near François Lake post office was examined which contains bitumen and two or more phosphate minerals. The country rock is basaltic lava 100 feet thick and apparently overlies Tertiary sediments. The Tertiary rocks occur in local, isolated patches overlying unconformably rocks of the Hazelton group. The lava flows are in part amygdaloidal with the vesicles partly filled with chalcedony and probably other minerals. The bitumen-phosphate vein lies between basalt walls and has a gentle dip parallel to the dip of the lava flows. As the vein has not been opened along the dip for more than a few feet nothing very definite could be learned of its origin. The wall-rock is rather friable, and the vein has the appearance of a filling between two flows of lava rather than the filling of a fracture. The possibility is also suggested that the material which gave rise to the phosphate minerals and bitumen accumulated on the surface of one lava flow and was covered by a later lava flow. The phosphate minerals and bitumen may have resulted from guano by a process of distillation in situ occasioned by the heat of the lava. The phosphate appears to be present as new minerals which have not yet been thoroughly investigated. The vein is less than a foot thick and gives no promise of having any commercial value.

TUNGSTEN DEPOSITS NEAR HAZELTON, BRITISH COLUMBIA

By M. E. Hurst

The properties described below were visited during the field season of 1924 while the writer was examining the arsenic occurrences near Hazelton, B.C. The tungsten deposits, together with those of arsenic, copper, lead, etc., occur in Rocher Déboulé mountains, southeast of Hazelton. This range consists of a central core of granodiorite, now exposed by erosion, which intruded the tuffs, argillites, and quartzites comprising the Hazelton series. These sediments, although silicified in places, were not subjected to widespread contact metamorphism. On the other hand the many shear zones and fissures which traverse both the granodiorite and the Hazelton series are evidence of the structural deformation and readjustment accompanying or following the intrusion. It is not surprising, therefore, to find that the mineral deposits occur chiefly along such shear zones or in the form of fissure veins, since these lines of weakness provided easily accessible channels for the ascending, mineral-bearing solutions. The tungsten deposits described below were probably among the earliest formed, since they occur in the granodiorite and contain such minerals as wolframite and scheelite which are characteristic of mineralization under high temperature and pressure conditions. Though the thickness of rock once overlying these deposits and now removed by erosion must have been great, it is likely that the veins will continue for a considerable depth below the present surface. This depth will be determined, of course, by the persistence and continuity of the fractures along, or in, which the deposits occur.

RED ROSE

This property is situated on the north side of Balsam creek, a tributary of Juniper creek which flows southwesterly into Skeena river just below Skeena Crossing, on the Canadian National railway. The claims are reached from the Skeena Crossing-Rocher Déboulé wagon road, which runs parallel to Juniper creek. A good trail branches off from the road about 8 miles above Skeena Crossing and runs easterly up the valley of Balsam creek to the Red Rose cabin (elevation 5,150 feet). From this point an indistinct trail leads northwesterly over slide rock to the crest of the divide between Balsam creek and a small creek lying to the north. The showings occur on the south slope of this divide at an elevation of 6,475 feet, or about 1,500 feet above timber-line. The principal outcrop is on the Yellow Hammer claim, one of a group of eight unsurveyed claims staked along the north side of Balsam creek and comprising the Red Rose group. This group is owned by Charles Ek, of Kispiox, B.C.

The tungsten showings lie on a spur of granodiorite exposed several hundred yards to the south of the main batholithic mass which forms the core of Rocher Déboulé range. The deposit consists of a quartz vein about 12 feet wide lying between walls of fine-grained, unaltered granodiorite. It outcrops for at least 100 feet before being covered by slide rock and even then its course can be traced for about 150 feet farther. The vein strikes north 75 degrees west (magnetic) and dips 50 degrees to the south, this being slightly steeper than the slope of the surface. The vein filling consists predominantly of quartz, usually milky or vitreous, and in many places well crystallized. Other constituents present in relatively minor amounts are, in order of abundance: wolframite (Fe, Mn) WO_4, greenish-yellow scheelite ($CaWO_4$), and chalcopyrite. These minerals are not uniformly distributed throughout the vein, but seem to be confined to certain mineralized sections or zones having no definite arrangement with respect to the walls of the vein. This variable distribution of the tungsten minerals in the vein renders sampling of little value, if not out of the question. In order to obtain an idea of the tungsten content a known tonnage of the material should be milled and the concentrates weighed and analysed for tungsten. In the exposures examined the concentration ratio would be so low that it is doubtful whether the deposit will have any economic value for some time to come. So far no development work has been done on the deposit and with the exception of tungsten no other constituents of possible value have been found.

BLACK PRINCE

This property is located at the head of Mud creek, which rises on the eastern slope of Rocher Déboulé range and flows into Bulkley river about 2½ miles southeast of Canyon station, on the Canadian National railway. A trail, now in a poor state of repair, leaves the New Hazelton-Telkwa wagon road about a mile west of the railway crossing and follows up the northwest side of Mud creek for about 6 miles to the Black Prince cabin (elevation 4,165 feet). The showings occur about 500 feet from the cabin and on a bluff of granodiorite which projects from the southeast side of Mud creek and lies between the two glacial lakes which occupy the step-like basin at the head of the creek.

The deposit occurs in a shear zone which intersects the granodiorite batholith several hundred yards from its eastern margin. This zone varies in width from 1·5 to 8 feet and contains from one to four parallel quartz veins 2 to 18 inches wide. It strikes north 56 to 65 degrees west (magnetic), dips 70 to 75 degrees to the southwest, and is exposed at intervals for about 550 feet vertically and 600 feet horizontally. The workings consist of a short tunnel and open-cuts driven in oxidized parts of the zone, which outcrop on the face of the bluff between elevations of 4,500 feet and 5,050 feet. In these openings the shear zone is marked by distinct walls and filled with iron-stained, partly altered fragments of granodiorite in addition to the quartz veins already mentioned. Much of the quartz in these veins is well crystallized and usually white, although on weathered surfaces it has a honeycombed and rusty appearance due to the leaching out of pyrite. In addition to quartz, the other minerals present in the veins or in the adjoining wall-rock are, in order of abundance: pyrite, chalcopyrite, molybdenite, and wolframite (Fe Mn,) WO_4. In a general way the mineralization is more extensive along the foot-wall of the zone, where pyrite and molybdenite are relatively abundant. Wolframite, although probably present, was not observed in the lower open-cuts, but only in the trenches or pits dug on the top of the ridge (elevation about 5,050 feet). There the shear zone narrows to 1·5 feet and is filled with cellular, rusty quartz in which occur occasional bunches of wolframite. This mineral, like molybdenite, is more resistant to oxidation than either pyrite or chalcopyrite, which explains its presence in the highly leached parts of the shear zone exposed at this elevation.

Samples taken from the various open-cuts were found to contain[1] on assay and analysis: gold, trace; silver, 0·6 to 6·4 ounces; tungstic oxide, trace to 4·0 per cent. It is evident, both from an examination of the property and from the analyses quoted above, that the percentage of tungsten in the deposit, so far as it has been exposed, is low. This fact, together with the narrowness of the quartz veins and of the shear zone in general, leads to the conclusion that the deposit does not hold much promise as a source of tungsten.

[1] Rept. of Minister of Mines, B.C., 1916.

WHITESAIL-TAHTSA LAKES AREA, BRITISH COLUMBIA

By J. R. Marshall

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Illustrations

INTRODUCTION

The field season of 1924 was occupied with a geological reconnaissance of part of the area bordering Whitesail and Tahtsa lakes. These bodies of water lie along the eastern margin of the Coast range, south of the Canadian National railway. The Eutsuk Lake map-sheet compiled by the Department of Lands, Forests, and Mines, British Columbia, was used as a base map. Mr. H. V. Warren rendered efficient service as assistant.

The area is easily reached from Burns lake, on the Canadian National railway, whence an excellent road leads to François lake, across which a government ferry operates. The road continues from the ferry landing on the south side of the lake to Ootsa on Ootsa lake, about 45 miles from Burns Lake station. Telephone communications have been extended to Ootsa lake, where there is a small scattered settlement, and a stage makes the round trip to Burns Lake twice weekly. From Ootsa, travel to Whitesail and Tahtsa lakes is by small boat or canoe. An alternative route to Tahtsa lake is from Houston on the Canadian National railway, over an old, little-used pack trail. From Houston, a good road leads to Wistaria, a small settlement on Ootsa lake, and thence to Ootsa, 14 miles to the east. From Wistaria, a pack trail follows along the north shore of Ootsa lake and Tahtsa river to the mineral claims on Sweeney mountain.

PREVIOUS WORK

The earliest geological information concerning the district is contained in a report by G. M. Dawson[1] who explored the country immediately to the east. In 1916 and again in 1919 J. D. Galloway[2] examined mineral claims on Whitesail lake and Sweeney mountain. In 1920 R. W. Brock[3] made a general reconnaissance of Ootsa, Whitesail, and Eutsuk lakes.

[1] Geol. Surv., Can., Ann. Rept., 1876.
[2] Ann. Rept. of Minister of Mines, B.C., 1916, 1919.
[3] Geol. Surv., Can., Sum. Rept., 1920, pt. A, p. 81.

GENERAL DESCRIPTION OF THE AREA

The area investigated during 1924 lies along the eastern margin of the Coast range, some of the peaks of which here reach elevations of about 7,500 feet with a vertical relief approximating 4,500 feet. The majority of the summits attain elevations of 6,000 to 7,000 feet with a vertical relief of 3,000 to 4,000 feet. A view across the Coast range, from any prominent peak, shows a number of parallel ranges trending northwest and southeast, with rounded summits presenting a uniform crest-line the evenness of which is occasionally broken by higher peaks. The valleys separating these ranges are deep and canyon-like and impart a very rugged aspect to the topography, which is otherwise characterized by the flat-topped and broad, massive, dome-shaped outlines of the mountains.

The Coast range, in this latitude, is bordered by a number of much dissected spurs which project northeast and have a general elevation of 6,000 to 7,000 feet, decreasing to the east to 5,000 feet. They merge on the west into the Coast range, and on the east into the Interior Plateau region. Chikamin range, between Eutsuk and Whitesail lakes, Whitesail range, between Whitesail lake and Tahtsa river, and Sibola mountains, north of Tahtsa river, are examples. They are rugged, steep-sided, deeply dissected mountain masses, with a vertical relief varying from 2,000 feet to 4,000 feet, and are characterized by broad, flat summits, dotted with meadows and many small lakes. Their summits, like those of the Coast range, are strikingly uniform in elevation. They are separated by deep, broad, U-shaped valleys, also trending east and northeast and, therefore, transverse to the axis of the Coast range. These valleys are occupied by large lakes or by rivers which form the trunk streams of the area. Radiating from these spurs are numerous small tributary streams with V-shaped valleys.

The Interior Plateau region, to the east, is a rolling, hilly country, with rounded, flat-topped ridges rising 800 to 1,200 feet above the general drainage level at 3,000 feet. Again, the sky-line is remarkably even with a gentle rise to the north. Viewed in detail the surface is broken, uneven, and even rugged where streams have incised, broad, U-shaped valleys.

Glaciation has greatly modified the topography. The continental ice-sheet planed off the upland surfaces and left many shallow depressions now occupied by small lakes. The underlying rocks were polished and furrowed and the material so eroded transported to lesser elevations. Some of the highest peaks in the area were covered by this ice-cap. The general profile of Chikamin peak, 7,100 feet in elevation, suggests stoss and lee sculpturing. The ridge immediately west of this peak is planed off to a park-like area at least 2 miles in width and erratics everywhere cover the slope. On nearly all of the ridges ascended similar erratic boulders were observed. Alpine glaciation, active even at present, has remodelled the pre-Pleistocene V-shaped valleys and given them their present U-shaped forms. These glaciers still occupy many of the higher slopes and extend below timber-line. Hanging valleys are numerous and picturesque, particularly at the heads of the larger lakes. Cirques are few and not well developed.

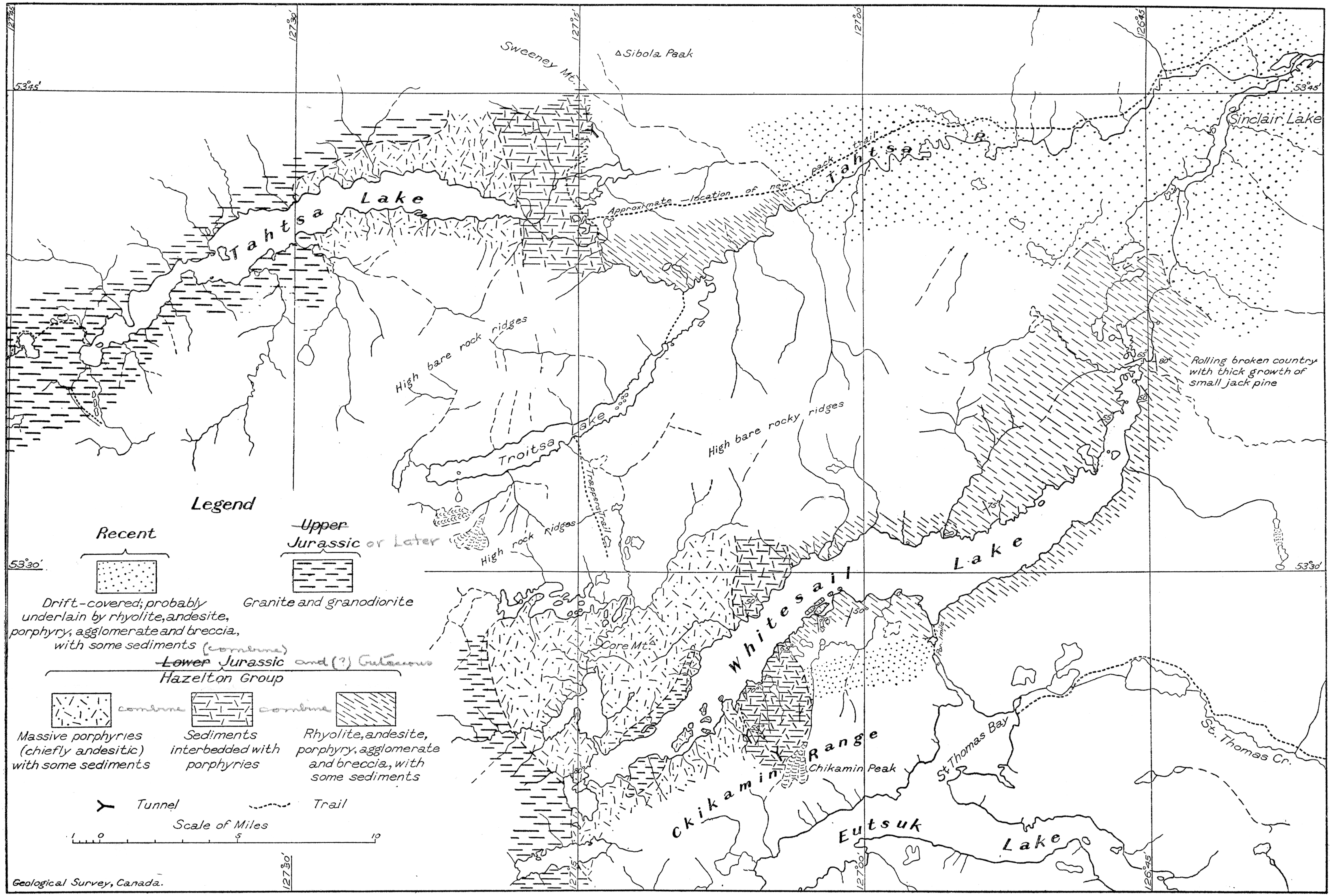

FIGURE 4. Geology in the vicinity of Whitesail and Tahtsa lakes, Coast district, B.C.

The drainage of the area is received by the three large lakes, Eutsuk, Whitesail, and Tahtsa lakes, whose main tributary streams rise in the glaciers of the Coast range. Eutsuk lake, 60 miles long, discharges east through smaller lakes and connecting rivers, to Nechako river. Tahtsa lake, 20 miles long and ½ mile to 2 miles wide, and Whitesail lake, 25 miles long and ½ to 3 miles wide, drain into Tahtsa river, which is 30 miles long, and empties into Ootsa lake, whose waters flow east to Nechako river. Tahtsa river and its tributary Whitesail river, though swift, are navigable at all seasons. Numerous log-jams are serious obstructions and during periods of high water force the waters into many new channels. Navigation on these rivers could be greatly improved by confining the water to one channel.

Dense forest extends to an elevation of 5,000 feet, above which only grassy or bare, rocky slopes are observed. The more common trees are Douglas fir, Englemann's spruce, western hemlock, lodge-pole pine, alpine or white balsam fir, and cottonwood. Red alder, willow, and devil's club are conspicuous on the open slopes. The salmonberry, huckleberry, and highbush cranberry are abundant along Tahtsa river and lake, less so along the Whitesail waters. Extensive meadows of beaver grass lie along the lower stretches of Tahtsa river.

The area is not a good game district. Moose, caribou, and deer are reported to frequent the country bordering Eutsuk lake, but none were seen about either Whitesail or Tahtsa lakes. The few tracks observed were apparently made by these animals while travelling back and forth from Eutsuk lake. Black bear were seen on the lower mountain slopes and mountain goat are plentiful on Chikamin, Tahtsa, and Sibola mountains. Marten, beaver, mink, muskrat, weasel, and a few wolverine are trapped. Other small animals observed were the red squirrel, chipmunk, and rabbit. Owls, crows, hawks, and eagles are common, but song-birds are few. Blue-grouse, willowgrouse, ptarmigan, and fool-hens are abundant on some of the higher slopes and geese and ducks plentiful in places. Whitesail and Tahtsa lakes are well stocked with lake and rainbow trout. Grayling and the common sucker are conspicuous in the rivers.

GENERAL GEOLOGY

The area is mainly occupied by a very thick assemblage of volcanic rocks with lesser amounts of waterlain tuffs, limestones, and argillites, in which a few poorly preserved fossils of Jurassic age have been found. These rocks are referred to the Hazelton group. They are intruded by a number of diorite dykes. About 1 mile west of Whitesail lake the volcanics are invaded by granite and granodiorite, belonging to an intrusive mass which extends into the Coast range for many miles to the west. Its line of contact with the volcanic rocks trends northwest across the range bordering Little Whitesail lake and crosses Tahtsa lake at almost its middle point. The western half of Tahtsa lake is bordered by granite and granodiorite. To the north of this lake the eastern edge of the intrusive mass trends northeast and appears to cross the north slope of Sibola range, beyond which it was not followed.

Table of Formations

Period	Formation	Lithology
Jurassic or younger............	Coast Range intrusives.........	Granite, granodiorite
Jurassic......................	Hazelton group.................	Fragmental and massive volcanic rocks, vesicular lavas, tuffaceous sediments, limestones, and argillites

HAZELTON GROUP

The rocks referred to the Hazelton group constitute a very thick series of flows with which are interbedded waterlain tuffs, limestones, and argillites. The flow rocks range from rhyolites to basic porphyrites, but massive andesites, either porphyritic, or non-porphyritic, form by far the greater part of the assemblage. Vesicular lavas are present, but are not abundant. The basic varieties are characteristically purple or green, whereas the tuffs and rhyolites, where not stained red, are commonly ash-grey, or white, and in places even black.

The Hazelton group strata of the district now reported upon are distributed so as to appear to form three lithologically distinct subdivisions, each of which characterizes separate areas. These subdivisions may correspond to three stratigraphical horizons, but this relation has not yet been established.

Subdivision No. 1 consists of lava flows with which are associated minor quantities of tuffs and other fragmental rocks. It includes the porphyrites, rhyolites, andesites, breccias, and agglomerates which outcrop on Whitesail river and continue westward on both sides of Whitesail lake to beyond Portage bay. The porphyrites are as a rule much weathered, and have a characteristic purple colour. The groundmass is invariably dense and holds abundant phenocrysts of decomposed feldspar. In some cases these lavas are vesicular, the vesicles being filled with calcite. They are overlain at the east end of Whitesail lake by white to dirty grey rhyolites, thin-bedded, well-banded, and in places showing flow structure. These form the low, rounded hills at the eastern end of the lake and along Whitesail river. They extend northeastward across Tahtsa river and are probably continuous eastward across Ootsa lake.

Westward along Whitesail lake the porphyrites are replaced by dark rhyolitic rocks, breccias, agglomerates, and andesites, but no definite sequence could be established. The andesites are characteristically green and everywhere porphyritic.

In a small bay on the south shore of the lake 2 miles west of Portage bay, a much weathered rock, with what appears to be pillow structure, was observed.

The rocks of this subdivision do not appear to be well mineralized. The rhyolites at the eastern end of Whitesail lake and on the ridges bordering Tahtsa river in its lower course, carry a little pyrite.

Subdivision No. 2 is composed of waterlain tuffs, limestones, and argillites, with interbedded bands of volcanic rocks, chiefly andesites. The volcanic rocks are decidedly subordinate to the sediments. The rocks of this subdivision are well exposed on Chikamin range and Sweeney mountain, and hold the mineral deposits of economic importance so far found. On Chikamin range tuffs occur at several different horizons separated from one another by beds of volcanic rocks. The greatest thickness of tuff observed in any one exposure occurs on the Nickel Plate claims, where one zone of silicified tuffs attains a thickness of 175 feet. On Sweeney mountain sediments interbedded with porphyritic andesites form distinct zones. In one of these zones grey tuffs and black argillites attain a thickness of about 700 feet. On the eastern face of the mountain fossiliferous argillaceous limestone 75 feet thick is interbedded with porphyritic andesite.

From the tuffs on Chikamin range some poorly preserved fossils were collected and determined as follows by F. H. McLearn:

Nerinea ? sp
Trigonia sp
Pecten sp
Astarte sp

From the argillaceous limestone on Sweeney mountain another collection of fossils was made and, as determined by F. H. McLearn, contains: *Trigonia tahtsaensis* McLearn. "The affinities of the Trigonia in this lot are Jurassic."

Subdivision No. 3 is developed west of the trail ascending Chikamin ridge from Whitesail lake, and consists of andesites, porphyritic and non-porphyritic, and rhyolites, with minor quantities of argillites. The porphyrites, breccias, and agglomerates of subdivision No. 1 were not observed among the rocks of this subdivision. The andesites are fresh looking, green and brick-red rocks, occupy fully two-thirds of this part of the area, and are also very abundant on the western part of Sweeney mountain. The rhyolites are invariably badly weathered and stained a brick-red from the decomposition of pyrite. Locally, near the west end of Whitesail lake they are traversed by small quartz veins carrying galena, zinc blende, and pyrite.

The Hazelton group in this area, as indicated above, is represented by a great volume of volcanic rocks with some true sediments. The thickness of the group could not be accurately estimated. A partial section on Chikamin ridge was estimated to be 13,500 feet thick.

Throughout the area these rocks have a general northwest-southeast trend and with few exceptions dip at steep angles. On Sweeney mountain both the volcanic and sedimentary members of the group are sheared and slickensided; on Chikamin ridge only the sediments show these effects.

COAST RANGE INTRUSIVES

The western part of the area is occupied by the Coast Range intrusives, which are younger than the rocks of the Hazelton group, and are in contact with them along a line having a general northwest-southeast course. The intrusives consist of granodiorite and diorite. An outlying body within the Hazelton group beds near the west end of Whitesail lake is formed of granite.

Dykes of diorite and porphyritic diorite cut the Hazelton group volcanics on Chikamin ridge. Diorite dykes also cut the Coast Range intrusives west of Whitesail lake and on Tahtsa lake. In all cases these dykes have an east-west trend. These dyke rocks may be related in origin to the Coast Range intrusives. Quartz veins carrying pyrite and chalcopyrite are associated with the dykes, and barren quartz veins occur in the Hazelton group rocks near their contact with the main body of the Coast Range intrusives.

ECONOMIC GEOLOGY

The east border of the batholithic area of the Coast range lies within the district. To the north and south the general vicinity of this line of contact has been proved to be favourable to the formation of valuable mineral deposits and, therefore, the district reported upon merits the attention of prospectors. As yet, little prospecting has been done, and only along parts of the trunk streams. The discoveries so far made prove that mineral deposits occur and that there exists at least one well-defined mineralized zone of considerable extent.

Gold, silver, lead, zinc, and copper have been found in veins on Chikamin ridge, south of Whitesail lake, and on Sweeney mountain north of Tahtsa river. Copper is also reported from the district immediately south of the area reported upon and gold from the area north of Sweeney mountain. The silver-lead-zinc deposits on Chikamin and Sweeney mountains are the important discoveries so far made.

The silver-lead deposits on Chikamin ridge are in beds of altered and sheared waterlain tuffs which outcrop near a number of small intrusive masses. Those of Sweeney mountain occur both in the sedimentary and volcanic members. The most spectacular showing, that in the Emerald group of claims, is in sheared waterlain tuffs lithologically similar to those outcropping on the Silver Tip claims on Chikamin ridge. These beds may be continuous across the area from Chikamin ridge to Sweeney mountain, and if so the country between Whitesail and Tahtsa lakes merits attention.

The known deposits are all low grade and the best showings occur in the sedimentary members of the Hazelton group. The waterlain tuffs appear to have been particularly susceptible to mineralization. The presence, however, of numerous small mineralized quartz veins in the volcanic rocks, on Whitesail lake, Chikamin ridge, and Sweeney mountain, suggests that important mineralization may be found in these rocks also. In the silver-lead ores of British Columbia and the Yukon, the higher values in many cases are carried by tetrahedrite and freibergite. Neither of these minerals has been observed associated with the deposits in the Whitesail-Tahtsa area, but the prospecting done does not warrant the conclusion that these minerals do not occur in some of the veins.

CARIBOO MINERAL CLAIMS

The Cariboo mineral claims are on the south shore of Whitesail lake, approximately 17 miles west of its outlet. They are located on the eastern border of an area occupied by beds of tuffs, argillites, and limestones, with subordinate interbeds of andesitic rocks. In this locality beds of green tuffs with interbeds of porphyritic andesite occupy the lake shore for three-fourths of a mile. The tuffs appear to be closely folded, have a general trend of 150 degrees, dip steeply, are much weathered, sheared, and fractured. The fractures as a rule parallel the strike of the beds; they are seamed with quartz and calcite, which form veinlets a fraction of an inch to 15 inches in width. The veinlets carry zinc blende, galena, pyrite, chalcopyrite, and arsenical pyrites, in lenses a few inches to 6 feet in length. Pyrite is sparingly present in the tuffs and andesites.

From the lake shore an adit has been driven south for 50 feet on the strike of a bed of tuffs, in which there are several veinlets of quartz. These veinlets, the largest of which is 14 inches wide, are distributed over a width of 3 feet and hold zinc blende, in lenses a few inches to 3 feet long and not over 6 inches wide. Galena, pyrite, and chalcopyrite are also present. From the face of the adit, a crosscut was driven to the east for 100 feet, and lies in barren rock. Galloway's[1] sample of a 14-inch vein in the tunnel assayed: gold, trace; silver, 1·2 ounces; zinc, 30·5 per cent.

About 200 yards west of the adit and 50 feet above the lake-level an open-cut has been made in a sheared tuff which is veined with quartz and calcite in parallel veinlets a fraction of an inch to 10 inches wide. These veinlets form a zone 2 feet wide and are mineralized with zinc blende, galena, chalcopyrite, and arsenical pyrites. Zinc blende and galena in about equal proportions predominate over the other minerals, and occur in lenses a few inches to 6 feet long and up to 6 inches in width. A specimen composed of about equal proportions of galena and zinc blende was selected for assay to ascertain what values, if any, the sulphides carried.

The assay[2] showed: gold, trace; silver, 23·6 ounces; lead, 45·17 per cent; zinc, 21·88 per cent. West of this a similar open-cut has been made on the shore in beds of tuffs sparingly mineralized as above over a width of 6 feet. None of these showings has been traced inland, and the amount of mineral showing does not warrant further development at these particular points.

SILVER TIP MINERAL CLAIMS

The Silver Tip claims are located on Chikamin mountain about 20 miles west of the foot of Whitesail lake. The workings on these claims are located in the bed of a small creek on the north slope of Chikamin $1\frac{1}{2}$ miles south of, and 1,200 feet above, the lake, and consist of an adit driven to the south for 40 feet on the strike of the rocks, and a crosscut to the east across the face for 20 feet. Some surface work has also been done in the creek bed north of the adit. At the time of examination four men were engaged in extending the crosscut eastwards.

The deposit is in a bed of waterlain tuff, fine-grained to dense, grey to pink, sheared, and stained with limonite. At the top the tuff grades into a coarser-grained rock composed of loosely cemented, rounded, and angular pieces of fresh quartz and weathered feldspars. The cementing material is calcite. This particular phase of the rock has a talcy feel, and resembles an arkose. An average specimen of the finer variety of tuff is composed of andesitic material, angular pieces of feldspar, and minor quantities of quartz in a dense groundmass. Bedding is well preserved, the strata trending 175 degrees magnetic and dipping 55 to 75 degrees southwest.

[1] Ann. Rept. Minister of Mines, B.C., p. 166.
[2] Assays made by Department of Mines, Ottawa.

The tuff is strongly sheared and slickensided surfaces are common. The shear zone, 25 feet in width, can be traced down the creek about 200 feet below the adit. Here the creek angles across the bed, which disappears beneath a heavy soil covering. A second bed of sheared tuffs 10 feet in width and parallel to the first, outcrops about 30 feet west of the adit, and is separated from the first-mentioned bed by porphyritic andesite. About one-fourth mile southeast of the adit and on the creek referred to above, tuffs interbedded with andesitic flows outcrop, but show no shearing effects. They are fine-grained to dense, grey and pink, and break with a very even fracture. The strike here is east and west, and the dip 40 degrees to northeast. From this bed some poorly preserved fossil remains were collected. It would thus appear that there are several distinct beds of tuffs interbedded with andesite flows. The bed in which the adit has been driven is mineralized with galena, zinc blende, pyrite, and a little chalcopyrite. Only the latter two minerals were observed in the other beds.

The mineral body consists of galena, zinc blende, pyrite, and a little chalcopyrite in veins of quartz. With the quartz are calcite and a talcy gouge and this latter in many cases forms the only vein filling. The veins vary from minute stringers to 15 inches in width, parallel the trend of the rock, and form a zone 7 feet in width. Of this width about 60 per cent is occupied by country rock, and 40 per cent by mineralized veins. Several of the veins can be seen to unite to form a single vein 15 inches wide, but which in a few feet again divides into several narrower veins. The proportion of sulphides to gangue in the veins is as a rule high. Many veinlets composed entirely of sulphides are visible in the roof of the adit. The proportion of zinc blende to galena varies from a negligible quantity to 30 per cent. The galena is coarse, cubical, fine steel, and massive. A specimen of the coarse, cubical galena was selected from a vein in the adit, for assay, to ascertain values if any, and gave: gold, 0·04 ounce; silver, 87·15 ounces; lead, 78·6 per cent. A specimen of the massive galena, selected from a vein in the adit, assayed: gold, 0·03 ounce; silver, 87·7 ounces; lead, 62·13 per cent.

Approximately 30 tons of hand-picked galena with very little admixed blende were visible on the dump at the mouth of the adit. A specimen of solid galena was selected here and assayed: gold, 0·05 ounce; silver, 111·9 ounces; lead, 83·24 per cent.

No information concerning the extent of the deposit other than what could be gathered from observations in the adit, and in the creek bed north of the adit, could be had. In the creek bed narrow lenses of sulphides can be observed for 50 feet north of the adit, but beyond that stream wash and soil conceal everything.

The assays indicate that the deposit is low grade. The specimens selected for assay, although chosen solely to determine what values, if any, the galena carried, were such as could be mined with careful hand-sorting and concentration. No estimate, however, can be made as to probable tonnage available.

NICKEL PLATE MINERAL CLAIM

The Nickel Plate claims lie southeast of the Silver Tip, and at an elevation of 1,850 feet above Whitesail lake. A good trail connects the two groups. A well-defined vein occurs in beds of silicified glassy tuffs. They resemble quartzites, save that they lack any suggestion of granular texture, are extremely hard, flint-like, and break with a distinct conchoidal fracture. The beds trend 160 degrees, dip 70 degrees to 80 degrees to the southwest, and are about 175 feet thick. Some very poorly preserved fossil remains were found in these beds.

The deposit is a well-defined and persistent vein which is exposed continuously for at least 2,500 feet, and is said to continue on the south slope of Chikamin range. From the first workings on the vein, about 2,600 feet in elevation above Whitesail lake to the top of Chikamin peak, there is a difference in elevation of about 1,700 feet and a continuous exposure of the vein with an average width of 15 inches, with mineral showing all along the outcrop. The trend and dip of the vein correspond to those of the tuffs—160 degrees and 70 degrees to 80 degrees southwest respectively. At an elevation of 2,600 feet above Whitesail lake a short adit has been driven south on the vein, which is here 2 feet wide. The vein material is fine-grained, white quartz. Fractures in the quartz are filled with galena, zinc blende, chalcopyrite, and pyrite. Tetrahedrite and ruby silver are also reported, but were not observed. The fractures are as a rule parallel, and with their longer axes with the trend of the vein, thus giving the vein a banded appearance. In width the fractures vary from the thickness of a knife-blade to 2 inches, and lenses of sulphides can be traced for a distance of 10 feet. The proportions of blende and galena here are about equal. A specimen of solid galena selected for assay gave: gold, 0·05 ounce; silver, 20·25 ounces; lead, 21·11 per cent. South of this adit several open-cuts have been made, but the deposit does not improve in appearance. About 1,000 feet south of the adit the percentage of blende to galena is lower, and at the second adit, 3,500 feet in elevation above Whitesail lake, the galena is practically free from blende. Here the vein is 18 inches wide. A fine, granular quartz and talcy gouge hold galena and negligible amounts of pyrite, in lenses from a few inches to 8 feet long. As a rule the sulphides are in excess of vein filling. A specimen of galena was selected here and assayed: gold, 0·04 ounce; silver, 116·0 ounces; lead, 53·41 per cent. Immediately above this adit the vein 18 inches wide has been stripped on the north face of the ridge for 300 feet. Twelve inches of this width is composed of solid galena, similar to the specimen selected from the adit passage. Heavy snow on the face of the ridge precluded an examination of what the owners consider the best showings.

OTHER MINERAL OCCURRENCES ON CHIKAMIN RANGE

On the east face of Chikamin ridge near the head of Chikamin creek an open-cut has been made in copper and iron sulphides, and south of this, in a deposit of magnetite. The country rock is porphyritic andesite intruded by numerous narrow dykes of porphyritic diorite. The trend of the country rock is uniform 160 degrees—dip 70 degrees to 80 degrees to the southwest. The intrusive bodies are, as a rule, narrow dykes, a few inches to 15 feet in width with east and west trend. Granular chalcopyrite and pyrite occur in quartz-calcite veins up to 6 inches wide in the dykes and in the andesites. No solid bodies of sulphides were observed. The sulphides are said to assay about $2 of gold a ton.

South of the open-cut referred to above a dyke of porphyritic diorite, 15 feet wide, invades porphyritic andesites. Near the contact of the two bodies is a contact metamorphic zone 20 feet wide consisting of bands of iron ore up to 8 inches in width, and bands of andesite up to 3 feet in width. Associated with the iron are andradite garnet and epidote with well-developed crystal forms. These minerals occupy veins and vugs in the andesite. The garnets with a distinct resinous colour are termed by the prospector, "resinblende." A specimen of the iron ore submitted to Mr. Poitevin for examination is reported upon as follows: "Specimen of iron ore consists of a peculiar magnetite having an extraordinary magnetism almost equal to lodestone. This magnetite is admixed with ankerite and siderite. A little secondary specular iron is also to be seen."

On the south slope of Chikamin range, veins of chalcopyrite are reported, but owing to the presence of snow on the slopes, could not be examined.

SWEENEY MOUNTAIN MINERAL DEPOSITS

The mineral discoveries on Sweeney mountain may be reached either by water or by pack-trail route. Tahtsa river is navigable in all seasons for ordinary boats. Recently, a pack trail which follows the north shore of Tahtsa river was built from the west end of Ootsa lake. From what is known as the Landing, about 3 miles east of the outlet of Tahtsa lake, a well-graded trail heads across the flat and ascends Sweeney mountain.

Sweeney mountain is formed of rocks of the Hazelton group, lithologically similar to rocks of the same group on Chikamin ridge. West of the westernmost peak of the mountain, the Coast Range intrusives invade the members of the Hazelton group.

The most important mineral discovery on Sweeney mountain is the silver-lead property, known as the Emerald group, owned by William Sweeney and associates. This property was optioned to Mr. James Cronin in 1917 and again in 1919. During the summer of 1919 Mr. Cronin began development work on these claims. A graded trail about 6 miles long was constructed from Tahtsa river to a point on the south slope of the mountain 2,300 feet above the river. At this point an adit was driven northwards on the strike of the rock for 125 feet. Since 1919 no further work has been done on this property.

The mineral deposit occurs in beds of sheared and altered tuffs and argillites. The tuffs, sheared, slickensided, and stained with limonite, are lithologically similar to the mineralized tuffs of the Silver Tip claims on Chikamin. They trend 330 degrees magnetic and dip 75 degrees to the northeast. The shear zone, 20 feet in width, is parallel to the trend of the rocks and extends northward across the crest of the ridge.

An adit 125 feet long follows the strike of the beds. Quartz fills fractures in the tuffs, forming veins up to 18 inches wide. The quartz is fractured in all directions, and these fractures filled with cubical and steel galena, and subordinate amounts of pyrite, chalcopyrite, and zinc blende. Pyrite and chalcopyrite are present in the tuffs and argillites. At the portal mineralization extends over a width of 6 feet. Wall-rock and quartz gangue occupy fully 60 per cent of this space. Throughout the length of the adit irregular splashes of galena, 8 inches to 10 inches maximum width and 18 inches in length, can be seen. The majority of the lenses are much smaller.

The proportion of wall-rock and quartz to mineral is high throughout, and averages respectively 70 per cent and 30 per cent. In places very little if any mineral is visible. At the face, the veined width is 9 feet, but very little mineral shows. A specimen of steel galena, selected from a 10-inch vein in the adit, assayed: gold, trace; silver, 74·6 ounces; lead, 57·74 per cent. On the surface north of the adit the deposit is a well-defined vein 400 feet long and 2 feet wide. Throughout this length solid lenses of galena 1 foot and 2 feet wide can be seen. A specimen of galena from a lens 1 foot wide assayed: gold, trace; silver, 62·85 ounces; lead, 81·74 per cent. Four hundred feet north of the adit the vein disappears abruptly. About 150 feet east and 200 feet north of this point a similar vein trends 330 degrees, dips 75 degrees northeast, and continues across the crest of the ridge. This may represent a faulted and offset portion of the adit vein. Lenses of galena 2 inches to 15 inches wide occur continuously along the strike of this vein to the crest of the ridge. A specimen of galena from one of these lenses assayed: gold, trace; silver, 48·30 ounces; lead, 80·24 per cent. The total length of the deposit from adit portal to the crest of the ridge is at least 2,000 feet, and the difference in elevation about 900 feet. The specimens selected for assay were such as could be mined with careful sorting and concentration. The assays of these indicate a low-grade deposit.

GLACIER MINERAL CLAIMS

The Glacier claims are located on the eastern face of Sweeney mountain, ½ mile east of and at about the same elevation as the Emerald adit. The deposit, which consists of galena, occurs in a sheared porphyritic andesite veined with white quartz. The shear zone trends north 35 degrees east, has a maximum width of 10 feet, and averages 6 feet in width over a length of 150 feet. The principal showing is beneath a glacier and consists of a 3-foot vein of quartz which trends north 35 degrees east and dips 65 degrees to the northwest. Irregular lenses of galena 2 inches to 2 feet in width follow the hanging-wall of the vein for a distance of 150 feet, and to a depth of 75 feet. A specimen of galena was selected and assayed: gold, trace; silver, 29·35 ounces; lead, 66·70 per cent. A sample taken across 5 feet by J. D. Galloway[1] assayed: gold, trace; silver, 1 ounce; lead, 4 per cent.

SUNSET MINERAL CLAIMS

These claims are located on the southeast face of Sweeney mountain. The rocks are sheared porphyritic andesites. The general trend of the shear zone is north 60 degrees east. Fractures in the andesites are veined with quartz which holds pyrite, marcasite, chalcopyrite, arsenopyrite, galena, a little zinc blende, and some hematite. The veins parallel the trend of the zone and vary in width from a fraction of an inch to 10 inches. The minerals form irregular lenses ½ inch to 6 inches wide. No large body of mineral was observed. A specimen of arsenopyrite with a little galena was selected for assay and gave: gold, 3·00 ounces; silver, 57·2 ounces.

Other claims have been staked on the eastern face of the mountain and in the flat below, but so far no large mineral bodies have been discovered.

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[1] Rept. of Minister of Mines, B.C., 1916, p. 165.

ORIGIN OF MINERAL DEPOSITS

The area reported upon lies along the eastern border of the Coast Range intrusives, which are regarded as the source of many of the mineral deposits in the interior of British Columbia. There are also a number of small intrusive bodies which may be related in origin to the Coast Range intrusives. On the southeast face of Chikamin range, dykes of porphyritic diorite are responsible for the mineralization which occurs there. On Sweeney mountain the deposits are sufficiently close to the Coast Range intrusives to derive their values from that body.

FUTURE OF THE AREA

The development of the area reported upon is entirely dependent on the discovery of economic minerals of sufficiently high values to permit extraction. The mineral discoveries to date do not warrant the construction of a railway. In the event of such discovery, entrance would be from the east, as the Coast range forms a barrier to the west. The waterways afford transport channel for present needs. Navigation on both Whitesail and Tahtsa rivers could be greatly improved at small expense.

The area contains no land suitable for agriculture, nor has the timber any commercial value. To the east lies a partly settled belt well suited for mixed farming and ranching.

CHILKO LAKE AND VICINITY, BRITISH COLUMBIA

By V. Dolmage

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Illustrations

INTRODUCTION

The greater part of the season of 1924 was spent by the writer in exploring and geologically mapping a region which includes Tatlayoko, Chilko, and Taseko lakes. This region is about 60 miles long and 35 miles wide and lies between latitudes 50 degrees and 52 degrees and longitudes 122° 30′ and 123° 30′. Chilko lake, which is over 40 miles long and occupies a central position in the area, is 140 miles northwest of Vancouver and 35 miles northeast of the head of Bute inlet, the nearest salt water. However, notwithstanding its proximity to Vancouver and to salt water, it can be reached only by a five-day journey from Vancouver. There are two routes; a longer one, which is open the greater part of the year, and a shorter one which crosses a 7,000-foot divide partly occupied by a glacier and blocked by snow for eight or nine months of the year. The longer route is by Pacific Great Eastern railway to Williams Lake, by motor to Redstone 100 miles by road westward from Williams Lake, and by horseback for 40 miles south to Chilko lake. The shorter route is by Pacific Great Eastern railway to Shalath, by motor to Bridge river and Gun creek, and by horseback to Warner pass and Taseko lake. This route, though shorter, takes a longer time to traverse as the distance travelled by horseback is much greater.

This large stretch of country, though only 140 miles from Vancouver, as the crow flies, is for the most part uninhabited and to some extent not even explored. The only inhabitants are: three or four ranchers north of Tatlayoko and Choelquoit lakes, one or two north of Chilko lake, several in the vicinity of Brittany creek and lakes, and several families of Indians in Nemaia valley. There are, also, three trappers and as many prospectors, the latter remaining in the district for only a few months during the summer. The ranchers raise horses and a few beef cattle.

The only previous geological work in this region was done by George M. Dawson[1], A. M. Bateman[2], and the late J. D. Mackenzie.[3] Dawson's map and report deal with a large area of central British Columbia extending from Fraser river to the coast. Bateman made a reconnaissance survey along a route from Bridge river to Chilko lake, but no map accompanies his report. In a reconnaissance survey from Taseko lakes to Fraser river, Mackenzie mapped a small part of the area adjacent to the southeast side of Taseko lakes. Considerable information concerning the mineral deposits and the general character of this region is contained in a report by W. F. Robertson[4], provincial mineralogist of British Columbia. This report is accompanied by an excellent sketch map, which was until recently the only serviceable map of the district. The region adjacent to Tatlayoko lake is also described briefly by John D. Galloway[5] of the British Columbia Bureau of Mines.

Prior to 1912 the only existing accurate geographic data pertaining to this region resulted from the surveys along the proposed lines of the Canadian Pacific railway. In 1912 Bateman made a sketch map of the south part of Chilko lake. Malcolm Goddard, a dentist of San Francisco, and an alpine enthusiast, climbed several of the highest peaks in that vicinity and made a good sketch map, and R. P. Bishop of the Lands Department of British Columbia surveyed the 120th meridian from the 52nd parallel south to Nemaia valley, sketched in Nemaia and the north end of Chilko lake from depression angles, and made a pacing compass traverse from Nemaia valley to Taseko lakes. In 1922 Bishop triangulated the whole region, including Tatlayoko, Chilko, and Taseko lakes, and this formed the foundation of the map accompanying this report.

Mr. Bishop accompanied the writer during the season and took charge of the topographic mapping. In the geological mapping the writer was ably assisted by Carl Tolman and William V. Smitheringale.

GENERAL CHARACTER OF THE DISTRICT

TOPOGRAPHY

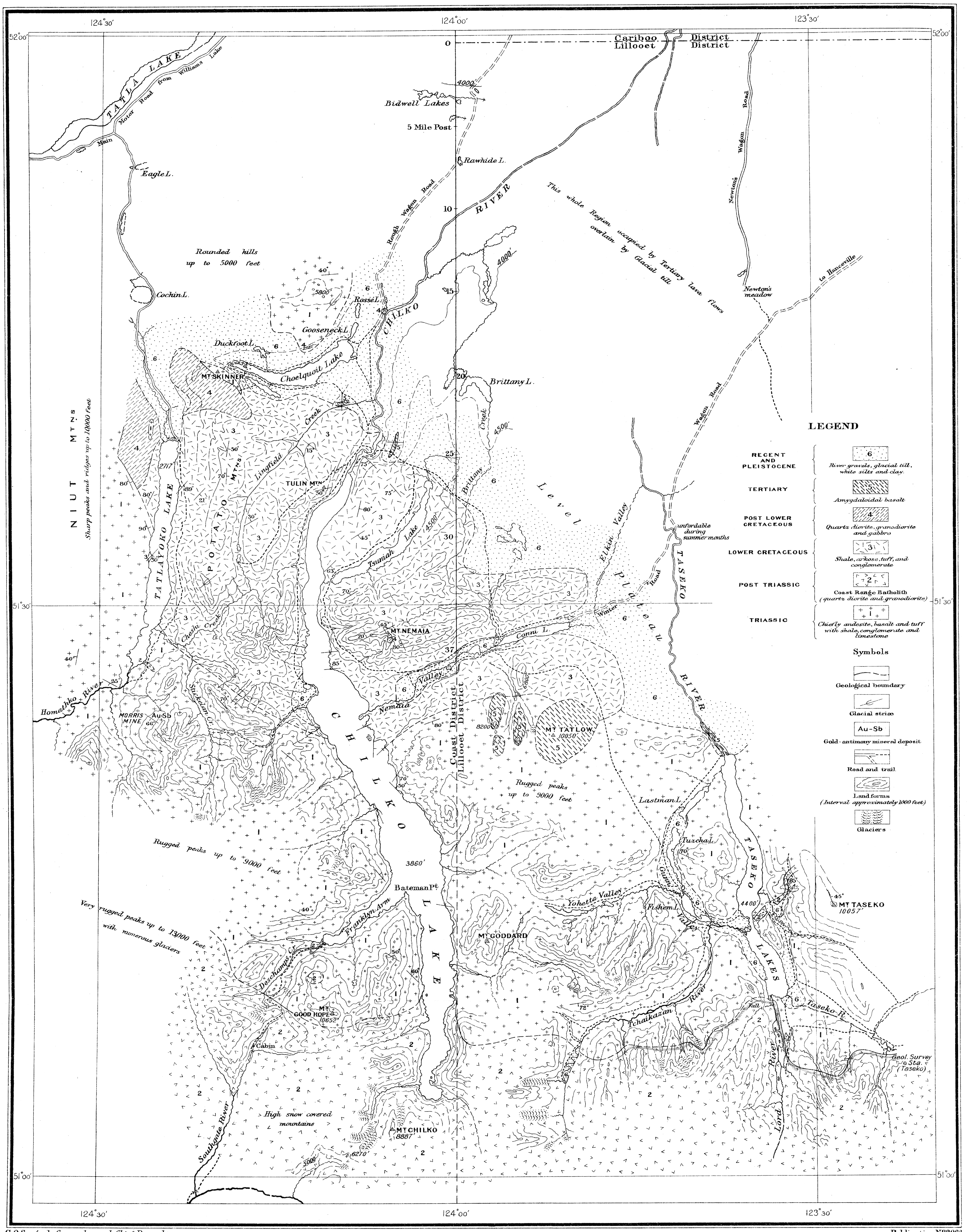
The boundary between two of the principal physiographic provinces of western British Columbia enters the area from the northwest a short distance south of Tatla lake, passes close to the northern ends of Chilko, Tsunia, and Connie lakes, and leaves the area a few miles north of Taseko lakes. Northeast of this boundary stretches the Interior Plateaux region of British Columbia and to the southwest rise the rugged mountains of the Coast range.

The Interior plateau occupies a belt of country in the central part of the province, about 500 miles in length and averaging 100 miles in width. It is an undulating and in places hilly region about 3,500 feet above sea-level, into which Fraser river and its tributaries have cut deep, gorge-like valleys. When viewed from one of the adjacent peaks of the Coast range, the steep, narrow valleys are entirely lost to view and the intervening areas appear as a comparatively level plain broken only in a few places by

[1] Geol. Surv., Can., Rept. of Prog., 1875-76, p. 233.
[2] Geol. Surv., Can., Sum. Rept., 1912, p. 177.
[3] Geol. Surv., Can., Sum. Rept., 1920, pt. A, p. 70.
[4] Ann. Rept., Minister of Mines, B.C., 1910.
[5] Ann. Rept., Minister of Mines, B.C., 1916.

Canada
Department of Mines
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER.
GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR.

Issued 1925



C.-O. Senécal, *Geographer and Chief Draughtsman.*
R. B. Yorston, *Draughtsman.*

Publication No. 2063

CHILKO LAKE AND VICINITY, COAST AND LILLOOET DISTRICTS, BRITISH COLUMBIA.

To accompany report by V. Dolmage, in Summary Report, Part A, 1924.

Scale of Miles

5 0 5 10 15 20

Sources of Information
Geology by V. Dolmage, 1924.
Geography, in part, from information supplied by Department of Lands, B.C.

low, rolling hills or an occasional sharp volcanic cone of recent origin. Within the area here described the Interior plateau is more than ordinarily level owing to the widespread flat-lying Tertiary lava flows upon which lies a mantle of glacial till of surprisingly uniform thickness. The even plateau surface is broken by only one range of low hills stretching northwest from Choelquoit lake. It is dotted with many, small, shallow lakes and undrained swampy depressions, from some of which quantities of wild hay may be gathered. On the slopes of some of the rounded hills and along the banks of the rivers the timber is sparse, and the ground covered with bunch grass which ordinarily affords excellent pasturage, but has been somewhat depleted by large bands of wild horses which now inhabit these parts. The flatter part of the plateau within the map-area is covered with coarse glacial till on which grow only fairly dense forests of smallish jackpine of no apparent value.

Between the Coast range and the plateau is a transitional zone characterized by rounded and flat-topped mountains which rise gradually towards the west. These mountains are too low to maintain glaciers and it is to this condition as well as to the soft nature of the rocks of which they are composed that they owe their smooth, rounded outlines. They are mostly below the snow-line and above timber-line and consequently form broad stretches of open country covered with grass and flowers. Between the northern ends of Chilko and Tatlayoko lakes a group of these mountains is known as Potato mountain owing to the quantities of wild potatoes which grow there and from which every summer the Chilkotin Indians gather their winter's supply. The gently eastward sloping sides of these mountains appear to conform with remarkable precision to an old land surface which slopes gradually down from the Coast range and merges into the plateau at a distance of 10 or 12 miles. It is by the dissection of this slope, chiefly by glaciers, that the mountains of this transitional zone are believed to have been formed.

There are in this transitional belt, however, a few exceptional peaks which rise to 8,000 and even 10,000 feet, thus extending into the zone of alpine glaciation, as a result of which they are occupied by large glaciers which have carved them into the jagged, fantastic shapes so characteristic of the peaks of the Coast range to the west. Their sharp outlines, superior elevations, and proximity to the plateau make them conspicuous landmarks well known throughout the country. The most prominent of these higher peaks is mount Tatlow, which is known to the Chilkotin Indians as "Tsoloss" and is a leading figure in many of their legends. It stands about 6 miles south of Nemaia valley and rises from the very edge of the plateau to an elevation of 10,050 feet.

Probably the most striking features of this part of the district are the immense, glacial valleys, which form a network of deep, broad trenches cut to about the level of the plateau or deeper, and thus divide the range into a number of completely separated mountain blocks. These valleys vary in width from 1 to 5 miles, have flat or hummocky bottoms, steep walls, and pass indiscriminately through the drainage divides. They are joined by similarly shaped tributary valleys which slope gradually up into the mountains, and also by smaller hanging valleys. At several places smaller valleys were observed which branch from the main valleys and after passing around a mountain block rejoin them.

Three of the main valleys run north and south and the others from east to west. The north-south valleys are cut below the level of the plateau and each is occupied by a long, narrow lake. Named from east to west the lakes are Taseko, Chilko (Plate II), and Tatlayoko lakes situated at elevations of 4,400, 3,860, and 2,717 feet respectively. Tatlayoko lake drains south through Homathko river to Bute inlet. The other two drain north to Fraser river. The two principal east-west valleys are Nemaia and Yohetta. They have been cut to about the same level as the plateau and are partly occupied by several small shallow lakes. Nemaia is the most attractive valley of the district (*See* Plate I B), has a width of 5 to 10 miles, is sparsely timbered, and has many large grassy meadows and wild-hay sloughs capable of supporting many cattle and horses. It extends from the plateau in the vicinity of Taseko river to Chilko lake, and, what appears to be a continuation of the same valley, extends from the opposite shore of Chilko lake through the divide to Tatlayoko lake. This through valley is shown in Plate I B. Yohetta valley to the south also connects Taseko and Chilko valleys. Near its western end it divides into two branches between which rises a group of rugged and lofty peaks, of which mount Goddard is the highest. Both these branches bend northward as they join Chilko valley.

All these valleys are believed to have been formed by glaciers which arose in the continental ice-sheet, and, as indicated by glacial striæ, moved westerly through Tsuniah, Nemaia, and Yohetta valleys; north through the southern parts, and south through the northern parts of Taseko and Chilko valleys; and through Tatlayoko valley and on down Homathko river to Bute inlet. The three principal north-south valleys, it is thought, were subsequently deepened by alpine glaciers flowing from the high mountains to the south during a long period of alpine glaciation which closely followed recession of the continental ice-sheet.

Excellent trails with easy grade can readily be made along the main valleys and up the tributary valleys to the timber-line meadows. Moreover, some of them, such as Tsuniah, Nemaia, and the northern parts of Taseko, Chilko, and Tatlayoko contain valuable grazing lands and considerable quantities of wild hay.

The long, narrow, deep lakes, though inclined to be windy, are easily navigated and form lines of communication between the southern and northern parts of the district. But by no means their least important quality is their great beauty, particularly that of Chilko lake. The water of Tatlayoko is clear and colourless, and that of Taseko white and opaque due to the large amount of rock flour produced by the glaciers which feed it, but the water of Chilko, particularly in its northern part, has a bluish, opalescent colour of remarkable beauty which contrasts pleasingly with the green vegetation along the shoreline, the red colour of the rocks above, and the white snowfields still higher. It would be difficult to imagine a more delightful camping ground than the shores of Chilko lake.

The Coast range is a broad belt of extremely mountainous country flanking the British Columbia coast and extending inland 60 to 80 miles to the Interior plateau. The part of the range included in the map-area lies south and west of a line running along the west side of Tatlayoko lake, thence to Franklyn arm on Chilko lake, and passing out of the area just south of Taseko lakes. This part of the area is an uninhabited, largely unexplored, and well-nigh impassable wilderness of rugged, ice-covered mountains and ridges separated by deep, steep-walled valleys (*See* Plate II). The region south of Chilko lake and between the headwaters of Bridge and Lillooet rivers is not known to have been crossed by a white man. Viewed from one of the higher mountains this region presents a vast number of jagged peaks and ridges rising to about the same elevation, with here and there an occasional peak projecting above the rest. The average elevation is about 8,000 feet, but some of the peaks are over 10,000 feet and one exceptional peak, judging by instrumental observations made on it from several triangulation stations, is over 13,000 feet and probably higher than mount Robson. Even more striking than the serrated sky-line is the vast amount of snow and ice to be seen in any extended view of this region, particularly when looking south, as then more snow and ice than rock are visible.

Late in the season two trappers by the names of Allaire and Thorpe attempted to cross from the headwaters of Lord river to Toba inlet or Powell lake, but after several weeks of strenuous exertion and much hardship they were compelled to return to the interior. The principal obstacles encountered were the large crevasses in the glaciers, which in several instances prevented the crossing of the divides.

CLIMATE AND VEGETATION

The climate of Chilko and Taseko valleys, owing to their high altitude and proximity to so many large glaciers, is quite cold. Hard frosts are likely to occur throughout the summer, thus making these valleys unfit for agricultural pursuits. Nemaia valley, which has an east and west trend, is protected from the cold winds from the glaciers and consequently has a milder climate. Tatlayoko valley is more than 1,000 feet lower and, therefore, much warmer and well suited to raising many kinds of vegetables, berries, and some grains. The rainfall is plentiful but moderate. In spite of the frosts the summer climate is on the whole exceptionally pleasant. West of the Coast Range divide there is a sudden change from a moderately dry, to an excessively wet, climate, which is accompanied by an equally abrupt change in the amount and character of the vegetation.

East of the divide commercial timber is found only in small, isolated areas such as the extreme south ends of the valleys of Chilko lake and Franklyn arm. West of the divide dense growths of large timber occur in the bottoms of all of the large valleys. There is considerable good timber in the valley of Tatlayoko lake.

The parts of the area underlain by Cretaceous shales have a distinctive vegetation. They have wide stretches of open country with good growths of bunch grass on the hillsides and small groves of aspen and spruce in the valleys. These areas contain the best grazing lands and are altogether the most attractive parts of the district.

GEOLOGY

The geological boundaries in this region follow in a general way the physiographic boundaries and strike in a westerly and northwesterly direction. The whole northeastern part is occupied by Tertiary lava flows, and the southwestern part by the granitic of the Coast Range batholith. The intervening part, about 30 miles wide, is occupied by Mesozoic sedimentary and volcanic rocks. The northern half of this strip of Mesozoic is composed entirely of sedimentary rocks in which Lower Cretaceous fossils were found, whereas the southern half is occupied by volcanic and sedimentary rocks from which Triassic fossils were recovered.

Table of Formations

Pleistocene and Recent........................	River gravels, glacial till, white silts, and clay
Upper Tertiary................................	Amygdaloidal basalt
Post-Lower Cretaceous.........................	Quartz diorite, granodiorite, and gabbro
Lower Cretaceous..............................	Conglomerate, arkose, sandstone shale, and tuff
Coast Range batholith.........................	Quartz diorite and granodiorite
Triassic......................................	Andesite, basalt, tuff, sandstone, conglomerate, argillite, and limestone

TRIASSIC

Rocks which have been classed as Triassic occupy a wide band extending from Tatlayoko to Taseko lakes. They are bounded on the south by the Coast Range batholith whose contact passes the head of Franklyn arm, crosses the southern end of Chilko lake, and extends east to Taseko lake. The northern boundary follows the south side of Nemaia valley from Tatlayoko lake eastward, passing out of the area at a point east of mount Tatlow. Small areas of these rocks also occur north of Choelquoit lake.

These rocks consist of thick flows of andesite and basalt, chiefly the former, interbedded with great thicknesses of andesitic and rhyolitic tuff and smaller amounts of sandstone, conglomerate, argillite, and limestone. The limestone was found only in the vicinity of Franklyn arm and the Morris mine; the other sedimentary beds are distributed throughout the formation.

The strata are compressed into a series of close folds striking west and northwest and dipping at angles of 50 to 90 degrees. In the section immediately south of Nemaia valley and west of mount Tatlow, beds appear to be slightly overturned to the north. West of Chilko lake and east of Taseko lakes the strikes are northwest, but between Chilko and Taseko lakes the strikes are more nearly east and west. The less competent beds, such as the argillites, are in places intensely sheared.

These rocks are clearly intruded by the Coast Range batholith and along the contact are metamorphosed and extensively impregnated with pyrite and pyrrhotite. In most places at the junction with the Cretaceous rocks the beds of both formations stand perpendicularly or are overturned. Because of this, and also because of the lithological similarity between members of the two formations and a considerable amount of shearing, there is some doubt as to where to draw the line marking their contact. In the vicinity of Tatlayoko lake the dips are less steep than is usual and the Triassic rocks appear to dip under the Cretaceous strata without any marked unconformity. This relation was noted by Dawson[1] and Bateman[2].

In the southern part of the area, in the vicinity of the Morris mine, fossils were found in the argillites of this formation. These were examined by F. H. McLearn of the Geological Survey, who found among them *Halobia* and *Daonella*, both of Triassic age. These beds can with some certainty be correlated with the Cadwallader series of Bridge River map-area.[3]

COAST RANGE BATHOLITH

The southern part of the area is occupied exclusively by quartz diorite and granodiorite. As similar rocks extend many miles to the south and west and as they are like the rocks which to a large extent compose the great Coast Range batholith, it is certain that they represent a part of this batholith. Two small stocks of similar rock occur in the neighbourhood of Franklyn arm within a few miles of the contact of the main batholith, and are believed to be part of it. A very large, dyke-like mass of quartz diorite porphyrite extends from the batholithic contact just south of Taseko lake, across the lake and over the top and beyond Limonite mountain. This dyke is thought to be an off-shoot of the batholith. O.K.

Microscopic examination of specimens from various parts revealed the presence of quartz diorite and granodiorite, similar in every way to the rocks which elsewhere compose the greater part of the batholith. Both types consist essentially of plagioclase, quartz, hornblende, biotite, and orthoclase, with magnetite, zircon, and sphene as accessories. The plagioclase, which is in many cases zoned, ranges from oligoclase to andesine-labradorite. Quartz is invariably present in large amounts. Orthoclase varies from 2 per cent to 15 per cent and occurs interstitially. Hornblende is the principal ferromagnesian mineral. It has a deep bluish green or brownish green colour with a strong pleochroism, and is strikingly similar to the hornblendes found in the rocks throughout the batholith. Biotite is commonly present and increases in amount with the orthoclase, that is, it is more abundant in the granodiorite than in the quartz diorite. Augite is absent from this section, as from most other sections of the batholith. A conspicuous amount of sphene irregularly distributed is another point of similarity between the rocks of this and other parts of the batholith.

The large porphyrite dyke occurring southeast of Taseko lake, though closely resembling the batholith in composition and believed to be genetically related to it, has certain characteristics worthy of mention. It was traced from Taseko lake up and over Limonite mountain, from where it could be seen extending northeasterly for many miles. On Limonite mountain it is more than a mile wide. It is a light grey, coarse-grained, markedly porphyritic rock with phenocrysts of plagioclase up to half an inch in length. The phenocrysts are in many places zoned and vary from andesine to labradorite. They are held in a medium to coarse groundmass of andesine-labradorite, brownish green hornblende, and small quantities of orthoclase and quartz. Chlorite and leucoxene were observed in one O.K.

[1] Geol. Surv., Can., Rept. of Prog., 1875 and 1876, p. 250.
[2] Geol. Surv., Can., Sum. Rept., 1912, p. 184.
[3] McCann, W. S., Geol. Surv., Can., Mem. 130, p. 28.
Drysdale, C. W., Geol. Surv., Can., Sum. Rept., 1915, p. 79.

specimen. In certain parts of this dyke and its apophyses, pyrite, pyrrhotite, and chalcopyrite are plentifully disseminated, and in one or two localities on Limonite mountain chalcopyrite appeared to be present in sufficient amount to make low-grade copper ore. An interesting feature of the dyke is that parts of it are made up of small, perfectly-formed spheres up to 2 inches in diameter, composed of the same constituents as the matrix but decidedly finer-grained. The spheres retain their shape on weathering out and lie in quantities at the bottoms of small talus slopes. The constituent minerals are not arranged radially or concentrically as in the case of a true orbicular structure, but differ from those of the matrix only in being of smaller and more uniform size. This difference, however, is sufficiently pronounced to distinguish this structure from that of ordinary spheroidal weathering.

The age of the Coast Range batholith is generally considered to be Upper Jurassic, though the possibility is conceded of it being younger. In this area there is no direct evidence of the age of the batholith, except that it intrudes Triassic rocks and is, therefore, post-Triassic. However, the presence in the district of two bodies of closely similar rocks cutting Lower Cretaceous strata not far from the edge of the main batholith, and the absence from the Lower Cretaceous conglomerates of pebbles resembling the batholithic rocks, tends to increase the suspicion that the batholith, or at least parts of it, is of post-Lower Cretaceous age.

LOWER CRETACEOUS

The Lower Cretaceous rocks are confined to the flat-topped or rounded mountain on both sides of Chilko lake north of Nemaia valley and to a small area west of Tatlayoko lake. They consist of thick, massive beds of arkose, sandstone, and shale, with several thin lenses of conglomerate. The arkose strata are the most extensive and are confined chiefly to the upper parts of the formation. In many of the coarse beds of arkose cross-bedding is well developed. The beds are composed of large fragments of fresh plagioclase, augite, and volcanic and cherty rock. The mineral constituents are so fresh and angular that under the microscope the rock resembles a tuff. The various constituents appear to be derived from the underlying Triassic volcanics and probably to some extent from the still older Cache Creek formation. None of them appears to be derived from the batholithic rocks. In the upper parts of the arkose beds were found several fossiliferous horizons. A few thin layers containing carbonized plant remains were observed. The conglomerate beds are composed of pebbles of porphyritic andesite and other volcanic rocks, and chert thought to have been derived from the Cache Creek formation. Careful search failed to discover any granodiorite or quartz diorite pebbles which could be attributed to the batholithic rocks. Great thicknesses of dark brown and black shale occur in the southeastern part of the area occupied by the formation.

The Cretaceous strata are steeply folded in the south, but in the vicinity of Potato mountains the dips flatten to as low as 25 degrees. To the south the Cretaceous rocks come into contact with the Triassic beds in a manner already described. In the northern part of the field they overlie volcanic rocks presumably of Triassic age. In the vicinity of the north end of Tatlayoko lake and on mount Nemaia they are cut by stock-like intrusions of quartz diorite. These intrusions, however, have had very little metamorphosing or mineralizing effect on the sediments.

Fossils found in the upper horizons contain among others, *Aucella crassicollis* Keyserling of definite Lower Cretaceous age. The beds can, with some certainty, be correlated with the Eldorado series of the Bridge River area.

POST-LOWER CRETACEOUS INTRUSIVES

Intruding the Lower Cretaceous sediments are several bodies of granitic rocks closely resembling those of the Coast Range batholith. The largest of these, later referred to as the Tatlayoko intrusive, occupies about 20 square miles in the vicinity of the northern end of Tatlayoko lake. A smaller body in the form of a stock occurs at the peak of Nemaia mountain. Besides these there are many small dykes in the northern part of the area.

The intrusion at the north end of Tatlayoko lake is composed of a medium coarse-grained quartz diorite in which the original hornblendes have been somewhat altered to chlorite and epidote. The Nemaia stock consists of a medium fine-grained diorite with little or no quartz. The feldspars range from andesine to labradorite and the hornblende is a dark brown variety. Towards the centre of the stock a coarser texture and a slightly more acid composition were observed. A specimen from a dyke occurring just north of Choelquoit lake was found to be a quartz diorite in which the hornblende is partly altered to chlorite and epidote.

Beyond the fact that these intrusives cut Lower Cretaceous strata nothing is known of their age. Their proximity to, and lithological similarity to, the Coast Range batholith suggest that they and the batholith are of the same origin and age, but this cannot be proved from existing evidence.

On the west bank of Chilko river, about 8 miles north of Chilko lake, a small outcrop of a coarse, fresh, augite gabbro was found. Its relations to the other formations were not determined and no other rocks of the same character were found in the district.

TERTIARY LAVAS

Tertiary volcanic rocks occupy the entire northeastern part of the area. They are covered with a thick mantle of glacial till and are exposed only along the stream valleys where they form what are known locally as the "rim rocks." A small area of nearly horizontal lava lying unconformably on the upturned edges of the Mesozoic rocks was observed in the vicinity of mount Tatlow. These lavas are thought to be a part of the Tertiary formations of the district.

The Tertiary lavas consist of horizontal or nearly horizontal flows of columnar-jointed, amygdaloidal basalt. A specimen from Lingfield creek was found to consist of labradorite, augite, olivine, and a large amount of reddish brown, opaque iron oxide. A specimen from the east side of Chilko river near its exit from the lake consists of labradorite, augite, and iron oxide, with no olivine. The augite crystals are larger than, and enclose many of, the labradorite crystals.

The age of these volcanic rocks is not known precisely, but their flat, undisturbed attitudes suggest a late Tertiary age. They may be correlated with Dawson's[1] "Upper Volcanics" which are classed as late Miocene.

PLEISTOCENE AND RECENT

The great bulk of the unconsolidated material of this region is of glacial origin. The plateau section extending from the base of the mountains northeast to the boundary of the area is covered with thick deposits of coarse glacial till containing boulders of quartz diorite, andesite, etc., up to 20 feet in diameter. The till is so coarse and full of large boulders that nothing will grow on it but small sparse forests of jackpine. Almost all the rivers of the area are fed by large glaciers and are loaded with white "rock flour" which is being precipitated along their valleys and in the lakes they enter. Tchaikazan river has formed a large delta of this white silt which extends almost across Taseko lake, virtually dividing it into two lakes joined by a narrow, swift river. Lord river is also rapidly filling up the southern end of Taseko lake with the same kind of material.

PRESENT STATUS OF MINING

Up to the present no minerals have been produced from the area. Very few discoveries have been made, and except the tunnels on the Morris property and on the Ducharne claims near Franklyn arm, no development work worth mentioning has been done. Only a small amount of prospecting has been performed and even less is being carried on at present. The writer knows of only four prospectors who were in this region during the past season. The country is an easy one to prospect. Much of the district, and particularly the parts where mineral is most likely to be found, is unusually easy to travel in, and pack-horses can be taken to almost all the mineralized sections. Horses are plentiful and cheap, and feed everywhere abundant. Game is fairly plentiful and the summer climate is almost ideal. Its remoteness from transportation is a drawback, but need not impede prospecting and in the case of gold ores need not prevent production. The geology of the region is such that the occurrence of mineral deposits may be expected.

Most of the prospecting was done prior to 1910 at the time when the Morris mine was discovered and developed. At that time many claims were staked in the mountains west of Tatlayoko lake, but, though indications of arsenic and gold were found, no serious development was done and all but two or three of the prospectors left the country. The district west of Chilko lake could be very well served by a wagon road down Homathko river to Bute inlet, a distance of 60 miles. Discoveries to date, however, certainly do not warrant such a large expenditure. At present the country is fairly well served by motor roads from Williams Lake on the Pacific Great Eastern railway, and machinery and other supplies can now be taken into the district more quickly and cheaply than might be expected. The long, narrow lakes are easily navigable and form excellent lines of communication between the northern and southern parts of the district.

[1] Reinecke, Leopold, Geol. Surv., Can., Mem. 118, p. 7.

ECONOMIC GEOLOGY

As regards mineral deposits the most important formations of the district are the Coast Range batholith and the Triassic rocks, and of particular importance are the border zones along the contact. Some mineralization was observed along the contacts of the post-Lower Cretaceous intrusives, but does not appear to be as important as the mineralization along the contact of the main batholith. Almost everywhere along the batholithic contact there is strong evidence of mineralization. The Triassic rocks are extensively altered to quartz and sericite and impregnated with pyrite and pyrrhotite. From a number of localities where the mineralization seemed to be more than ordinarily intense samples were taken which have been assayed by the Mines Branch, Ottawa.

On the north side of Skinner mountain, at the contact of the Tatlayoko intrusion, the Triassic rocks are strongly silicified and impregnated with pyrite, but a sample taken from here was found to contain no gold. Other samples taken by prospectors are reported to carry small values in gold. A sample from the conspicuous red mountain west of Tatlayoko lake and just south of the above-mentioned intrusion, gave traces of gold. A sample of small quartz vein carrying pyrite and arsenopyrite, found by the writer on the mountain just north of Franklyn arm, gave 6·46 per cent arsenic, 6·46 ounces of silver, and 0·38 ounce of gold to the ton. The vein is only 5 inches wide and was traceable for only a few feet.

West and south of the head of Franklyn arm extensive beds of limestone are in contact with the two small intrusions of granodiorite represented on the map and also, a little farther south, with the main batholith. Here, Mr. Alec. Ducharne, the only white inhabitant of the shores of Chilko lake, has made a few open-cuts in the limestone where it has been metamorphosed and mineralized with copper, zinc, and iron sulphides. Although no large bodies of commercial ore have yet been discovered it is highly probable that if the contacts of the limestone with the intrusives were explored, deposits of the contact metamorphic type would be discovered and there is a possibility the deposits may be of commercial size and grade. Judging by Ducharne's claims the ores would probably carry values in gold and zinc as well as copper.

Near the west shore of Chilko lake in the vicinity of the batholithic contact the Triassic rocks are intensely silicified and impregnated with pyrrhotite and pyrite, the pyrrhotite being noticeably more abundant near the contact. A specimen of rock containing pyrrhotite was found to contain a trace of gold and 0·09 ounce of silver to the ton. A specimen of the pyritized rock contained only traces of silver and no gold.

A specimen of pyritized quartz diorite from near the batholithic contact at the head of Tchaikazan river contained 0·03 ounce of silver to the ton.

East of Taseko lake in the valley of Taseko river, the rocks adjacent to the contact of the batholith are even more highly pyritized than usual and the many limonite deposits of this district, which attracted so much attention in 1919 and 1920, were formed, and are being formed, from the oxidation of the pyrite. In this district occurs the so-called Taylor property described on a following page, from the surface soil of which surprisingly rich gold ore has been taken.

During the season Mr. Morris, discoverer of the Morris mine, and Mr. Feeney discovered some arsenopyrite veins in the mountains west of Tatlayoko lake, but the gold content of the ore was found to be disappointingly low.

Some small, rich pockets of placer gold are reported to have been found in Lingfield creek by the prospector for whom the creek is named, but much careful panning has failed to reveal any more gold. This gold may have originated in the vicinity of the intrusive lying north and east of Tatlayoko lake.

MORRIS MINE

The most important deposit in the district is that of the Tatlayoko Lake Gold Mines, Limited, better known as the Morris mine. It was discovered in 1907 by Mr. I. T. Morris of Vancouver, who is still one of the principal owners. Considerable development was done shortly after the discovery and more recently a small sawmill was built about a mile from the south end of Tatlayoko lake. The company still maintains offices in the Dominion building in Vancouver.

The deposit is situated 3 miles southeast of the south end of Tatlayoko lake. It is at an elevation of 5,900 feet, just above timber-line, and 3,200 feet above the lake. A good wagon road extends south from the lake for about a mile, to where the sawmill was built. From near the end of the road a trail leads up the steep slopes to the mine. The trail is at present partly overgrown and difficult to follow, but could be repaired at a small cost. There is a comfortable camp site at the lake shore, and at timber-line about one-half mile from the mine a good camp was built, but has since been destroyed by snow.

The deposit consists of three quartz veins outcropping on the sides of a steep rocky gulch (*See* Figure 5). The veins cut Triassic sediments, chiefly argillites and fine sandstones, but with one thin bed of fine cherty conglomerate. A short distance northeast of the veins is a stock of quartz diorite probably related to the Coast Range batholith, the edge of which is situated a few miles to the south. Many dykes cut the sediments and range in composition from diorite to basalt, the majority being basaltic. Many, if not all, of them are younger than the veins, since they cut the veins or cut other dykes which cut the veins. One basalt dyke follows the main vein throughout its length, crossing it and recrossing it and holding included fragments of it.

The largest or main vein is exposed on a steep, rocky slope for a vertical distance of 450 feet and an horizontal distance of 850 feet and is followed underground for 382 feet by a tunnel beginning at its lower outcrop. The vein varies in width from 8 inches to 5 feet, but probably averages less than 2 feet.

At a point 345 feet southwest and 200 feet lower than the above tunnel is No. 2 vein. This could not be traced on the surface owing to the precipitous nature of the slope up which it passes, but has been traced underground by a tunnel for 240 feet. Owing to its irregular dip it was difficult to follow and the tunnel is, therefore, crooked. The vein is comparatively uniform in width, averaging about 8 inches.

Above the main tunnel and nearer the quartz diorite stock occurs No. 3 vein. This was not seen by the writer, but Mr. Morris states that it

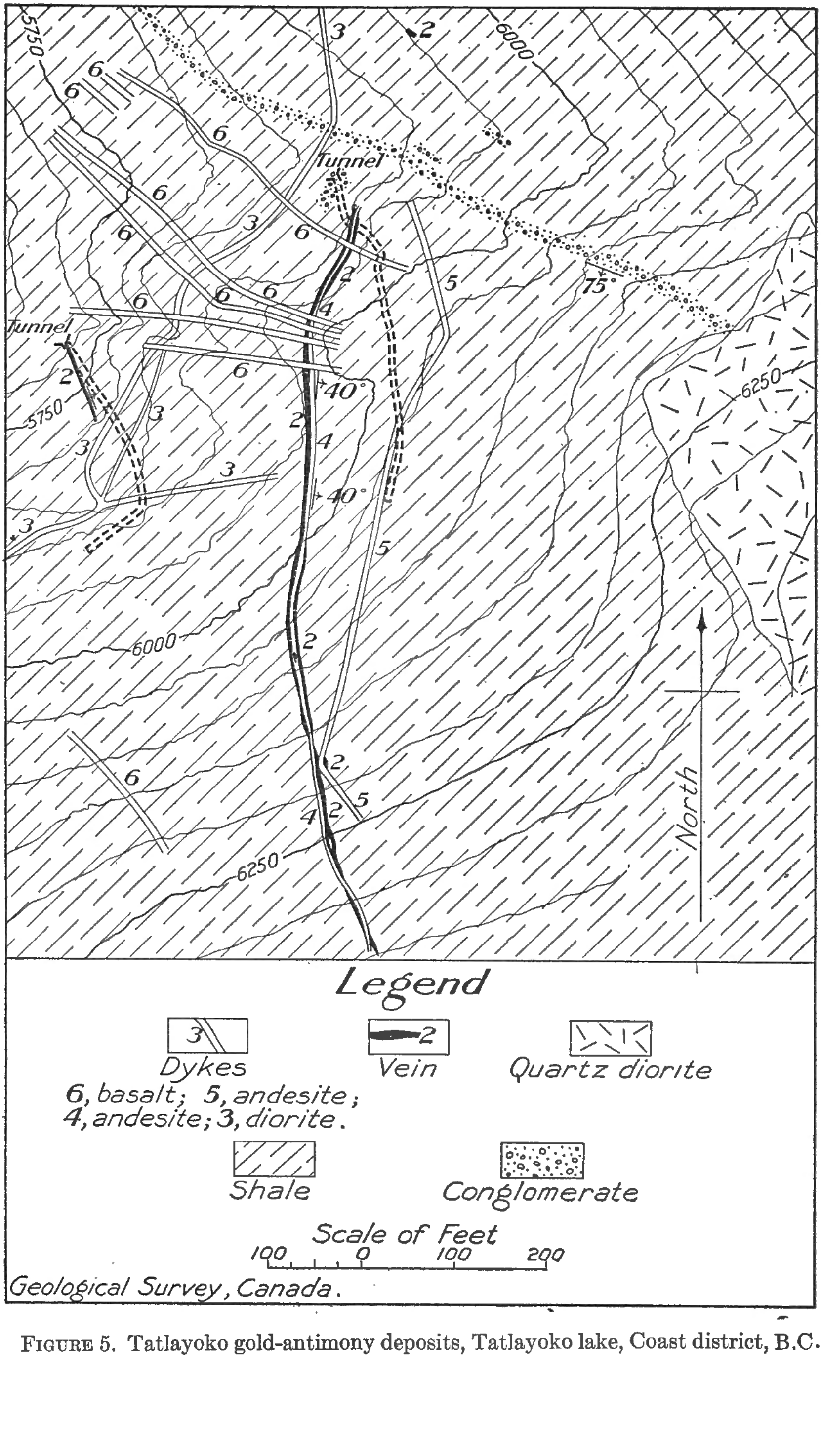


FIGURE 5. Tatlayoko gold-antimony deposits, Tatlayoko lake, Coast district, B.C.

was traced for several feet and is similar in width and composition to the other veins.

The veins consist of quartz through which is disseminated fairly evenly arsenopyrite, pyrite, stibnite, and two or three undetermined minerals visible only under the microscope, but which, judging from the assays, are probably silver-bearing. These minerals are closely associated with the stibnite which tends to occur in the central parts of the veins, whereas the gold, arsenopyrite, and pyrite are more plentiful along the margins. The rock adjoining the veins has been altered to a very dense greyish green material resembling chert.

The following assays were made from samples taken from the tunnels by the writer at points which appear to contain an average amount of metallic minerals.

No.	Location	Width of vein sampled	Gold	Silver	Antimony	Arsenic
		ins.	ozs.	ozs.	%	%
1	204 feet from entrance to main tunnel.....................	18	1·68	46·05	1·79	5·54
2	21 feet from entrance to lower tunnel.....................	12	0·19	3·17	0·3	2·0
3	164 feet from entrance to lower tunnel.....................	12	1·19	7·59	3·9	4·11

Samples collected by J. D. Galloway[1] gave the following results.

	Ozs.
Across 6 inches, 265 feet from portal main tunnel..........................	gold 0·08 silver 0·8
Across 18 inches, 110 feet from portal main tunnel...........................	gold 0·5 silver 10·3
Across 18 inches, 100 feet from portal main tunnel..........................	gold 0·08 silver 0·9
Picked specimens from dump showing high proportion of antimony.........	gold 0·02 silver 4·2
Across 8 inches, 150 feet from portal lower tunnel............................	gold 0·5 silver 6·3

Samples taken by W. Fleet Robertson[2] assayed as follows:

	Ozs.
(1) Across 12 inches from raise 60 feet from portal main tunnel...............	gold 0·28 silver 2·6
(2) Hanging-wall, quartz 80 feet from portal of main tunnel....gold $8.00	silver 16
(3) Across 30 inches, 80 feet from portal main tunnel............gold, trace	silver 0·4
Across 30 inches, 80 feet from portal main tunnel............................	gold 0·14 silver 1·0
Across 30 inches, 80 feet from portal main tunnel............................	gold 0·2 silver 30·4
Lower tunnel..	gold 2·90 silver $1.50

Mr. Morris has many assays showing values higher than any of the above and in some instances amounting to $80 to the ton in gold and silver.

[1] Rept. Minister of Mines, B.C., 1916, p. 170.
[2] Rept. Minister of Mines, B.C., 1910, pp. 156 and 157.

A test made by G. S. Eldridge and Company of Vancouver, on a 200-pound sample of this ore supplied by the owners, shows that 42 per cent of the gold and silver values were recoverable; that the gold was associated with the arsenic, and the silver with the antimony; that concentrates could be made carrying 7·5 ounces of gold and 107·9 ounces of silver to the ton; and that if either the antimony, or the arsenic, or both, could be recovered, which was considered possible, the value of the concentrates would be greatly enhanced.

WHITEWATER CAMP

In the valley of Taseko river, a short distance east of the map-area, are several gold deposits which have attracted considerable attention. The most widely known is the Taylor or Windfall mine. In 1920 Mr. Taylor discovered some very rich gold-bearing eluvium on the south bank of Battlement creek about half a mile above its junction with Taseko river. After taking out a considerable amount of gold by panning and by the use of an arrastre, Mr. Taylor bonded the property to a Vancouver syndicate under the name of Whitewater Gold Fields, Ltd. This company began development work late in the winter of 1923, or early in 1924, and drove three tunnels, none of which encountered any commercial bodies of ore. A small Ross mill was installed and some of the rich soil was run through it. On the strength of certain glowing reports a considerable amount of English capital was invested in the company. In mid-summer Mr. Wilkinson, the engineer representing those who supplied the capital, made an examination of the property, but found it so entirely different from what the reports had led him to expect that he reported adversely and work immediately ceased.

The gold occurs both in eluvium and in a small tourmaline vein from 2 to 6 inches wide. The eluvium, as well as the outcrop of the vein, is confined to an area of a few hundred square feet situated on the southeast side of the canyon of Battlement creek. The only rocks in the vicinity are a thick bed of silicified tuff and two quartz porphyry dykes about 12 feet wide, one of which is exposed in a tunnel about 70 feet southeast of the vein and the other on both sides of the canyon about 200 feet northeast of the vein. The bed of tuff is several hundred feet thick, is exposed for 10 or more miles east of the deposit, and dips at an angle of about 20 degrees to the north. At many places throughout its length the tuff has been almost completely altered to silica and its original dark green colour changed to pinkish white. The silicification is confined to wide bands, some of which are vertical and others parallel to the bedding of the tuff. The latter are the larger and in places constitute almost the entire exposed thickness of the tuff. Well-formed crystals of pyrite up to half an inch and averaging more than a quarter of an inch in diameter are plentifully disseminated throughout the tuff in both the silicified and unsilicified parts. The quarty porphyry dykes are cut by a set of closely spaced cracks parallel to their walls and have been altered to a pure white, very fine-grained material in which the original quartz phenocrysts are clearly visible. Small veins of talc less than half an inch wide were observed cutting the silicified tuff in many places.

The eluvium consists of iron-stained clayey material and small angular fragments of silicified tuff rendered porous by the leaching of the pyrite crystals. It is from 1 to 3 feet thick, and confined to an area of a few hundred square feet. Mr. Wilkinson estimates from a careful sampling that in this area there is probably $20,000 worth of gold.

The gold-bearing vein was found at short intervals over a distance of about 50 feet along the steep side of the canyon. Its strike and dip are irregular, but appear to be somewhat parallel to the bedding of the tuff. Such an attitude would cause the vein to reach the surface a short distance southeast of the brink of the canyon and to outcrop at a lower elevation on the opposite side of the creek, but up to the present it has not been found at either of these points. It varies from 2 to 7 inches wide and averages probably less than 3 inches. It consists of tourmaline, rutile, quartz, sericite, and talc. The tourmaline varies from black to almost colourless and in places is pink. It composes the greater part of the vein and is also disseminated in the adjoining rocks. The pyrite has been almost completely removed, leaving numerous cavities partly filled with limonite and in some of which were seen surprisingly large amounts of coarse cellular gold. Many other small tourmaline-bearing veins were observed in the tuff, but none carrying gold.

Three tunnels were driven by the bonding company, two on the southeast side of the creek immediately southwest of the area covered by the auriferous eluvium, and one on the northwest side of the creek. These are in silicified tuff carrying much pyrite and several small irregular patches of pink or pale greyish tourmaline. No gold values, however, were found, except in one or two small seams of white gouge less than half an inch wide. A few high assays were obtained from very small samples scraped from these seams.

The gold seems to have been concentrated by the action of surface solutions, but the amount found in the eluvium appears to be much too large to have been derived from so small a vein dipping at such a low angle. The association of tourmaline and rutile indicates that the vein was formed at high temperatures by rising solutions and, therefore, probably at a considerable depth. The vein is not, therefore, in any way related to the present surface and it would be not impossible for it or similar veins to occur at some depth below the present exposures.

The eluvium has not been transported any great distance from its source and further careful prospecting by ground sluicing might discover a more probable source for the material than the small vein described above.

A few miles southwest of Taylor's camp on the opposite side of Taseko river and 1,000 feet higher in elevation are other gold deposits of a different character. They occur on the northwest face of a steep mountain composed entirely of quartz diorite belonging to the Coast Range batholith. In the quartz diorite are two fracture zones striking in a northeasterly direction. Within these zones the quartz diorite is cut by an intricate ramification of small quartz veins averaging not more than half an inch in width. The quartz diorite is altered to sericite, epidote, and other minerals. In the quartz veins and to some extent in the quartz diorite are small amounts of pyrite, chalcopyrite, galena, and zinc blende. On the surface these have been altered to limonite, azurite, malachite, and cerussite, and in places small specks of native gold were seen. From the oxidized surface material considerable amounts of gold can be panned and high assays have been obtained.

Although the sulphides are present in quantities much too small to make copper lead or zinc ore, it was hoped, in view of the appreciable amounts of gold found on the surface, that the unoxidized parts might contain sufficient gold to enable the large fracture zones to be profitably mined. However, a sample taken across the face of an open-cut crossing one of the zones diagonally for 60 feet contained only traces of gold and silver.

PEMBERTON AREA, LILLOOET DISTRICT, BRITISH COLUMBIA

By C. E. Cairnes

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Illustrations

INTRODUCTION

The greater part of September, 1924, was spent by the writer in a geological investigation of a part of Lillooet district tributary to Lillooet river and Lillooet lake and extending about 15 miles on either side of the Pacific Great Eastern railway in the vicinity of Pemberton station. Much of this time was spent examining mining properties, most of which have already received some attention in earlier reports published by the Geological Survey and the Provincial Department of Mines. A few, however, are comparatively recent discoveries, and an account of them is incorporated in the following general review of mining conditions in this section of Lillooet district.

The writer desires to express his appreciation of the many courtesies extended him by property holders in the district, who by their generous assistance greatly facilitated the work. Thanks are specially due to Messrs. C. Barbour, Thos. Simington, John Jack, and T. Lewis. In the field work the writer was ably assisted by Messrs. R. H. B. Jones and J. A. C. Harkness.

NATURE OF THE COUNTRY

The area investigated lies immediately north of the New Westminster District boundary. It is traversed for 23 miles by the Pacific Great Eastern railway, which follows in a northeasterly direction the valleys of Green and Birkenhead rivers. These streams are nearly in line with each other and enter Lillooet river from the southwest and northeast respectively. They occupy valleys transverse to the general trend of the mountain ranges and are less prominent and more irregular in their course and outline than the great longitudinal valley occupied by Lillooet river and lake.

Lillooet River valley forms the most conspicuous topographic feature in the district. It has an average width, in the area under consideration, of from 1 to 1½ miles and near the railway is more than 2 miles wide. Its elevation there is about 700 feet above sea-level. Beyond the limits of the map-area the valley extends to the northwest for over 40 miles and has a drainage area, above Agerton, of 800 square miles. To the southeast it maintains its course to Fraser river, including in this distance of about 100 miles, the large expansion occupied by Harrison lake, 36 miles long and 84 square miles in area. Lillooet lake, another expansion of the river and partly included in the map-area, is 22 miles long and 17 square miles in area. On either side of, and for from 25 to 30 miles above, the crossing of the railway, Lillooet valley is referred to, generally, as Pemberton meadows and includes some exceptionally fine agricultural land whose total area has been estimated to be about 40,000 acres. Lillooet river meanders at a low gradient down this valley and by reason of the level character of the valley floor is subject to flood conditions arising from torrential storms, prolonged thaws, or heavy precipitation during the rainy season. Many prominent sloughs have been developed by these conditions. Owing to these floods, agricultural enterprise has not been as successful as it might be and different schemes have been proposed to prevent conditions which have been so detrimental in the past, particularly in that section between Agerton and the head of Lillooet lake. These proposals involve a straightening of the channel of Lillooet river through Pemberton meadows; an enlargement of the outlet of Lillooet lake into Little Lillooet lake; and the clearing away of obstructional debris near the foot of Little Lillooet lake.

The mountains rise abruptly on either side of Lillooet River valley to heights of 7,000 feet or more. For the greater part the slopes, except where broken by cliffs, are clothed in an abundant coniferous vegetation up to an elevation of about 5,000 feet. Above this altitude arctic shrubbery and scattered individuals or clumps of dwarfed conifers persist and on the more gently sloping uplands fine pasturage is commonly available during the summer and early autumn months.

HISTORY OF MINING

The area reported on includes part of the old route to Lillooet from Port Douglas near the northern end of Harrison lake. This route afforded access from lower Fraser river to the interior of the province during and following the early days of placer excitement in Cariboo district. It was, however, well known to the Hudson's Bay Company prior to these discoveries. In 1858, Sir James Douglas, Governor of the Company, had an excellent trail constructed along this route. During 1860 and 1861 a good wagon road was built along the site of the trail and served as a convenient route from Lillooet to Pemberton valley and vicinity.

Little mining activity in this area is recorded until 1895 when a number of claims were staked on Pool creek where, it was reported, three distinct veins had been found. Assays from the ore croppings on one claim gave a return of $10 a ton.[1] In the following year further references to these properties reported a seam width of from 40 to 60 feet between a slate hanging-wall and granite footwall. This was said to be wonderfully rich in gold, silver, and copper.[2]

In 1897 the attention of the prospector was diverted to the Bridge River country and except for a little prospecting near Onemile creek[3] there is little record of further mining activity in this area for a number of years.

[1] Rept. of Min. of Mines, B.C., 1895, p. 665.
[2] Rept. of Min. of Mines, B.C., 1896, p. 547.
[3] Rept. of Min. of Mines, B.C., 1913, p. 249.

In 1910 a certain amount of prospecting was reported in the mountains to the west of Pemberton meadows.[1] In 1913 Brewer[2] mentioned the discovery of ore near the head of Lillooet lake, on what is now called the Margery group of claims. Some prospecting at this time on Owl creek resulted in several claims being staked in that vicinity. Subsequently, considerable development work was done on a copper property on Owl creek and is the subject of a detailed report by the Provincial Mineralogist.[3]

The years 1913 to 1915 include the period of construction of the Pacific Great Eastern railway between Squamish and Lillooet. The years following saw a very considerable renewal of mining activity in the area. Properties at the head of Tenquille creek received a large share of attention, and developments there are recorded in both provincial[4] and federal reports.[5]

In 1918, Thompson[6] reported examining properties lying on the southwest side of the head of Lillooet lake. These included the Eagle group of claims referred to by Camsell in his report of the previous year. Camsell[7] also made an examination, in 1917, of the Margery group, previously referred to by Brewer, and situated about 2 miles northwest of the head of Lillooet lake. From 1918 there is little reference to mining activity in the area until 1922 and 1923, when further developments were reported in Tenquille Creek area.[8]

GENERAL GEOLOGY

The geological formations in Pemberton area include highly deformed volcanic and sedimentary rocks of Upper Triassic age; sediments of Cretaceous (?) age; batholithic rocks intruded in Upper Jurassic or Cretaceous times or perhaps during both periods; and unconsolidated glacial and stream deposits. The Upper Triassic and batholithic rocks occupy the greater part of the map-area. Most of the mineral deposits occur in these rocks and are genetically related to neighbouring batholithic intrusives. Overlying the Triassic rocks, apparently unconformably, is a series of sediments, probably Cretaceous, occupying a single small area in the upper basin of Tenquille creek. The batholithic intrusives are regarded as representing two periods of intrusion, one of which may have occurred before, and the other after, the deposition of the Cretaceous (?) sediments. No conclusive evidence, however, establishing such relations, could be obtained and no attempt was made to map the different intrusives separately.

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[1] Robertson, W. Fleet, Rept. of Min. of Mines, B.C., 1910, p. 146.
[2] Brewer, Wm., Rept. of Min. of Mines, B.C., 1913, p. 249.
[3] Rept. of Min. of Mines, B.C., 1916, pp. 270-272.
[4] Rept. of Min. of Mines, B.C., 1916, p. 269; 1918, p. 232.
[5] Geol. Surv., Can., Sum. Rept., 1917, pp. 18-19 B.
[6] Rept. of Min. of Mines, B.C., 1918, p. 233.
[7] Geol. Surv., Can., Sum. Rept., 1917, pp. 19-20 B.
[8] Rept. of Min. of Mines, B.C., 1922, p. 138; 1923, pp. 166-168.

Table of Formations

Era	Period	Description
Quaternary..........	Pleistocene and Recent...........	Morainic deposits; gravel, sand, and clay
Mesozoic............	Cretaceous?......................	Sandstone, slate, and conglomerate
	Post-Upper Triassic; possibly in part or entirely Cretaceous	Batholithic intrusives, chiefly granodiorite and quartz diorite
	Upper Triassic....................	Andesitic lavas; pyroclastic rocks including tuffs, breccias, and agglomerates; tuffaceous sediments; slate, argillite, limestone, and conglomerate; chloritic, sericitic, and talcose schists

UPPER TRIASSIC

Rocks of Upper Triassic age form a broad belt, referred to by Camsell as the Pemberton band,[1] extending northwesterly across central parts of the area on either side of the railway between Pemberton and Spetch stations. Near to and southeast of the railway, the members of the Pemberton band include both volcanic and sedimentary rocks, and in many cases it is difficult to distinguish between the two classes. In this locality no fossils were found in these rocks. The volcanic members are in excess of normal sediments, and include a large proportion of fragmental types such as tuffs, breccias, and tuffaceous sediments. The normal sediments are chiefly slates and impure sandstones. Narrow lenses of limestone were observed near the southwestern shore of the head of Lillooet lake and are associated with mineral deposits in that vicinity. Some conglomerate was noted in cuttings along the railway to the north of Indian Reserve No. 2. The pebbles and cobbles in the conglomerate are commonly well rounded, but have been deformed by regional stresses. The finer-grained matrix appears to be composed, in part at least, of volcanic detritus. A rather prominent rock type, observed most frequently in the vicinity of Lillooet lake, is a hard, fine-grained, almost black, fragmental rock commonly mineralized with disseminated grains of pyrite. Its appearance under the microscope and its associations in the field suggest that it is of tuffaceous origin. Its hardness may be in part the result of induration by silica related to the neighbouring intrusions. Intercalated with the fragmental members of the series are volcanic flows chiefly of andesitic composition and mostly light to dark green. These vary from markedly porphyritic to aphanitic, and from comparatively massive to intensely sheared and schistose.

The rocks of the Pemberton band in Tenquille Creek area include types very similar to those farther to the southeast. They differ in that the sedimentary members are fossiliferous and form a larger proportion of the series. Limestone is here an important constituent. It is abundantly fossiliferous in certain horizons and is associated with a number of large mineral deposits.

[1] Geol. Surv., Can., Sum. Rept., 1917, p. 15 B.

Fossil collections obtained from these limestone beds were examined by Prof. H. W. Shimer, of the Massachusetts Institute of Technology, who reports as follows:

"The specimens belong apparently to the same Upper Triassic coral fauna occurring on Pirsson creek, B.C., and in the Sutton formation of Vancouver island. The material is too poorly preserved for definite identification, but the following species were noted:

Isastrea cf. *vancouverensis* (433 F.C.)
Calamophyllia suttonensis? (420 F.C.)
Calamophyllia sp. (420 F.C., 422 F.C., 427 F.C.)

The last species has twice the diameter of corallites of *C. suttonensis* with the same bushy manner of growth."

The general trend of the Triassic rocks is about the same in all the areas examined. South of Tenquille creek the average of a number of observed strikes, varying from north 10 degrees west to north 70 degrees west, is north 37 degrees west. Near the railway and Lillooet lake the average trend appears to be more nearly north 45 degrees west. The dips are lower, on the average, in Tenquille Creek area than farther southeast and are predominantly northeasterly. Near the railway the dips are commonly steep, and evidence of shearing is abundant.

Near the contacts of the batholithic intrusives of the area these older rocks exhibit marked metamorphism and mineralization and such mineral deposits as occur in them are related to these intrusives. The limestone beds were particularly susceptible to metamorphism and to replacement by mineralizing solutions.

The discovery of Upper Triassic fossils in members of this series at the head of Tenquille creek renders possible the correlation of these horizons with the Upper Triassic rocks of the Vancouver group on Vancouver island;[1] the Cadwallader series of Bridge River area[2]; the Jura-Triassic rocks in the vicinity of the Pacific Great Eastern railway[3]; and the Upper Triassic of Chilko lake and vicinity[4]. It does not, however, exclude the possibility that strata of earlier Triassic or of Jurassic age may be included with the Upper Triassic series of this area.

CRETACEOUS (?)

The rocks of a small area south of Tenquille creek have been separated from the Upper Triassic rocks, chiefly because of their marked lithological difference. No fossils were found in these rocks, which include sedimentary types varying from coarse conglomerate to sandstones and shales or slaty rocks. These exhibit less alteration and deformation than the underlying Triassic strata. The pebbles and cobbles in the conglomerate are well rounded and include a variety of granitic rock types as well as volcanic and sedimentary varieties. The shaly members at one point were observed to contain numerous large pyrite cubes up to one-half inch across. Other mineralization in the form of quartz veins carrying pyrite and a little chalcopyrite has been noted in these rocks, and it was concluded that this mineralization had probably originated with the neighbouring batholithic

[1] Clapp, C. H., Geol. Surv., Can., Mem. 96, p. 123 (*See also* footnote 1).
[2] McCann, W. S., Geol. Surv., Can., Mem. 130, p. 29.
[3] Camsell, C., Geol. Surv., Can., Sum. Rept., 1917, p. 15 B.
[4] Dolmage, V., Geol. Surv., Can., Sum. Rept., 1924, p. 64A.

intrusives. No actual batholithic contacts with these Cretaceous rocks were observed, but in this connexion it is interesting to observe that the nearest intrusive body lies to the east of the Cretaceous rocks and forms a part of the eastern intrusive belt which is regarded as including the later batholithic rocks of the area. The strike of the Cretaceous sediments, as observed at a couple of points, is about north 15 degrees west with easterly dips varying from nearly horizontal to about 50 degrees.

There is evidence to support the view that these sediments are Cretaceous. They are too deformed to be Tertiary, but, on the whole, show less deformation and alteration than the Upper Triassic rocks of the area. The inclusion of abundant granitic pebbles in the conglomerate points to an important time interval between the deposition of the Cretaceous (?) beds and the irruption of the plutonics whose subsequent exposure and erosion supplied the granitic detritus for the conglomerate. In mineral composition the granitic pebbles somewhat resemble the more acid types of the western belt of plutonic rocks and the central intrusive bodies, but they show less alteration and less evidence of deformation.

BATHOLITHIC ROCKS

The intrusive rocks of the area represent a complex of types differing both in structure and composition and probably, also, in age.

Broadly speaking, the principal areas of batholithic rocks form parts of two belts crossing Birkenhead and Green rivers, respectively, in a northwesterly direction and separated by a broad band of Upper Triassic rocks in which smaller areas of intrusive bodies are also exposed. There is evidence that the two main intrusive belts unite to the south of the map-area near the headwaters of Boulder creek and that the older sedimentary and volcanic rocks represent remnants of the extensive cover that overlay the batholithic rocks. For convenience in description, these intrusives will be referred to as the rocks of the eastern belt, western belt, and central areas, respectively.

The eastern intrusive belt crosses the railway between Spetch station and the eastern edge of the map-area and has a width, in this vicinity, of about 5 miles. It extends southeasterly to, and along, the eastern shore of Lillooet lake which it crosses near the mouth of Boulder creek. Except in its more southern exposures the rocks of this belt east of Lillooet lake are, in general, fairly uniform in character. They are chiefly massive, moderately coarse-grained granodiorite or quartz diorite. Between the head of Lillooet lake and a point about 3 miles south of Joffre creek hornblende is the dominant mafic mineral, but farther north and along the railway biotite is abundant. Glassy quartz and white to pinkish feldspars are the other essential minerals present and where these are most abundant the rock verges to granite in composition. The continuation of this belt north of the railway appears to include very similar types, but to the south and for about 3 miles north of the district boundary, there is an area underlain by what is probably an older intrusive. The rock there is characterized by a pronounced gneissic or foliated structure and has about the average composition of a hornblende-biotite granodiorite. Although foliation is not peculiar to this intrusive the other instances observed are confined rather to the border phases of the intrusive bodies and appear to have resulted less from deformational stresses subsequent to consolidation of the intrusive than from primary flow structure or from replacement and injection along the margins of the older intruded rocks. The granodiorite referred to above is, however, markedly foliated over all exposures examined and the foliation appears to have been developed by crushing after intrusion and consolidation of the magma. Near the contact of this gneissic rock with the more massive intrusives to the northwest a number of broad dykes cut the gneiss and contain inclusions of it. These dykes are probably apophyses from the batholithic intrusives to the northwest and resemble them in composition, although finer in texture. A belt of altered gneissic rock conspicuous from a distance by its reddish coloration extends around the flank of the mountain between Twin One and Twin Two creeks and was found to owe its alteration to the intrusion of broad dykes which had effected a slight mineralization of the older rock. No significant ore mineralization was, however, noted in connexion with this alteration.

The western belt of batholithic intrusive follows along the eastern margin of Lillooet River valley, and where it crosses the railway is about 10 miles wide. Near its contacts with older rocks, as in the vicinity of Pemberton, foliation is quite pronounced and trends from about north and south to 20 degrees east of north. Farther from the contact this structure is less apparent. Wherever examined the rocks of this belt were observed to be predominantly hornblende types of granodiorite, quartz diorite, and diorite. Biotite is conspicuous in some places. The rocks as a whole appear to have suffered considerable deformation and the mafic constituents commonly show advanced alteration to chloritic products. They are intruded by occasional dykes of coarse-grained granite which in certain instances, at least, much resembles the granite in the massive eastern intrusive belt.

Between the two main intrusive belts are a number of smaller areas of plutonic rock which, taken as a whole, have more resemblance to the western than to the eastern belt. They are commonly hornblende types of quartz diorite and diorite and show evidence of considerable shearing and alteration of their constituent minerals. They have strongly metamorphosed the older rocks with which they come in contact and are related to the mineral deposits on Owl and Tenquille creeks.

Facts bearing on the age of these batholithic rocks may be summarized as follows: (1) They are all intrusive in the Upper Triassic rocks of the area. (2) There is no definite proof that any of them is younger than the Cretaceous (?) sediments. (3) They differ markedly in structure in different localities, varying from notably gneissic rocks through intermediate types (in many places exhibiting shearing and alteration of their constituent mafic minerals but, except near their borders, showing little foliation), to others which are massive and fresh looking. (4) Both the gneissic intrusives east of Lillooet lake and the intrusives of the western belt and central areas respectively are intersected by broad granitic dykes that closely resemble massive members of the eastern belt. (5) No such dykes were observed cutting these massive intrusives of the eastern belt. (6) The Cretaceous (?) sediments are quite highly deformed, although not so much so as the underlying Triassic rocks. They are, also, traversed by quartz veins carrying a little sulphide mineral. (7) There are granitic pebbles in the Cretaceous sediments. (8) The age of the Coast Range batholithic rocks, including the intrusives of the Pemberton area, has commonly been regarded as Upper Jurassic, although in a number of instances granitic rocks, possible connected with these Coast Range intrusives, have been found cutting Lower Cretaceous sediments. It is unlikely that any of these intrusives are Tertiary, for they have never, as far as the writer is aware, been observed cutting Tertiary strata, whereas the latter, at a number of localities, overlie the Coast Range intrusives unconformably.

From the foregoing considerations the following deductions may be made. The intrusives are post-Triassic and probably belong to two main periods of intrusion. The interval between the two periods may have been a long one, as would be indicated if the granitic pebbles in the Cretaceous (?) sediments were derived from the older intrusives and if these Cretaceous (?) sediments were older than the batholithic rocks of the second period of intrusion. Neither of these conditions has been definitely established. Depending, too, upon whether the sediments are Upper or Lower Cretaceous in age, the interval between the two periods of batholithic intrusion might either fall entirely within the Cretaceous period or be included in part in the Upper Jurassic. The apparent scarcity of granitic pebbles in Lower Cretaceous conglomerates west of Fraser valley is some indication that the Cretaceous sediments of this area are Post-Lower Cretaceous, in which case the two periods of batholithic intrusion might have both occurred in Cretaceous time following orogenic revolutions of the late Jurassic (or early Cretaceous) and Upper Cretaceous periods respectively.

In view of the lack of definite evidence of the age of the batholithic intrusives in this area, it has been deemed advisable to place the intrusives below the Cretaceous (?) sediments in the table of formations as has, heretofore, been done.[1]

GLACIAL AND RECENT

The area has been glaciated to a height of at least 7,000 feet. With the possible exception of the highest peaks the entire area was covered by an ice-sheet whose movement on the higher ridges seems to have been southerly to southwesterly. Large glacial erratics are common on the upland slopes. Small mountain glaciers still remain on the more shaded northerly flanks of some of the higher peaks and ridges. The larger valleys are typically glacial in outline, and tributary streams enter from steep hanging valleys and thereby furnish excellent sites for the development of waterpower.

Much material was eroded during the period of glaciation. A large part of this accumulated in the valley bottoms and was subsequently reassorted by fluviatile agencies. Part of this glacial material has been carried down Lillooet valley beyond the limits of the area. The delta lands at the head of Lillooet lake are, doubtless, composed in great measure of original glacial materials (Plate III A). No high banks were observed along Lillooet river which, by reason of its low gradient and the resulting constant shifting of its course, has been able to develop a nearly flat valley

[1] Camsell, C., Geol. Surv., Can., Sum. Rept., 1917, pp. 14 B and 15 B.

plain. The steeper tributary valleys have, however, left high benches along their courses. These, particularly noticeable along Birkenhead river, are composed for the most part of well-sorted gravels, sands, and silts of glaciofluviatile origin.

The original height of morainic materials accumulated in the main valleys above Lillooet lake at or about the time of the retreat of the valley glaciers may possibly be closely approximated on Pemberton portage between Birkenhead river and Lillooet lake. The glaciated through valley followed by this portage is in line with Owl Creek valley (Plate III A) and was probably followed by Owl creek in pre-Glacial time, in which case it doubtless marked the course of an important tributary valley glacier moving into the main valley of Lillooet river at what is now the head of Lillooet lake. The waters of Birkenhead river, also, would have followed this route in pre-Glacial time. This route, now followed by the wagon road over Pemberton portage, rises to about 400 feet above the mouth of Owl creek and probably marks the site of an old river channel buried under unconsolidated materials chiefly of morainic origin. The large accumulation of debris, at the close of the Glacial period, near the confluence of the three large valleys of Birkenhead, Green, and Lillooet rivers, doubtless resulted in considerable disorganization of drainage in that vicinity. The diversion of Owl creek and Birkenhead river from the portage route to their present course would have resulted from the accumulation of an excess of these morainic materials along the portage sufficient to dam the combined streams in this direction.

ECONOMIC GEOLOGY

GENERAL STATEMENT

A résumé of mining history in Pemberton area has been given in an earlier section of this report. Prospecting was, no doubt, stimulated by the construction of the Pacific Great Eastern railway and resulted in the staking of a number of properties. Among them, the Boulder Creek properties near the southwestern shore of the head of Lillooet lake; the Margery group near Pemberton portage; the Copper Queen group on Owl creek; and properties near the head of Tenquille creek; have attracted the most attention.

The ore mineralization of each locality is related genetically to adjacent batholithic intrusives. The common type of ore mineralization in this area is the high-temperature replacement of limestone by a variety of ore minerals including magnetite, hematite, pyrrhotite, pyrite, sphalerite, chalcopyrite, galena, and arsenopyrite. The copper content is of chief economic importance in these complex deposits. Values in gold and silver are usually present, but are mostly very low. These mineral deposits occur near some intrusive body regarded as having effected the metamorphism and mineralization of the limestone. Examples of this type of deposit are represented on the Margery group; on the Boulder Creek properties; and on the Crown, Copper Mountain, and other properties near the head of Tenquille creek.

In addition to limestone replacements there are instances in the area where other rocks have been replaced by ore minerals, chiefly along shear zones or other lines of weakness. The variation in the character and volume of the mineralization depends upon a number of factors such as the temperature of the mineralizing solutions and the character of the wall-rock. Such mineral deposits are likely to prove more persistent, both in length and in depth, than the limestone replacements previously referred to. They are, also, more regular in outline. Characteristic examples of this type of deposit are certain zones of mineralization on the Boulder Creek properties. In addition, the Pemberton mine, on Onemile creek; the Gold King and Crown claims south of Tenquille creek; and, north of this creek, Moffat and White's properties; contain deposits which may be referred to this type of mineralization.

There are, finally, certain vein deposits which may be either close to, or at some distance from, the intrusive regarded as genetically related to the mineralization. In those deposits, particularly, that are far from the supposed parent intrusive, the minerals are such as are commonly regarded as having formed under somewhat lower temperature conditions than those composing the replacement deposits, and are represented chiefly by pyrite, arsenopyrite, galena, and sphalerite in about that order of abundance. Quartz is commonly an abundant gangue mineral. The veins may be simple or may occur in zones of shearing in rocks that have suffered little or no replacement. Usually the walls are well defined, but some dissemination of ore minerals may occur in the wall-rock adjoining the veins. Most of the deposits on the Li-li-kel property at the head of Tenquille creek are mineral veins. Vein deposits also occur on other properties in the area, but are mostly of minor importance.

DESCRIPTION OF PROPERTIES

Boulder Creek Properties

The Boulder Creek properties, discovered in 1915, include thirty-four claims on either side of Boulder creek, and extend northwesterly parallel to the shore of Lillooet lake. This stream enters the southwestern side of the lake about 3 miles from its head. From the head of the lake—opposite the properties—a wagon road 5 miles long connects with the railway at Owl Creek station, 63 miles by rail from tidewater at Squamish.

The properties include four groups of claims, namely: the Boulder group of eight claims lying on either side of the creek and including the Copper King Crown-granted mineral claim; the Apex group of eight claims adjoining the Boulder group to the southeast; the Lake group of eight claims adjoining the Boulder group to the northwest; and the Eagle group of ten claims lying to the northwest of the Lake group and extending to the head of Lillooet lake.

The most abundant rocks on these properties are regarded as Triassic and consist of volcanic and sedimentary members, of which the former are the more abundant. These volcanic rocks include sericitic and chloritic schists, fine-grained and more massive greenstones, and bedded pyroclastic rocks ranging from tuffs to coarse breccias or agglomerates. The sedimentary members are chiefly argillaceous, but include some very cherty varieties. Small beds or lenses of limestone were also observed at different points to the northwest of Boulder creek. All these rocks stand at high angles and have a fairly uniform trend of north 45 degrees west.

In addition to these older rocks there are batholithic and dyke intrusives varying both in composition and in texture. Collectively these intrusives have greatly metamorphosed the older rocks and are genetically related to the mineralization that has taken place. The largest area of intrusive rocks is exposed along the shore of Lillooet lake below the delta at the mouth of Boulder creek. Its contact with the older rocks follows up the valley of a steep gulch about a mile east of Boulder creek and swings to the west around the head of Schist creek. The hills towards the west of Schist creek are said to be composed of a similar intrusive type which is dominantly a hornblende-biotite granodiorite or quartz diorite. At certain points within this batholithic area dyke-like bodies of pinkish granite were observed. A smaller area of a dioritic intrusive occurs along the southern bank of Lillooet river immediately above the head of the lake and opposite Indian Reserve No. 3. Between the two areas of batholithic intrusives the older Triassic rocks are penetrated by a large number of dykes which are probably closely related to the batholithic rocks that, no doubt, everywhere underlie the Triassic beds. The dykes are not all of the same age, for some were observed to cut others, and the older dykes are, in part, considerably sheared and mineralized, characteristics not pertaining to the younger dykes.

The several groups of claims are traversed in a northwesterly direction by a zone of mineralization 3½ miles or more long and varying up to about 600 feet in width. On the Apex group this zone reaches a height of nearly 6,000 feet, but at Boulder creek and farther to the northwest its average elevation is less than 1,000 feet above Lillooet lake. The principal mineralized areas along this zone, and, consequently, the points where most development work has been done, occur near the ends and at its intersection by Boulder creek. Elsewhere mineralization is indicated only by a brownish-red iron oxide stain on the rock surface. The strike of the zone coincides with the main axis of deformation of the enclosing rocks. The zone is a sheared belt along which ascending mineral vapours, solutions, and magmas found comparatively easy access. The country rock adjoining, and included in, the zone has been greatly altered, and its original character is in many cases difficult to determine. The limestone members in places have been completely altered to lime-silicate rocks composed chiefly of epidote, garnet, and quartz. Usually this alteration is accompanied by some replacement by such ore minerals as magnetite, hematite, pyrrhotite, and pyrite and, to a lesser extent, by chalcopyrite and sphalerite. The volcanic and other sedimentary members, especially where most sheared and schistose, are, in places, very noticeably impregnated by iron sulphides and, to a lesser extent, by copper sulphides.

The principal showings on the Eagle group occur about 700 feet above, and within half a mile of, Lillooet lake. Here an adit 110 feet long has been driven southwesterly through a series of volcanic and sedimentary rocks that strike about north 25 degrees west and dip at high angles to the northeast. They show considerable shearing and faulting and a general sparse mineralization by pyrite. About 50 feet from the portal the adit intersects a 5-foot band of heavily mineralized greenstone cut by a narrow diorite dyke. Adjoining this rock to the northeast is a band of altered limestone about 5 feet wide which also shows some mineralization. The ore minerals are chiefly pyrite and magnetite with subordinate proportions of chalcopyrite, pyrrhotite, and sphalerite.

A few yards to the southwest of the adit are a couple of open-cuts showing conspicuous mineralization across a width of several feet of country rock composed chiefly of crystalline limestone and lime silicate rock (garnetite). The mineralization in these open-cuts is similar to that encountered in the adit except that the proportion of chalcopyrite appears to be a little higher. It is difficult to say whether these showings, and the one in the adit, are parts of one ore-body which has been disrupted by faulting or whether they are separate ore-shoots diagonally crossing the general trend of the main zone of mineralization. Some post-mineral faulting has occurred, but its significance could not be determined.

About 200 feet northwest of these open-cuts is a prominent gulch striking up the hillside at about north 60 degrees west. The gulch is noticeable from a distance by reason of the coating of reddish iron oxide on the rocks. Here an adit 20 feet long has been driven along a heavily mineralized deposit about 30 feet wide developed in altered rocks, including some limestone, near the contact of an acid feldspar porphyry dyke. The central part of the deposit is composed chiefly of solid hematite. On either side the deposit is composed mostly of mixed magnetite and pyrite, but contains a varying proportion of country rock as gangue. Very little other ore minerals are present and in spite of the heavy mineralization the values in copper, silver, and gold are reported to be very low. The deposit can be traced by the reddish oxide stain for 100 feet or more up the gulch, but the average width of heavy mineralization was not ascertained.

The principal showings on the Lake group occur on the Red Jacket claim and include a type of mineralization very similar to that on the Eagle group. At the principal showing a number of dykes, some later than others, intersect a limestone bed and some chloritic greenstones of uncertain origin. Pyrite is conspicuously disseminated across a width of about 18 feet of these greenstones and the mineralization appears to follow the trend of the main ore zone of which it forms a part. Locally, other minerals, including chalcopyrite, pyrrhotite, sphalerite, and magnetite, are fairly abundant. No systematic sampling has been attempted on this showing and the work done is not sufficient to prove its value either at the surface or in depth.

On the Copper King claim of the Boulder group a very fine natural section of the main mineralized zone has been exposed in the canyon of Boulder creek, near the mouth of its tributary Schist creek. Considerable stripping and open-cut work have been done at this point. The mineral zone has a width of over 300 feet and is abundantly impregnated with pyrite whose oxidation products have produced a rusty stain over the surface exposures. The rocks in this section vary in composition and structure. In part they are slaty argillaceous types; in part cherty fragmental rocks; in part what may be altered limestone; and in part dark green chloritic rocks of probable volcanic origin. These types are interbanded and strike northwestward. They are intersected by a number of narrow porphyrite dykes. The mineralization shows little uniformity in either character or distribution. Pyrite is the most abundant ore mineral and occurs either finely disseminated through the country rock or locally concentrated into blebs or bunches. In certain beds chalcopyrite is an important constituent, and over widths of a few inches may give high assay values in copper. In addition to pyrite and chalcopyrite some magnetite, sphalerite, and pyrrhotite were also observed. The section shows much faulting and shearing in at least two main directions, one nearly parallel with the general trend of the rocks and the other 20 degrees or so farther to the west, a direction corresponding closely to the general trend of the dyke intrusions, and the one which appears to coincide most closely with the more important mineralized shoots or veins. A series of four samples[1] obtained over widths of 15, 20, 20, and 30 feet, respectively, across the mineralized zone, gave the following assay returns:

Sample No.	Width sampled	Copper	Silver	Gold
	Feet	%	oz. per ton	
1	15	1·5	0·68	trace
2	20	0·45	0·22	"
3	20	0·10	0·52	"
4	30	0·30	0·54	$1.40 per ton

Regarding these samples Dr. Uglow says, in part:

"Although the samples taken are below the limit of present commercial value, it is to be remembered that they were taken practically across the outcrop where the sulphide minerals in the shear zones have undergone thorough oxidation and leaching. It is probable, therefore, that samples taken across corresponding widths of the unoxidized rock would give results higher in copper values."

The showings on the Apex group of claims occur at about 5,000 feet above the level of the lake and at the southeast end of the principal mineralized zone. The mineral deposits occur near the main intrusive contact in rocks which are chiefly, at least, of volcanic origin, facts which may possibly account for the occurrence of a somewhat different proportion in the ore minerals than at the localities previously described. The zone has here a maximum width of about 600 feet. The most abundant mineral is pyrrhotite, which at one point forms a nearly solid dyke from 8 to 10 feet wide striking more or less in line with the intrusive contact. Elsewhere the ore zone on these claims shows an extensive impregnation by iron sulphides, chiefly pyrrhotite, but in spite of the abundant mineralization assay returns have shown only low values in gold, silver, or copper.

In addition to the main ore zone, which includes the mineral deposits so far described, there are other evidences of mineralization on these properties (particularly in the steep canyon of Boulder creek between the main zone of mineralization and the lake shore), that may indicate the presence of other zones running nearly parallel with the main one. Only a little prospecting has been done at these places which are more densely timbered and, consequently, more difficult to explore. Some mineralization was also noted close to the lake shore below the principal showing on the

[1] Report to owners by Dr. W. L. Uglow, of British Columbia.

Lake and Eagle groups of claims, but no important concentrations of ore minerals were observed in this locality.

General impressions of these Boulder Creek properties may be summed up as follows. The ore mineralization is probably related to the larger intrusive bodies in the locality rather than to the numerous dykes encountered at the various showings. Many of the dykes appear to be, and probably are, post-mineral in age. It is evident that they were intruded at different times as some intersect others and the older dykes in some instances are sheared and mineralized, features absent in the younger dykes. The positions of the chief centres of mineralization are within the main zone of mineralization, which is a zone of fracturing and shearing. This line of weakness corresponds in direction to the general trend of deformation of the older rocks, a deformation induced prior to the intrusive activity in the area. The position of the principal centres of mineralization appears to be related to a series of intersecting lines of movement which cross the main zone at different angles, but most commonly in a direction of about north 65 degrees west. The heaviest mineralization is at those points of intersection where there are limestone beds or other rocks whose original composition or subsequent deformation has rendered them most susceptible to replacement by mineralizing solutions. The bulk of ore minerals on these properties is, undoubtedly, very great. Unfortunately the grade, except locally, is extremely low, although, in respect to the copper values at least, better returns may be obtained below the zone of oxidation. The properties have the advantage of being near transportation, and ample waterpower could be furnished by Boulder creek.

Margery Group

The Margery group lies about 1½ miles northeast of the wagon road crossing Pemberton portage between the head of Lillooet lake and the Pacific Great Eastern railway (Plate III A). A trail, passable for horses only part of the way, leads to the cabin and workings which lie about 2,400 feet above the wagon road. The distance from the foot of the trail to Owl Creek station is about 5 miles. A brief reference to this property is given by Brewer,[1] and in 1917 Camsell made an examination of its mineral deposits[2]. Little work has been done on the property since that time.

The ore mineralization occurs in lenses of limestone and other members of the Triassic rocks of the area. These rocks have been intruded by dykes of diorite and porphyrite in the vicinity of the showings, and by a large belt of batholithic rocks farther up the mountain slope. Considerable metamorphism of the older rocks has resulted from these intrusions and the limestone, in particular, has undergone change to a "garnetite" rock in which the minerals garnet, epidote, calcite, and quartz are the essential constituents. Simultaneously with, or closely following, this metamorphism the ore minerals were introduced. These include pyrite, magnetite, sphalerite, arsenopyrite, and chalcopyrite.

The two principal showings occur a few hundred yards to the east and north, respectively, of the cabin. The more easterly deposit appears to follow a zone of shearing or fracturing extending about north 45 degrees

[1] Rept. of Minister of Mines, B.C., 1913, p. 249.
[2] Geol. Surv., Can., Sum. Rept., 1917, pp. 19 B-20 B.

west along the side of the hill. The chief mineralization occurs where this zone encounters a bed or lens of limestone. At this point an adit was driven along the ore-body, but unfortunately had caved in and could not be examined. Some specimens, piled up near the portal, gave a fair idea of the character of the mineral deposit. In these specimens crystals of green epidote, reddish garnet, calcite, and quartz, representing alteration products of the limestone, were associated with ore minerals including yellowish to dark brown sphalerite, arsenopyrite, pyrite, and a little chalcopyrite. The ore minerals occurred as disseminations through the lime-silicate rock, as well as along fracture planes in it. The general impression was that the ore minerals were introduced towards the close of the period of metamorphism of the limestone.

At the more northerly showing, on the Black mineral claim, surface stripping and open-cut work had exposed a heavily mineralized lens about 25 feet wide in altered rock near the foot-wall of a diorite dyke. This dyke has a width of about 30 feet and strikes between 20 and 40 degrees west of north. The adjoining rocks are so altered as to render their original character difficult to determine, but from the presence of such minerals as epidote, garnet, and quartz associated with the ore minerals it seems likely that the original rock at this point was either limestone or a calcareous sediment. Elsewhere the country rock includes argillaceous and, probably, tuffaceous strata.

The mineralized lens is composed chiefly of pyrite and magnetite, but contains some chalcopyrite and a varying proportion of the associated country rock. A fair mineralization was noted on either side of the dyke for a distance of 100 feet or so from the ore-body, but was most abundant below the dyke where, in the writer's opinion, there is the best chance for finding an extension of the main deposit.

No sampling of this property was attempted as the values were said to be exceedingly erratic. Specimens containing free gold were reported to have been obtained and picked specimens run high both in gold and copper. Some platinum, also, has been reported, but is not to be expected in this type of ore deposit.

Owing to the abundance of intrusive rocks, the sheared and deformed character of the older rocks, and the presence of some limestone, this section holds some promise of future prospecting. The mineralization is not necessarily confined to the limestone, but its alteration and replacement by ore minerals affords the most conspicuous clue to the position of mineral deposits.

Owl Creek and Vicinity

A number of claims were staked, and considerable prospecting was done, in the basin of Owl creek, in 1913 and following years. This stream empties into Birkenhead river near Owl Creek station.

The most important discovery was made on the Copper Queen claims near the eastern border of a tongue of dioritic intrusive rock that extends for about 5 miles northerly from the railway, and, where it crosses Owl creek, has a width of about half a mile. Wherever examined, this intrusive was observed to be sparsely mineralized by pyrite. An adit about 230 feet long has been driven in a south 30 degrees west direction into this intrusive and cuts at about right angles a number of shear zones of a width up to about 8 feet. These zones have been extensively mineralized by both pyrite and chalcopyrite. From two of them, and across a width of 5 feet in each case, Robertson[1] obtained samples that ran about 5 per cent copper, with traces of gold and silver. The more solid rock between the fissures, is, also, but more sparsely, mineralized by the same sulphides. Leaching of the copper ore by surface water is exceptionally pronounced on this property. Its easy accessibility and convenience to transportation, as well as its very fair copper values, make this property worthy of attention. Further prospecting along the borders of the intrusive in which the ore occurs is advisable.

Other properties in the vicinity of Owl creek include the Iron Man group, a copper property lying at an elevation of about 5,000 feet on the mountain between Owl creek and Birkenhead river and immediately north of the Copper Queen. This property was not visited by the writer, but has been described by Camsell[2], who considers that although the surface showings are fair, the ore is not likely to go deep enough to make the deposits worth working.

Pemberton Mineral Claim

The Pemberton mineral claim was discovered and located by William N. Tuck on July 27, 1918. It is situated three-tenths mile south of Pemberton station and one-fifth mile south of Onemile creek. The discovery was made 100 feet north of mile 57 on the Pacific Great Eastern railway.

The rocks are here schistose types of the Triassic formation trending northwest and southeast and dipping to the southwest. The ore mineralization follows the strike of the schist and apparently represents a replacement along a shear zone in these rocks.

The ore minerals include pyrite, chalcopyrite, and pyrrhotite, and at the point of discovery show a fairly heavy concentration across a maximum width of about 6 feet. The values are chiefly in copper.

The mineralization is said to have been traced for nearly a mile to the northwest and some work was done about 1898 near Onemile falls about half a mile up the creek from the railway, and is probably the locality referred to by Brewer in his report for 1913.[3]

The genesis of the ore is referred to the large intrusive belt cutting across Onemile creek to the west of Pemberton station.

Tenquille Creek Properties

A number of properties are located on either side of the head of Tenquille creek, a stream flowing easterly into Birkenhead river some 9 miles above the divergence of this river from the line of the railway near mile 71 from Squamish.

Attention was drawn to this section in 1916 by discoveries of copper ore carrying low gold values, and specimens of high-grade silver ore carrying native silver.[4] By 1918 a number of properties had been staked and prospecting was being vigorously prosecuted, although, owing to difficulty of access, but little actual development work had been done.[5]

[1] Rept. of Minister of Mines, B.C., 1916, pp. 270-272.
[2] Camsell, C., Geol. Surv., Can., Sum. Rept., 1917, p. 19 B.
[3] Rept. of Minister of Mines, B.C., 1913, p. 249.
[4] Rept. of Minister of Mines, B.C., 1916, p. 269.
[5] Rept. of Minister of Mines, B.C., 1918, p. 232.

The camp was visited by Hanson in 1917[1] at which time attention was chiefly centred on properties to the north of the head of Tenquille creek. During the following year activities were still mostly confined to this locality. More recently considerable development work has been done on properties to the south of the head of Tenquille creek. In 1923 the various properties were visited and subsequently reported upon by the District Engineer.[2] The present report is confined chiefly to properties south of Tenquille creek.

The Tenquille Creek properties may be reached by either of two routes. One leads from Pemberton and the other from mile 72, 15 miles by rail northeast of Pemberton. From Pemberton the road up Lillooet valley is followed for 15 miles to Taylor's ranch, at which point the river may be crossed by canoe or forded by horses. A trail, about 7 miles long, leads from there up the steep mountain slope to the divide overlooking the headwaters of Tenquille creek. The ascent of 6,000 feet may be negotiated by horses in about 4 or 4½ hours, for although the average grade is very steep the footing is excellent. The alternative route leads from mile 72 on the railway up Birkenhead river and Tenquille creek, a distance in all of about 14 miles. The grade over this route is comparatively gentle and except for occasional bogs is preferable to the other by which the same elevation is reached in about half the distance.

Tenquille creek holds a direct easterly course from Maud lake to where it empties into Birkenhead river. The walls of its U-shaped glaciated valley rise steeply above the broad valley floor. The upper basin of the creek in the vicinity of Maud lake broadens to a considerable size and is drained by a number of fair-sized tributaries.

The rock structure in this section is complex and requires more careful study in order to interpret the sequence and thickness of the formations and the significance of numerous faults. In a general way the basin of Tenquille creek and the areas immediately surrounding it may be said to be underlain by a series of Mesozoic rocks which include many fossiliferous horizons, chiefly in limestones, from which collections were made, and subsequently determined as Upper Triassic in age.

In addition to limestone the series includes argillaceous and slaty beds; massive strata of fragmental rocks which contain a few fossils, but have, on the whole, a tuffaceous appearance; and an abundance of greenish, massive to schistose, rocks of probable volcanic origin. The general trend of the series is about north 37 degrees west and the dip is predominantly northeasterly, but owing to an abundance of faulting and shearing there are many local irregularities in the structure. In line with the principal axis of deformation of these rocks, a direction corresponding closely with their average strike, is abundant evidence of shearing and schistosity. Across these shear zones, and nearly at right angles to them, is a prominent system of faulting along the line of which certain mineralized veins in the district are prominently developed. The shearing and faulting appear to have been developed at different stages in the history of these rocks. For the greater part they are pre-mineral in age and afforded convenient loci for the development of mineral deposits. In certain instances, however,

[1] Geol. Surv., Can., Sum. Rept., 1917, p. 19 B.
[2] Rept. of Minister of Mines, B.C., 1923, pp. 166-168.

there has been subsequent movement along the old lines of weakness, resulting in the displacement and brecciation of the deposits.

A small area of what appear to be later sedimentary rocks was observed to the south of Tenquille creek near the Li-li-kel group of claims. This series, referred to the Cretaceous period, includes well-stratified shales, sandstones, and conglomerate and shows less evidence of deformation than the other sedimentary rocks of the area which appear to underlie them unconformably. They show, however, some evidence of mineralization and are regarded as probably older than the intrusive rocks of the area. The latter include bodies of batholithic dimensions as well as numerous dykes of which some represent apophyses from the larger intrusive bodies. These intrusives include such acid types as quartz porphyry, but are for the greater part more basic in composition, approaching diorite or quartz diorite and including porphyrite dyke equivalents.

Ore Deposits. Prospecting in this area, although facilitated by the open character of the country and abundance of rock exposures, has been retarded by physical difficulties, the cost of getting in supplies, and by the quantity of snow which covers the country at this high elevation for the greater part of each year. Geological conditions are excellent for the accumulation of mineral wealth. There is here an intimate association of intrusive and intruded rocks. The latter include an abundance of limestone strata and were sufficiently sheared and deformed in pre-mineral times to provide convenient channels for the passage of ore-bearing solutions.

Mineralization has been exceptionally heavy at a number of localities in the vicinity of the larger intrusive bodies. To the south of Tenquille creek the larger deposits have resulted chiefly from the high temperature replacement of limestone beds or lenses, whereas north of the creek the replacement is said to involve chloritic and sericitic schists. Farther from the main intrusive contacts the mineral deposits are more frequently of the vein type, but more or less replacement along shear or fracture zones also occurs. The ore minerals present vary according to the character of the deposit. Near the larger bodies of intrusive rocks the chief ore minerals south of Tenquille creek include magnetite, sphalerite, pyrrhotite, and pyrite with a little chalcopyrite. North of Tenquille creek, pyrite, chalcopyrite, and sphalerite are the abundant ore minerals. In the vein deposits farther from the main contacts galena, sphalerite, arsenopyrite, pyrite, and chalcopyrite are the common ore minerals.

Crown Group. The Crown group of eight claims includes the high summit of Crown (McLeod) mountain on the divide between Lillooet river and Tenquille creek. A large cabin has been constructed near the summit of the mountain at an elevation of about 7,000 feet. Excellent trails lead from here to different showings on the property. The principal development work has been done within a hundred yards or so to the northwest of the cabin on a zone of mineralization which follows a shallow depression or saddle striking about north 35 degrees west across the southwestern tip of the mountain. This zone of mineralization is apparently coincident with, and related to, a zone of shearing which, in turn, is closely parallel to the average trend of deformation of the rocks in this part of the area. In the vicinity of the principal workings on the Crown property the shear zone dips steeply to the northeast across one, or possibly two, beds or lenses of altered limestone (magnetite-garnet rock) whose aggregate width probably does not exceed 50 feet and may be considerably less. This altered limestone dips to the northeast, but apparently less steeply and along a direction nearer north than that of the shear zone. It underlies a series of fragmental, green, tuffaceous sediments and overlies a dense, whitish, felsitic rock of uncertain but, probably, volcanic origin. This felsite is intersected by dykes of quartz porphyry that may be related to neighbouring batholithic quartz diorite intrusives which, in turn, are regarded as the source of the mineralization on this property.

Where intersected by the shear zone the original limestone has undergone complete transformation to a rock composed chiefly of magnetite and garnet, but including some epidote and minor proportions of pyrite, sphalerite, galena, hematite, pyrolusite, chalcopyrite, and limonite.

Two shafts, one about 40 and the other 70 feet deep, sunk on the line of the shear zone, intersect the mineral deposits. The deeper shaft follows a mineralized brecciated zone about 40 inches wide in which the chief silver values occur. The rock involved is so altered as to render its identification difficult, but it resembles the felsitic rather than the overlying altered limestone or "garnetite" rock. The mineralized zone has been impregnated by galena, sphalerite, and pyrite. Samples taken by the management have assayed high in silver. The values may occur in part as native silver, as some fine specimens are reported to have been found near the surface. Faulting has occurred at and near the bottom of this shaft, resulting in a displacement of the silver-bearing zone or ledge and the introduction of a block of the overlying garnetite rock.

The silver-bearing ledge was also encountered at the mouth of the other shaft where good values were obtained on the outcrop across a width of between 3 and 4 feet. A crosscut driven from the bottom of the shaft failed to locate the ledge, which pitches to the northeast in line with the main axis of shearing. Its absence is probably due to the faulting referred to above.

It seems likely that the minerals present in the silver-bearing zone or ledge belong to a later period of mineralization than that which caused the metamorphosis of the limestone to a magnetite-garnet rock. Both periods of mineralization were evidently consequent upon the shearing so notably developed in the vicinity of the shafts, but it is not improbable that this shearing developed by stages and afforded convenient channels for ascending mineral-bearing solutions of different composition.

In addition to evidences of shearing and post-mineral faulting, the rocks near the shafts are traversed by a number of open fractures which are probably a comparatively recent development and may be closed at no great depth. They have, however, permitted very considerable leaching and oxidation by surface waters and, very locally, may have caused some enrichment in the silver values. The native silver reported near the surface is probably of secondary origin.

Sampling by the management in the deeper shaft and within 15 feet of the surface has given some very satisfactory returns. A sample of high grade obtained at a depth of 4 feet gave an assay of 648·6 ounces in silver. Another sample from 100 pounds of ore representing about 5 tons of ore mined in this shaft, gave an average return from two assays of 141·31 ounces in silver, 4·1 per cent lead, and 3·2 per cent zinc. That the silver values in this sample occurred only in part with the galena is indicated by an assay made on a specimen of the latter which ran 29·9 per cent lead, 8·8 per cent zinc, and 21·90 ounces in silver. The values obtained at greater depth along this silver-bearing zone have not been very encouraging and, in fact, are such as to suggest that attractive values do not extend to any considerable depth. This possibility is also indicated by the results obtained from trenching to the northwest and southeast of the shafts in line with the main zone of shearing. In these directions the same, or very similar, rock types occur, and some mineralization has been noted, but the silver values are low. Post-mineral faulting, also, has introduced an element of uncertainty in development work.

Other outcrops of metamorphosed limestone carrying heavy concentrations of magnetite across widths of several feet have been exposed a short distance to the southeast of the shafts, and some development work has been done. In this direction and within a radius of several hundred yards of the shafts, occur thick beds of less altered limestone bearing some copper minerals, chiefly chalcopyrite, and prominently stained with copper carbonates.

Copper Mountain Group. The Copper Mountain group includes four claims, and is located on Copper mound, a somewhat conical-shaped peak rising to an elevation of over 7,000 feet, or about 1,700 feet above the pass between the heads of Tenquille and Wolverine creeks. The peak of this hill is composed of a faulted series of volcanic and sedimentary rocks intersected by several quartz-porphyry sills and dykes and surrounded by quartz porphyry and more basic intrusive batholithic rocks. Viewed from hills to the southeast the centre of this peak appears to be traversed by a fault following a northwest-southeast direction along a nearly perpendicular plane. The rocks to the northeast of this fault have a massive appearance and dark colour. Those on the other side of the fault have a bedded structure and more variegated appearance. This fault was not precisely located owing, possibly, to the cliffy topography of the hill precluding examination along other than special routes where the contact was not exposed. The northeast side of the hill is composed chiefly of dark green, andesitic rocks including fragmental types such as tuffs, breccias, and agglomerates. The southwest flank of the hill, on the other hand, is composed chiefly of well-bedded rocks including thick beds of limestone. These strata are traversed by a number of faults striking in a general northwesterly direction and showing displacements of 200 feet or more. The sediments, and particularly the limestone, are notably fossiliferous.

Mineralization is evident at a number of localities on Copper mound and especially so at certain showings on the slope overlooking the head of Wolverine creek and about 300 feet above the creek. Here, a thick bed of limestone runs nearly parallel with Wolverine creek, and dips at a low angle to the northeast under a massive greenish rock resembling an andesite flow, but possibly fragmental in origin. Within the limestone belt and at three closely adjoining localities heavy ore mineralization has been exposed. The three showings cover a vertical range of about 75 feet and may represent a single broad zone of mineralization. At the upper showing and across a width of about 20 feet a deposit composed chiefly of pyrrhotite and magnetite and containing only a little gangue has been exposed over a length of several yards. The intermediate showing is of similar character, except that the percentage of magnetite is higher. The lower showing contains a considerable percentage of sphalerite as well as magnetite. A little chalcopyrite is present in all three showings. Veinlets of pyrite cut across the zinc and magnetite ore, and crystals of calamine were observed along fractures in the ore-body. A sample obtained by Davis from this lower showing gave an assay return of 8 per cent in zinc.[1] Low assays in gold and copper are said to have been obtained from these showings, but no systematic sampling has yet been attempted.

At a number of smaller showings on this property, and chiefly as a result of the replacement of limestone, other ore minerals—galena, arsenopyrite, pyrite, and chalcopyrite—occur, but in none of these showings is the concentration of ore minerals very pronounced. The hill as a whole is deserving of further prospecting and more careful sampling of such mineral deposits as have been discovered.

Seneca Mineral Claim. The Seneca mineral claim is situated immediately to the south of the eastern end of Maud lake and not far to the east of the body of quartz diorite intrusive that outcrops between the lake and Copper mound.

A lens or narrow bed of limestone dipping to the northeast under a cherty sedimentary rock has been altered to a lime-silicate rock composed chiefly of reddish garnet, green epidote, calcite, and quartz. Associated with these minerals is a fairly heavy concentration of magnetite and pyrite with a little chalcopyrite and sphalerite. Very little work has been done on this showing and such sampling as has been attempted indicates that the chief values are in copper with low values in gold.

Wonder Mineral Claim. This claim, located about half a mile to the southeast of the lower end of Maud lake, crosses the gulch of a tributary of Tenquille creek. The showings occur nearly midway between the head and mouth of this tributary at an elevation of about 6,200 feet. The principal showing—on the southeast side of this creek—is in beds of limestone and slate that strike north 40 degrees west and dip at high angles to the northeast. The ore minerals, including zinc blende, galena, and chalcopyrite, occur in these rocks in veins up to 6 inches in width. These veins could not be traced for more than a few feet, but are worthy of further exploration.

Silver Bell Group. The Silver Bell group of three claims extends south from Tenquille creek about a mile east of Maud lake. The formation here is a massive to slightly schistose, greenish rock striking about north 70 degrees west and dipping 35 degrees to the north. This rock appears to be fragmental and is probably a volcanic tuff or a tuffaceous sandstone. Cutting across it is a comparatively soft, basic dyke 4 feet wide striking northwest and southeast and dipping 85 degrees southwest. An adit has been run on this dyke to tap a mineralized zone which is intersected by the dyke 247 feet horizontally and 179 feet vertically above the portal of the adit. At the time of examination the adit had been projected for 110 feet along the dyke and a crosscut was being started from near-

[1] Rept. of Minister of Mines, B.C., 1923, p. 168.

the face to intersect the mineral zone which, judging from its direction and pitch as shown on the surface, should—if it continue in depth—be encountered within a distance of 40 feet.

The mineral deposit—a mixture of iron, copper, zinc, and lead sulphides in a quartz gangue associated with a large proportion of silicified and otherwise altered country rock—occupies a fracture zone running at an angle of about 25 degrees with the dyke and pitching at a high angle to the northeast. At the intersection of the dyke a sample taken by the owners across the mineralized part of the zone, here about 2 feet wide, was said to have assayed $2.75 in gold and 2 ounces in silver. Twenty-eight feet, vertically, below this point another sample across a mineralized width of 5 feet 3 inches gave an assay return of $6 in gold and 12 ounces in silver. This sample, however, included from 6 to 8 inches of higher-grade material containing considerable galena and pyrite and some sphalerite and chalcopyrite, and probably most of the values were concentrated in this part of the sample.

Gold King Group. This group of four claims adjoins the Silver Bell group to the southwest and runs up the valley slope towards the summit overlooking the head of Owl creek. The lie of these claims corresponds with the trend of a zone of mineralization striking about north 30 degrees west. The lowest and largest deposit occurs a short distance above the junction of two small tributaries of Tenquille creek at an elevation of about 6,000 feet. Below their junction the combined water drops steeply into Tenquille creek and would furnish a fair source of power for the properties nearby.

The rocks near the lower showing are well-bedded sediments striking north 15 degrees west and dipping 45 degrees to the northeast. They include dense, cherty types, others more arenaceous in appearance, and some limestone. The ore minerals occupy a fractured or fissured zone in these rocks and at the lower showing enclose a horse of country rock several feet wide, which has been silicified and impregnated by the mineralizing solutions and is capped by a porous aggregate of quartz crystals coated with iron oxide. Adjoining this horse to the southwest the mineralized zone has a width of about 9 feet and on the other side of the horse is about 1 foot wide. The ore minerals include an abundance of pyrrhotite, considerable zinc blende and pyrite, and some chalcopyrite. In the wider part of the showing there are bunches of ore minerals containing a fair quantity of galena. Crystalline quartz is an abundant gangue mineral and the drusy character of the ore suggests that it was deposited in a partly open and highly fractured zone. A sample taken by Davis[1] across the ore zone to the southwest of the horse gave an assay return of: gold, trace; silver, 1·6 ounces to the ton; lead, nil; zinc, 5 per cent. Another sample across 2 feet of vein material in an open-cut about 100 feet farther up the gulch gave: gold, 0·06 ounce; silver, 1·2 ounces to the ton; lead, nil; zinc, 5 per cent.

Ore mineralization is exposed at other points farther up the hill over a distance of about two claims' length. It is uncertain whether there is any direct connexion between these showings and the lower ones, although they are all, apparently, located on the same, or closely parallel,

[1] Rept. of Minister of Mines, B.C., 1923, p. 167.

lines of fracturing. Below the lowest showing the formation is obscured by an overburden of soil and rock talus. Mineralization is likely to be more pronounced in this direction than farther up the hill.

Li-li-kel Group. The Li-li-kel group of eight claims adjoins the Gold King group to the east and runs in a southwesterly direction towards the summit of Tenquille Creek valley. The prevailing rocks on this property are massive to schistose greenstones of volcanic origin. Included with them are belts of porphyritic, grey and reddish, volcanic flows. Intercalated with these volcanic rocks are sediments, including, chiefly, argillaceous types and limestone beds. The structure is rendered complex by deformation accompanied by abundant faulting and shearing. The general trend, however, appears to be from north 30 degrees to north 40 degrees west, with an average dip of 40 degrees northeast. Aside from occasional dykes which do not appear to have any direct bearing on the ore mineralization, this group of claims lies farther from any considerable intrusive body than any of the properties yet described. The mineral deposits are principally of the vein type with an abundant quartz gangue and holding a suite of ore minerals including pyrite, arsenopyrite, galena, sphalerite, and chalcopyrite. In all, thirty-three veins are reported to have been found, but many are very small and doubtless of little economic interest. The more important veins are referred to below.

In a general way it appears that the formations on this, as well as adjoining properties have been subjected to movements along two principal directions which are of importance from an economic standpoint. There is a direction of major shearing running approximately northwest and southeast corresponding with the general trend of deformation of the older rocks. Crossing these shear zones is a second line of movement less violent in character and represented chiefly by faults along which minor shearing has occurred. The direction of this line of movement varies from about south 35 degrees west to south 60 degrees west, and is consequently nearly at right angles to the more pronounced direction of shearing. The principal mineral veins coincide with the direction of cross-faulting, but the largest single deposit occupies a zone of shearing running in a northwest-southeast direction. It appears, therefore, that this cross system of shearing and faulting antedates the period of mineralization, and that prospectors should pay particular attention to evidence of ore-bodies at points of intersection.

The most important of the mineral deposits discovered up to date follows a line of faulting and shearing running in a general southwesterly direction up the slope of the hill from an elevation of 4,900 feet, or 400 feet above Tenquille creek, to about 6,900. The lower 350 feet includes the most important section of this deposit and the only section on which any development work has been done. The country rock is a dark green, fine-grained, and fairly massive rock of, probably, volcanic origin. Along the line of the fault or shear zone in which the ore minerals occur this rock commonly constitutes a large proportion of the gangue and in such cases has a decidedly brecciated appearance. This structure is not noticeable in the wall-rock and has evidently resulted from shearing along the zone occupied by the ore minerals.

At an elevation of 5,200 feet an adit has been driven for 25 feet along the mineralized zone which here strikes south 35 degrees west and dips

75 degrees to the east. At the face of the adit mineralization occurs across a width of 30 inches exclusive of what seems to be a horse of country rock a foot or more in width. The deposit is highly quartzose and through it are disseminated crystals of pyrite and a silver mineral identified as polybasite. A sample taken by the writer across the mineralized part and assayed by the Department of Mines, Ottawa, gave: gold, a trace; silver, 10·85 ounces to the ton; and no lead. A short distance below the adit the mineral zone has been faulted down the hill for a distance of several yards, but has been picked up again and is apparently continuous from this point down the hill in a more easterly direction over a vertical range of about 100 feet. On this latter distance it widens at points to from 2 to 8 feet and includes stringers or small lenses of nearly solid galena. This sulphide is said to assay about 25 ounces in silver, but much higher silver values have been obtained in the more silicified and brecciated parts of the mineralized zone, in which little or no galena is present but in which silver minerals occur. Of these silver minerals polybasite has been identified and it is probable that others are present.

About 150 feet vertically above the adit an exposure of this mineralized zone showed native silver in fracture planes in the deposit. This silver is no doubt of secondary origin. Above this point the continuation of the zone is less certain. A number of small cross veins were observed at different elevations. These contained pyrite, chalcopyrite, and sphalerite as the chief ore minerals. Quartz, together with a large proportion of included fragments of the wall-rock, formed the gangue.

At an elevation of about 5,700 feet a vein 12 inches wide strikes south 55 degrees west, and dips about 80 degrees southeast. Its continuity was not determined, but at the point of examination it was observed to contain a large percentage of arsenopyrite which was reported to carry very fair gold values.

About 300 feet above this arsenical vein, and overlying a thick stratum of limestone, that strikes northwest and southeast and dips to the northeast, there occurs a belt of fine-grained, hard, banded sediments somewhat sheared in appearance and containing a zone of heavy mineralization about 25 feet in width. The chief mineral is pyrite, but other sulphides, including sphalerite, arsenopyrite, pyrrhotite, and galena, are present. The continuation of this zone has not been explored. Samples across this zone are said to have shown very fair gold, and low silver, values.

Properties North of the Head of Tenquille Creek

The writer was unable to visit properties north of Tenquille creek and the reader is referred to previous reports[1] for developments in that locality.

The prevailing rocks on the northern slope of the head of Tenquille and Wolverine creeks are schists of both sedimentary and volcanic origin. These have a northwesterly trend and dip steeply to the northeast. Interbedded or intercalated with these schists are more massive sediments, including impure sandstones and some conglomerate. These older rocks are all intruded by porphyritic dykes and sills and by a dioritic body exposed on the summit of the divide to the west of the properties, which is probably the chief source of mineralization in this locality.

[1] Geol. Surv., Can., Sum. Rept., 1917, p. 19 B.
Rept. of Minister of Mines, B.C., 1923, p. 168.

NICKELIFEROUS MINERAL DEPOSIT, EMORY CREEK, YALE MINING DIVISION, BRITISH COLUMBIA

By C. E. Cairnes

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Illustrations

INTRODUCTION

In August, 1923, the Pride of Emory group of eight claims was staked in the basin of Emory creek, Yale mining division, British Columbia. In October of the same year a second group, comprising seven claims and recorded as the Star of Emory group, was staked to the west of, and immediately adjoining, the Pride of Emory group. The original discovery was made by a trapper, Carl Zofka, on what is now called Discovery claim. Zofka's attention was first attracted to this locality by the appearance from a distance of a reddish bluff which on closer inspection revealed a large deposit of nearly solid sulphide mineral. Specimens were taken to Hope and on subsequent assay and analysis revealed an important nickel content as well as a small percentage of copper and low values in gold and silver. The aggregate assay was sufficient to cause some local excitement and resulted in the staking of the above groups of claims.

In company with one of the owners, Mr. L. B. Cleaves, the writer visited the locality in the following July and spent parts of two days in an examination of the mineral deposit on Discovery claim and in more general geological observations.

The discovery of this nickeliferous deposit is of particular interest in that it represents the first recorded occurrence in British Columbia of a mineral deposit which has been staked primarily for its nickel content. The property has acquired additional interest and significance in that the nickeliferous deposit is of a type somewhat analagous, both in mineral and geological associations, to occurrences of nickel minerals in Alaska; to the great deposits of nickel ore at Sudbury, Ontario; and to other nickeliferous bodies, in the United States and other parts of the world.

LOCATION

The nickeliferous deposit is located high up on the southern slope of the basin of Emory creek. This stream enters Fraser river from the west about 2 miles above Choate, a flag station on the Canadian Pacific railway. Choate is situated 6 miles above Hope and 95 miles by rail from Vancouver. A foot trail, unsuitable for pack horses, leads off from the railway a few hundred yards below Emory Creek crossing and affords a somewhat circuitous route to the property over a distance estimated at about 14 miles and requiring seven hours of diligent travelling. A more convenient trail could be constructed over the divide between Emory and Stulkawhits (Texas) creeks and down the latter stream. Such a route would probably be not over 7 miles in length and would reach the railway close to Choate station.

GEOLOGY

The district in the vicinity of the properties is underlain chiefly by batholithic rocks having an average composition of quartz diorite or basic granodiorite. These commonly show some foliation, but are massive in their general structure.

The batholithic rocks are in contact, near the nickeliferous deposit, with a massive, coarsely crystalline pyroxenitic hornblendite intrusive which trends about northeast and southwest and has an average width in this vicinity roughly estimated at about 300 yards. The northwestern contact is clearly exposed on the divide between Emory and Stulkawhits creek and the relations there indicate that the pyroxenitic intrusive has been injected into the more acid batholithic rock and is probably in the nature of a large dyke. This basic intrusive is important in that it includes the nickeliferous deposit dealt with in this report. It is also of unusual interest because of its peculiar composition which varies from a rock composed almost entirely of sulphide minerals segregated with crystals of hypersthene to one in which hornblende is the most abundant constituent and sulphides merely accessory minerals. Where present the hornblende commonly forms large, massive, dark green crystals which on examination in thin section are seen to contain numerous sharply-defined crystals of pyroxene. This pyroxene is mostly orthorhombic and probably hypersthene. Here and there, in the thin sections examined, were observed occasional minute interstitial grains of an almost colourless mineral which is probably feldspar. The scarcity, however, of other than ferromagnesian silicate minerals in this rock, forms a notable contrast to the norite intrusive with which the nickeliferous deposits at Sudbury, Ontario, are associated.

In addition to the intrusive rocks there is a small but prominent hill of older, fine-grained schistose rocks exposed on the divide east of the mineral deposit on Discovery claim. Outcrops of very similar rock were encountered, and seem to form parts of a narrow belt along or near the southeastern contact of the pyroxenitic intrusive with the batholithic rocks. These older strata probably represent sediments which have been greatly altered and partly replaced by the later intrusives, but were not observed to be of economic importance.

MINERAL DEPOSITS

The most important mineral deposit is exposed on Discovery claim between 4,000 and 4,500 feet above sea-level and about 500 feet below the summit of the divide between Emory and Stulkawhits creeks. Here a bluff dips to southwest under a swamp. The face of this bluff across a width of about 75 feet and over a vertical height of 30 feet is composed of a nearly solid sulphide deposit through which are disseminated, in varying proportions, dark green crystals of hypersthene. Except along the foot of the bluff, where the underlying rocks are concealed by a swamp, this sulphide deposit is surrounded by a hornblendic phase of the basic pyroxenitic intrusive. Although sufficient work has not been done to indicate its dimensions either above or below the level of the swamp, the deposit has the appearance of being somewhat lens-shaped. It is intersected by a series of nearly parallel vertical fractures running about 20 degrees east of north.

The primary ore minerals include pyrrhotite, pentlandite (FeNi)S, chalcopyrite, and magnetite in about this order of abundance. Pyrrhotite is by far the most abundant sulphide and is strongly magnetic. The nickel iron sulphide pentlandite is difficult to distinguish in hand specimens from the pyrrhotite through which it is disseminated in comparatively minute grains. With the aid of the reflecting microscope, however, it is readily distinguished by its lighter colour, more conspicuous fracturing, and by the formation along its cleavage and fracture lines of narrow bands of a darker coloured, secondary mineral of doubtful composition. Chalcopyrite is scattered through the mineral deposit in an irregular fashion. Picked specimens may show an important percentage of this copper sulphide, but in the bulk of the deposit only occasional grains or blebs can be recognized. Magnetite occurs as occasional small grains scattered through the sulphide mass or enclosed in crystals of hypersthene.

The secondary ore minerals include: a sulphide of uncertain composition forming bands of microscopic width along fracture lines in the pentlandite; a mineral, probably marcasite, secondary after pyrrhotite; and oxidation products on the surface of the mineral deposit. Further reference to the first two of these secondary minerals is given in subsequent paragraphs in this report.

ASSAYS

A sample over the surface of the mineral deposit was taken by the writer across a width of 45 feet. This sample, assayed by the Mines Branch, Ottawa, was reported to contain: gold, trace; silver, at the rate of 0·18 of an ounce Troy to the ton of 2,000 pounds; copper, 0·58 per cent; nickel, 1·67 per cent. The surface of the deposit, however, everywhere shows evidence of leaching and oxidation and, although some attempt was made to get as fresh material as possible for this sample, the true values in this mineral deposit can only be determined when some depth is attained in future development work. Other samples taken at or near the surface by different persons have given very similar results to the above. Other samples, again, over widths of several feet, have shown a considerably higher nickel percentage as well as better values in the other metals.

GENESIS AND MINERALOGY

ORIGIN AND EXTENT OF BASIC PYROXENITIC INTRUSIVE

The genesis of the nickeliferous mineral deposit seems closely related to the origin of the pyroxenitic intrusive in which it occurs and which, as already pointed out, shows some evidence of intrusion into the more acid batholithic rocks. This basic rock is reported to have been traced for some distance to the southwest down the basin of Stulkawhits creek as well as in the opposite direction towards the South fork of Emory creek. Its general shape, therefore, resembles that of a large dyke and as such it is regarded to be. Occurring as it does for the most part in the valley bottoms of the tributary streams, where it is covered with soil and talus debris, it is less well exposed than the granitic rocks on either side and probably owes its position to its greater susceptibility to weathering and erosion. Except near the main divide, where the discovery was made, or where exposed in the stream beds, its presence is largely a matter of conjecture and its exploration for other mineral deposits both laborious and uncertain.

DISTRIBUTION OF NICKEL VALUES

Wherever examined this basic intrusive was observed to be more or less freely mineralized by pyrrhotite. Samples of the rock have invariably shown some trace of nickel, but except where the sulphide mineralization is unusually heavy the actual percentage of nickel is much too low to be of commercial value. At the principal showing on Discovery claim pyrrhotite is by far the most abundant sulphide and its association there with a minor proportion of the nickel mineral pentlandite suggests that pentlandite is present elsewhere in the basic intrusive and is responsible for the traces of nickel found in it.

GENESIS OF THE NICKELIFEROUS DEPOSITS

The occurrence, shape, and mineral composition of the principal nickeliferous deposit on Discovery claim and the common but sparse distribution of sulphides, particularly pyrrhotite, throughout the basic pyroxenitic intrusive, tended to lead the writer to believe, while examining the property, that the mineralization was magmatic and genetically connected with the injection of the basic intrusive. This belief has since been strengthened by microscopical studies of thin sections and polished specimens. A thin section of a specimen from the discovery deposit disclosed a number of hypersthene crystals surrounded by sulphide minerals (Plate III B). The pyroxene crystals are conspicuously corroded and embayed by the sulphides, a process which may have taken place in the magmatic chamber prior to intrusion and subsequent crystallization of the sulphide minerals. The occurrence, however, of the sulphide deposit close to the southeastern contact of the basic intrusive with the batholithic rocks, suggests that this contact may represent the base of the pyroxenitic intrusive and that an immiscible sulphide melt, together with crystals of hypersthene, may have gravitated towards this base subsequent to the injection of the basic magma. In any case there seems little doubt that the sulphides formed part of this magma, although scant evidence could be obtained to indicate where their segregation with hypersthene took place.

An interesting feature of this nickeliferous deposit is that the associated gangue is chiefly, if not entirely, hypersthene, whereas the basic intrusive adjoining the deposit contains an abundance of hornblende. Until examined microscopically it was thought that this hornblende was probably secondary after hypersthene or some other pyroxene mineral. Microscopic evidence, however, favours the view that this hornblende is a primary constituent. It occurs in comparatively large compact crystals, some of which show excellent twinning. Through the larger crystals are scattered an abundance of small crystals of pyroxene showing no system of orientation and mostly, at least, orthorhombic and probably hypersthene. This association does not suggest metamorphic or secondary processes, but the result of primary crystallization. Nowhere is there evidence that metasomatism has played any important rôle in the composition of this basic intrusive. The hornblende crystals show no evidence of having developed by secondary processes. The included smaller pyroxene crystals are sharply defined and individually oriented. In the sulphide deposit many crystals of hypersthene and occasional small grains of magnetite are scattered through the sulphide mass. Evidently both of these minerals crystallized before the sulphides and have been markedly corroded in the sulphide melt. Minute veinlets of the sulphides may occur in the hypersthene or magnetite, but the walls of these veinlets show no evidence of alteration.

PARAGENESIS

A study of polished specimens from the mineral deposit on Discovery claim has served to indicate a fairly definite order of crystallization in both the metallic and silicate minerals. Probably the first mineral to deposit was magnetite. It occurs in minute, in some cases angular, but in many cases rounded, grains scattered through both silicate and sulphide minerals. Its inclusion in hypersthene indicates that at least some of it crystallized before this silicate mineral. Both the magnetite and hypersthene had completed crystallization before the sulphide minerals began to deposit. The order of crystallization of the sulphides seems to have begun with pentlandite whose relations to the pyrrhotite and chalcopyrite are somewhat analogous to those of the sulphides to the hypersthene (Plate IV). Inclusions of crystals or crystalline masses of pentlandite commonly occur in either chalcopyrite or pyrrhotite. The pentlandite may be corroded or replaced by either of the other sulphides, or these sulphides may follow crystallographic structures of the pentlandite with little or no evidence of corrosion. The relations of the pyrrhotite to the chalcopyrite are less evident and there has probably been considerable overlap in their deposition. At least part of the pyrrhotite crystallized before the chalcopyrite began to deposit, but it seems likely that much of the chalcopyrite had crystallized before all the pyrrhotite was deposited.

SECONDARY SULPHIDE MINERALS

When studied under the reflecting microscope polished specimens from the nickeliferous deposit on Discovery claim revealed one mineral that is undoubtedly secondary after pentlandite and another mineral which is probably secondary after pyrrhotite. Both of these minerals are regarded as having developed from the action of supergene waters on the sulphide deposit subsequent to its consolidation and later exposure by erosion. The first of these secondary minerals forms bands of microscopic width, following, in a remarkably persistent manner, cleavage and fracture lines in the pentlandite (Plate V). This mineral is distinctly darker than the pentlandite, but is, as nearly as the eye can distinguish, of the same shade as the pyrrhotite which it also resembles in hardness. Microchemically, however, this mineral gives a negative reaction with KOH which tarnishes the pyrrhotite areas a deep brown. Where, as commonly occurs, the line of contact of the pentlandite with the pyrrhotite is jagged or serrate following crystallographic structures of the nickel mineral, a narrow border of the secondary mineral follows the edge of the pentlandite and is indistinguishable from the adjoining pyrrhotite until the test with KOH is applied, when the boundary between the secondary mineral and the pyrrhotite is sharply defined. This microchemical separation has led the writer to believe that the mineral secondary after the pentlandite is itself a nickel mineral. In its other microchemical properties this secondary mineral closely resembles either the "bravoite" or "Nickel Mineral X" from certain nickeliferous deposits in Alaska and elsewhere[1], but nowhere has the writer noted any mention of a resemblance in colour of these minerals to that of pyrrhotite, nor, unfortunately, has he had an opportunity of comparing specimens from other localities. The secondary mineral from the deposit under present consideration occurs in bands that are too narrow to be separated mechanically and subjected to analysis. For the present, therefore, its identity other than that of a secondary mineral derived from pentlandite cannot be established.

Another and probably secondary mineral microscopically resembling either pyrite or marcasite occurs in very small blebs, thin shreds, and tiny veinlets in some of the pyrrhotite masses in those polished specimens examined. Its mode of occurrence and association favours the view that it is marcasite.

[1] Buddington, A. F., Econ. Geol., vol. XIX, No. 6, pp. 521-541.

THE GENESIS OF THE TEXADA ISLAND MAGNETITE DEPOSITS

By C. O. Swanson

CONTENTS

INTRODUCTION

Texada island lies in the strait of Georgia about 75 miles northwest of Vancouver, British Columbia. The island has an average width of 3 miles and a length of 30 miles, and represents a partly submerged ridge paralleling the mainland. It is more or less mineralized throughout, and has been the scene of a considerable amount of mining activity. The principal mines occur on the northern end of the island where high-grade copper ore was mined for a score of years. The main deposits of iron ore are located on the west coast of the island, where a discontinuous line of magnetite lenses, a little over a mile in length, occurs at the contact of an acidic stock with the Marble Bay limestone. The positions of the three largest lenses, the Prescott, the Paxton, and the Lake, are shown on the accompanying Figure 7, which is based on a geological map prepared by McConnell[1].

Recently much interest has been aroused in the iron ores of British Columbia, and a survey of this resource is being made by the Geological Survey. While assisting in this work during the field season of 1923, the writer was permitted to make a detailed study of the Texada iron ores. As the economic aspects of these deposits had already been investigated, the work of the writer centred around the problem of their genesis. The writer wishes to express his thanks to the members of the Department of Geology, University of Wisconsin, particularly Drs. C. K. Leith and A. N. Winchell, and to many others who have rendered assistance in this investigation.

PREVIOUS WORK

The iron ore deposits of Texada island have been examined by a number of geologists and mining engineers. The first observations on record were made by Richardson,[2] who regarded the magnetite as a steeply-

[1] McConnell, R. G., "Texada Island, B.C.," Geol. Surv., Can., Mem. 58, 1914.
[2] Richardson, James, Geol. Surv., Can., Rept. of Prog., 1873–4, pp. 99-100.

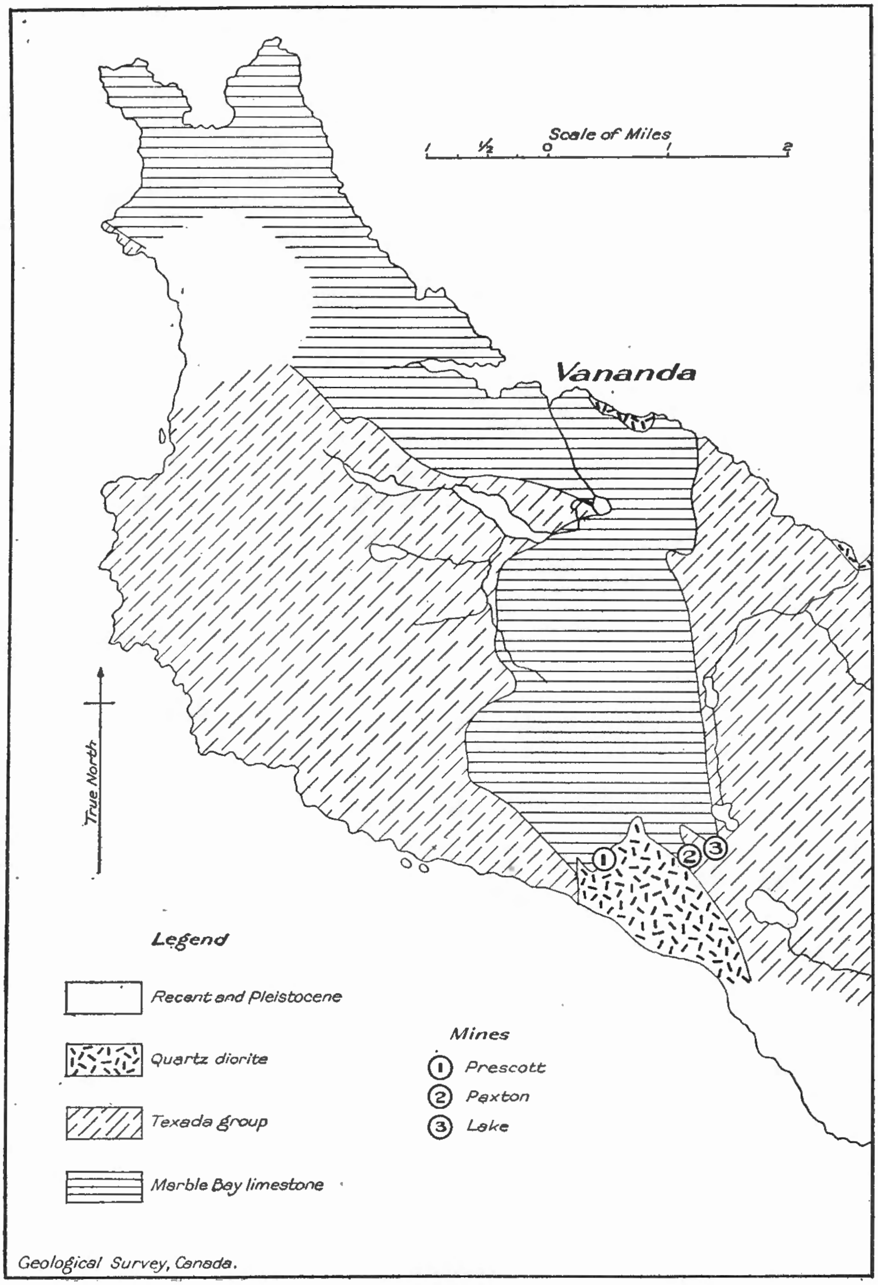

FIGURE 7. North end of Texada island, B.C.

dipping bed grading downward into limestone. Some time later, after the mines had been partly opened up and ore shipped, Dawson[1] examined the area. He correctly classified the ores as contact deposits due to the intrusion of a granitic mass into the stratified rocks, more particularly the limestone. His description notes the irregular chimney-like shapes of the deposits, and their occurrence in either the limestone, the volcanics, or the granitic rocks. Kimball[2] believed the magnetite deposits to be supergene replacements due to weathering. LeRoy[3] came to the same conclusion as Kimball, and thought that the magnetite formed before the intrusion of the quartz diorite, to which, however, he attributed the associated copper deposits. The observations of Leith[4], and also those of McConnell[5], who made a careful survey of the entire island, led to the conclusion that these ores are typical examples of contact metamorphic deposits. From the standpoint of the mining engineer, the ores have been described by Brewer[6] and Lindeman[7].

OUTLINE OF THE GEOLOGY

With the exception of recent and glacial sediments, all the rocks of Texada island are of Mesozoic age. The following table from the memoir by McConnell gives the sequence of the various formations.

Formations of Texada Island

Quaternary	Recent	Creek gravels, peat, etc.
	Glacial	Boulder clays, sands, silts, etc.
Mesozoic	Upper Cretaceous	Soft sandstones, sands, clays, and shales.
	Lower Cretaceous or Upper Jurassic	Diorites and diorite porphyries in small stocks and dykes.
	Upper Jurassic (?)	Quartz diorite referred to the period of the Coast Range batholith.
	Lower Jurassic (?)	Texada group: porphyrites. Texada group of LeRoy (in part).
	Triassic or Jurassic	Marble Bay formation: limestone.
	Triassic	Anderson Bay formation: schists, tuffs, agglomerates, amygdaloids, and marbles. Texada group of LeRoy (in part).

The area in the immediate vicinity of the iron ore deposits contains the Marble Bay limestone, the Texada group, the quartz diorite (Gillies intrusive), and the diorite porphyry. Accordingly, only these formations will be considered in the following outline.

During the summer of 1921 a forest fire over-ran the area in the vicinity of the ore-bodies and burned down or killed all the trees except those in the swamps. The moss and underbrush were entirely removed from the higher ground, laying bare large and continuous exposures of the bedrock, so that the areal distribution of the formations can be seen almost at a glance. The black magnetite, the brownish-red zones of replacement, and the greyish-green Texada group are specially well marked.

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[1] Dawson, G. M., Geol. Surv., Can., Ann. Rept., vol. II, 1886, pp. 36 B-38 B.
[2] Kimball, I. P., "Secondary Occurrences of Magnetite on Islands of British Columbia by Replacement of Limestone and by Weathering of Eruptives," Am. Geol., vol. 20, 1897, pp. 16-23.
[3] LeRoy, O.E., "Preliminary Report on a Portion of the Main Coast of British Columbia and Adjacent Islands," Geol. Surv., Can., 1908.
[4] Leith, C. K., "Iron Ores of Canada," Econ. Geol., vol. 1, 1908, pp. 277-279.
[5] McConnell, R. G., "Texada Island, B.C.," Geol. Surv., Can., Mem. 58, 1914, pp. 77, 78.
[6] Brewer, W. M., "Report on the Iron Ore Deposits of Vancouver and Texada Islands," Dept. of Mines, B.C., Bull. No. 3, 1917, pp. 32-35.
[7] Lindeman, E., Mines Branch, Dept. of Mines, Can., Rept. 47.

Both the limestone and the intrusive stock show light-grey exposures, but the rounded profile and close jointing of the limestone serve to distinguish it from the igneous rocks. The lenses of magnetite are exposed at elevations of 300 to 500 feet above sea-level for a distance of a little over a mile. At the Prescott mine the hillside has a uniformly steep slope down to the sea, but, on either side of this point, benches intervene between the main mountain and the shore. Between the Paxton and Lake mines there is a fairly flat, swampy area, above which the two bodies of magnetite project at the ends of small ridges. The purer deposits of magnetite, being hard, compact, and fairly stable chemically, resist both disintegration and decomposition and form small knolls or ridges. This contrast is accentuated by the rapid erosion of the associated rocks containing calcite, garnet, epidote, and pyrite.

MARBLE BAY LIMESTONE

The limestone in this area forms the southern end of a belt running diagonally across the island to its northern tip. As the formation occupies the higher ground and has nowhere more than a thin residual cover, its boundaries are easily followed. Most of the limestone is a light grey, medium-grained, crystalline rock composed almost entirely of calcite. Recrystallization has practically obliterated all evidence of stratification, producing a generally massive rock with little or no flow cleavage. The original bedding can be seen in only a few places where the limestone is dark grey and finer grained than usual. The outcrops of the limestone are light grey and commonly well rounded. A distinctive structural feature is the closely-spaced columnar jointing. Most of the limestone consists of interlocked grains of calcite ranging from 0·5 to 1·0 mm. in diameter. A very small amount of muscovite and hematite commonly constitutes the only impurity. The weathered surface of the rock in many places shows faint, regular bands of various shades of grey. On a freshly broken surface these bands are very indistinct, and in thin section the rock appears entirely homogeneous. Some dark schistose limestone occurs near the northern edge of the area. One zone containing several, narrow, slaty bands was followed for 1,500 feet. No large offsets were found in this distance, but there are many small faults with horizontal displacements of a few yards.

The intrusive diorite stock clearly cuts the Marble Bay formation. The relation of the limestone to the Texada group is obscured, as the contact between the two formations is covered in this area.

TEXADA GROUP

The Texada group, or porphyrite, to use McConnell's term, occupies the lower elevations at each end of the area examined. The best exposures occur near and southwest of the Lake mine. The rocks are greyish or brownish green, and commonly show a rounded profile which resembles that of the limestone. Most of the outcrops have a massive, bedded appearance. In places the tabular masses differ in composition, but as a rule the rocks appear the same on both sides of the joints.

Petrographically the series is complex. The most abundant rock is a massive, fine-grained porphyry, which is dark green on fresh surfaces.

The rest of the series is largely a rock with distinct white phenocrysts of plagioclase. A few light-coloured andesitic dykes occur, in places arranged in parallel zones. Some agglomerates, amygdaloidal rocks, and other types are found. Part of the series shows a development of flow cleavage, but most of the rocks are massive. The distribution of the various types is irregular, and the structure of the series was not determined.

The porphyrite has clearly been invaded by the diorite stock. The boundary between the two formations is usually marked by a wide contact-breccia, in which the rocks of each are sharply marked. At lower Gillies bay McConnell[1] observed a small bed of limestone overlain and underlain by porphyrite. The texture and structure of the Texada group suggest that it is a volcanic series broadly conformable with the limestone, and containing the usual complement of intrusives, some of which invaded the limestone.

GILLIES INTRUSIVE

The acid intrusive, which cuts the limestone and the porphyrite, is called "quartz diorite" by McConnell. This term describes the greater part of the stock, but is naturally not applicable to the contact phases, dykes, and other minor igneous rocks which form parts of the stock much in evidence around the ore-bodies. The use of the term quartz diorite would, therefore, be confusing in this report, and the term *Gillies intrusive,* or simply *intrusive,* is adopted as a designation for the stock as a whole. These terms are not used to refer to the porphyrite or the diorite porphyry. On the northern end of the island, especially along the coast, there are many exposures of the intrusive cutting the Marble Bay limestone and the Texada group. Both the copper and iron ores seem to have been derived from this intrusive. It has been found in the deepest levels of the Marble Bay copper mine at Vananda,[2] and probably underlies the entire northern end of the island. The quartz diorite is no doubt a part of the great Coast Range batholithic intrusion.

Fairly homogeneous quartz diorite or tonalite is exposed over large areas below the road at the Prescott mine, between this point and the Vananda trail, and south of the Paxton mine. This part of the stock, though containing a few small dykes, veins, and inclusions, is fairly uniform, and stands in marked contrast with the altered intrusive near the Prescott and Paxton ore-bodies and other places where there are many dykes, and where a large part of the intrusive has been replaced by contact metamorphic minerals, and the unaltered remainder rarely resembles the normal tonalite. The relations between many of the intrusive rocks are completely obscured by masses of secondary silicates, but certain of the commoner phases show clearly their relations to one another, and can be arranged in a definite sequence. Such a classification is useful, for the sequence, distribution, and alteration of these phases establish certain facts of interest in connexion with the ore-bodies. The common phases of the intrusive distinguished in the field are the dioritic inclusions, the tonalite, the alaskite, and the hornblendite porphyry.

[1] McConnell, R. G., "Texada Island, B.C.," Geol. Surv., Can., Mem. 58, 1914, p. 25.
[2] Dolmage, Victor, "The Marble Bay mine," Econ. Geol., vol. 16, 1921, p. 375.

Dioritic Inclusions

Parts of the tonalite contain fragments of igneous rocks that do not resemble any part of the adjacent Texada group, and probably represent some of the earliest products of the crystallization of the dioritic magma. As would be expected, xenoliths of clearly recognizable porphyrite are also found in the intrusive. The dioritic inclusions vary somewhat in composition, but are mostly fine-grained rocks with granitic textures. Biotite and hornblende are present in a few of the fragments, but in most of them augite is the principal mafic mineral. The specimens examined in thin section contain augite and andesine in about equal amounts. Roughly, 5 per cent of the rock is magnetite, which is associated with, and has replaced, the augite. A considerable amount of titanite also appears as small subhedral grains.

One of the inclusions examined contains a small vein which ends against the enclosing tonalite. This vein consists mostly of augite and magnetite. A few irregular grains of quartz appear in the vein, usually near its contact. The magnetite occurs mostly as irregular masses between the grains of augite, which have been partly replaced. The titanite, also, appears to have completed its crystallization after the augite. The augite in the vein has the same appearance as that in the diorite, and magnetite has replaced augite in both. At its contact the vein grades into the diorite, and the main distinction is that the magnetite and augite are concentrated in the vein and are associated with a little quartz, whereas the diorite contains a large amount of andesine. The vein clearly formed before the main mass of the intrusive (the tonalite) invaded and included blocks of the diorite, and it seems clear that the vein crystallized from material concentrated by the consolidation of the diorite.

Tonalite

The main mass of the intrusive is a medium-grained, light-grey rock which is broken by rectangular joints. One set of joints dips at a low angle into the hillside and gives a step-like appearance to the surface. Along some of the fractures there has been a little movement, which developed a soft, crumbly schist and offset dykes a few feet.

Even the specimens selected as fresh tonalite are considerably altered. The freshest of these have the following approximate mineral composition:

	Per cent
Plagioclase	60
Orthoclase	10
Quartz	9
Augite	8
Biotite	5
Chlorite	4
Hornblende	2
Magnetite	2
Apatite and titanite as accessories	

The quartz and feldspar show a variety of textural relations that greatly modify the appearance of the rock. The quartz is always irregular in outline, but the feldspar is present partly as subhedral, twinned grains of plagioclase, and partly as anhedral masses associated with the quartz. In parts of the rock these masses are coarsely crystallized and enclose several grains of subhedral plagioclase and mafic minerals. In hand specimens these crystals can be observed by the reflection of light from their cleavage surfaces, and some of them reach a length of 15 millimetres. Where the large crystals are abundant the rock has a porphyritic appearance and for this reason two textural varieties of tonalite are described.

Part of the tonalite has a normal granitic texture, showing interlocking grains of variable size, but no very large crystals. The plagioclase is andesine, in rudely rectangular grains which in places show some crystal form, but mostly have an uneven contact with one another. A few irregular patches of orthoclase and quartz appear between the subhedral grains of andesine, or penetrate them irregularly.

In the slides containing the large crystals of feldspar, to which the name groundmass feldspar may be conveniently applied, the smaller subhedral grains of plagioclase commonly show zonal growth. The more basic parts, which greatly predominate, approximate labradorite. Optically, the outer zones are more sodic. In one place the outer band of a zoned grain is in crystal continuity with an irregular patch of groundmass feldspar. The groundmass feldspar is irregularly intergrown with quartz and shows no semblance of crystal outline. Many of the crystals are large and, in places, join with one another to form a matrix for the smaller grains of subhedral plagioclase and mafic minerals. The groundmass feldspar is composed of both orthoclase and plagioclase. In thin sections no distinction could be made between these two minerals as the plagioclase is not twinned, but the presence of both was proved by measuring their optical constants and their indices of refraction by the oil immersion method. The fragments of orthoclase used in measuring the indices were about twice as thick as a thin section, and slightly brownish, whereas the plagioclase was clear and colourless. In the slides this difference in colour was not apparent. Most of the groundmass feldspar appears to be orthoclase.

The two textures are markedly different from one another when a typical example of each is taken, but there are all gradations between these extremes. Neither kind of texture is so distributed as to distinguish large parts of the tonalite, but both are irregularly associated with one another and may grade into one another in a single specimen. The large size of the masses of groundmass feldspar indicates an abundance of mineralizers in the liquid from which they crystallized, and the variable texture of the tonalite seems to be the result of the entrapping of some of the liquid residual from the consolidation of the main mass of the rock. Magnetite was evidently a constituent of this residual liquid, as it appears throughout the tonalite as one of the last minerals to crystallize. Most of it is associated with the mafic minerals, but in places it includes small cores of the groundmass feldspar.

Ferromagnesian minerals form about 20 per cent of the tonalite. The augite is subhedral to euhedral, perfect basal sections being common. It is considerably altered to chlorite. The biotite occurs in fairly large grains with a jagged outline, and is slightly altered to chlorite. A small amount of chloritized hornblende is present, and in places small grains of augite are present in the hornblende, indicating that this mineral is a product of a reaction between the augite and the residual liquid. Magnetite occurs as small crystals or irregular branching masses, which have partly replaced the other minerals, particularly the augite. Titanite is very unevenly distributed. In form it is subhedral to anhedral and obviously finished its crystallization after the subhedral grains of plagioclase. Apatite is a very minor accessory, and was apparently the first mineral to form, as small crystals are completely enclosed in the augite.

Alteration of the tonalite apparently took place during two general periods. The first period is believed to have occurred during the primary consolidation of the rock and to be due to reactions between the earlier formed grains and the residual liquid[1]. Such reactions are a necessary result of the crystallization of any igneous rock, and must take place during a considerable length of time and under changing conditions. The formation of the zonary grains of plagioclase and the masses of orthoclase and quartz involve continuous and discontinous reactions which occurred fairly uniformly throughout the rock and probably early in the consolidation. As the residual liquid decreased and changed in character, the products of reaction were more irregular in distribution and of a different nature. The minute flakes of sericite which are abundant in some of the grains of feldspar are probably the result of reactions that took place during the consolidation of the tonalite. The altered grains are surrounded by prefectly fresh minerals, and show no tendency to be distributed in zones. Primary reaction of this general nature was, no doubt, effective during the formation of most of the evenly distributed grains in the tonalite, including those of magnetite, biotite, and hornblende. The alteration which chloritized the augite and hornblende, and developed a small amount of disseminated epidote in the feldspar, is noticeably confined to certain patches in which all the grains are affected and is believed to have occurred at a later period. This replacement resembles closely the incipient epidotization of the tonalite which appears near the ore-bodies and is associated with microscopic veins of calcite, chlorite, and quartz. Such alteration clearly took place in the completely consolidated intrusive, and it seems probable that the fairly widespread chloritization of the tonalite is due to solutions which permeated the rock for considerable distances from the centres of replacement during the formation of the ore.

Alaskite

A large number of light-coloured, white, or pink dykes cut the tonalite. They are especially abundant near the altered parts of the intrusive west of the Prescott and Paxton mines, but can be found almost anywhere in the exposed part of the Gillies stock. The dykes vary from mere films, which give the intrusive a ribbed or net-like surface, to bodies several feet thick. The rock consists of 40 per cent albite-oligoclase, 20 per cent orthoclase, and 40 per cent quartz, as subhedral or anhedral grains ranging from 0·1 to 0·5 mm. in diameter. Ferromagnesian minerals are practically absent. These dykes appear to be a variety of alaskite in which acidic plagioclase predominates over orthoclase.

Hornblendite Porphyry

A few dykes of hornblendite porphyry cut the tonalite and the alaskite. The outcrops are dark green, and the dykes can easily be followed

[1] Bowen, N. L., "The Reaction Principle in Petrogenesis," Jour. Geol., vol. XXX, pp. 177-198, 1922.

across the exposures of the intrusive. The dykes range in thickness from a few inches to 2 or 3 feet, and rapidly pinch out along their strike. Although the freshly broken surface of the rock is almost black and has a bright appearance, thin sections show that the dykes are suprisingly altered, fully one-third of the original hornblende being changed to secondary minerals of which calcite is the most abundant. The phenocrysts and most of the matrix were originally hornblende. A few remnants of plagioclase are present, but the amount of this mineral probably never exceeded 10 per cent. Calcite, chlorite, and epidote constitute the secondary products, which have largely obscured the original texture of the rock.

Diorite Porphyry

The area contains several large dykes of diorite porphyry. These rocks are described by McConnell,[1] and are considered to have been formed, along with small diorite stocks, by a second major intrusion following closely after that of the quartz diorite. Near the iron mines the diorite porphyry is not abundant. A pair of dykes, which cut the Lake ore-body, were followed along an approximately straight line to the 640-foot contour on the Vananda trail. They cut all the rocks and replacements encountered in this distance. Below the Prescott mine another similar dyke cuts the altered part of the intrusive. It is, therefore, evident that the diorite porphyry came in after the formation of the ore-bodies, and accordingly its only significance in this connexion is to record a limit to the period of contact metamorphism caused by the Gillies intrusive.

METAMORPHISM

After their formation, the porphyrite and the Marble Bay limestone were dynamically metamorphosed by folding. They were then intruded by the Gillies magma, and at about this time significant changes of the type known as contact metamorphic were effected in both the intrusive and the invaded formations. These changes, among other things, formed the ore deposits. Intrusion of the dykes of diorite porphyry was apparently accompanied by very little metamorphism, and clearly took place after the period of contact metamorphism due to the Gillies intrusion. Cretaceous rocks exposed a short distance south of the iron mines have only slight inclinations due to initial dip, showing that little deformation occurred after the intrusion of the Gillies magma. The last metamorphic changes in the rocks are due to weathering.

This report will treat in detail only the changes that are genetically related to the formation of the ore deposits, namely, contact metamorphism and weathering. Of the changes described, contact metamorphism is the only one that appreciably modified the rocks now exposed, and the discussion of the weathering is included mainly to emphasize the insignificance of this phase of the metamorphism in the area.

WEATHERING

There is no general zone of oxidation in the rocks of this area, a fact no doubt due principally to the removal of the weathered products by

[1] McConnell, R. G., "Texada Island, B.C.," Geol. Surv., Can., Mem. 58, 1914, p. 77.

glacial erosion. Thin sections taken from the surface of the formations show little or no limonite or kaolinite. However, parts of the replacements are superficially leached and stained by iron oxides. The presence of calcite is probably the most important factor favouring weathering. That this mineral is being dissolved faster than the remainder is shown by the relatively rapid removal of calcite from small residual masses of limestone in the magnetite, leaving as apparent vug fillings the quartz and other minerals which impregnated the calcite. The solution of calcite from the parts of the replacements containing disseminated grains of this mineral allows the rocks to be permeated to a slight depth by surface waters, and a small zone of iron-stained, leached rock results. In places the pyritic parts of the ore are considerably oxidized, but much of the pyrite disseminated in the intrusive is perfectly fresh, even at the surface.

The general absence of the products of weathering makes the area a convenient one in which to study the other alterations. The effects of the ore-bearing solutions are not confused by changes due to meteoric waters, and fresh specimens can be taken almost anywhere.

CONTACT METAMORPHISM

A person walking down the hillside above the Prescott mine would observe only outcrops of crystalline limestone until the contact of the Gillies intrusive was approached. In this vicinity masses of magnetite, garnet, and other minerals would be seen in the limestone. On passing the large Prescott ore-body it would be found that its lower contact is with the altered intrusive. Below this point fairly fresh phases of the intrusive would be observed grading into the amphibole-epidote rocks which represent most of the altered intrusive, and here and there masses of magnetite and garnet would be found, in places containing masses of coarse calcite. Farther from the contact a fairly uniform, grey tonalite appears, but even in this rock there are small veins and patches of epidote. Similar relations exist near the other ore-bodies in the area, and the distinctive changes observed, which are clearly related to the intrusive and just as definitely took place after a large part of it had consolidated, are described under "Metasomatism". A more careful examination would reveal other changes in the rocks, which are described under "Recrystallization". These preceded the metasomatism, and were probably caused by the act of invasion of the Gillies magma.

Recrystallization

The changes included under this heading are mainly textural and did not materially modify the composition of the rocks. They are confined to the limestone and the porphyrite.

Recrystallization of the Marble Bay Limestone. Many lenticular or tabular masses of very coarse limestone occur near the intrusive. These are most common in the area north of the Prescott mine, where the limestone surrounds irregular apophyses of the intrusive, a distribution which seems to be the result of the erosion of the irregular roof of the stock. The very coarse limestone contains rhombs of calcite as much as 4 inches across. The change to normal texture is gradational, but occurs in the space of a few inches. This coarse texture was no doubt caused by the intrusive, but is not associated with the deposits of garnet, epidote, pyrite, and magnetite. The tabular shape of the zones, their irregular distribution, and their proximity to the intrusive suggest that recrystallization was controlled by solutions given off or set in circulation by the intrusive. The absence of the contribution characteristic of the solutions which later formed the ore-bodies, and the presence in the porphyrite of a similar recrystallization which clearly preceded the deposition of pyrite and epidote, indicate that the coarse crystals were formed during the intrusion.

Recrystallization of the Texada Group. The irregular distribution of the different rocks composing the Texada group makes it difficult to follow in the field the changes in the texture of any one phase. Moreover, this series has a complex metamorphic history which it may be well to summarize.

The first alteration was, probably, caused by a phase of the volcanic activity which formed the rocks. This resulted in the widespread development of calcite, chlorite, epidote, and other minerals, which tended to obscure the original texture and composition of the rocks. Some parts of the series were affected more than others, but nowhere was the identity of the rock obliterated. This alteration clearly preceded intrusion of the Gillies stock, as fresh granitic dykes cut the porphyrite in all stages of such metamorphism. The next changes in this series were caused by orogenic movements which folded all the formations that existed in this area before the invasion of the Gillies stock, and changed some of the porphyrite to schist. Later, the Gillies intrusion recrystallized .parts of the series, a change for which evidence will be given. Finally, the metasomatism associated with this intrusion caused local and pronounced changes in the porphyrite. These may be distinguished from the earlier hydrothermal alteration by the intensive nature of the replacement, which in places completely destroyed all evidence of the original formation; by their irregular distribution; and by the fact that dykes of the Gillies intrusive which cut the altered areas are also replaced.

The clearest evidence of the recrystallization caused by the Gillies intrusion is furnished by a study of the rocks near the metasomatic deposits. The most abundant rock of the Texada group is a fine-grained, dark-green porphyry which, in the slides studied, shows a well-defined secondary texture. The phenocrysts are mostly altered andesine, penetrated irregularly by needles of hornblende. The matrix consists of hornblende, quartz, plagioclase, titanite, calcite, chlorite, and epidote. The hornblende is commonly concentrated in zones in which the individual grains are unusually distinct and which with associated quartz distinctly replace the matrix and also the parts of the altered phenocrysts of andesine lying along the course of the band-like area or zone. The massive porphyrite where not recrystallized by contact or dynamic metamorphism, contains a large number of grains of calcite, epidote, and chlorite, whose irregular outlines give the rock a very indistinct texture against which the zones of recrystallized hornblende and quartz stand in marked contrast. The rocks also contain a few well-defined veins which show a central band of very small, interlocking quartz grains, and marginal bands of hornblende crystals. In places these veins grade into the recrystallized zones. Some of the specimens were taken near a lens of magnetite and garnet, accompanied as usual by pyrite and epidote as patches and veins in the wall-rock. In the thin sections, microscopic veins of pyrite and epidote cut the recrystallized zones of quartz and hornblende.

The texture of the hornblende and quartz zones is obviously secondary and later than the formation of the calcite, chlorite, and epidote, an alteration probably due to the original volcanic activity. It is also clear that the recrystallization of the hornblende and quartz preceded the formation of the veins of pyrite and epidote, which accompanied the replacement of the porphyrite by garnet and magnetite. As the recrystallization did not develop flow cleavage it is not the result of dynamic metamorphism, and is attributed to the intrusion of the Gillies magma. The veins and zones of recrystallized hornblende and quartz are analogous to the masses of coarse calcite in the limestone, and the formation of both is considered to have been controlled by aqueous solutions given off or set in circulation by the invading magma.

Extent of Recrystallization. The changes in the limestone and the porphyrite, which have just been described, are believed to show clearly their genetic connexion with the intrusive, and, in the case of the porphyrite, the time relation is fairly definite. It must be understood that the changes described were not the only ones caused by the invasion of the magma. The more uniform effects of the heat and pressure of the intrusive probably caused considerable recrystallization in the limestone and the porphyrite.

The purity of the limestone, and the fact that the rocks were dynamically metamorphosed before the Gillies magma was intruded, make it very difficult to determine the amount of recrystallization for which the intrusive alone was responsible. Almost all of this formation on the northern part of the island is recrystallized, but, as this formation appears to be a cover over the quartz diorite exposed here and there along the coast, and mines scattered through this part of the island give evidence of the extensive influence of the intrusive, the mere uniformity does not necessarily show that the recrystallization of the formation as a whole is the result of dynamic metamorphism. It is probable that the Gillies magma and other similar intrusions in the northern part of the island are largely the cause of the massive structure and the medium, crystalline texture of the limestone. The fact that the texture of the limestone is commonly the same at the immediate contact as farther away shows that the recrystallization of the formation by the intrusive was either widespread or insignificant, and the relations given above favour the alternative that the recrystallization was extensive.

In the porphyrite, the extent of the recrystallization due to the intrusive is obscured by the widespread hydrothermal alteration of the rock and the fact that textural changes in this formation are difficult to follow. However, as the dynamic metamorphism of this formation would probably develop flow cleavage, and in fact has done so in places, the presence of well-defined grains of hornblende with no parallel arrangement indicates thermal metamorphism due to the intrusive. The slides examined are from specimens of the rock probably situated at no great distance from an underlying contact, although they come from exposures which are as much as 1,000 feet from the nearest visible large area of the intrusive. It is, therefore, concluded that the porphyrite was considerably recrystallized by the intrusive.

Metasomatism

The deposits of magnetite and the associated rocks containing garnet, amphibole, epidote, chalcopyrite, pyrite, and other minerals possess several distinctive features, among which may be mentioned their irregular distribution, the marked chemical changes involved in their formation, and the fact that they originated through the replacement of the intrusive as well as of the limestone and the porphyrite. They are dominantly metasomatic, and it is clear that the changes involved are in no way similar to those effected by the recrystallization of the limestone and the porphyrite by the intrusion of the Gillies magma; in fact they resemble no other changes which are recorded in the area. Accordingly a fairly sharp line can be drawn between the country rocks and the metasomatic deposits.

Probably the best way to bring out the general relations of the metasomatic deposits is to describe one of the large replacements, such as the Paxton lens. Near the road south of the lens, tonalite is exposed, and, except for the presence of small veins and patches composed dominantly of epidote, the rock is uniform in character to within a few feet of the ore-body, against which a narrow zone of the tonalite is largely replaced by amphibole and epidote. The ore-body shows a rather abrupt contact with the amphibole-epidote rock, but, as will be shown later, at least part of the magnetite replaced the intrusive. Along the east side of the knoll there is a contact breccia showing the porphyrite cut by the intrusive, and the magnetite lens is bounded on this side by more or less altered phases of the intrusive and the porphyrite. In the ore-body there are a few masses of coarse calcite impregnated by quartz, pyrite, amphibole, and other minerals. To the west, and also above two open-cuts, on the south face, blocks of the altered intrusive and the porphyrite occur in the massive garnetite and magnetite. In short, the exposures show a large ore-body and many smaller masses of magnetite and garnet surrounded by, and enclosing, fragments of partly replaced rocks whose original nature can be determined by observing gradations into less-altered phases or by the lithologic character of the rocks shown in hand specimens or in thin sections. Examination of the gradation from one of the fragments into the massive magnetite or garnet shows that for a certain distance the replacement of the rock can be followed, but that eventually all trace of the original minerals is lost. Accordingly, the metasomatic deposits can be arbitrarily separated into two classes; those including a large part of the masses of magnetite and garnet, in which there is little or no record of the original rock, and those which can be recognized as replacements of the intrusive, the limestone, or the porphyrite.

Most of the large bodies of magnetite and garnetite resemble the Paxton deposit in being replacements of two or more formations, and it was not found possible to determine how much of each of the original rocks was replaced. Accordingly, the nature of these masses of magnetite and garnet may be described at this point.

The large magnetite replacements are fairly pure. Analyses given by McConnell[1] for the Prescott, Paxton, and Lake ore-bodies show 82 to 89 per cent of magnetite. The most conspicuous impurities are calcite, quartz, and the sulphides. Crystals of epidote are common in vugs and along joints in the magnetite. The sulphides are locally abundant, and analyses of the main ore-bodies show 0·2 to 1·9 per cent of sulphur. In places the ore contains 1 per cent or more of copper. The typical garnetite is also fairly pure, and when fresh has a brown colour. A determination of the indices of several specimens shows that the andradite molecule is dominant. Much of the garnet is slightly greenish, due to the presence of chlorite, and many of the outcrops are heavily stained with iron oxides. In places, a light-green rock is found in contact with the intrusive. This consists of vesuvianite and a garnet that is almost pure grossularite. The vesuvianite powder has a faint yellowish colour which distinguishes it from the garnet, and under crossed nicols shows anomalous brown or deep-blue colours. Its birefringence is small, the lowest and highest indices being 1·705 and 1·709.

The distinction between the deposits in which the original rock was not identified, and those which are ascribed to metasomatism of some one of the formations, is naturally indefinite, and whether a certain deposit is put in one class or the other may depend entirely on various assumptions and deductions. For example, much of the coarse, fibrous amphibole rock is just as pure, and shows just as little record of the original formation, as any part of the magnetite lenses, but as this rock was found only at the limestone contact, it is treated as a replacement of the limestone. That is, various criteria can be used to recognize certain parts of the deposits as replacements of certain formations, and it is, therefore, possible to describe separately the metasomatism of the limestone, the porphyrite, and the intrusive.

Metasomatism of the Marble Bay Limestone. All the large iron ore deposits are at the edge of the limestone, and of these the Lake ore-body is the only one that is not also adjacent to the intrusive. In addition there are many small deposits entirely surrounded at the surface by limestone. Scattered through the large replacements are patches of coarsely crystalline calcite, showing a zonary arrangement of minerals similar to that observed at the main limestone contact. This fact confirms the natural deduction that the masses of coarse calcite are remnants of the limestone formation, as they apparently maintained a gradient favourable to the segregation of the introduced constituents similar to that maintained at the main limestone contact. That the limestone played an important part in the metasomatic processes is apparent, not only from the field observations in this area but also from those observed in many similar deposits elsewhere.

Characteristically the metosomatic deposits are in abrupt contact with the limestone. In the intrusive there are extensive irregular replacements which are apparently the result of alteration proceeding from fractures in the rock, and veins of epidote and calcite occur along joints at some distance from the contact. No similar structures occur in the limestone, which, except for occasional crystals of specularite, amphibole, and

[1] Op. cit., p. 89.

other minerals, is almost pure calcite even at its contact with massive garnetite or magnetite.

A general zonal distribution is apparent in the deposits. Against the main limestone contact the succession is: crystalline limestone, coarse amphibole rock, garnetite, and magnetite. The masses of coarse calcite contained in the lenses of magnetite show a similar arrangement of the garnetite against the magnetite, but a well-defined amphibole zone is absent, and the calcite is not pure but is impregnated with amphibole, quartz, and sulphides. This distribution of minerals is by no means uniform, but it is found in so many places that it is considered as the normal development.

The outermost zone of amphibole rock, which occurs at the contact of the deposits with the main limestone formation, has a coarse columnar cleavage normal to the contact. The prisms of amphibole commonly project radially into the limestone and the interstices between them contain intermingled quartz, sulphides, and calcite. In places the chalcopyrite is concentrated in masses, some of which formed copper ore that has been mined in a small way. The prisms of amphibole rock, which at first glance appear homogeneous, are really a mixture of minerals in which amphibole predominates to the extent of imposing its cleavage on the whole mass. Some of this rock is black, but most of it is dark green. In thin section fragments of pyroxene can be observed in the amphibole. As these are arranged in groups with parallel extinction, and in places merely form specks in the amphibole, it is clear that the amphibole is in part a replacement of the pyroxene. The indices of these minerals were measured, and a comparison with the graphs prepared by A. N. Winchell[1] for the amphibole and pyroxene groups shows that the amphibole in this rock is near grünerite in composition and that the pyroxene is probably a solid solution of 70 per cent hedenbergite and 30 per cent diopside. Owing to the complexity of these isomorphous series and the fact that the minerals in the amphibole rock are not everywhere of the same composition, it is impossible to determine the amphibole and pyroxene definitely, but it is clear that they are composed dominantly of the iron molecules. Small veins of calcite, chlorite, pyrite, chalcopyrite, and magnetite cut the amphibole rock. In the slides there are minute veins and irregular masses of quartz and calcite which in places are penetrated in every direction by needles of grünerite. Pyrite occurs mostly as a replacement along the cleavages of the grünerite, which is also partly replaced by chlorite.

Small, platy groups which resemble specularite but are highly magnetic are common in the limestone adjacent to the amphibole rock. Their composition was in doubt until some of the material was investigated by means of the X-ray diffraction apparatus of the University of Wisconsin, which photographs the reflections of monochromatic X-rays from the atomic planes of mineral powders.[2] Briefly stated, the pattern obtained is controlled by the size and kind of atomic lattice, and the kind of atoms in the mineral examined. Each mineral gives a characteristic pattern, and a fine state of subdivision of the material improves the results. The platy groups in the limestone, which appear homogeneous under the microscope,

[1] Personal communication.

[2] The apparatus is described by Wheeler P. Davey, "A New X-ray Diffraction Apparatus," General Electric Review, Sept., 1922.

consist of a mixture of magnetite and hematite, as all the lines of both these minerals (and no others) appear on the photograph taken.

The garnetite, which commonly lies between the magnetite ore-body and the amphibole zone, is a massive, brown rock. The indices determined from several specimens show that the garnet which composes most of this rock is dominantly andrate. In thin sections the garnet is clear and shows well-defined zonary bands, which are apparent by the colour variations seen with parallel light and the differences of birefringence with crossed nicols. In places it is minutely broken, and, as in the amphibole rock, the fractures are mostly filled with calcite and quartz. Epidote is not common at the main limestone contact with the large deposits, but where the replacement is small and occurs between the limestone and the intrusive, epidote is associated with the calcite and quartz. A small amount of chlorite appears with the calcite and quartz as a replacement of the garnet or in the veins. Part of the magnetite and the sulphides also occurs with the same relations. No distinct contact between the amphibole and the garnet was observed in the thin sections, as the movement which fractured both rocks also caused a granulation along most of the contact, and in this zone calcite, quartz, and needles of amphibole commonly replace both the garnet and the massive amphibole.

The magnetite in many places cuts through the garnetite in small, branching veins connecting with more irregular masses of ore, and even occurs as dyke-like masses in the limestone. However, the main deposits are more or less lens-shaped bodies surrounded by a zone of silicates. The contact of the ore is commonly indistinct as the magnetite occurs as irregular disseminations through the margin of the bounding garnetite, giving it a dark colour resembling the ore. In thin sections the magnetite shows minute fractures which contain calcite, chlorite, and quartz. In places, sharp crystal outlines of magnetite project into the veins and elsewhere irregular masses of quartz and calcite appear in the magnetite. A small amount of replacement of the magnetite apparently took place, but this mineral was also deposited in the veins. On the whole it appears that the magnetite was relatively stable under the conditions that existed while the fractures were being filled, whereas the garnet was in places extensively altered.

Around the masses of coarse calcite that occur in the ore-bodies the arrangement of the metasomatic minerals is apt to be very orderly. The calcite is commonly impregnated with pyrite, chalcopyrite, quartz, amphibole, chlorite, and the platy masses of specularite and magnetite. In places a few crystals of garnet occur in the calcite, but this mineral is mostly concentrated in a band immediately adjacent to the magnetite. The mineralogy and relations are practically the same as those described from the main limestone contacts.

The small deposits that occur in the limestone away from the main ore-bodies have been opened up in places by pits and tunnels, in search of copper ore. The deposits mostly contain a large amount of sulphides, particularly pyrite, associated with garnet, amphibole, chlorite, quartz, calcite, specularite, and magnetite. A few contain siderite, whose indices are practically identical with those given for the pure mineral.

In a few places, jasper, serpentine, and olivine occur in the limestone replacement. The jasper is associated with calcite and pyrite as small veins which cut the garnetite, or project a few inches into the limestone from the ends of tongues of garnetite. The altered area east of the Prescott mine contains a small amount of serpentinized limestone. In thin sections the serpentine shows cores of olivine, which, like the hedenbergite, appears to have been very unstable under the influence of later solutions. These were apparently phases of solutions that produced the ore, as the serpentine is in part replaced by pyrite.

Metasomatism of the Texada Group. The Paxton and Lake ore-bodies are partly bounded by rocks of the Texada group. Near the contacts the magnetite commonly contains fragments of the porphyrite, and small veins of magnetite cut the formation. The ore which replaced the porphyrite is mostly fine grained, and in places is interbanded with pyroxene. The actual contact of the magnetite with the porphyrite is sharp. Near the large ore-bodies there are narrow, distinctive zones of a cherty-appearing mottled green and brown rock, which grades into the normal formation, but no extensive areas of garnetized porphyrite were found. Above the Paxton lens irregular deposits of magnetite and garnetite surround fragments of the porphyrite and a few highly altered remnants of the intrusive. In parts of the contact breccia heavily epidotized apophyses of tonalite cut through fresh-appearing porphyrite. Such facts indicate that the porphyrite was replaced only locally and with difficulty.

Numerous deposits occur entirely surrounded by porphyrite, but the only ones of any size lie southeast of Lake mine. These show the characteristic features of the deposits in the porphyrite, and, as they are clearly replacements of this formation alone, they will be used as a basis for the more detailed description of the metasomatism. Parts of the deposits are almost pure magnetite. A sample taken by McConnell[1] assayed over 69 per cent iron. A dioritic dyke cuts the porphyrite and passes between two of the southern lenses, where it is heavily garnetized. The northern exposures of ore are part of one continuous lens at least 200 feet long and from 2 to 10 feet thick. The best exposures occur along an outcropping ledge where the magnetite is shown in the porphyrite as a band from 2 to 4 feet thick. The rock on the east side is a dark-green auganite in which much pyrite appears along the joints for several feet from the contact. At the east edge of the magnetite a thin zone of dense, mottled green and brown rock appears, and at the west edge of the lens of ore the outcrop shows a wider band of similar rock, which is on the average 6 inches across. Beyond this is a light green andesine with an irregular contact against a dark green auganite similar to that on the east side of the magnetite lens. The auganite forms the main mass of the formation west of the deposit, and both it and the andesite contain pyrite and epidote along joint-planes for a distance of 10 feet or more from the magnetite.

The auganite on the east side of the magnetite contains altered phenocrysts of labradorite and hornblende, in a matrix composed of indistinct grains of epidote, hornblende, plagioclase, and titanite. Zones consisting of well-crystallized grains of hornblende, quartz, and, in places, epidote, show relations similar to those described under "Recrystallization", and

[1] McConnell, R. G., "Texada Island, B.C.," Geol. Surv., Can., Mem. 58, 1914, p. 89.

are believed to be due to the metamorphism caused by the invading Gillies magma. Considerable pyrite is present as irregular impregnations or in veins, which also contain epidote. The epidote is coarsely crystallized, and a vein 0·1 mm. wide may consist of one crystal for a distance of 4 to 5 mm.

The zone of mottled rock in contact with the magnetite is mostly an aggregation of very small grains whose diameters range from 0·01 to 0·05 mm. The mineral grains of much of this matrix are indistinguishable, but some of them can be identified as hornblende, garnet, and epidote. In the matrix are larger, rounded masses of garnet which are not birefringent and have a cloudy appearance due to inclusions. Most of these inclusions are mere specks, but a few can be recognized as remnants of hornblende or plagioclase. Small veins of epidote and pyrite cut the rock, and a little magnetite occurs in it as irregular masses. Where a vein of epidote intersects a zone containing disseminated magnetite or garnet, these minerals commonly persist in it, but in places epidote veins cut through the larger masses of garnet. However, the veins do not penetrate the magnetite lens.

There is a sharp contact between the dense, mottled rock and the magnetite lens. In places this lens is almost entirely fine-grained magnetite, but commonly it consists of magnetite and pyroxene and shows a pronounced banding. The indices of the pyroxene were measured and correspond to those given for a solid solution of 65 per cent hedenbergite and 35 per cent diopside.[1] The bands of pyroxene always contain some magnetite which replaced part of the pyroxene. The lens contains small, irregular masses consisting of a mixture of indistinct grains of hornblende, plagioclase, and other minerals, which partly replaced magnetite and pyroxene. A few grains of clear garnet occur intergrown with the pyroxene.

At the west contact of the magnetite lens there is another zone of dense, mottled rock, which grades into a light-coloured andesite. This rock is not as much altered as the auganite, and the andesine which makes up most of it is commonly clear and distinct. Hornblende is the principal ferromagnesian mineral and shows relations similar to those observed in the auganite. Veins of pyrite and epidote are common in this rock, and are more abundant here than on the east side of the magnetite lens. The auganite west of the andesite is similar in all respects to that east of the magnetite.

Metasomatism of the Gillies Intrusive. The metasomatic changes were more widespread in the intrusive itself than in the limestone or the porphyrite. Extensive areas near the Prescott mine and northwest of the Paxton are much altered, and even in the comparatively fresh tonalite epidote occurs at distances of 1,000 feet or more from the large deposits of magnetite and garnet.

Magnetite, members of the garnet, amphibole, pyroxene, and epidote groups, pyrite, chalcopyrite, pyrrhotite, calcite, chlorite, vesuvianite, and titanite all appear to have been formed in significant amounts in the intrusive, producing many different rocks which commonly grade into one another with no definite boundaries.

[1] Winchell, A. N., "Studies in the Pyroxene Group," Am. Jour. of Sci., 1923, p. 510.

Two open-cuts driven into the southern edge of the Paxton ore-body show the contact of this deposit with the intrusive, which is here fresh, massive tonalite. Such a relationship is unusual in this area, as, at the Prescott mine and elsewhere, fine-grained or porphyritic phases of the intrusive are common adjacent to the massive garnetite or magnetite. The tonalite south of the Paxton lens, except for some epidote along the joints, is fresh, to within a few feet of the ore-body. The zone of altered rock against the magnetite is from 3 to 6 feet wide and shows a definite gradation. The first distinctive change in the tonalite is marked by the appearance of irregular, green patches of epidote, small veins of pyrite, and large grains of amphibole in a rock of bleached, quartzitic appearance. This grades into a dark green phase consisting mostly of epidote and amphibole, and impregnated with sulphides. Against the ore-body in the east cut there is a thin band of brown garnet rock, which contains a large amount of magnetite, pyrite, chalcopyrite, and pyrrhotite, and gradually gives way to the dark green rock on one side and the massive magnetite on the other. Near its contact the lens of magnetite contains small patches and veins of calcite, quartz, sulphides, and, locally, epidote.

Thin sections show that the outermost band differs from the tonalite mainly in an increased content of quartz. This mineral occurs as irregular grains, some of which are large and surround several other minerals. Most of the rock consists of altered plagioclase, containing small flakes which appear to be largely epidote, although a little sericite is also present. The plagioclase is cut by veins of quartz and epidote, and in places is penetrated by needles of amphibole. Augite is rare and appears mostly as small fragments in an irregular aggregate of amphibole, chlorite, epidote, and pyrite. The amphibole occurs as large grains, which are considerably replaced by chlorite. A few veins of epidote, quartz, and calcite cut the rock. Small euhedral grains of apatite occur in the augite, the amphibole, and elsewhere, and have resisted all the alteration. A few fresh anhedra of titanite are also present.

The dark green rock which occurs nearer the magnetite is composed mostly of epidote, amphibole, and quartz. The size of the grains varies considerably, and the three minerals are intimately intergrown. Chlorite is common as a replacement of the amphibole, and calcite occurs in irregular masses. The apatite and titanite retain the characteristics noted above.

The narrow brown zone against the magnetite consists mostly of garnet broken by fractures containing quartz, calcite, epidote, and chloritic hornblende. Small, irregular masses of quartz, calcite, and pyrite are common in the amphibole, and in places needles of amphibole occur in the quartz and calcite. Titanite is more common in this rock than in the outer zones, and seems to be partly a replacement. The relations show that there has been a general overlapping sequence in the formation of the minerals, with quartz, calcite, chlorite, and pyrite predominating as the products of the later reactions.

The garnetite grades into the ore-body which, near its contact, contains many grains of garnet partly replaced by magnetite and the sulphides. Pyrite and chalcopyrite show a tendency to penetrate the finest fractures in the garnet, and in this way are somewhat segregated from the magnetite which occurs as more or less equidimensional patches irregularly replacing the garnet. The pyrrhotite is in the form of uneven masses intergrown with the magnetite. Pyrite and chalcopyrite are common as small veins and irregular patches in the ore, and calcite and quartz occur with the same relations. Some fairly large masses of calcite also appear near the contact. Whereas these are probably remnants of limestone, it is clear that some of the partly replaced grains of calcite were transported into the intrusive, and thus it is that no sharp distinction can be made between that part of the deposit which replaced the limestone and that which replaced the intrusive.

The amphibole in these deposits varies considerably in composition, and its character is in many cases obscured by its alteration to chlorite. In places the crystals are black, but most of them are dark green. Determinations of the indices show corresponding variations, but all indicate that the amphibole belongs to the actinolite-hornblende series. The common variety has the same indices as those given for ordinary hornblende.

Garnetite containing blocks of the altered intrusive extends for 150 feet west of the Paxton lens. The outer contact of this zone is fairly definite, and many good exposures show the regular joints of the intrusive continuing without a break into the massive garnetite. Directly north of the west cut a fine-grained porphyry lies adjacent to the magnetite. In the altered areas the contacts between the different phases of the intrusive are generally centres of replacement, and such is the case with this exposure of the porphyry, as all the outcrops containing both the porphyry and the tonalite show a highly altered zone between the two rocks.

The gradation from the fresh porphyry to the magnetite is similar in appearance to that observed at the tonalite contact. The exposure of the porphyry is small, and the freshest specimen, taken 8 feet from the ore-body, is considerably altered. The rock contains phenocrysts of plagioclase and hornblende in a matrix so fine that most of the grains cannot be identified. Some of the phenocrysts of plagioclase are relatively fresh, and their composition was determined as andesine. Most of the plagioclase contains a large amount of zoisite. This mineral is intimately associated with epidote, and a gradation between the two seems to occur, as much of the epidote has a low birefringence (about 0·014), and many of the grains are mottled, showing a variation in birefringence which corresponds to a change in colour. The grains with the birefringence of ordinary epidote are distinctly yellow in certain positions, whereas those with the low birefringence are practically colourless. What is called zoisite shows an anomalous greyish blue colour. Some of the phenocrysts of hornblende are fairly fresh and have good crystal form, but most of them are badly altered, containing small grains of epidote and zoisite, and much chlorite along the cleavage planes. Veinlets of quartz, zoisite, and epidote are common, but pyrite is not abundant in this phase of the altered porphyry. The porphyry is characterized by a large amount of titanite and apatite. These minerals are fresh and euhedral, and in places occur as large crystals.

Nearer the magnetite the porphyry becomes slightly darker and greenish. In thin sections the most noticeable feature is the almost complete replacement of the plagioclase by zoisite, epidote, and quartz, which are intergrown in groups showing a marked contrast with the dense groundmass. In many places none of the original plagioclase is left, but in parallel light the outlines of the replaced phenocrysts can be seen. The hornblende shows no semblance of crystal form, and most of it appears as chloritized shreds in an aggregate of grains of epidote and quartz. The rock contains a large amount of pyrite in distinct cubes or as irregular, branching masses. Apatite has resisted alteration, the large crystals are perfectly fresh, and formed an effective barrier to the replacement which occurred in the minerals along their contact. Small aggregates of hematite flakes are common in this phase of the altered porphyry.

This phase grades into a green rock composed mostly of epidote. No traces of the original phenocrysts of plagioclase or hornblende appear, but grains of titanite are present. These are mostly fresh, but a few contain irregular masses of quartz. Zoisite and epidote with low birefringence are not as abundant as in the outer zones. Chloritic amphibole is intergrown with the epidote and the rock contains irregular masses of quartz, some of which are large and enclose several small grains of epidote.

Adjacent to the magnetite is a dark-green rock, which consists almost wholly of chloritic amphibole and epidote, in about equal proportions. Magnetite and pyrite occur as irregular grains replacing these minerals, particularly the amphibole. The groundmass of the porphyry, which in the outer zones constitutes most of the rock and is an aggregate of indistinguishable grains, is less abundant in the epidote and amphibole-epidote phases, and consists of small, but easily recognized, grains of the metasomatic minerals. Adjacent to the magnetite it is represented by a few small areas showing a mosaic of amphibole grains. Most of the titanite appears as fresh crystals, but in places irregular grains of this mineral contain chlorite and quartz. The grains of titanite are larger near the magnetite, and are partly replaced. Part of the titanite was probably deposited by the earlier metasomatic reactions, as well as altered by the later ones.

South of the large Prescott ore-body there are a number of exposures of a porphyry similar to that at the Paxton mine. As usual its relationship to the other phases of the intrusive is obscured by alteration, but, judged by the change in texture shown in an outcrop where the rocks are fairly fresh, the tonalite intrudes the porphyry. The contact of the porphyry with the magnetite is well shown in a cut in the small lens southeast of the main ore-body where the arrangement of metasomatic minerals is similar to that just described. The margin of the magnetite lens contains fragments of the amphibole-epidote rock, and furnishes convenient specimens for the study of the actual contact. The ore grades into the silicates through a zone containing irregular masses of magnetite, which have partly replaced the chloritic amphibole forming most of the included fragments of altered porphyry. Quartz and calcite appear as small veins or irregular masses in the magnetite and the silicates. A few fresh crystals of apatite occur in both the magnetite and the amphibole.

The area between the road and the large Prescott lens consists mostly of garnetite and the altered intrusive. A large number of contacts are well exposed. At most of these the intrusive is not tonalite, but is fine-grained or porphyritic, and commonly contains a large proportion of ferromagnesian minerals. In a few of the exposures the intrusive becomes finer near the garnetite. These facts suggest that the replacement was concentrated in a heterogeneous part of the intrusive containing blocks of limestone, as most of the ore-bodies contain masses of calcite.

The contacts described show the magnetite or garnet separated from the intrusive by a narrow, altered zone, which in places may be included in the width of a single thin section. Such occurrences are the exception rather than the rule, but they are convenient to study for the possibility of confusing the altered products of one rock with those of another is largely eliminated. The descriptions show that there is a general zonal arrangement of the minerals at these contacts. Where garnet has replaced the intrusive, it occurs in narrow zones adjacent to the magnetite, or as parts of large masses of garnetite. The characteristic minerals formed in the intrusive are amphibole and epidote. Amphibole is the more abundant of these minerals near the magnetite, but farther away the alteration consists mostly of epidote. There are extensive areas of amphibole-epidote rocks in certain parts of the intrusive, which occur roughly as zones marginal to the ore-bodies and the large masses of garnetite. The clearest evidence of zonal arrangement on a large scale is shown by the dominance of epidote and calcite in the alteration of the intrusive at some distance from the large, massive replacements. This lateral arrangement of the minerals corresponds with the general time sequence observed in any one specimen. The epidote, quartz, calcite, chlorite, and pyrite which are predominant in the outer zones of the replacement also occur as small veins or replacements of the garnet, amphibole, and magnetite deposits. The epidotization of the comparatively fresh phases away from the main ore-bodies is a characteristic feature of the intrusive, and is described separately below.

Masses of green rock, composed dominantly of epidote, occur in the tonalite at distances of 1,000 feet or more from the centres of replacement. These appear as irregular patches, grading into the intrusive, as indistinct replacements along joints or small sheeted zones, or as well-defined replacement veins, with every gradation between the three types. Along the contacts of fresh alaskite dykes epidosite is common as an alteration of the tonalite. In most cases such dykes are themselves replaced somewhere along their strike, particularly at a crossing zone of epidosite. This selective tendency of the alteration is a common feature. In places, highly altered tonalite is found in contact with fresh-appearing porphyrite, and elsewhere pegmatitic phases of the intrusive have been replaced to a much greater extent than the surrounding rock of normal texture.

The irregular patches of epidosite in the tonalite consist partly of an aggregate of grains of epidote averaging one millimetre in diameter. Such areas grade into the epidotized tonalite, in which grains of epidote, calcite, and quartz occur as a complex intergrowth which irregularly replaces large crystals of feldspar and, to a much smaller degree, hornblende. The calcite has a very uneven outline, and may occur as scattered grains or in fairly large masses. In one of the rocks a vein of calcite cuts across the entire section. Calcite occurs in many of the feldspar grains as a dissemination with a general pattern corresponding to the cleavages of its host. The shape of the quartz grains is very irregular, with a general tendency towards a vermicular habit. Most of the epidote is in more or less equidimensional grains with which is associated a small amount of zoisite. The chlorite is found near the hornblende as small masses, which rarely show a fibrous structure. Magnetite is uncommon. The titanite appears as small, subhedral, fresh-appearing grains which seem to have resisted all the alteration. As compared with the unaltered quartz diorite the dominant feature is the replacement of the feldspar by epidote, calcite, and quartz.

The specimens of the altered alaskite dykes show a mass of epidote and quartz, with a few grains of titanite, grading into a rock in which the feldspar is largely replaced by epidote. An uncommon feature found in this connexion is the development of myrmekite, in which vermicular quartz and albite form an intergrowth replacing oligoclase.

The epidosite, which occurs as well-defined veins, contains the highest concentration of epidote. One of the largest of these veins, which is about 2 feet wide, is 90 per cent epidote. Irregular masses of calcite form almost all the rest of the rock. Quartz and chlorite are also present, but in minor amounts. A few highly calcitized remnants of feldspar and fresh grains of titanite occur in the vein, showing that it is a replacement vein. One of the small veins in the magnetite was examined by the oil immersion method, and found to consist almost entirely of epidote. A small amount of calcite was the only other constituent observed. The epidote in this vein has the following indices: Np, 1·729; Ng, 1·747; and Ng, 1·758; which, according to a graph prepared by A. N. Winchell,[1] indicate 10 per cent of ferric oxide in the epidote.

Small veins of quartz or calcite cut parts of the replacements, but were not found very far from the main ore-bodies. They commonly carry pyrite and chalcopyrite, and may be considered as large examples of the microscopic veins described at the contacts of the ore-bodies, just as the minute veins of epidote are duplicated on a grander scale by the epidosite.

Pyroxene was not observed as a metasomatic mineral in the typical gradations from the magnetite or garnetite to the fresh intrusive, and most of the extensive alterations seem to be composed dominantly of amphibole and epidote. However, parts of the stock contain a large amount of pyroxene as a replacement. The typical epidote, amphibole-epidote, and pyroxene rocks are easily distinguished, and of these the pyroxene rock is the least abundant, but, as much of the intrusive is a greenish rock lacking definite character, pyroxene may be more abundant than it appears.

West of the Paxton lens there are exposures of pyroxene rock in which the original texture is so well preserved that the bleached outcrops are easily mistaken for those of the fresh intrusive. The rock is greyish green, and contains patches with a milky colour resembling quartz. Thin sections, however, show that quartz is a very minor constituent. Most of the rock consists of speckled pyroxene and plagioclase. The plagioclase is highly altered, but twinning can be recognized in a few of the grains. The alteration is very uniform throughout the grains, and is shown both by opaque specks and colourless flakes with high birefringence. A few of the largest of these flakes were identified as epidote. The pyroxene occurs in grains of uneven outline which constitute roughly half of the rock. Many of the crystals are large, and have branches which irregularly penetrate the

[1] Personal communication.

plagioclase. They also contain remnants of partly replaced plagioclase, and a large number of small anhedra of titanite. The concentration of the titanite in the pyroxene suggests that it is a replacement, and not a primary mineral. Epidote occurs in clear grains, and in small veins which cut all the other minerals. Quartz is unusually rare, and is associated with the epidote. Apatite is present as fresh euhedral grains which have resisted all the replacement. A small amount of chlorite appears, mostly as a replacement of the pyroxene

Near the Prescott ore-body there are small masses of dense, green rocks which commonly grade into fine-grained ore through narrow zones impregnated with magnetite. Where the ore occurs between this rock and calcite, the variation in its texture is very noticeable, as the contact against the calcite is sharp and shows large crystals of magnetite. The dominant mineral in the green rock is a pyroxene whose indices agree with those of the series diopside-hedenbergite[1]. In various specimens, 70 to 90 per cent of the diopside molecule is indicated. Associated with the pyroxene are minor amounts of epidote, amphibole, and chlorite.

Metasomatism of Intrusive-limestone Contacts. The foregoing descriptions show that most of the metasomatism occurred in the limestone and the Gillies intrusive. The general localization of the replacements is along the contact of these two formations, and most of the deposits show the same relations on a smaller scale. For example, extensive areas northwest of the Paxton mine and southwest of the Prescott show masses of calcite and blocks of the altered intrusive in the massive deposits, and irregular veins of magnetite are commonly found between patches of calcite and amphibole-epidote rocks. In describing the gradation shown by the Paxton open-cuts, it was noted that masses of partly replaced calcite occur in rocks that were originally parts of the intrusive, and that, a short distance away, the same deposit contains larger masses of calcite that were no doubt remnants of the limestone. These relations, which prevail in most of the deposits, make it difficult to obtain any conception of the relative amounts of replacement of the different formations by the massive magnetite or garnetite. Accordingly, it is of interest to describe an exposure, such as the one sketched in Figure 8, which shows on a convenient scale the replacement of both the intrusive and the limestone, as the metasomatism of both rocks is clearly due to the same primary solutions.

The small, irregular vein of magnetite contains no record of the original rock, but on either side the replacement of the adjacent rocks is clear. As each type of replacement has been described on the foregoing pages, only a brief summary of the salient features is given. The comparatively fresh intrusive is a diorite, consisting mostly of andesine, which is thoroughly impregnated with small flakes of sericite, calcite, and epidote, and locally contains irregular grains of calcite and epidote. Quartz is practically absent. The primary hornblende is largely altered to chlorite, calcite, and epidote, but secondary amphibole is present as small needles in the calcite and as groups of interpenetrating grains. In the more highly altered diorite, the metasomatic minerals predominate, and grains of andesine are about all that is left of the original igneous minerals. The

[1] Winchell, A. N., "Studies in the Pyroxene Group," Am. Jour. Sci., 1923, p. 510.

rock, which consists mostly of amphibole and epidote, contains about 10 per cent of quartz, and 20 per cent of calcite. The garnet in contact with the amphibole-epidote rock is slightly birefringent and clouded by many inclusions. Some of these are large enough to be recognized as remnants of andesine, but many are mere specks. The vein of magnetite shows a rather even boundary in thin sections, but has partly replaced the garnet on either side. The garnetite against the calcite is clear and

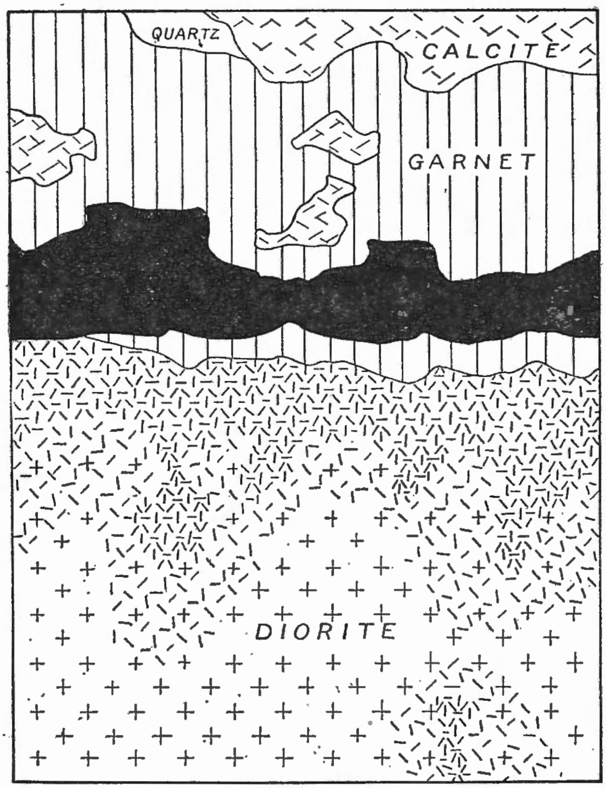


FIGURE 8. A narrow replacement between diorite and calcite. Magnetite (solid black). Increasing intensity of alteration of the diorite indicated by increasing density of pattern. One-quarter natural size.

shows a well-defined zonary structure. The whole replacement and the comparatively fresh diorite are cut by small veins consisting mostly of calcite and quartz.

As the garnetite on one side of the magnetite is cloudy and contains remnants of the intrusive, and that on the other side is quite clear, it is concluded that the vein of magnetite marks the original contact of the diorite with the limestone. Measurements made in the field show that the amount of garnetite which replaced the limestone at this place is roughly ten times as much that which replaced the intrusive. The relations shown on this exposure are fairly simple, and furnish a record of the reactions, which, proceeding on a large scale from many adjacent centres, formed the main deposits where the interaction of the various solutions, more or less individualized along different channels, produced a result whose details are complex and confusing.

GENESIS OF THE ORE DEPOSITS

EVIDENCE OF REPLACEMENT

Many microscopic relations, such as the garnet pattern corresponding to the cleavages of oriented remnants of a feldspar grain, and the preservation of the outlines of andesine phenocrysts by grains of zoisite, epidote, and quartz, show definitely that replacement occurred, at least on a small scale. Confirming this conclusion are numerous details observed in the field, such as intersecting veins of garnet in the limestone; the localization of alteration along joints in the intrusive, particularly at intersections; the penetration of the limestone by large prisms of amphibole; the irregular veins of magnetite along joints in the limestone; and many other features. Evidence of replacement on a larger scale is furnished by the study of the zones of alteration around the magnetite lenses, where the progressive stages of the alteration show the substitution of certain minerals by others without any evidence of volume change in the rock. The large areas of the altered intrusive are similar in texture and composition to the phases observed in the gradations near the ore-bodies, and contain crystals of apatite and partly replaced grains of feldspar and other minerals. Such evidence applies to the alteration which formed the bulk of the deposits, and it is, therefore, clear that replacement was quantitatively the dominant process, and that all the minerals of the deposits are at least partly metasomatic.

The foregoing evidence does not apply to the comparatively pure masses of magnetite and garnet. Although the margins of these are clearly replacements, and partly replaced blocks of the limestone and the intrusive are common in them, it might nevertheless be conceived that these features are merely contact phases of deposits formed by some other process such as the injection of an ore magma. As the purity of these deposits, and other factors influencing them, make it impossible to trace the actual replacement through more than a narrow contact zone, it is necessary to rely on less direct evidence concerning their formation. The irregular, rounded shapes of the deposits, and the absence of any record of deformation of such nature as to accommodate their injection or enlargement by the force of growing crystals, strongly suggest that they are replacements, for it is inconceivable that they could be cavity fillings. Even near an ore-body as large as the Paxton, the garnetite faithfully preserves the regular joint system of the intrusive. In many places the contacts are perfectly sharp, showing no change in the structure on either side, and nowhere is there anything resembling a gouge, although against the large ore-bodies the contacts are commonly fractured, the joints showing a rhombohedral pattern suggesting shear due to the different co-efficients of contraction of the magnetite and the country rock.

Although it is not possible to trace the remnants of the replaced rock more than a short distance into the magnetite, it is possible to follow certain textural variations in the field. The textures of the replacements are no doubt governed by many factors, but it is nevertheless possible to observe a definite control exerted by the original rock. In the southwest corner of the area, the small lenses of magnetite, which are definitely shown to be replacements of the porphyrite by their content of partly replaced grains of plagioclase and other minerals, are dominantly fine-grained. The descriptions given on the preceding pages have repeatedly noted the fact that the magnetite is coarse grained against the calcite and fine grained against the garnet, amphibole-epidote, or other silicate rocks. Thin sections of such contacts show that the magnetite has replaced the adjacent grains. This feature will be referred to again under the following heading, and for the present purpose it is sufficient to point out that the magnetite in such exposures as the one sketched in Figure 9 is no doubt a replacement. The large ore-bodies, particularly the Prescott, show irregular variations

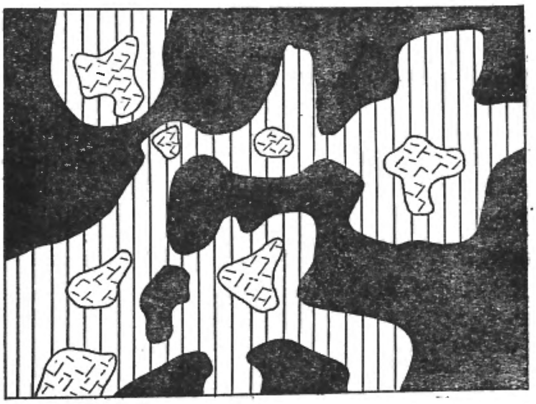


FIGURE 9. An exposure showing magnetite (solid black), garnet (vertical ruling), and calcite (lines suggesting rhombohedral cleavage). Scale, 1 inch to 1½ feet.

in texture analogous to the differences observed in the partly replaced contact zones, a fact which strongly suggests that the ore-bodies as a whole are replacements.

In short, it is clear that the extensive alteration of the intrusive is the result of the replacement of that rock, and that a large part of the massive ore-bodies and the garnetite are also replacements. That is, the bulk of the deposits are definitely replacements. As no evidence was found to suggest that a different process caused the formation of any part of the deposits (except the small veins of quartz, calcite, and other minerals which are partly fillings of fractures), it is concluded that the deposits as a whole are metasomatic.

PARAGENESIS OF THE METASOMATIC MINERALS

The magnetite, garnet, pyrite, epidote, and other minerals which distinguish the metasomatic deposits are closely associated with one another. Almost all the ore-bodies contain pyrite and chalcopyrite intergrown with the magnetite, and intimate mixtures of grains of magnetite, garnet, and pyroxene are common as replacements of the porphyrite. Amphibole, epidote, calcite, pyroxene, and quartz form intergrowths in the altered intrusive, and most of these minerals, together with magnetite and pyrite, occur in many of the microscopic veins which cut the garnetite. The small deposits which occur in the limestone away from the main contact contain almost all of these minerals as a complex intergrowth, and similar relations are shown by many of the masses of calcite in the large deposits. The association is shown on a larger scale by the fact that most of the ore-bodies are completely surrounded by silicate replacements and the exposed area of the altered rocks is roughly proportional to the size of the adjacent ore-body. Finally, the close association of garnet, magnetite, chalcopyrite, and other minerals is characteristic of deposits of this class wherever they occur. This fact was impressed upon the writer by the examination of numerous iron deposits along the coast of British Columbia, where the commercial possibilities are not controlled by the quantity of magnetite present as much as by the size of the individual ore-bodies and their freedom from such impurities as garnet and sulphides.

In spite of the broad relations which indicate a single period of deposition, the first impression from a study of the details is that there were successive stages of mineralization, involving the formation of garnet, magnetite, and sulphides and quartz, in the order named. Many of the details which would convey such an impression are given in the descriptions of the metasomatism. Magnetite in small veins commonly cuts the garnetite and in thin sections the contacts between these minerals show corresponding relations. Similarly, quartz, pyrite, and chalcopyrite are in many places later than the magnetite. But it is apparent that any attempt to apply this conception to all the details meets with difficulties at every hand. Moreover, the general zonal distribution of the minerals, which is shown in a quantitative way by the position of the copper lodes at the limestone contact, and the dominance of epidote in the altered intrusive away from the main replacements, involve a close and orderly association of minerals which it is difficult to explain on the assumption that the deposition took place in successive stages. A careful examination of the changes shown at the typical contacts confirms the conclusion that the deposition of the minerals was largely effected by one surge of primary solutions, and at the same time explains the presence of the persistent time relations observed between certain minerals at any one place.

Figure 9 is a sketch of an exposure at the Prescott mine. The masses of calcite are impregnated with sulphides and are separated from the magnetite by zones of garnetite. A detailed description of a gradation of this kind is given under "Metasomatism." It is clear that such a complex and yet orderly, arrangement of minerals would be highly unlikely if the garnet, magnetite, and sulphides were introduced at different times. Moreover, the textural relations show that this was not the case. Figure 10 is a sketch of a specimen taken from the same exposure. The fact that the magnetite which replaced the calcite is much coarser grained than that which replaced the silicates has been frequently noted on the preceding pages, and such a relation is apparent in the specimen shown by the figure. Thin sections show that the magnetite adjacent to the garnet has partly replaced this mineral, and in the specimen there is a remarkably persistent band of dense magnetite against the garnet. The magnetite in contact with the small masses of calcite is, on the contrary, coarse grained. As most of the magnetite has a coarse texture, it is concluded that the magnetite in this specimen is dominantly a replacement of calcite, the replacement of garnet being merely a minor feature. The deduction that the magnetite, garnet, and other minerals were formed through the introduction of one set of primary solutions seems to be a necessary corollary from the special relations shown.

Similar relations were observed in other parts of the deposits. At the main limestone contact, where a zone of amphibole rock commonly lies between the limestone and the garnetite, many small masses of calcite are common in both the amphibole rock and the garnetite. At the contact of the magnetite with the altered intrusive small grains of partly replaced feldspar were found in the magnetite, the garnet, and the amphibole-

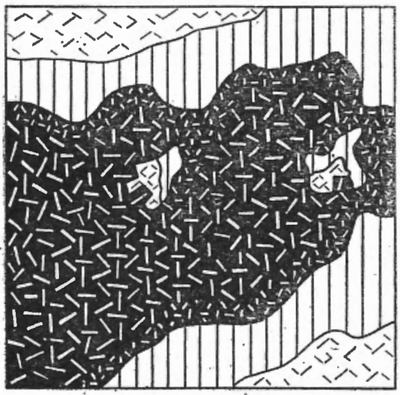


FIGURE 10. A specimen from the exposure represented by Figure 9. Magnetite (solid black, variation in texture by white lines), garnet (vertical ruling), and calcite (lines suggesting rhombohedral cleavage). Two-thirds natural size.

epidote rocks, or they may be present in the magnetite and not in the garnet. In the replacement of the porphyrite, remnants of feldspar appear in the magnetite-pyroxene lens and in the dense, mottled rock. Such relations confirm the conclusion reached from a study of the texture shown by Figure 10, and the general zonal arrangement at the contacts is a further indication that the magnetite, garnet, amphibole, epidote, pyrite, quartz, and other minerals owe their formation to the introduction of one set of primary solutions and that all are dominantly replacements of the original rocks.

The persistent marginal replacement of garnet, amphibole, and other minerals by the magnetite; the dominance of calcite, quartz, epidote, and the sulphides in veins cutting the replacements; the chloritization of the amphibole; and other relations showing more or less of a sequence in the alterations at any one place require some explanation if the above conclusion is to be accepted. It is believed that a consideration of the special relationships and certain characteristics of the different minerals furnishes such an explanation.

From the relations observed in thin sections taken at many places in the deposits, the minerals can be classified according to the relative ease with which the constituents forming them seem to have been transported, that is, according to what may be called their comparative mobility. For example, where magnetite and pyrite occur together as replacements of garnet, the pyrite commonly penetrated the finest fissures, whereas the magnetite appears as more or less equidimensional patches, showing that the pyrite was more mobile than the magnetite under the conditions prevailing at the time of this replacement. From similar relations it appears that magnetite, garnet, and pyroxene were characteristically immobile, amphibole somewhat less so, and epidote, pyrite, chalcopyrite, calcite, and quartz were relatively mobile. Another classification of the minerals can be based on their relative stability. The magnetite was relatively stable, that is, once formed it appears to have resisted all further alteration. The amphibole, pyroxene, and olivine seem to have formed the other extreme, all being more or less altered to chlorite or serpentine. Garnet was less stable than magnetite, for in many places microscopic veins cutting both these minerals are sharply defined in the magnetite, but grade into irregular replacements in the garnet. As a rule, epidote, quartz, and the sulphides are fresh. The mobility is a measure of "intensity" of conditions required to bring in the necessary constituents and to provide the proper environment for the deposition of each mineral. Where this "intensity" was exceeded, the mineral was moved farther away. Once formed, the various minerals, under the influence of lower pressure, temperature, and other factors, showed differing tendencies to change to some other mineral. For example, magnetite, which was immobile, and epidote, which was mobile, were both stable, whereas amphibole was unstable. That is, the additional factor of the inherent resistance to change of the crystal structure or its adaptability to different environments, is involved in the stability of each mineral. A discussion of the "intensity" of the conditions of formation of the different minerals would bring in a consideration of the temperature, pressure, and concentration of the original solutions, and their time and space relations, that is, their previous history at any one point; but, lacking this, the assumption is made that the effect of the temperature, pressure, and concentration of the solutions at any one time and place was such that the different minerals were more mobile at the centres of replacement than farther away.

The relations shown in Figure 9 indicate the concentration of the solutions along certain channels, as parts of the original limestone remain in the form of masses of coarse calcite. From such centres gradients were established, the more mobile minerals, such as pyrite, penetrating farther into the limestone than the less mobile, such as magnetite; and garnet formed in the intermediate zone. All the minerals replaced calcite, which, under the existing conditions, was the most mobile, and tended to migrate from the immediate vicinity. If the time factor be considered, it is clear that the continual access of the solutions would make the mobility gradient flatter, for the gradual conduction of heat, for example, would tend to allow the deposition of any one mineral to occur farther away from the main source of material. As a result, the zone in which magnetite was being deposited gradually encroached on that in which garnet was formerly stable, and the replacement of garnet by magnetite occurred. This was no doubt more difficult than the replacement of calcite, and, because of this or other effects, the period of metasomatism in this particular place was soon at an end. A cooling of the entire mass followed, and stresses were set up, partly from this process, and partly from the contraction of the rock mass as a whole. The calcite probably yielded by flowage; the harder magnetite and garnet were broken. The fractures formed allowed the easy penetration of solutions from other centres of replacement. These deposited calcite, quartz, chlorite, and pyrite, the more mobile minerals, in the garnet and magnetite. The garnet was partly replaced, but the magnetite, being more stable, shows little alteration.

Speculative as it is, the foregoing outline explains the observed facts, and it is clear that, with slight modifications, it can be applied to the gradations from the ore-bodies into the main limestone formation, the intrusive, and the porphyrite. Successive periods of mineralization are not postulated, but the rough sequence observed at any one place is ascribed to the time and space relationships existing during the replacement which is assumed to have been caused by the introduction of primary solutions which were everywhere essentially the same, although they permeated the rock from many different channels during a period of some duration, and in this way gave rise to a complex assortment of secondary solutions whose composition varied with their previous history. The larger veins which cut the replacements bear a close resemblance to the microscopic veins of calcite, pyrite, chalcopyrite, and quartz found throughout the deposits, and are probably the distant representatives of replacements that took place at greater depths, although no absolute proof can be given to show that they were not formed by primary solutions of a later generation and different composition. Such veins, however, are small and not numerous, and their origin does not affect the main conclusion reached.

TIME RELATIONS OF THE PERIOD OF METASOMATISM

The fact that the dykes of diorite porphyry cut all phases of the replacements puts one definite limit to the possible extension of the period of metasomatism. The other limit is fixed by the fact that the tonalite, porphyry, and other phases of the Gillies intrusive were extensively replaced, which makes it clear that the metasomatism occurred after a large part of the intrusive had consolidated. Most of the replacement also appears to have taken place after the alaskite intrusion, but on the west side of the Paxton knoll there is a deposit of garnetite cut by alaskite dykes, which are themselves epidotized. The garnetite contains in addition to one small sheet, about 2 inches thick, which is alternately alaskite and epidosite, several other altered dykes. This relationship is entirely analogous to that shown on a small scale by the typical thin sections of garnetite, and is believed to indicate the following history at this particular point: (1) the formation of the garnetite with the usual gradation into the fresh intrusive through amphibole-epidote rocks; (2) the fracturing of the mass after the first surge of solutions ceased; (3) the intrusion of the alaskite; and (4) the alteration of the alaskite by solutions permeating from adjacent centres of mineralization. As most of the alaskite dykes in the area are partly replaced, and none of them cut the main deposits, the period of metasomatism may be fairly well defined as mainly following, but partly overlapping, the time of the alaskite intrusion.

SOURCE OF THE SOLUTIONS

The metasomatic deposits containing the ore are roughly confined to the contact of the Gillies intrusive. The mineralogy and structure of the deposits show that the solutions forming these deposits were hot and under high pressure. They were active during a relatively brief period, which partly overlapped the time of the alaskite intrusion. The rocks composing the Gillies stock are the only ones in the area which have a significant amount of primary magnetite, and in these the magnetite was nearly the last mineral to complete its crystallization. Such relations, which are to some extent duplicated in all deposits of this kind, strongly suggest that the solutions were magmatic, and that, in some way, the crystallization of the intruded magma effected their segregation.

The mere fact that iron is much more abundant than copper or sulphur in the earth's crust would lead to the expectation that tracing the concentration of the magnetite through the stages of the consolidation of the intrusive would be less difficult than following chalcopyrite or pyrite. Other factors, such as the relative stability of sulphides and oxides in magmatic solutions, are also effective. Whatever the reasons, magnetite is fairly abundant as a primary constituent of certain phases of the intrusive, whereas the sulphides are not, and some interesting relations are brought out by a study of various phases of the intrusive with regard to time, space, and composition.

The dioritic inclusions, which record the early crystallization of the magma, contain about 5 per cent of magnetite. During the consolidation of this diorite, part of the residual magma was no doubt entrapped in pockets which supplied the material for the final crystallization of the rock, and for small veins such as the one described. The composition of both the vein and the last minerals formed in the diorite shows that the residual liquid contained a large amount of magnetite in solution. The diorite which composes the inclusions is not abundant, and its consolidation probably formed a small shell which was later invaded by the main mass of the magma. The next definite record is furnished by the tonalite constituting the bulk of the intrusive, whose final consolidation occurred after a long period during which there were many minor surges of the magma, as shown by the heterogeneity of parts of the stock. The consolidation of the tonalite also entrapped parts of the residual liquid, from which the coarse groundmass feldspar and quartz crystallized. Magnetite was one of the constituents of this residual liquid, as it is partly a replacement of the feldspar, but it is not as abundant in the tonalite as in the diorite inclusions. This fact indicates the concentration of part of the magnetite somewhere in the intrusive. The record of the final activity of the Gillies magma shows products of very diverse nature. The tonalite is cut by many small alaskite dykes which are composed of quartz, orthoclase, and acidic plagioclase, the minerals which crystallized last in the tonalite. They contain practically no magnetite or ferromagnesian minerals. Partly overlapping the time of the alaskite intrusion, but mostly later, was a period of intense metasomatism which formed deposits characterized by their content of magnetite and sulphides. A few small dykes of hornblendite porphyry were intruded during this general period. They cut a few of the alaskite dykes, but do not appear in the ore-bodies, and are themselves highly altered. The alaskite, the hornblendite porphyry, and the metasomatic deposits show a rude areal association, as all are most numerous in certain irregular areas roughly distributed along the contact of the stock.

This brief outline suggests strongly that the ore-bearing solutions were concentrated by some process attending the consolidation of the intrusive. The composition of the alaskite, particularly, shows such a close resemblance to that of the groundmass minerals of the tonalite that it is almost certain that the alaskite was formed by the intrusion of part of the residual liquid left by the consolidation of the main mass of the stock. The association in time and place shown by the alaskite, the hornblendite porphyry, and the replacements, indicates a similar source for the different solutions from which all three were formed. There is a gradual decrease in the amount of magnetite found in the successive intrusions, and the record of the final magmatic activity shows a marked segregation of the ferromagnesian minerals, the magnetite and sulphides, and the acidic feldspar and quartz. How and where the segregation occurred remains an unsolved problem. The concentration of the iron-oxides and the sulphides might be explained on the basis of a slag-matte relationship, but the great penetrating ability of the replacing solutions, suggesting a concentration of mineralizers, and the separation of the alaskite and hornblendite porphyry magmas, show the control of additional factors, such as the spacial relations of the different residual fluids.

NATURE OF THE SOLUTIONS

The nature of the ore-bearing solutions must be deduced from what is known about their origin and activity. It is clear that the composition of the solutions was changing continuously, and that all the material added at any one place was not necessarily part of the original solutions. For the present purpose it is sufficient to note that iron, silica, sulphur, copper, and fluorine were no doubt constituents of the primary solutions. What is known of the composition and crystallization of magmas suggests that the primary solutions also contained water-gas, carbon monoxide, carbon dioxide, and other mineralizers whose presence is not indicated by the deposits. From the mineralogy and structure of the deposits, it must be assumed that the solutions were hot and under high pressure, and that their composition, temperature, and pressure were such as to allow them to penetrate through very minute openings in the rocks for considerable distances from the main channels of supply. The fact that the deposits are replacements shows that there was a large removal as well as addition of material, and the laws of chemistry seem to demand the assumption that a continual transfer of material occurred, for otherwise the reactions would soon have reached a point of equilibrium. This continual movement of the solutions was no doubt greatly influenced by the nature of the rock replaced at any one place, as shown under "Factors controlling the deposition." But, whatever controlled the free movement of the solutions, it seems clear that such movement occurred. It is, therefore, concluded that the primary solutions contained iron, silica, sulphur, copper, fluorine, water-gas, carbon monoxide, carbon dioxide, and other constituents; that they were under high temperature and pressure; that their great penetrating ability indicates a large gaseous content; and that they were moving continually through certain parts of the rock mass for a period of some duration.

This conception is more in accord with the older views on the nature of ore solutions than with that recently advanced by Spurr.[1] The solutions which formed the Texada iron deposits seem to have differed from those which Spurr calls ore magmas in the fact that they formed deposits which are almost entirely replacements; that they were moving continuously through the rocks, removing certain constituents and adding others all along their route; and that they possessed extreme penetrating ability. The marked dissimilarity between the metasomatic deposits and the aplitic and pegmatitic phases of the alaskite shows clearly the difference between the ore-bearing solutions and what are ordinarily considered as magmas. Both of these solutions entered the exposed section at about the same time and place, but the alaskite is dominantly in the form of well-defined dykes, whereas the metasomatic deposits are typically irregular lens-like replacements.

FACTORS CONTROLLING DEPOSITION

As the deposits were formed after a large part of the intrusive had consolidated, it is of interest to inquire why they are dominantly located near the limestone contact. A complete explanation would require a definite knowledge of the structural conditions at the time of replacement, and a clear understanding of the process of replacement and the factors controlling it. It is clear that no more than a surmise can be made as to either the conditions during replacement or their effects on the process, but in a general way the control of certain factors can be indicated.

The broadest relations of the deposits can be roughly described by stating that the replacements occur at the contact of an acidic intrusive with limestone and porphyrite. The geology of the area indicates that the intrusion of the Gillies magma favoured the limestone. Relations such as those described by Collins[2] show that assimilation has been effective in the intrusion of large igneous masses, and, in the area studied, it is probable that the Gillies magma made its way largely by this process, for the limestone shows no evidence of having been greatly deformed (*See* the conclusions given under "Structure"), and the abundance of primary hornblende and augite in the altered intrusive containing many blocks of replaced limestone is suggestive of the effects of assimilation. The dominance of plagioclase over orthoclase, as compared with the relative proportions of these minerals in the main Coast Range batholith (of which the Gillies stock is supposed to be a part), also suggests the addition of lime to the Gillies magma. Bowen[3] has shown that the assimilation of

[1] Spurr, J. E., "The Ore Magmas," 1923.
[2] Collins, W. H., "Onaping map-area," Geol. Surv., Can., Mem. 95, 1917, p. 58.
[3] Bowen, N. L., "The Behaviour of Inclusions in Igneous Magmas," Jour. of Geol., vol. XXX, 1922, p. 549.

limestone tends, among other things, to cause a segregation of the magnetite, by substituting lime for ferrous oxide in the pyroxene molecule and throwing the ferrous and ferric oxides out in the form of the magnetite molecule. This suggests that the intrusion of a magma into limestone is, in itself, a significant factor in the concentration of the magnetite, as this molecule was apparently segregated in the ore-bearing solutions by the consolidation of the magma, whereas the ferrous and ferric oxides in the pyroxene molecule would probably crystallize more uniformly throughout the intrusive.

The most obvious feature of the deposits themselves is their erratic distribution on both a large and small scale. This shows that the ore-bearing solutions did not permeate the rocks uniformly, but were concentrated along certain channels. It follows as a necessary deduction that the structural conditions at the time of the metasomatism controlled the major distribution of the deposits, and that influence of the environment into which the solutions were directed was only to modify the nature and extent of the reactions.

The period of replacement occurred after the consolidation of a large part of the intrusive, and there is no evidence of any major deformation in the area either during or immediately after this period. However, much minor faulting took place about this time. The stresses set up by the cooling of the rock mass probably caused this movement. Accordingly, some conception of the thermal conditions prevailing during the consolidation and cooling of the intrusive is desirable.

The graphs of Ingersoll and Zobel[1] are instructive in this connexion. Figure 11 is a reproduction of one of these, showing the temperatures that would exist around a mass of granite in limestone after cooling from an assumed initial temperature for various periods of time. The graph is calculated on the assumption that all the heat is conducted through the rocks, and the results are not applicable to igneous intrusions without some modifications, as the transference of heat within the unconsolidated part of the magma, the heat derived from the process of crystallization and the reactions between minerals, and the transference of heat into the invaded formation by magmatic vapours and heated meteoric waters, are neglected. In addition, local modifications would be caused by the irregular shapes of igneous masses and the complex nature of intrusive action. It is impossible to make a quantitative estimate of the effect of these factors, but it is probable that the relations shown in the graphs would not be greatly modified. In any case, the general conditions are indicated, and the curves serve the useful purpose of bringing out some significant facts that would otherwise be obscure.

If any one curve in Figure 11 be compared with the other, it will be found that near the source of heat the rock is cooling; farther away it is becoming hotter, and at some intermediate point it has reached its maximum temperature. A similar study of a curve for a later period shows that the point which has just reached its maximum temperature is farther away from the contact, though the maximum is, of course, lower. In terms of the stresses resulting from the temperature changes, the graphs

[1] Ingersoll, L. R., and Zobel, O. J., "An Introduction to the Mathematical Theory of Heat Conduction," 1913, Ginn & Co.

show that there was a slow migration into the invaded rocks of a zone of compression followed by one of tension.

The application of these deductions to the Gillies magma indicates that, during the early stage of the cooling, the intrusive was under tension, while the country rock was still under compression. As a result the intrusive was probably broken by fractures concentrated near the contact where the decrease in temperature was greatest. Their gradual extension inward into the intrusive would liberate the solutions confined under high pressure, whose escape into the more fractured zone at the contact would result in a sudden decrease in their pressure. The graphs also show a much higher temperature gradient at the contact than elsewhere. The decrease in the

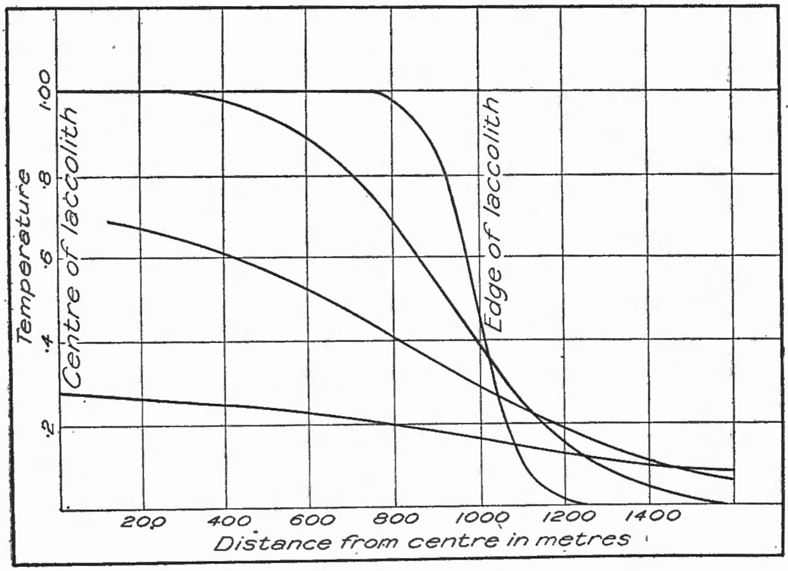


FIGURE 11. Computed temperature curves for a laccolith 1,000 metres in radius, which has been cooling from an initial temperature $\Theta°$, for various periods of time. (After Ingersoll and Zobel.)

temperature and pressure of the solutions would, therefore, be greatest near the contact, and for this reason most of the deposition would be expected there. In the exposed rock section, the replacements show in every direction a gradation into zones characterized by the more mobile minerals. Accordingly, it must be concluded that the immediate source of the solutions was from below, and that they were introduced at some depth to the relatively permeable contact zones which they followed upwards.

The rough association in time and place between the metasomatic deposits and the alaskite and hornblendite porphyry dykes seems to bear out the conditions postulated. The shape of the deposits, also, indicates the general validity of the deductions. At the contact of the deposits with the main limestone formation an abrupt change from the unaltered rock to massive magnetite, garnet, or amphibole rocks is characteristic.

This suggests that the limestone was not fractured, but impervious to the solutions, a condition to be expected in a rock mass under compression, particularly if the rock flows easily. On the other hand the replacement of the intrusive is typically associated with fractures, a fact that has been repeatedly noted in the foregoing pages. In short, the shape and distribution of the deposits are fully in accordance with the conception that the limestone formation was under compression and the intrusive under tension at the time of the replacement.

If it be concluded that the general structural conditions were as postulated, the erratic distribution of the deposits at or near the contact needs no further explanation. However, the replacements show other characteristics which can be partly accounted for by the physical and chemical nature of the various formations into which the ore-bearing solutions were led by the main system of channels.

From a consideration of the physical permeability of the rocks, resulting from the deduced conditions of stress, it is apparent that the alteration of the intrusive would be favoured. Moreover, the heterogeneous parts of the intrusive would be especially susceptible to permeation, as the differential stresses set up in such masses by the variable contraction of the different rocks and their varying reaction to external strain would cause more fracturing in these parts. The extensive alteration that occurred in the intrusive near the Prescott and Paxton mines is no doubt partly due to this effect, but the chemical factor was also effective, for these areas show many remnants of limestone. The marked localization of the replacement in the tongues of limestone projecting into the intrusive, and in the parts of the stock where blocks of limestone were included, was probably due to the fact that such rock masses were unfavourable places, both physically and chemically, for replacement.

The large amount of replacement in the main limestone formation must be attributed to its chemical nature. Even the most elementary consideration of the reactions involved by the replacement of calcite, as compared with those required by the replacement of feldspar, the mineral composing most of the intrusive, gives some explanation of the marked localization of the purer deposits, such as the ore-bodies, whose formation required a much freer addition and removal of material than was needed where an impure mass of sulphides, magnetite, epidote, and other minerals replaced the intrusive. In the replacement of calcite, carbon dioxide was liberated. The gaseous content of the solutions was thereby increased, and the pressure was, probably, raised. In addition, lime was taken into solution. A large number of geological observations show that lime is a characteristically mobile constituent in all phases of metamorphism.[1] As a general result, the tendency of the reactions was to increase the fluidity of the solutions, offsetting in part the decrease in temperature and pressure attending their migration and whatever endothermic reactions they caused. In this way the removal of material which would tend to impede the reactions and the addition of new constituents was favoured. On the other hand, the replacement of such minerals as plagioclase involved the removal of alumina and no liberation of a gaseous phase. Compared with lime, alumina is very immobile, and its removal must have been difficult. The

[1] Leith, C. K., and Mead, W. J., "Metamorphic Geology, 1915", Henry Holt and Co.

replacement of the limestone and the intrusive by magnetite and andradite, the dominant minerals in the main massive deposits, involved the addition of iron and the removal of lime, alumina, and other constituents. In the adjacent altered phases of the intrusive, the principal change was the formation of epidote from plagioclase. A simple calculation shows that the replacement of 1 cubic centimetre of plagioclase (Ab_2An_1), by epidote (in which the ratio Al: Fe=3:1), requires the addition of 0·130 grams of Al_2O_3, 0·604 grammes of CaO, 0·420 grammes of Fe_2O_3, and 0·063 grammes of H_2O; and the removal of 0·347 grammes of SiO_2 and 0·210 grammes of Na_2O. Compared with the changes involved in the formation of the massive replacements of garnet and magnetite, the epidotization is distinguished by the deposition of lime and alumina. Although the nature of the solutions is not known, these chemical comparisons show that the alumina was deposited, and probably transported, in close association with the lime. This suggests that the replacement of the limestone was a significant factor in the alteration of the intrusive, both in effecting the removal of the alumina where magnetite and andradite replaced the feldspar, and in supplying lime for the epidotization of the adjacent intrusive.

Butler[1] has recently suggested another chemical factor in the replacement of limestone. This is based on the data given by Findlay[2] for the reaction:

$$3FeO + CO_2 = Fe_3O_4 + CO$$

In a system containing the components shown, the concentration of CO_2 required to cause the reaction to proceed from left to right is a minimum at a temperature of 490°C. It is, of course, clear that higher concentrations of CO_2 will cause the formation of Fe_3O_4 over a considerable range of temperature. For example, if the components of the gaseous phase have the ratio, CO_2: CO = 70: 30, Fe_3O_4 is the stable oxide from 350°C. to 750°C. These relations are definite for the system considered, but it is clear that their application to complex geochemical systems must be used very cautiously, and that the indication of general tendencies is all that is to be expected. The presence of silica in the reacting magmatic solutions is a complication to be added to the ones mentioned by Butler. In steel-making use is made of the fact that the presence of lime prevents the reduction of phosphorous oxides by forming calcium phosphate, and in the contact reactions the presence of silica probably prevented the oxidation of part of the ferrous oxide by forming ferrous silicates. At least, it is certain that magnetite and pyroxene were formed together in parts of the deposits. The presence of CO_2 no doubt tended to increase the proportion of ferric oxide in the deposits, and the general purity of the magnetite lenses in the limestone is partly explained by these relations.

The addition of calcite to the ore-bearing solutions probably increased their mobility, and, as a result, the replacement of limestone tended to increase the range over which all the constituents would be deposited. But the presence of CO_2 no doubt formed the characteristically immobile magnetite molecule from part of the ferrous oxide that might otherwise have been transported and deposited as amphibole and pyroxene, and in this way caused a preferential segregation of magnetite. Such relations

[1] Butler, B. S., "A Suggested Explanation of the High Ferric Oxide Content of Limestone Contact Zones," Econ. Geol., vol. 18, 1923, pp. 398-404.

[2] Findlay, Alex., "The Phase Rule and Its Applications," 1917, pp. 313-319, Longmans, Green & Co.

probably explain the presence of relatively pure veins of magnetite in contact with unaltered limestone.

A brief summary of the factors which are believed to have controlled the character and position of the deposits is as follows. The deposits were formed by magmatic solutions in which the materials were concentrated by the crystallization of the intrusive. The assimilation of limestone by the magma may have been a factor of great significance, as ferrous and ferric oxides were thereby thrown out of the pyroxene molecule and made available for segregation as magnetite. The release of the solutions from the intrusive was effected by fracturing caused by the cooling of the mass, and, as a consequence, the distribution of the deposits is mainly controlled by the structural conditions at the time of replacement, which favoured the movement of the solutions along the general contact zone. From a consideration of the physical permeability and the chemical composition of the rocks into which the solutions were led, it is concluded that the porphyrite was unfavourable both physically and chemically, that the intrusive was favourable physically but not chemically, and that the limestone was favourable chemically but not physically. The chemical factor was probably in control, as the constant removal of material, facilitated by the addition of calcite to the solutions, was as necessary for the formation of extensive replacements as the access of new material. The heterogeneous parts of the intrusive which included blocks of the limestone, and the tongues of limestone projecting into the stock, were especially suited to replacement, both physically and chemically, and contain the largest deposits. Finally, the oxidizing effect of the carbon dioxide was probably effective in the formation of the relatively pure deposits of magnetite.

DEEP BORINGS IN BRITISH COLUMBIA AND THE YUKON

By E. D. Ingall[1]

The Borings Division of the Geological Survey exists for the purpose of accumulating and studying records of borings made in any part of Canada, so that the information of a general geological character thus rendered available may be utilized for the guidance of operators, and in geological research in arriving at a fuller understanding of the strata in depth.

Within the province of British Columbia, and Yukon Territory, deep-boring operations were not extensively prosecuted during 1924, and but little information was reported to the Division. Diamond-drill borings intended to ascertain the extent of ore reserves in metalliferous mines made in the various mining camps, do not come within the scope of the Borings Division.

The deep borings in search of gas and oil in Fraser River Delta deposits were not continued, except that of the Empire Oil and Gas Company on N.E. sec. 27, tp. 10, E.C.M., which was reported to have attained a depth of about 5,500 feet. No reports or sets of samples have been received from this company.

The only deep boring in British Columbia from which samples, etc., were received was that of the Crow's Nest Oil and Gas Company on Sage creek, Flathead River valley, Kootenay district. The operations this year were in continuation of the boring test for petroleum begun some ten years ago. The belief that oil would be got in commercial quantities in depth was based on the occurrence of seepages of oil at the surface. Samples of cuttings from this well were first received in January, 1919, since which date boring operations have been continued each year during the summer. The elevation of the top of this boring is approximately 5,200 feet above sea-level, judging by the contoured map-sheet of this district issued by the Department of the Interior. During 1924 twenty-seven samples of cuttings were received from this well from between depths of 2,500 feet and 3,000 feet. The strata pierced are presumably Precambrian and belong to the Lewis series as described in Memoir 38 by Daly, who stated the succession was constituted as given below.

"Beginning at the top, the formations included in the Lewis series have been listed in the order of the following table:

Formation	Thickness in feet	Dominant rocks
	Top	Erosion surface
Kintla	860+	Argillite
Sheppard	600	Siliceous dolomite
Purcell lava	260	Altered basalt
Siyeh	4,100	Magnesian limestone and metargillite
Grinnell	1,600	Metargillite
Appekunny	2,600	Metargillite
Altyn	3,500	Siliceous dolomite
Waterton	200+	Siliceous dolomite
	13,720	
	Base concealed	

[1] Information regarding boring records for the Prairie Provinces, etc., will be found in Part B of the Geological Survey Summary Reports, and for eastern Canada in Part C.

The site of the boring was visited in 1918 by Bruce Rose, of the Geological Survey staff, and from him it was ascertained that the hole started about the middle of the Appekunny subdivision. The geological problem presented to the operators was that of determining from time to time their position in the geological section as established by Daly. To this end the samples of drill cuttings were examined microscopically and the material compared with Daly's descriptions of the strata. They were also treated with hydrochloric acid and the proportion of insoluble residue measured.

The generalized results are given in the log below:

LOG OF CROW'S NEST OIL AND GAS COMPANY'S BORING

Sage Creek, Flathead Valley, B.C.

Feet	
.......– 125	Rather highly calcareous metargillite and quartzite
(125 – 1,000)	Samples missing
1,000 – 1,330	Mostly white quartzites with occasional darker and more argillaceous beds. Fair amount of carbonate constituents in most samples
1,330 – 1,420	Free effervescence with HCl, but too much siliceous residue to call it limestone or dolomite
1,420 – 1,560	Considerable effervescence with HCl, but residue remains unaltered in bulk and appearance. Red, green, and white
1,560 – 1,600	Buff, siliceous dolomites
1,600 – 1,640	Siliceous dolomite
(1,640 – 1,840)	Samples missing
1,840 – 2,000	Grey to dark grey and buff, occasionally rusty, highly siliceous dolomitic limestones. Residue insoluble in acid 52 to 85 per cent
2,000 – 2,330	Light and dark grey magnesian limestones, less highly siliceous than preceding beds. Residues after acid treatment 50 to 65 per cent. Occasional samples 45 per cent, others 70 per cent.
(2,330 – 2,420)	Samples missing
2,420 – 2,460	Quartzitic over 90 per cent insoluble in HCl
2,460 – 2,880	Siliceous limestones and dolomites averaging about 50 per cent insoluble residue after acid treatment. Mostly grey and buff with some red beds. (Samples missing 2,610-2,650 feet)
(2,880 – 2,960)	Samples missing
2,960 – 3,000	Calcareous quartzite

The material received did not show any marked variations in appearance, but below 1,640 feet the acid test indicated a decided increase in the proportion of carbonates (lime, magnesium, etc.). This change of character occurs at about the point where it was expected the hole would leave the Appekunny and pass into the more calcareous and dolomitic Altyn below.

It is not known how far boring activities in this district and near Waterton lake to the east have been influenced by the hypothesis held by some that an overthrust movement has brought the older beds on top of the younger Cretaceous formations, which occur on the west side of Flathead river and which are oil and gas-bearing to the east in Alberta. If this explanation of the geological relationships of the region suggested by the earlier geologists is not the correct one, and the younger formations do not underlie the older, the problem of boring for oil in this district takes on quite a different aspect, and the character and thickness of the members of the series being drilled are the chief consideration. The cuttings received corroborate Daly's lithological descriptions and leave the impression that any considerable degree of porosity cannot be expected in such strata. There remains then, the suggestion made by Dowling that the oil encountered represents the lighter constituents of oil which have travelled long distances through the fissure systems of the strata.

Results are given below of tests made by Mr. Maddox, for percentage of soluble constituent, of the cuttings received during the year, covering depths from 2,500 to 3,000 feet.

Crow's Nest Oil and Gas Company, Sage Creek, Flathead River, B.C.

Depth	Effervescence[1]		Per cent	Colour original rock	Description of material insoluble in hydrochloric acid
Feet	Cold	Hot	Insoluble		
2,500	5	5	33	Buff	White or light grey, very fine-grained, easily disintegrated material in small fragments as a rule. No quartz grains seen. 2,590—material is as a rule similar in appearance to the remaining samples, but is in much larger fragments, considerably more coherent, and in several cases shows fine, black, parallel bands closely spaced
2,505	5	5	39	Buff	
2,530	4	5	32	Buff	
2,555	5	6	46	Light grey	
2,560	5	6	50	Buff	
2,570	5	6	49	Buff	
2,580	5	6	57	Grey	
2,590	2	5	71	Dark grey	
2,600	5	6	63	Light grey	
2,610	5	6	62	Light grey	
2,650–70	7	7	26	Brownish grey	
2,680–90	6	7	49	Red	
2,700–15	6	7	44	Red	
2,705	7	7	24	Buff	
2,720	5	6	45	Brownish red	Red, fine-grained amorphous material, a few white chert fragments
2,725	6	7	40	Brownish red	Red, fine-grained amorphous material, a few white chert fragments
2,732	4	7	34	Brownish red	As above
2,755	4	5	57	Red and grey	Red, soft, fine-grained material; grey, shaly material in many places showing fine mica flakes and a little pyrite; in many cases with small black streaks; white, soft, very fine-grained material
2,765	3	5	58	Brownish red	
2,785	7	7	47	Very light grey	White, very fine-grained, soft material
2,790	5	7	67	Grey	Very light brown material, much more compact than above
2,800	5	7	49	Brown	Pink, fine-grained material; red, laminated, very compact material; some chert
2,810	3	5	50	Reddish brown	Dark brownish red, fairly compact material; a little grey laminated rock high in pyrite
2,815	5	6	55	Reddish brown	Dark brownish red, fairly compact material
2,820	5	6	48	Reddish brown	Dark brownish red, fairly compact material; a few mica flakes
2,830	6	7	50	Dark brown	Brownish red, very fine-grained material; a little chert
2,840	7	7	20	Cream	White, soft, opaque material with a little red material
2,850	7	7	30	Cream	White, soft, opaque material
2,860	6	7	30	Cream	White, soft, opaque material; light red similar material
2,870	6	7	31	Cream	White, soft, opaque material
2,880	6	7	39	Cream	White, soft, opaque material
2,895	7	7	28	Very light grey	Pure white, soft, very fine-grained material at 2,895, 2,900, 2,920 feet. At 2,910 feet the same material, but more grey in colour. At 2,920 feet still more grey in colour. Chert in small amounts in all except at 2,920 feet. A little pyrite at 2,940 feet. Negative reactions for free oil, sulphates, and phosphates
2,900	7	7	20	Very light grey	
2,910	5	7	33	Light and dark grey	
2,920	4	7	35	Very light and dark grey	
2,940	6	7	25	Light grey	
2,970	6	7	28	Light grey	Mottled grey material
2,980	7	7	15	Light grey	Mottled grey material
3,000	5	6	52	Light grey	Cream-coloured material

[1] The numerical conventions employed in the expression of the speed of effervescence are as follows: 1, extremely slow; 2, very slow; 3, slow; 4, medium; 5, fast; 6, very fast; 7, extremely fast.

Particulars of the wells in British Columbia and the Yukon, regarding which information was received by the Borings Division during 1924, are given below:

Legal sub-division	Location					Description						Remarks
	Section	Town-ship	Range	Meridian	At or near	Year made	Ele-vation (above sea-level) feet	Total depth in feet	(Gas, oil)	Character of water	No. of samples received	Name of drilling company
8	27	10	....	E. of Coast mer.	Otter Sta.....	1918–24	230	5,573	Gas and oil	Fresh	....	Empire Oil and Nat. Gas Co.
....	36	19	XVIII	W. of 6th......	Kamloops....	1920–24	....	717	....	....	....	Kamloops Nat. Gas, Oil, and Coal Co.
....	24	10	IV	E. of Coast mer.	....	1924	300	827	....	....	....	Utility No. 3.
....	....	....	....	....	Sage creek, Flathead river	1917–24	5,200	3,002	Oil.......	....	157	Crow's Nest Oil and Gas Co.

OTHER FIELD WORK

Geological

W. E. Cockfield. Mr. Cockfield completed the geographical and geological mapping of an area of 4,500 square miles in southern Yukon, between latitudes 60 degrees and 61 degrees and longitudes 134 degrees and 136 degrees, which was begun in 1922. This area includes a section of the eastern margin of the Coast Range granite batholith, in which Conrad, Whitehorse, and Wheaton mineral areas occur and which is geologically favourable for the existence of other metalliferous deposits. The results of the investigation are now being prepared in the form of a memoir and a geological map on a scale of 1 inch to 4 miles, for encouragement and direction of prospecting in the area.

W. L. Uglow. Mr. Uglow completed a detailed investigation of the iron ores of British Columbia, which was begun in 1922 by G. A. Young and continued in 1923. This investigation was undertaken at the request of the provincial Department of Mines and municipal organizations, with a view to ascertaining whether the known iron ore deposits would warrant establishment in the province of an iron and steel-making industry. A report upon the results of the investigation is now being prepared.

W. A. Johnston. During September Mr. Johnston paid a brief visit to Barkerville area, Cariboo district, B.C., for the purpose of collecting additional information regarding placer-mining operations, to include in a memoir on the subject under joint authorship with W. L. Uglow, which is now in course of publication.

J. F. Walker. Mr. Walker completed a systematic geological survey of Windermere map-area, in southeastern British Columbia, which was begun in 1921 by S. J. Schofield and continued in 1922 and 1923 by M. F. Bancroft. The map-area lies near Invermere, on the Kootenay Central branch of the Canadian Pacific railway. It comprises 700 square miles of territory in which lead-silver ore has been found and mined, and its geology is an essential link in the geological study of southeastern British Columbia. A geological map on a scale of 1 inch to 2 miles and a memoir descriptive of the geology and mineral deposits are now in course of publication.

M. E. Hurst. Mr. Hurst examined in detail various deposits of arsenical ores in British Columbia which had not previously been examined by other officers of the Geological Survey, or which required re-examination. In 1923 Mr. Hurst dealt in like manner with eastern Canada, with the intention of preparing a report upon the occurrences of arsenic throughout Canada. This investigation is now complete and the report is being prepared.

C. H. Crickmay. Mr. Crickmay made a detailed investigation of the geology in the vicinity of Harrison lake, southwestern British Columbia. He paid special attention to the matter of obtaining palæontological evidence of the age of the strata. Laboratory investigations upon the materials collected are now being conducted at Stanford university.

Topographical

A. C. T. SHEPPARD. Mr. Sheppard carried out the phototopographical surveys necessary for the completion of a map-area in West Kootenay, B.C., lying between latitudes 49° 45′ and 50° 00′ and longitudes 117° 00′ and 117° 30′. The total area is 386 square miles and includes New Denver, Silverton, Slocan City, and Sandon. The scale of work was 3,000 feet to 1 inch, with a contour interval of 200 feet.

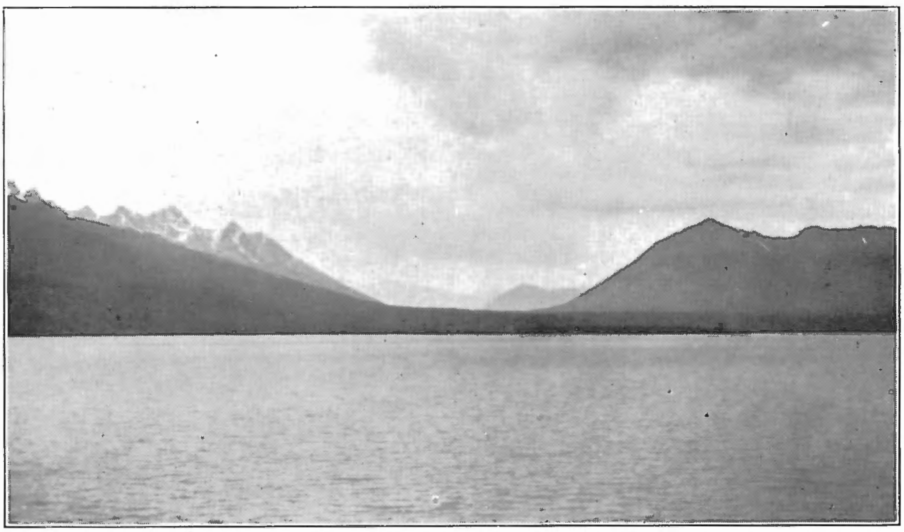
A secondary triangulation control was carried down Kootenay valley and connected to the International Boundary line, 49th parallel. Connexion was also made to the astronomical station at Proctor, B.C.

In all, forty-eight stations were permanently marked on the ground and the positions of these in latitude and longitude determined. These marks are to serve as a base for future geological work in the valley and for the use of the Provincial Government in their work. A complete list of these stations, with their descriptions and geographic positions, has been furnished to the Surveyor General of British Columbia and the topographical maps are being prepared.

J. A. MACDONALD. J. A. Macdonald, junior topographical engineer, had charge of a sub-party on the phototopographical work.

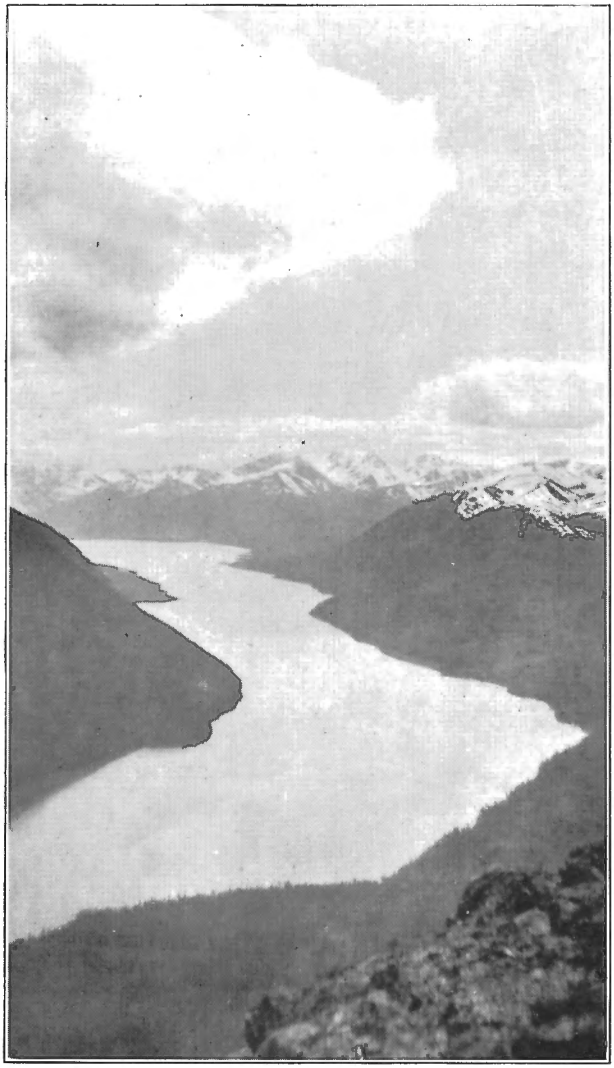
D. A. NICHOLS. Mr. Nichols topographically surveyed an area of 190 square miles at Kamloops, B.C., lying between latitudes 50° 30′ and 54° 45′, and longitudes 120° 15′ to 120° 30′. The map-area was mapped on the scale of 3,000 feet to 1 inch, with a contour interval of 100 feet. Plane-table methods were used, controlled by triangulation. Besides the town of Kamloops, the area contains mineral properties and physiographic features of interest.

A. View along Silver hill looking north. (Page 9.)



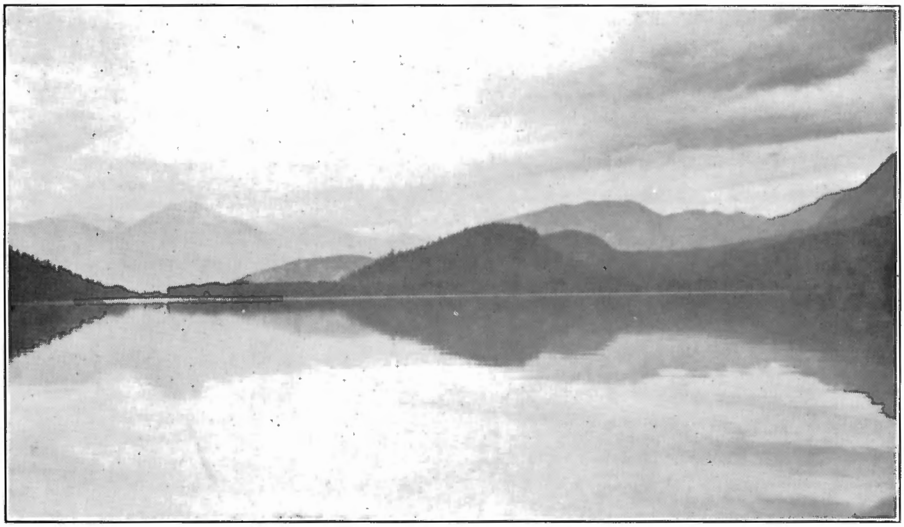
B. Nemaia valley, west of Chilko lake. (Page 62.)

PLATE II

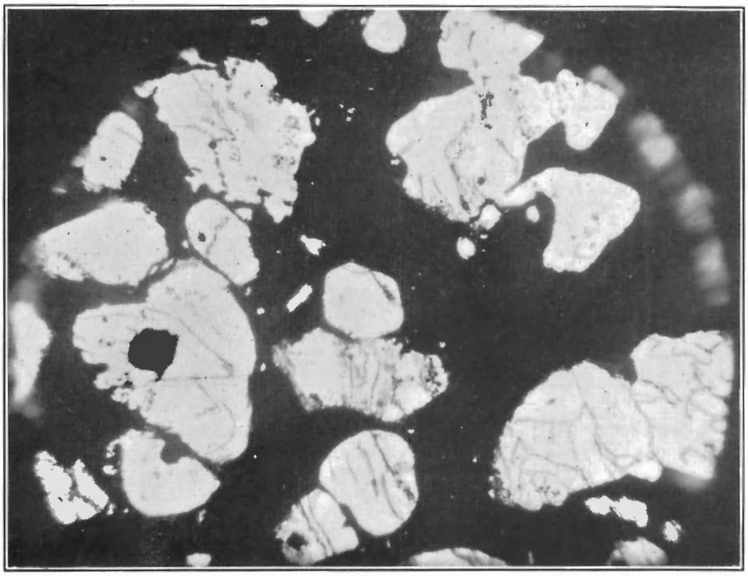


Chilko lake, looking south from mount Tullin. (Page 62.)

PLATE III

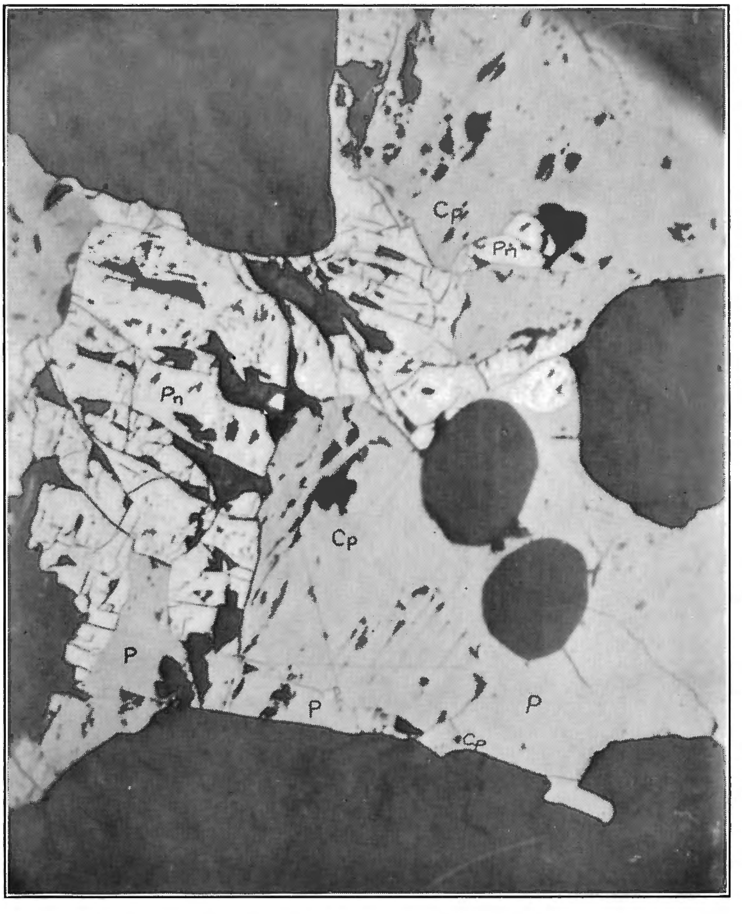


A. View of the head of Lillooet lake. Lillooet river enters on the left. The low pass on the right, known as Pemberton portage, is traversed by a wagon road leading to the Pacific Great Eastern railway about 5 miles distant from the head of the lake. In line with this pass is the valley of Owl creek. (Pages 83, 89.)



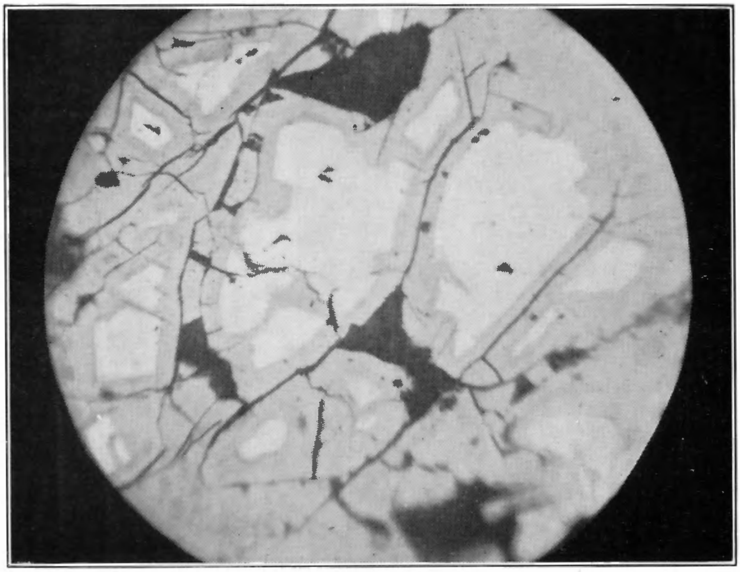
B. Corroded crystals of hypersthene (white) surrounded by sulphide minerals (black). X 80. (Page 103.)

PLATE IV



Crystals of hypersthene (black) corroded by sulphides; pentlandite (Pn) corroded and replaced by chalcopyrite (Cp) and pyrrhotite (P). X 84. (Page 104.)

PLATE V



Pentlandite showing development of unknown secondary mineral along lines of fracture and cleavage. X 280. (Page 105.)

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The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are three parts, A, B, and C. A review of the work of the Geological Survey for the year forms part of the Annual Report of the Department of Mines.