CANADA
DEPARTMENT OF MINES
HON. CHARLES STEWART, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1923, Part A

CONTENTS

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1924

No. 2031

SUMMARY REPORT, 1923, PART A

GEOLOGY AND ORE DEPOSITS OF KENO HILL, MAYO DISTRICT, YUKON

By W. E. Cockfield

CONTENTS

Illustrations

INTRODUCTION

Silver-lead ore deposits were discovered at Keno hill in July, 1919, by L. Beauvet. Almost immediately the Yukon Gold Company, Limited, secured options of purchase on the original claims, and as a result a stampede to the hill took place. Over 500 claims were located in the next few months and this number has since been very materially increased. During the winter of 1919-20 the Yukon Gold Company prospected their holdings and secured options on a number of other claims. In 1920, a subsidiary company, Keno Hill, Limited, was formed to operate the original group, and the entire holdings of the parent company have since been turned over to this subsidiary.

Ore shipments from Keno hill commenced during the winter of 1920-21, and the tonnage shipped has increased in each succeeding winter. In 1921, the Sadie-Friendship vein was discovered and has since proved of such importance that its production will soon surpass that of the original discovery. The Yukon Gold Company acquired the Sadie and Friendship claims and the Treadwell Yukon Company, Limited, secured a group of claims on the northern extension of the same vein. A third company, Onek Mining Company, Limited, also entered the field in 1921, securing options on a number of claims scattered over the hill; but in 1922 this company suspended operations, and has not since renewed them.

The writer wishes to express his thanks for the many favours and courtesies received while engaged on the examination of the deposits. Particular thanks are due to Messrs. Livingston Wernecke and W. B. Hargreaves, of Treadwell Yukon Company, and to Messrs. F. R. Short and A. K. Schellinger, of Keno Hill, Limited, for information without which the compilation of this report would have been impossible.

A. H. Bell, C. R. Stockwell, C. S. Evans, and H. T. Ellis acted as assistants.

LOCATION

Mayo is situated 180 miles up Stewart river, one of the main tributaries of Yukon river, which it enters 72 miles above Dawson. Mayo serves as a business centre for the surrounding district to which it gives its name. From June until October the White Pass and Yukon Route maintains a regular steamer service on Yukon and Stewart rivers, in connexion with their railway service from the coast to Whitehorse. In winter, Mayo can be reached by mail stage either from Whitehorse or Dawson.

Keno hill is 40 miles northeast of Mayo. A good wagon road to it has been constructed by the Yukon government from Mayo and the journey may be made in a few hours by automobile. Telephone communication has been established between the mines and Mayo, and the Federal government has recently established wireless stations at Mayo and Dawson, thus connecting Mayo with outside points by means of the Yukon Telegraph line.

Hitherto, practically all haulage in Mayo district has been done by horse-drawn vehicles, chiefly in the winter time, when the roads were at their best. During the winter of 1922-23, however, the Treadwell Yukon Company introduced caterpillar tractors and reduced the cost of haulage about two-thirds. As the previous cost of hauling ore to Mayo had been nearly half the cost of shipping from mine to smelter, the saving is important.

TOPOGRAPHY

Mayo district lies within Yukon plateau. The hills are prevailingly flat-topped and separated by broad, deep valleys. Keno hill is a typical wedge-shaped ridge, lying between Lightning, Christal, Faith, and Ladue creeks. It is 10 miles long by 6 miles wide at the western end, tapering to the east, and is surmounted by five hillocks locally known as Keno, Minto, Monument, Caribou, and Beauvet, which rise a few hundred feet above the general level. The northern slope of the hill is steep, but is broken by a series of benches, representing the outcrops of harder formations. The southern slope is more gentle, being controlled to some extent by the dip of the strata.

GENERAL GEOLOGY

The greater part of Mayo district is underlain by schists, which are intruded by sills and laccoliths of greenstone, and by dykes and sills of granite porphyry and quartz porphyry. Keno hill lies within this schist belt, and consequently the rocks outcropping are those enumerated above. The schist series consists of quartzite, quartz-mica schist, graphite schist, sericite and chlorite schist. The greenstones intruding this schist series are themselves largely sheared and altered. The quartz and granite porphyries are massive and fresh in appearance and are believed to be offshoots from a granite mass which outcrops some miles to the east, and which probably extends under a considerable part of Mayo district.

The quartzite, quartz-mica schist, and graphite schist are believed to belong to the Nasina series, described by McConnell in his report on Klondike district. This series has been referred by Cairnes to the Precambrian. In the type sections the rocks consist of alternating bands of blue and white, thinly laminated quartzites, that pass gradually into dark grey quartz-mica schists, and finally into black, graphite schists. In the Keno Hill area, however, the quartzites as a rule are more blocky and homogeneous than is the case in Klondike region. Under the microscope the minerals present are seen to be the same in all cases, but to vary in abundance according to the type of rock. Quartz, the most abundant constituent, appears as a fine mosaic of grains, in some cases highly granulated, in others with sutured texture showing recrystallization. A subordinate amount of feldspar is associated with the quartz. The micas, biotite, and sericite are arranged in parallel bands, or sweep in a series of waves through the granulated mass of quartz and feldspar. Chlorite, calcite, magnetite, pyrite, and graphite are also present, the last named becoming locally abundant enough to form a graphite schist. In many cases, however, graphite is most abundant along the planes of schistosity. This series represents a great thickness of siliceous and argillaceous sediments now altered into quartzites, quartz-mica, and graphite schists.

The sericite and chlorite schists are present only in minor amounts. The sericite schist has been recognized only on the first and third levels of Treadwell Yukon Company's workings, where it is intrusive into the quartzites, and the chlorite schist on the Lake group. Under the microscope these rocks were seen to consist mainly of varying amounts of quartz and feldspar, sericite, and chlorite, with numerous accessory and secondary constituents. All the specimens examined are fine grained and highly altered. These rocks are believed to be similar to McConnell's Klondike series, which consists of altered acid and intermediate volcanics.

The rocks included under the field name of greenstone occur as sills and laccoliths throughout the area. They are frequently sheared and altered, and now consist of secondary minerals to such an extent that it is difficult to determine their original composition. They are dense, green, medium-grained to aphanitic rocks. In spite of their alteration they are more resistant than the schistose rocks, and consequently project above the surrounding surface (Figure 3). Microscopically, the rocks are seen to consist largely of hornblende, or augite and feldspar. In some of the specimens examined the hornblende was quite fresh, but most of it is altered to chlorite. Calcite is also a common secondary constituent. The commoner variety is porphyritic, and in this type the alteration to secondary minerals is as a rule complete. The coarser-grained varieties are hornblende diorites and augite diorites.

The quartz and granite porphyries occur as dykes and thin sills. They are light-coloured to white rocks of massive appearance, showing crystals of quartz and feldspar. An important feature of these rocks is that they contain particles of the minerals of the ore-bodies, such as pyrite, galena, and occasionally tetrahedrite. These are commonest along joint-planes, but occur, also, in the body of the rock. The phenocrysts consist of corroded quartz and orthoclase in a microfelsitic to microgranitic groundmass of quartz, feldspar, and muscovite.

The greater part of the surface of Keno Hill area is covered with soil, talus, muck, boulder clay, and vegetation. Rock outcrops are not numerous and these belong chiefly to the harder formations, such as quartzite and greenstone. The covering of superficial deposits renders prospecting difficult, as it is commonly frozen down to bedrock, and the thawing in summer is relatively shallow. Much prospecting has been done in the past by using snow water in the spring for ground-sluicing. It is possible that further discoveries will be made on Keno hill as more prospecting is done, either of new veins, or along the extension of veins already known to exist.

ORE DEPOSITS

The ore deposits of Keno Hill area are practically all fissure veins, that is, they represent vein material deposited in fault fissures. The faults which gave rise to these veins are all of the normal type, and this applies also to post-mineral faults. No reverse faults have been recognized. The displacement is as a rule small and the maximum horizontal displacement noted is 500 feet.

The veins may be divided into two classes, which in an earlier report[1] were termed longitudinal and transverse, depending on whether they follow the trend of the strata or cut across the strata. These two fault systems represent two stages of mineralization, the longitudinal faults being the earlier. In general, these strike north 30 to 40 degrees east magnetic, and the transverse faults make an angle of 70 to 80 degrees with them. There is, however, considerable variation in direction of the faults in different parts of the area, and mineralization rather than direction is the criterion to determine to which class a vein belongs.

The strata in the area have a general east-west trend, but near the hillock known as Monument hill the beds bend sharply to the south and continue southward across Lightning creek where they gradually resume their former direction. It is believed that the transverse faulting is directly attributable to this flexure, owing to the bending of resistant beds such as quartzite and greenstone. The origin of the longitudinal faults has not been satisfactorily solved; they may, however, be due to stresses developed at the time of intrusion of the granite mass referred to before.

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

[1] Cockfield, W. E., Geol. Surv., Can., Sum. Rept., 1920, pt. A, pp. 3-4.

PRODUCTION

The following table gives the total production of Keno hill, and estimated values of silver and lead. Tonnage figures are those published by the collector of customs, Dawson; the values are estimated, as in some cases the smelter returns are not available. It is expected that the output for 1923-24 will equal that of 1922-23.

Production and Estimated Values of Silver and Lead from Keno Hill

Year	Tons	Value, silver	Value, lead	Total value
		$	$	$
1920–21	2,102	218,395	100,900	319,295
1921–22	3,231	471,320	197,770	669,000
1922–23	7,982	1,056,902	379,253	1,436,155
Totals	13,315	1,746,527	677,923	2,424,450

MINERALOGY OF THE ORE DEPOSITS

The following ore and gangue minerals have been identified from the Keno Hill deposits.

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

Argentite (Ag_2S) inuncommon. It has been noted as small microscopic enclosed in masses of cerussite. It is of local occurrence and not disseminated through the deposits.

Argentite (Ag_2S) is uncommon. It has been noted as small microscopic crystals occurring with galena.

Galena (PbS) is one of the most important minerals and was found in every deposit examined. It is commonly coarsely-crystalline and not intimately intergrown with the other ore or gangue minerals. The coarse galena has a gneissoid appearance. The fine-grained, steel galena is somewhat rare, but carries average values in silver.

Sphalerite (ZnS) occurs in most of the deposits. It is yellowish brown and resinous in appearance.

Covellite (CuS) is very rare. A few small particles were noted in ore from No. 9 vein, Keno Hill, Limited.

Chalcopyrite ($CuFeS_2$) is not common and where found is as a rule intimately associated with galena.

Pyrite (FeS_2) is fairly abundant, occurring both with arsenopyrite and with galena.

Arsenopyrite (FeAsS) occurs with quartz and pyrite in veins of the older series.

Pyrargyrite or ruby silver (Ag_3SbS_3) is rare. It occurs with freibergite and galena, and was noted only in a few of the deposits, where it is of local occurrence and not disseminated through the deposit. It is believed to be secondary in origin.

Freibergite ($(CuAg)_8 Sb_2S_7$) is common and is one of the chief silver minerals of the area. Where this mineral is present even in small quantities the silver content of the ore is increased. It is associated with siderite, galena, and sphalerite.

Polybasite (Ag_9SbS_6) is rare and was noted only in the microscopic study of specimens from the Gold Queen. It is believed to be secondary.

Jamesonite ($2PbS, Sb_2S_3$) is rare, but was noted in several veins on the top and southern slope of the hill. This mineral may possibly belong to the quartz-arsenopyrite stage of mineralization.

Quartz (SiO_2) is common as a gangue mineral, particularly in veins of the earlier mineralization, though not confined to these. It is rarely coarsely crystalline.

Limonite ($2Fe_2O_3, 3H_2O$) and *Manganite* (Mn_2O_3, H_2O) are abundant in the oxidized material at the surface of the deposits. The latter is believed to be derived from the siderite, and the black "manganese" stain is a common, and as a rule a good, indication of a vein lying not far beneath, and has been used in tracing some of the veins.

Siderite ($FeCO_3$), or its equivalent mangano-siderite ($(MnFe) CO_3$), is the most abundant gangue mineral of the deposits. Near the surface it is black to dark brown in colour, but with depth invariably changes to white or light brown. It is mostly fine in grain, but many coarsely-crystalline masses were noted. Siderite is nearly always accompanied by freibergite, galena, and sphalerite.

Calcite ($CaCO_3$) is not common as a gangue mineral and is mostly associated with siderite.

Cerussite ($PbCO_3$) is not common and is confined to within a few feet of the surface. It occurs as a rule in white, earthy masses.

Malachite ($CuCO_3Cu(OH)_2$) and *Azurite* ($2CuCO_3Cu(OH)_2$) occur as oxidation products only at the surface.

Barite ($BaSO_4$) is rare as a gangue mineral, having been noted at a few points only.

Location of Ore-Shoots. In a former report the rule was enunciated that where a transverse vein intersects a longitudinal vein and passes upward from a hard rock such as quartzite or greenstone, into schist, the vein below the schist is an extremely favourable location for the formation of an ore-shoot. This is most probably due to the fact that the fissure through the harder rocks remained relatively open to the ore-bearing solutions, whereas in the schist the fault was more or less sealed by a clayey impervious gouge, forming a dam which forced deposition below it. This rule, though not absolute, has been proven in practice; the ore-shoot on No. 9 vein, Keno Hill, Limited (Figures 1 and 2), and on No. 3 vein of the same company, may be cited as examples. It cannot, however, be affirmed that the schist is always barren of ore, for ore-bodies are known

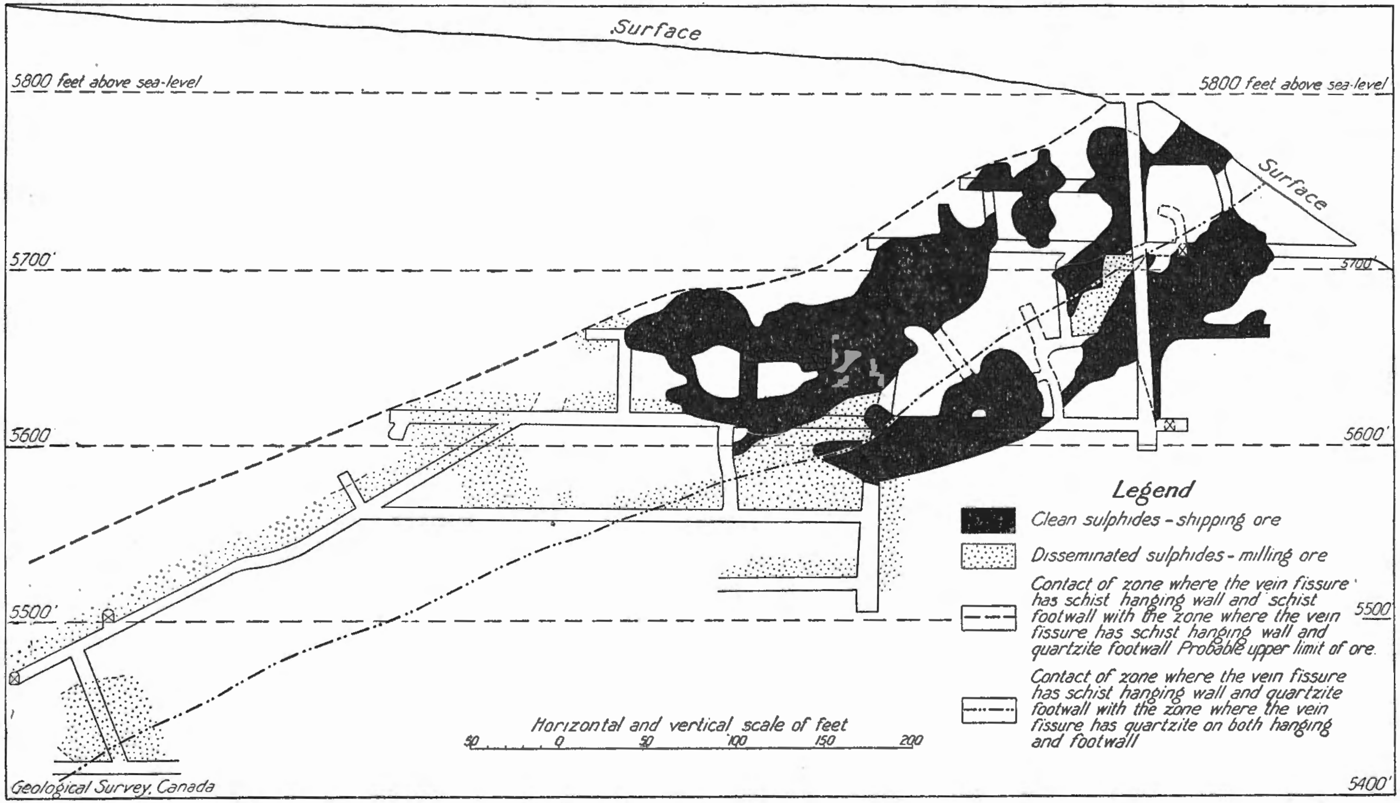


FIGURE 1. Projection on a vertical plane of vein No. 9, Keno Hill, Limited, showing occurrence of ore-shoots.

to occur in it; but the rule given will be found to apply in a majority of cases to the transverse veins.

In the longitudinal veins, the causes of localization of ore-shoots are not so well understood, but in many cases the occurrence of black graphite schist along either wall of the fault is accompanied by ore.

GENESIS

By far the greater number of veins on Keno hill represent a simple filling of fault fissures. Replacement of wall-rock operated only to a slight extent, except in the Sadie-Treadwell vein. The ore minerals in most cases are fastened to the polished walls of the fault fissures, but do not project into them. It is not believed, however, that at the time of mineralization the faults existed as open fissures 4 to 6, or more, feet wide, but rather that the small openings formed by the faults grew in width as the ore minerals were deposited. It has been demonstrated that the force exerted by a crystal in growing is equal to that required to crush it when formed.[1] Whether this force was active, or whether the force exerted by the mineralizing solutions was sufficient to open the fissures, is unknown.

In certain cases there is evidence of solution of the wall-rock. This is shown in No. 9 vein of Keno Hill, Limited, where large, drusy cavities lined with crystals of siderite and galena occur in the foot-wall. Replacement of wall-rock occurs in the Sadie-Treadwell vein, which presents many characters not exhibited in the other veins of the area. This vein, or rather "mineral zone", follows an old line of weakness represented by quartz-arsenopyrite veins. It was probably re-opened by a fault which branches frequently and reunites, with cross-faults between the main fractures. The country rock in the vicinity was badly shattered and the jointing emphasized, and the ore-bearing solutions penetrated each minute crack, widening it, and, in places, replacing the country rock. In places the mineral zone is a network of tiny veinlets of siderite enclosing fragments of country rock. As a rule these fragments lie in their original positions, but in certain instances the particles of rock were rotated. These veinlets represent on a small scale what has taken place on a large scale. Veins of ore project out into the country rock, in many cases at right angles to the main trend of the ore zone. Examination of thin sections has shown that these veins grew by replacement of the country rock. Fragments of quartzite or residual masses of granulated quartz and feldspar are included in siderite. In some cases, also, individual grains of quartz are seen with siderite projecting into them. It is consequently believed that the Sadie-Treadwell ore zone represents a fault complex along which the deposit grew by widening of fissures as the minerals were deposited, and by replacement.

Source of Mineralizing Solutions

The veins in Keno Hill area traverse quartzite schists and greenstone alike. The greenstones must, therefore, have been consolidated sufficiently to permit of fracturing at or before the time of mineralization. Moreover, the greenstone bodies by reason of their small size would be unlikely to

[1] Becker, G. F., and Daly, A. L., "The Linear Force of Growing Crystals," Wash. Acad. Sci. Proc., vol. 7, 1905, pp. 283-288.

hold solutions for long periods, particularly after the development of the faults. The acid dyke rocks carry small amounts of galena, pyrite, and tetrahedrite. As these were not injected until long after the greenstones were consolidated, and even sheared, it is doubtful if the greenstones had any effect on their mineralization.

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

Secondary Enrichment

The term primary is here applied to deposits which have not been changed in chemical or mineralogical composition by superficial agencies; and secondary to deposits formed by the action of superficial agencies on primary ores. The evidence as to primary or secondary origin may be divided into two main heads: (*a*) geological, (*b*) mineralogical and textural.

Geological Evidence. In northern latitudes large bodies of secondary ores are not common, as low temperatures retard chemical activity, and freezing prevents solution. Climates have, however, undergone great changes in geologic times, and it does not follow because the processes of weathering are now inactive in any district that they have always been so. Deposits of secondary origin are, however, rare in Canada and Alaska, though there are important exceptions such as the St. Eugene mine[1], and the Premier and Dolly Varden.[2] In Yukon, a zone of permanent frost extends practically from the surface down to varying depths. The workings of Keno Hill, Limited, on No. 9 vein, at a depth of 400 feet were still in frost; on the other hand Treadwell Yukon Company reached unfrozen ground between the 200 and 300-foot levels. This frozen zone forms an exceptional barrier to the processes of weathering and as it is believed to date back to the Pleistocene,[3] it follows that any secondary deposits must antedate glaciation, with the likelihood of their removal by glacial erosion. In considering the geological evidence it is, therefore, well to deal with those deposits where the workings exhibit the greatest vertical section of ore. These may be considered under two types, the massive galena deposits as exemplified by No. 9 vein, and the galena-siderite-freibergite type, of which Treadwell Yukon Company's vein may be considered typical.

---

[1] Schofield, S. J., Geol. Surv., Can., Sum. Rept., 1911, pp. 158-164. Econ. Geol., vol. 7, pp. 351-363, 1912.

[2] Schofield, S. J., and Hanson, G., Geol. Surv., Can., Mem. 132, 1922, pp. 39-42.
Hanson, G., Can. Min. Inst. Bull., Aug. 1922, pp. 892-895.

[3] Tyrrell, J. B., "The Frozen Muck of the Klondike district," Trans. Roy. Soc., Can., vol. XI, ser. III, sec. IV, 1917, pp. 39-46.

The rapid exhaustion of rich shipping ore in No. 9 vein might at first sight seem to imply secondary enrichment. However, the location of the ore-shoots is controlled by a bed of schist near the present surface that acted as a dam to the mineralizing solutions, and the maximum load was deposited in the fissure close to the dam. Continuing downward is a body of disseminated ore. The drop in values is largely due to inclusion of crushed country rock and gangue minerals in the vein, both of which occur sparingly in the upper workings. Assays of clean galena from the lower workings show nearly as high a silver content as that from the upper workings. In the second place post mineral fractures, though rare, do occur in this vein, but there is no evidence of circulation along such channels, which must have been good conduits for downward-moving waters, and no evidence of enrichment in their vicinity.

In the Treadwell Yukon vein, the controlling factors of deposition have not yet been recognized. Consequently the relationship of this deposit to the present surface is not so well understood. It has suffered from intense post-mineral faulting, both longitudinal and transverse to the ore-body, which is cut up into a series of fault blocks. These faults would serve as excellent channels for downward-circulating waters, and along them one would expect to find secondary deposition if any is present, but there is no sign of any.

Mineralogical and Textural Evidence. The important minerals of the Keno Hill deposits are galena, freibergite, siderite, and zinc blende. These are usually considered to be primary minerals. Emmons states that galena is primary[1] and siderite usually so. Of the latter he says[2] " siderite.. .. .. ..is found in the gangue of deposits formed at moderate depths by hot ascending water. High temperatures are not necessary for its genesis, however, for it is most abundant in cherty iron carbonate ores of sedimentary origin. In lode deposits siderite is in the main primary." Although certain instances of secondary tetrahedrite have been cited,[3] this mineral is in the main primary. Neither tetrahedrite nor the argentiferous variety, freibergite, has been formed synthetically under conditions that prevail in the secondary sulphide zone. Zinc blende may also be assumed to be primary in the absence of definite proof to the contrary.

Native silver, pyrargyrite, covellite, and polybasite have been found and these are all deemed secondary. Native silver occurs in vugs in the galena, and pyrargyrite as small specks probably as an alteration of freibergite. Instances of both pyrargyrite and polybasite in veinlets cutting freibergite were seen. All these secondary minerals, however, are in such small quantities that prolonged search is necessary even to secure specimens. With the exception of the instances noted, none of the common textures of secondary deposits is developed. The geological evidence and the mineralogical composition of the main ore-bodies, therefore, both point to a primary origin, and the writer is of the opinion that secondary enrichment played a relatively minor role in the formation of the deposits. From a study of the deposits, and comparisons with deposits in other districts, it is believed

1 Emmons, W. H., "The Enrichment of Ore Deposits," U.S.G.S. Bull. 625, 1917, p. 359.
2 Emmons, W. H., op. cit., p. 454.
3 Emmons, W. H., op. cit., pp. 278-280.

that they were formed at moderate depths by hot ascending solutions; that the mineralizing solutions had their origin in the magma that gave rise to the acid dykes and sills; and that changes in the ores with depth will depend upon changes in primary deposition. The deposits resemble in many ways the ores of the Slocan[1] district of British Columbia, and in some points also resemble those of Wood River district[2] of Idaho, though the resemblance to these is not so striking.

SILVER VALUES

In large shipments of ore the silver has proved to be remarkably uniformly distributed through galena when free from gangue. The shipments already made from Keno hill average very close to 200 ounces to the ton, and this may be taken as the average silver content of galena on the hill. It has been demonstrated[3] that silver may exist in galena in the form of sub-microscopic particles or in solid solution only up to 0·2 per cent. Under the microscope the Keno Hill galena shows crystals of argentite and freibergite intergrown with the galena.

DESCRIPTION OF PROPERTIES

Over a thousand claims have been staked in the vicinity of Keno hill, so that it is manifestly impossible in this report to describe every property. Certain claims or groups of claims which contain good representatives of the different types of veins on the hill have, therefore, been selected for description, especially those on which the amount of work done affords more information or which have thrown light on the genesis and mode of occurrence of the ore-bodies. There are properties not described on which veins have been located, and which future development may prove to be fully as important as some of the properties described.

KENO HILL, LIMITED

Original Group. Keno Hill, Limited, was organized in 1920 to work certain claims then held by Yukon Gold Company. The original property consisted of seven claims: Roulette, Keno, Scotty, Solo No. 2, Pinochle, Wolverine, and Reco; and a number of fractions. These claims are staked across the top of the ridge and extend into Faro gulch on one side and Charity gulch on the other. Frame buildings have been erected near the summit of the hill, and a power-line, 4 miles long, connects the property with a 100 K.W. steam-power plant on Duncan creek.

The principal veins of the original group are shown in Figure 2. These consist of two longitudinal veins, No. 1 and No. 6, and a number of transverse veins. No. 9 has been the principal producing vein, although Nos. 1, 3, 4, 5, and 12 have each contributed a small tonnage. There are adits

[1] LeRoy, O. E., Geol. Surv., Can., Sum. Rept., 1909, pp. 131-133. Ingalls, W. R., Rept. of the Zinc Commission, Ottawa, 1906, p. 238. Carlyle, W. A., Bull. No. 3, Bur. of Mines, Victoria, B.C.

[2] Lindgren, W., U.S. Geol. Surv., 20th Ann. Rept., pt. 3, pp. 218-231.

[3] Nissen, A. E., and Hoyt, S. L., "Silver in Argentiferous Galena", Econ. Geol., 1915, vol. 10, pp. 172-179.

Guild, F. N., "Microscopic Study of the Silver Ores," Econ. Geol., 1917, vol. 12, p. 306.

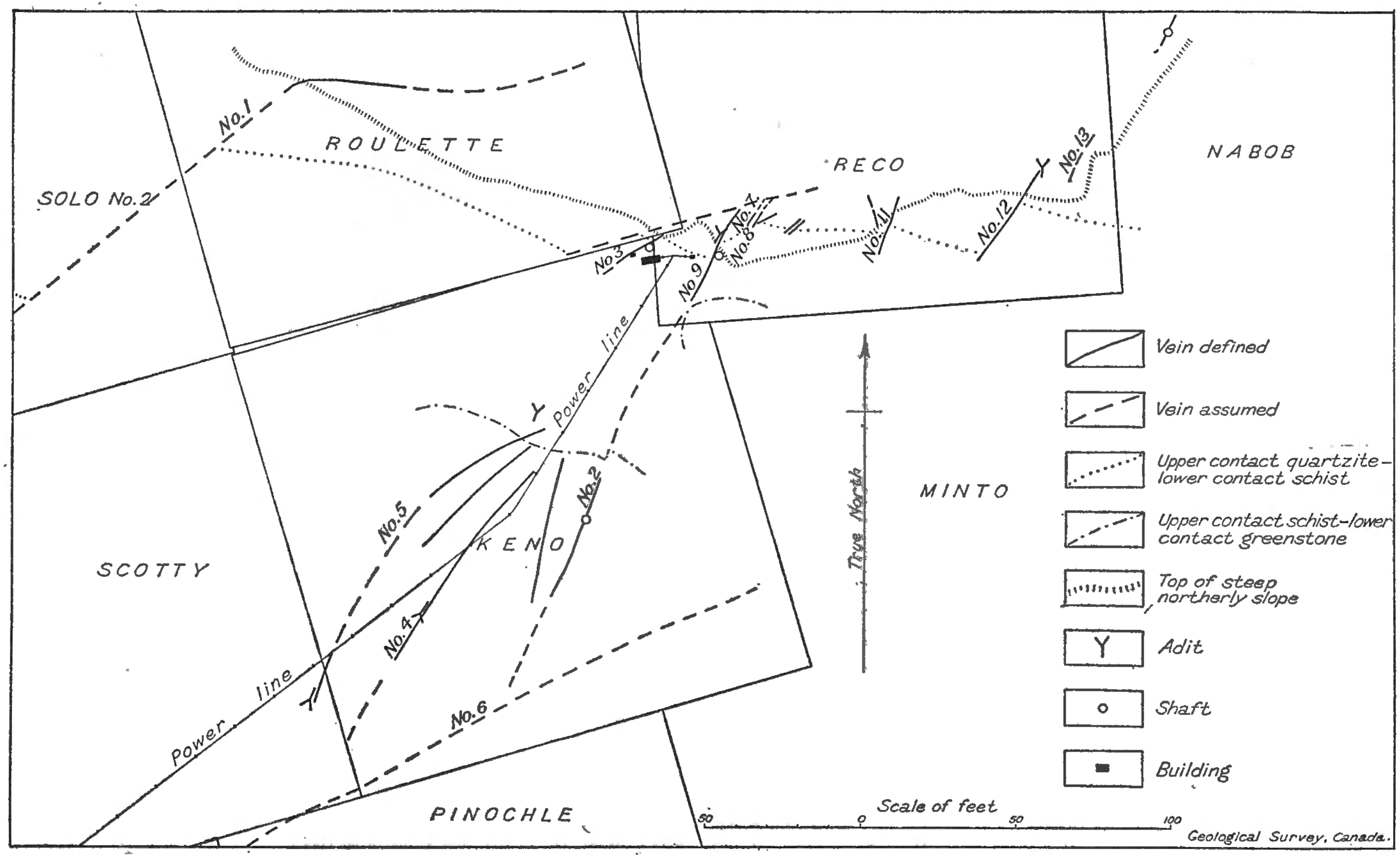


FIGURE 2. Plan of part of the original claims of Keno Hill, Limited, showing principal veins.

on each of these productive veins. On vein No. 3 a shaft has been sunk to a depth of 150 feet, with levels at 30, 75, and 150 feet. The first level is 140 feet long. It reaches the surface on the steep slope of Faro gulch and forms an adit. The second level is 180 feet long, and is connected with the first by a winze with an intermediate level. This winze also connects the second and third levels. Five small ore-shoots were encountered in these workings. The only one of considerable size extended from the surface down slightly below the first level. It was 40 feet long and pitched to the south, following the zone where the vein fissure has schist on both hanging and foot-wall. Other smaller ore-shoots occurred near the entrance of the adit, and near the junction of the shaft and second level. The balance of the ore found in these workings consisted of small stringers.

Vein No. 9 has produced 8,000 tons of high-grade shipping ore, averaging close to 200 ounces of silver to the ton. The ore-shoots of clean sulphides of this vein are shown in Figure 1. It will be noted that the ore is confined to the zone where the vein fissure has schist on both hanging and foot-wall. The development work is shown in the figure and need not be described. With the exception of small stringers, practically no ore of shipping grade has been discovered below the second level, although the workings have been carried to a depth of 400 feet. In the upper workings there were considerable masses of clean galena which could be shipped directly from the mine. In the lower workings the galena becomes disseminated and although high in grade will require milling before shipment. In the upper workings zinc averages 0·5 per cent, and in the lower workings from 7 per cent to 8 per cent. The possibility of other ore-shoots in this vein following the zone of schist on both walls of the fracture downward, has not been exhausted. The vein, if persistent, must also intersect a second longitudinal vein (No. 6) where chances for further ore-shoots would be increased.

Vein No. 1 has three adits, 230, 140, and 150 feet long. These are approximately 60 feet apart on the dip of the vein, and are connected by winzes. They tapped an ore-shoot 60 feet long and 14 inches thick in the upper workings, which, however, pinched out below. As this vein is one of the main fractures on the hill, having been traced across the original group and also found on the Maple Leaf claim of the Shamrock group, it is possible that other ore-shoots will be found along it. Vein No. 6, the second longitudinal vein crossing the property, is mineralized with quartz, arsenopyrite, pyrite, and jamesonite. The workings on it consist of several open-cuts. This vein carries small values in gold.

Vein No. 2 is probably the continuation of No. 9. A prospect shaft was sunk on it in 1920, but no further work was done. In veins Nos. 4, 5, and 12 small ore-shoots were encountered, but the largest ore-body in any of the veins, No. 9 excepted, proved to be less than 200 tons.

As a rule the veins on the original group had little gangue material. The ore where found was reasonably clean. More siderite was encountered in the veins in greenstone, i.e. Nos. 2, 4, 5, than in the others. Practically all the development done on the original group has been on fissures of the transverse type. These have proved to be disappointing. The ore-shoots have proved small, with the exception of No. 9 vein, and even this is small compared with deposits of a similar type in other districts.

Keno Hill, Limited, has suspended operations on the original group in order to prosecute the development of the Sadie-Treadwell vein, where the deposit gives greater assurance of permanency.

SADIE-FRIENDSHIP GROUP

This group of claims was staked in 1920 and acquired by Yukon Gold Company in 1921. It consists of the Sadie and Friendship claims (Figure 3). Prospecting showed promise of a considerable body of ore, but little work was done until the winter of 1922-23 when a camp was erected, using a small boiler plant for power. Three prospect shafts, 35, 20, and 75 feet deep, were put down following the dip of the vein. From a short level close to the surface 360 tons of ore were extracted. The workings were allowed to fill with water, and work was suspended for the summer. With the closing of the workings on the original group electric power from the plant on Duncan creek became available. Buildings were erected, and a new shaft is now being sunk to a depth of 200 feet with crosscuts to the vein at 65, 130, and 200 feet.

The workings were flooded at the time of the writer's visit, so an examination of the property could not be completed. The vein (Figure 3) as traced by shafts and open-cuts is apparently the same as that worked by Treadwell Yukon Company. From its course it is apparently faulted a number of times, but this could not be definitely established otherwise than by the offset of the vein, as the surface is everywhere covered with soil and vegetation, and the only outcrops are a few bodies of greenstone. It is considered likely that the faulting shown in the Treadwell Yukon Company's workings continues into this property. The extension of this vein to the south of the Sadie property has not yet been found. This is probably due to faulting, and it will be noted from Figure 3 that the vein is offset each time toward the west.

LUCKY QUEEN

Amongst the claims being prospected by Keno Hill, Limited, is the Lucky Queen owned by H. Morrison. It is situated on Gambler gulch, on the northern slope of the hill. The workings consist of two short adits, and a winze 40 feet deep, but these were inaccessible in the summer of 1923 owing to caving. The information with regard to the property was furnished by A. K. Schellinger, engineer in charge of operations for Keno Hill, Limited.

The vein is about 2 feet wide and is composed largely of crushed country rock, cemented with quartz carrying freibergite. The freibergite occurs as stringers in the quartz, possibly 5 or 6 feet long and 1 or 2 inches in thickness. These stringers also penetrate the wall-rock. Near the winze is a cross-fissure carrying galena. During 1922-23, the company took out 20 tons of ore averaging about 200 ounces to the ton. Included in this shipment were seven sacks of selected ore averaging 700 ounces of silver to the ton.

The type of mineralization, i.e. quartz and freibergite, is unusual on Keno hill, and is exhibited only at a few points such as the Stone claim

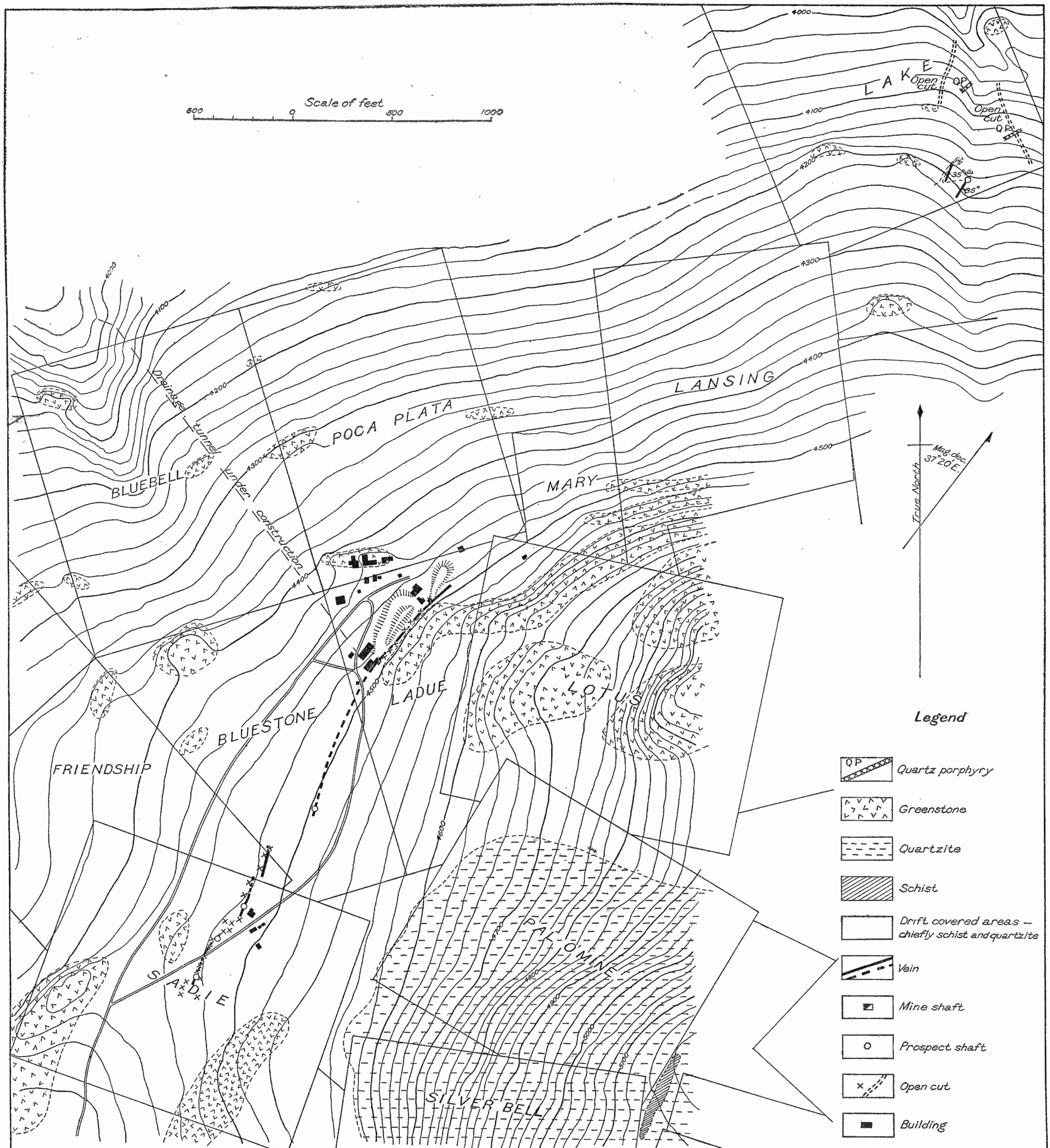


FIGURE 3. Sadie-Friendship and Treadwell properties and adjoining claims, Keno hill. Geology from information supplied by L. Wernecke of the Treadwell Yukon Co., Ltd., the Keno Hill, Ltd., and from surveys by W. E. Cockfield, 1923. Topography by the Treadwell Yukon Co., Ltd.; claim surveys by H. G. Dickson, D.L.S.

and the Lucky Queen. The reasons for the difference from the ordinary siderite-freibergite type are not apparent.

TREADWELL YUKON COMPANY, LIMITED

This company in 1921 acquired a number of claims on the western slope of the hill, adjoining the Sadie-Friendship group. The chief holdings include the Bluestone, Ladue, Lotus, Mary, Lansing, Bluebell, Poca Plata, Tunnel, Travice, and Silver Bell claims, and a number of fractions (Figure 3).

The workings are situated on the northern extension of the Sadie-Friendship vein, at an elevation of 4,500 feet. Three shafts have been sunk. No. 1 and No. 2, which attain depths of 280 and 175 feet respectively, are on the Ladue claim and about 400 feet apart. No. 3 is a prospect shaft on the Bluestone, which has been temporarily abandoned. Levels known as the 50, 100, and 200-foot have been driven connecting No. 1 and No. 2 shafts at depths of 50, 90, and 160 feet and the 300-foot level is being driven both north and south from No. 1 shaft. In addition, a drainage tunnel 3,000 feet in length is being driven to tap the vein at a depth of 500 feet. Comfortable buildings have been erected and the property is fully equipped with all the necessary mining machinery. Power is obtained chiefly by gasoline engines, but one Diesel engine has been installed and steam-power is also being used.

The ore is deposited along a shear zone, consisting of a fault which branches and reunites, with cross-faults at varying angles between the main faults. This faulting shattered the country rock, and possibly also emphasized the jointing. The ore-bearing solutions filled the fissures and penetrated the country rock along all available openings, so that in places the country rock is cut by a reticulating series of veinlets of siderite. The growth of the ore-bodies along the openings is due in part to the replacement of country rock. The ore minerals are irregularly distributed. In many places they are sufficiently concentrated to permit of handsorting to a grade that can be shipped, in others concentration will be required. With the establishment of a concentrating mill on the property it is likely that the whole deposit will prove workable, and the cost of mining will be reduced by lessening the amount of development necessary at present to extract the shoots of clean ore.

Stopes have been started on the 50 and 100-foot levels. During the winter of 1922-23 the company shipped approximately 4,000 tons of ore, and a shipment of 6,000 to 7,000 tons is expected this winter.

Similar ore was found in the prospect shaft on the Bluestone claim, but this has not yet been developed. On the Lansing claim float from the same vein has been discovered. The total distance from the Sadie claim to the Ladue claim over which the vein has actually been traced is 2,200 feet; and it is extremely likely that prospecting will show it to continue farther north and south. The deepest workings at present are 280 feet, and the ore at that point is as high in grade as at the surface. As pointed out before, the evidence is in favour of primary deposition, and consequently much greater depths may be attained. Production from this source may be expected for some years to come.

LAKE GROUP

The Lake group consists of three claims, Lake Nos. 1, 2, and 3, staked in an easterly direction from the northeast corner of the Lansing claim. These claims are owned by A. Hollenbeck, D. Cunningham, and R. Stewart.

Development work is practically all confined to the Lake No. 1 adjoining the Lansing claim, and consists of a shaft and a series of ditches used for ground-sluicing and a number of open-cuts. Float has been discovered at a number of points, but the main work has been confined to two veins (Figure 3) occurring close to the southern boundary of the property.

The southern vein outcrops 100 feet from the boundary of the property, and strikes north 27 degrees east astronomic and dips 35 degrees to the southeast. It is 5 feet wide, and is mineralized with siderite, quartz, galena, chalcopyrite, freibergite, pyrite, and zinc blende. A shaft was sunk 15 feet, but sinking had to be suspended on account of the flow of surface water. Further work will be done this winter. To the west of the shaft the vein is cut by a southeasterly dipping normal fault of small displacement.

The second showing lies 150 feet to the north of the shaft and consists of a shear zone in schist, nearly parallel to the vein at the shaft. A short open-cut has been driven along the vein, which exhibits mineralization similar to that of the southern vein.

Galena float presumably from one of these veins was found in the open-cut near the eastern edge of the claim, but bedrock had not been reached. Further float has been discovered close to the centre line of the claim in the creek bed, and it is considered likely that an important vein crosses close to this point.

The veins exposed near the southern boundary of the property may possibly represent the northerly extension of the Sadie-Treadwell vein. This cannot be ascertained at present, as the surface of the intervening area is everywhere covered with drift, talus, and vegetation; moreover the area sustained considerable post-mineral faulting which in itself would render the course of the vein uncertain. The veins exposed are promising, and further work should be done both on these and on the opening of other veins indicated by float.

ONEK MINING COMPANY, LIMITED

The Onek Mining Company, Limited, was organized in 1922 to secure options on a number of claims in the Keno Hill area. This company was under the control of the Slate Creek Mining Company. A number of claims were prospected, but the chief work was done on a group, the Fisher, Lone Star, Galena Farm, and Rando (Figure 4), situated on the southern and western slope of the hill close to Keno Hill townsite. Operations were discontinued in 1922 and have not since been resumed.

A vein has been traced by means of a number of open-cuts across the Fisher, Lone Star, and part of the Galena Farm claims. On the Lone Star claim it is faulted about 100 feet to the north as shown by the line of open-cuts (Figure 4). The underground workings consist of a vertical shaft 135 feet deep and two levels at 50 and 100 feet, which are 30 and 97 feet long respectively. The vein gives evidence of continuity on the surface and there is no evidence of change in mineralization to the depth that workings have been carried. The mineralization consists of siderite, galena, and lead carbonate. A fairly persistent streak of galena varying from 2 to 20 inches in thickness is exposed in the workings. The values shown by a number of assays range around 80 ounces of silver to the ton. On the 50-foot level the galena averaged 80 ounces of silver; on the 100-foot level assays across a face of 12 inches yielded as high as 140 ounces. In the bottom of the shaft across a face of 8 inches the galena assayed as high as 165 ounces. On the

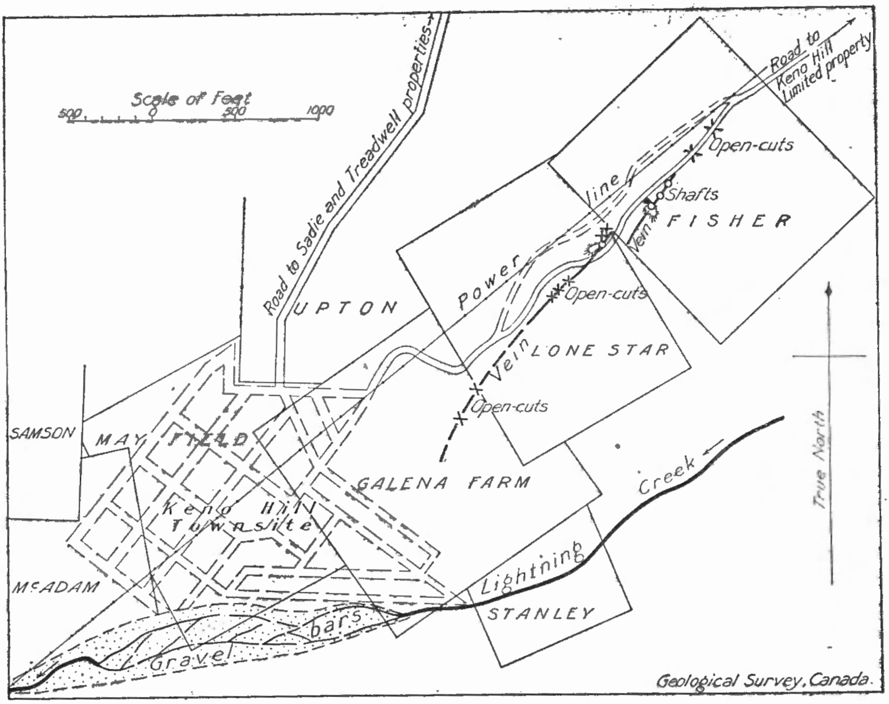


FIGURE 4. Claims of Onek Mining Company, Limited, and adjoining claims.

50-foot level the galena averages 20 inches in thickness; on the 100-foot level it varies from 3 inches up to 20 inches, and between the 100-foot level and the bottom of the shaft the vein flattens somewhat, and splits into two branches; the northern branch gave the assay referred to above, whereas the south branch has 4 to 5 inches of galena assaying 6 to 10 ounces. The values contained in the galena on this property are considerably lower than the average of the shipping ore from other properties which are shipping.

Onek Mining Company, Limited, also prospected a number of other claims, but the workings on these are not so extensive as on this group, and in many cases consisted only of representation work.

GAMBLER GROUP

The Gambler group is situated in the basin at the head of Faro gulch and consists of four claims, the Gambler, Lakeview, Madge, and Lost

Chord, owned by A. Lamb, A. R. Thompson, C. Suttlemier, and A. H. Dever. The Gambler and Lakeview claims have been surveyed.

One of the main longitudinal veins of the area crosses this property. It has been found at intervals across the basin of Faro gulch, and probably extends much farther than it has been traced. Two adits have been driven on this vein on the Gambler claim. The upper is 50 feet above the lower and 81 feet south of it, and is 50 feet in length. An underhand stope 18 feet long and 12 feet deep is situated 18 feet from the entrance. The lower adit is 40 feet in length.

The vein, which varies in width from 4 to 6 feet, is mineralized with quartz, arsenopyrite, galena, zinc blende, freibergite, and siderite. The ore-shoot mined in the stope varied from 2 feet in width at the top to 3 feet 10 inches at the bottom. This stope yielded 53 tons of ore, about half of which assayed 230 ounces of silver and 34 per cent lead, and the remainder 135 ounces silver and 46 per cent lead. The ore in the stope is not yet exhausted. In the face of the lower adit, which lacks some 40 feet of being under the stope, is a seam of galena 16 inches thick.

Although the vein is one of the main fractures of the area it has been prospected only at one or two points. Other ore-shoots probably occur, and further prospecting should be done along this vein.

SILVER BASIN CLAIM

The Silver Basin claim is owned by R. Rasmusen and lies on the western slope of Silver Basin gulch. Development consists of one short adit and a number of open-cuts and trenches. Five veins, numbered in the order of their discovery, have been exposed in these workings. No. 1 vein is exposed in an adit which lies several hundred feet from the western boundary of the claim. It strikes north 67 degrees east astronomic and dips to the southeast at 60 degrees. The vein where exposed cuts quartzite, but a short distance above passes into schist. The mineralization is typical comprising galena, siderite, and freibergite. In running the adit a small shoot of ore was encountered which, however, was passed through. Further work on this vein is desirable, but this should not be carried into the overlying schist. No. 2 vein strikes north 74 degrees east astronomic and dips 37 degrees to the southeast. It is exposed in a small open-cut to the northeast of the adit, where it has a width of about 1 foot. The mineralization is mainly quartz and arsenopyrite, but a small amount of galena occurs. Vein No. 3 is exposed in several open-cuts at the top of the quartzite band referred to above, and a short distance below a sill of quartz porphyry. The strike and dip are variable, but the strike averages north 48 degrees west and the dip 75 degrees to the southwest. The mineralization is practically the same as vein No. 1. Vein No. 4 is one of the most important showings on the property. It is exposed in a series of open-cuts near the eastern boundary of the claim, and has a width of 4 feet. It strikes north 23 degrees west and dips to the southwest at 50 degrees. The mineralization shows quartz, galena, siderite, and freibergite. This vein has been traced over 100 feet by means of open-cuts, and also appears on the adjoining claim, Silver Basin No. 4, owned by M. Michie. The ore minerals are disseminated. Vein No. 5 lies 150 feet east of No. 3 above the quartz porphyry sill referred to. It is only partly exposed in an open-cut where it has a width of 8 feet and is mineralized with quartz, arsenopyrite, galena, freibergite, siderite, barite, and occasional flakes of native silver. It is cut off in the open-cut by a steeply dipping normal fault, the throw of which is small.

Four of the five veins discovered on this claim belong to the earlier or quartz-arsenopyrite type. There is ample evidence that transverse veins also occur, and it is likely that these are mineralized. These transverse faults are well shown in the upper bed of the quartzites which cross the property, and it is believed that further trenching will uncover veins other than those described.

SHAMROCK GROUP

The Shamrock group, consisting of seven claims and two fractions, owned by Messrs. A. Erickson, T. McKay, L. Beauvet, and A. Nichol, is situated near the summit of Keno hill, immediately to the west of the original holdings of Keno Hill, Limited. The workings consist of an adit 240 feet in length with three crosscuts, and three prospect shafts, from the bottom of one of which a drift was run. These workings are all on the Shamrock claim. On the Reno are two open-cuts, and one on the Maple Leaf.

The adit taps a vein 80 feet from the entrance, which is followed to the end of the workings. This vein varies from 6 inches to 3 feet in thickness. The mineralization consists of galena, with lead carbonate. Three tons of ore were stoped from above the drift and shipped.

The prospect shafts above the adit apparently encountered two parallel veins; the workings, however, had caved at the time of the writer's visit and very little could be seen. New shafts being sunk to the north encountered float from the same veins. From these workings a shipment of 60 tons was taken which assayed 170 ounces of silver and 74·8 per cent lead.

On the Maple Leaf claim an open-cut partly exposes a vein which is thought to be the continuation of Keno Hill, Limited, No. 1 vein. On the Reno claim two new veins were discovered during the past summer. These were only partly exposed, but showed heavy galena mineralization.

BUTYER GROUP

The Butyer group consists of two claims, the Stone and Rye, owned by M. Butyer, who also owns a half interest in the intervening claim, the Scot. The principal workings lie on the Stone claim. The vein is exposed in three open-cuts on the northern slope of the hill, and an adit 245 feet in length taps the vein below. In the adit, the vein has a width of 12 feet and is mineralized with quartz, siderite, freibergite, chalcopyrite, and a little galena. The vein is considerably disturbed by post-mineral faulting. In the open-cuts above, the vein strikes north 57 degrees east and dips to the southeast. It has a width of 12 feet, and the filling is composed of schist fragments, with the interstices filled with siderite, galena, zinc blende, freibergite, and chalcopyrite.

S. Thurber and associates have a group of claims situated at the foot of the western slope of Keno hill, lying on the divide between Lightning and Christal creeks. This group consists of the following claims: Malcolm, Butte, Pippin Nos. 1 and 2, Mary, Ora, and Anaconda. The Solomon Fraction belonging to S. Thurber is not included in the group.

The workings consist of a shaft and crosscut on the Solomon Fraction, an adit on the Ora, and a number of open-cuts and trenches on the other claims. The shaft on the Solomon Fraction is 28 feet deep and vertical, and is followed by an incline of 15 feet and a crosscut of 15 feet. The deposit consists of a shear zone, the width of which has not been determined, which strikes approximately north 35 degrees east astronomic and dips 46 degrees east. The minerals present consist of quartz, arsenopyrite, pyrite, zinc blende, siderite, calcite, chalcopyrite, and galena. The ore minerals occur disseminated in a gangue of quartz, siderite, and calcite. The galena and chalcopyrite lie chiefly along the foot-wall of the deposit, and, passing over toward the hanging-wall, pyrite and zinc blende are apparently more common. At the time of the writer's visit the workings were largely filled with water and ice, so that only a very incomplete examination of the property could be made, and consequently no samples were taken. Values in gold are reported from this property. On the claims to the north of the Solomon Fraction are a number of open-cuts exposing shear zones which are, however, not so heavily mineralized as the zone at the shaft workings. The distance between these cuts is too great to prove that they are on the same vein zone as the shaft workings.

On the Ora No. 1, on the north side of Lightning creek, is an adit about 40 feet in length on a vein striking north 27 degrees east astronomic and dipping to the southeast at 45 degrees. The vein is mineralized with quartz, siderite, pyrite, zinc blende, but chiefly with pyrite disseminated in a gangue of quartz.

On the Butte claim there is a vein only partly exposed, with calcite, siderite, and a little galena.

THUNDER CLAIM

The Thunder mineral claim is situated on Sourdough hill, which lies south of Keno hill across Lightning creek. It is owned by M. Mellish and is under lease to J. Gillis, J. McHugh, and J. Curley.

The workings, in addition to several open-cuts, consist of a shaft and incline 8 feet deep and a drift south from the shaft of 65 feet. There is also a crosscut 6 feet long about 15 feet south of the shaft. The vein was originally discovered in two open-cuts; in the upper cut galena and siderite were found, and in the lower cut, siderite. The shaft lies about midway between the two cuts, and the underground workings are being driven towards the upper cut.

The vein as exposed in the underground workings varies considerably in strike, dip, and thickness. The average strike is about north 30 degrees east astronomic and the dip from 70 degrees to the southeast to vertical. The vein has a thickness of from a few inches to 7 feet. The greater part of the vein filling is siderite. The chief ore minerals are freibergite and galena. These both occur in small bunches, the former apparently favour-ing the hanging-wall, whereas the latter occurs at random in the vein and also impregnating the wall-rock. Associated with the freibergite are the oxidation products, malachite and azurite. Pyrite, arsenopyrite, and chalcopyrite also occur in small amounts, the pyrite occasionally enclosing the galena. Where the freibergite is present high values in silver are obtained.

CONCLUSIONS

In spite of the fact that the clean shipping ore from the veins on the original holdings of Keno Hill, Limited, is exhausted, the camp is in a much better position at present with regard to probable tonnage than in 1920, owing to the discovery of new veins, particularly on the western and northern slopes of Keno hill. The most important of these discoveries is the Sadie-Treadwell vein, which has a known extent of 2,200 feet and a much greater probable length. Workings have been carried to a depth of 300 feet without diminution in values. The ores are primary and should extend to greater depth; and, though it is conceded that changes in the primary mineralization may take place with depth, no sudden drop in values is looked for. Workings to tap this vein at a depth of 500 feet are already in progress.

Although considerable prospecting has been done, by far the greater number of claims may be classed as unprospected. This is due chiefly to two causes. In the first place the frozen ground renders trenching exceedingly difficult and costly, and surface water interferes with sinking. In the second place supplies are costly, rendering it difficult for the prospector without financial aid to maintain himself on his claim for extended periods. A large amount of work has been done by the use of water for ground-sluicing, and several important veins have been discovered. Over much of the hill, however, water is available for this purpose only for very short periods. Discoveries have been made on Bunker and Sourdough hills to the south and Galena hill to the west, and in some instances the typical Keno Hill mineralization is developed. Further discoveries on these hills are expected.

SILVER LEAD DEPOSITS OF BEAVER RIVER AREA, YUKON

By W. E. Cockfield

CONTENTS

Illustrations

INTRODUCTION

During the summer of 1922 silver-lead deposits were discovered in the vicinity of Beaver river, a tributary of Stewart river. A stampede to the locality occurred and many claims were staked, some of which were subsequently allowed to lapse through non-performance of assessment work. Extremely large deposits of low-grade ores were reported. The discoveries lie along a range of hills 6 miles north of Beaver river. The most westerly deposits discovered are on McKay hill from 6 to 8 miles west of Braine creek. Access to this new mineralized area is most commonly from Mayo (Figure 5) by way of Keno hill, thence along McQuesten valley to the foot of McQuesten lake, from whence a low pass leads to the valley of the North fork of McQuesten river. This valley is followed to its head, where another low divide is crossed to the valley of Beaver river. The distance by this route from Mayo to the workings on McKay hill is 88 miles. A water route is also available. Gasoline launches, it is reported, can ascend Stewart and Beaver rivers from Fraser falls, to within 20 miles of the mouth of Braine creek. Stewart river is navigable for steamers from the mouth of Fraser falls.

While studying the Keno Hill deposits in 1923, the writer paid a brief visit to the Beaver River area. Only the deposits on McKay and Horseshoe hills were examined, but enough was learned from prospectors working in Braine Creek basin to show that these are of the same general type.

TOPOGRAPHY

Beaver River area is part of the Ogilvie range, a spur of Mackenzie mountains, whereas most of Mayo district lies within the Yukon plateau. The Ogilvie range is somewhat more rugged than the plateau; the hills though not necessarily higher lack the broad, flat-topped summits so characteristic of the plateau province, and consist of a series of branching, knife-edged ridges. In general the topography is governed more by the character and structure of the bedrock than is the case in the plateau province. The valleys are markedly U-shaped, implying intense glaciation.

GENERAL GEOLOGY

The consolidated rocks of the district are chiefly black slates, banded red and green slates, quartzite, conglomerate, and limestone. No fossils were obtained from these beds, which have been classed by Keele as probably Devonian in age. The strata strike east and west magnetic and dip to the north at varying angles. In places, however, they have been very

FIGURE 5. Sketch map showing position of McKay hill, Beaver River silver-lead area, in relation to Keno hill and Mayo.

much disturbed. The igneous rocks of the district comprise both intrusive and extrusive types, both of which may be classed under the field name of greenstone. The age relations of the two types could not be determined, but they may belong to one period of igneous activity. The intrusive rocks are augite diorite, a dark green, fine-grained rock. Under the microscope it exhibits plagioclase feldspar (andesine), pyroxene (augite), and a considerable amount of secondary calcite and chlorite. The extrusive types include lavas and tuffs, both of which are so highly altered to calcite and chlorite that their composition cannot be determined although they are believed to be andesite. The lavas contain amygdules filled with calcite. The tuffs exhibit fragments of lava cemented with secondary calcite. In the vicinity of the ore-bodies these rocks are leached and stained with iron.

ORE DEPOSITS

The ore deposits in the district consist of veins of coarsely crystalline quartz with disseminated sulphides, chiefly galena and tetrahedrite, although pyrite and chalcopyrite are also present. The general strike of the veins is north magnetic; the dip is at steep angles, chiefly to the east. Where exposed they almost invariably intersect greenstone outcrops, but it is not believed that they are confined to this type of country rock. Although the bulk of the mineralized float consists of disseminated ore there are probably also considerable shoots of clean sulphides, as demonstrated by the float from vein No. 8, where an open-cut exposed about 10 tons of pure galena including one block 3 by 2 by 1½ feet and another 5 by 4 by 1½ feet.

On McKay hill the chief mineral showings lie on four claims: the Carrie and Whiterock, owned by L. B. Erickson; the Black Hawk, owned by C. Beck; and the Snowdrift, owned by W. McKay. Only the necessary assessment work to hold these claims has been done, consisting of a few trenches. The claims are staked along the crest of the ridge known as McKay hill (Figure 6), two of the claims extending north, and two south, from the crest. The character and position of the veins must be inferred almost entirely from float, as they outcrop only in a few instances and at no place has a vein been stripped over its full width. However, using this float as an indication, the writer believes that there are ten veins crossing the original holdings. These, he has numbered from 1 to 10, commencing at the eastern boundary of the property.

No. 1 vein lies on the eastern slope of McKay hill and crosses the Black Hawk claim at an elevation of 4,800 feet. No particulars as to its width, strike, and dip can be given, as the only indication is a line of float crossing the ridge in a northerly direction. On the summit of the ridge this float has a width of 3 feet, comprising 2 feet of apparently barren quartz, and 1 foot of quartz with disseminated galena. A sample (No. 15) was taken of the mineralized quartz and the assay results will be found in the table on page 27.

Vein No. 2 is 500 feet west of vein No. 1 and approximately parallel with it. This vein is, also, indicated only by float. Two samples, No. 16 representing the more heavily mineralized float, and No. 17 representing the average of the float, were taken for assay.

Vein No. 3 lies 100 feet west of vein No. 2 and is exposed on the crest of the ridge at an elevation of 5,100 feet. The hanging-wall and 18 inches of the vein are shown, the remainder being covered. 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 75 degrees to the southwest. The quartz lying along the hanging-wall is barren for a width of 1 foot and is filled with vugs lined with large quartz crystals. The remaining 4 to 6 inches exposed is well mineralized with tetrahedrite,

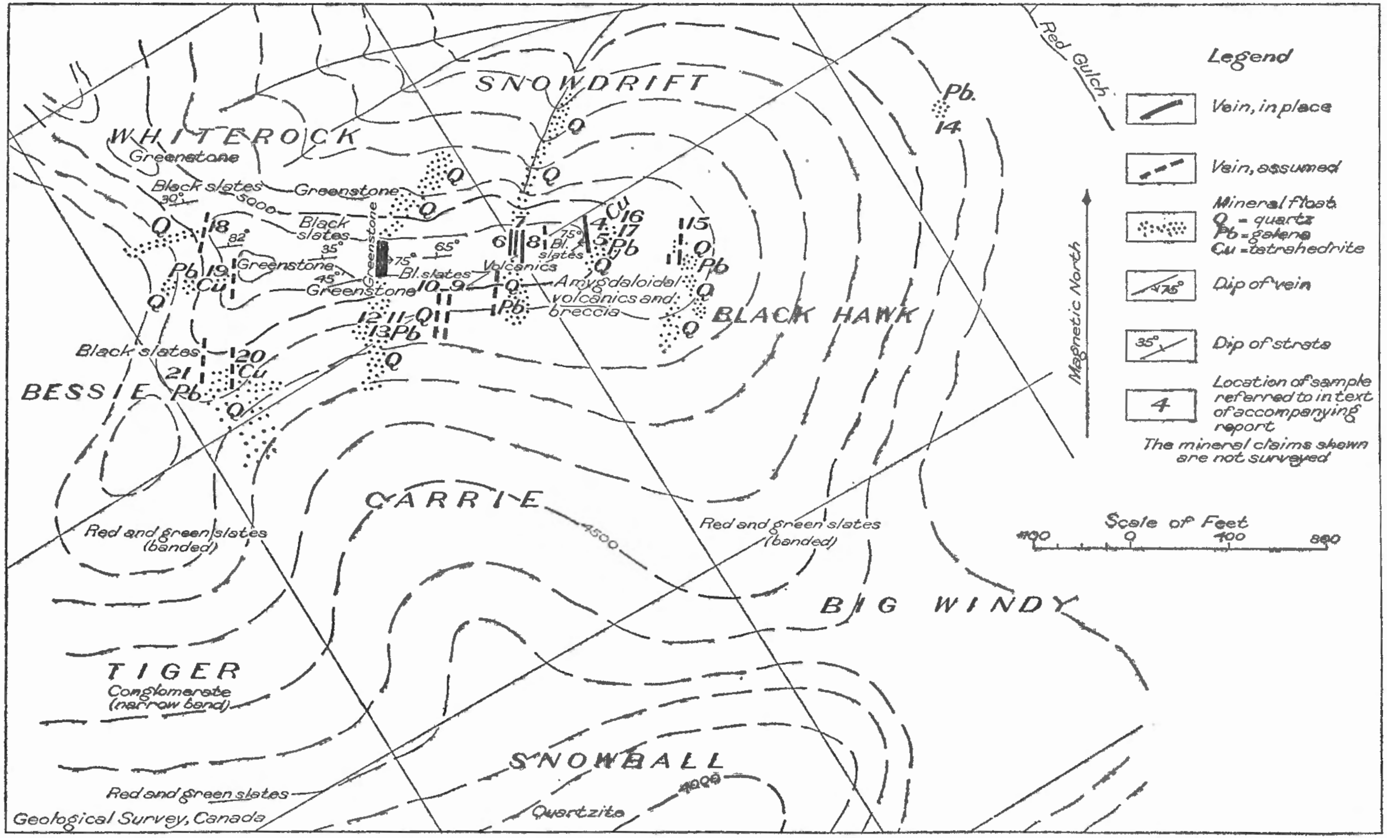


FIGURE 6. Sketch plan of part of McKay hill, Beaver River silver-lead area, showing position of veins and location of samples.

azurite, and malachite. The remainder of the vein is covered, but probably consists mainly of quartz and galena. Two samples were taken. No. 4 is a cut across the 4 or 6 inches mineralized with tetrahedrite and No. 5 is intended to represent the average of the vein material both in place and as float.

Vein No. 4, lying 50 feet west of vein No. 3, is a narrow stringer of quartz, apparently barren. It was not sampled.

No. 5 vein is one of the larger showings on the property. It is exposed at the common corner of the four claims mentioned above. Though only partly uncovered, it apparently consists of a sheeted zone 35 feet wide and of the following section from east to west:

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

The float extends 2,500 to 3,000 feet on the surface and it is possible that the vein persists for this distance, although on account of the steep slope on both sides of the outcrop some of this float may have come from the outcrop. Three samples were taken: No. 6 of the 3-foot vein; No. 7 of the central vein; and No. 8 of the 10-foot vein.

Veins Nos. 6 and 7 are indicated only by float lying 50 and 75 feet west of vein No. 5, and a short distance below the crest of the ridge. No. 6 shows quartz float 4 feet wide, and No. 7 considerable galena and tetrahedrite which have been exposed in a small open-cut. Sample No. 9 was taken on vein 6 and No. 10 from the clean ore on the dump of the open-cut on vein No. 7.

No. 8 is a large quartz vein on the crest of the ridge, striking north magnetic and dipping 85 degrees to the east. It is about 50 feet wide, but may possibly be a sheeted zone similar to vein No. 5, for the outcrop is only partly exposed. It consists of barren quartz. Following the course of this vein to the south, however, an open-cut has uncovered between 7 and 10 tons of galena, including the large blocks referred to above. The vein has not yet been found in place at this point. Three samples were taken. No. 11 is a cut across the smaller of the two blocks of galena 1½ feet in thickness, No. 12 an average sample of the dump, and No. 13 a sample of a smaller dump slightly downhill. These samples are of interest chiefly in determining the silver content of a considerable mass of clean ore.

Vein No. 9 lies just west of the summit of McKay hill. It is shown only by float composed of quartz, tetrahedrite, and galena. Sample No. 19 was taken to represent the average of the vein material in the talus.

Vein No. 10 is the only one noted as occurring in the slates; it outcrops in a small saddle 250 feet north of the summit of McKay hill. The mineralization consists of quartz, tetrahedrite, and galena. A small trench has been dug in the saddle, but does not expose the vein very well. Sample No. 18 was taken of the vein material on the dump.

Samples Nos. 20 and 21 were taken from the talus on the southern slope of McKay hill. It was not clear what veins this float was from; it may possibly have come from veins Nos. 9 and 10 or from two veins which are not exposed on the summit of the hill. Sample No. 20 represents picked tetrahedrite and No. 21 clean galena.

Adjoining the group described 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 all be included in the original group, although grouping for representation work has not yet taken place. On the east and north of the original group is the Yellow Rock group, consisting of six claims owned by A. N. Martin, O. Dahl, E. Anderson, and C. Williamsen. On this group representation work only has been done and none of the cuts exposes mineral in place. In one cut on the eastern slope of McKay hill float was found. Sample No. 14 was taken.

HORSESHOE HILL

Horseshoe hill lies east of McKay hill across a small valley known as Red gulch. The rocks exposed are similar in every way to those of McKay hill. One vein was found cutting through the saddle which lies north of the southernmost ridge of the hill. Here the Independence group of four claims has been staked by A. N. Martin, E. Anderson, O. Dahl, and C. Williamsen. The vein is not exposed, but a large amount of float, consisting of quartz, galena, and tetrahedrite, crosses the saddle. Three samples of this mineralized float were taken, No. 1 from the east side of the saddle, No. 2 from the west side of the saddle, and No. 3 from across the middle of the saddle.

In the table showing the assay results the numbers of the samples correspond to the numbers shown in Figure 6. The gold, silver, and copper assays are by W. C. Sime, Territorial Assay Office, Keno hill, Mayo. Lead assays Nos. 7, 11, 12, 13, 14, 16, 19, 21 are also by W. C. Sime, and other lead assays by the Mines Branch, Department of Mines, Ottawa.

Sample No.	Silver oz. per ton	Value silver per ton[1]	Per cent lead	Per cent copper
		$		
1	1·00	0 63	62·30	
2	0·60	0 38	42·36	
3	1·00	0 63	29·15	
4	38·00	23 94	4·58	8·84
5	26·00	16 38	19·76	
6	4·00	2 52	22·83	
7	10·00	6 30	44·00	
8	5·50	3 47	39·38	
9	0·30	0 19	13·28	
10	45·00	28 35	59·45	
11	14·00	8 82	78·20	
12	20·10	12 66	76·00	
13	10·00	6 30	78·40	
14	6·15	3 87	39·40	
15	6·10	3 84	41·06	
16	26·80	16 88	73·00	
17	6·50	4 10	25·59	
18	11·00	6 93	44·95	
19	13·20	8 32	54·00	
20	62·10	39 12	9·57	15·04
21	17·80	11 21	63·40	

[1]Silver calculated at 63 cents an ounce. None of the samples assayed any gold.

There has not been sufficient work done on the veins to permit of obtaining a clear idea of their genesis and character. They must be judged by the poor exposures seen, or more frequently solely by float in the talus on the hill side. The sampling is, however, as representative as was possible in the circumstances. As the average silver content of the ores is only 15 ounces they can hardly be mined under present conditions of mining and transportation in Mayo district. When one considers that the cost of mining, shipping, and smelting the Keno Hill ores is over $100 a ton, and that these deposits lie 50 miles closer to Stewart river than do the Beaver River deposits, it will be seen that present shipment of Beaver River ores to smelters on the Pacific coast for treatment is out of the question. The tetrahedrite ores apparently run higher in silver than do the galena ores, but even these do not approach the Keno Hill ores in silver content. However, the mineralization of Beaver River district is widespread and very little work has been done on the deposits to date. It is, therefore, possible that further prospecting will reveal higher grade ores which can be mined at a profit, particularly if the water route by Beaver and Stewart rivers should prove feasible.

The size of the deposits cannot be readily determined at the present time. In nearly all cases the veins are concealed by talus and, consequently, it is impossible to say whether they are extensive or consist merely of small lenses of ore. Until further work is done any estimate of tonnage can be nothing more than a guess.

Recent dispatches from Mayo have reported the discovery during the winter of high-grade ores in Beaver River district. The new discovery is reported to lie 7 miles from Carpenter hill, on Braine creek, and assays of material brought to Mayo run from 250 to 1,100 ounces in silver. A further discovery of high-grade ores has also been made near Carpenter hill on Braine creek.

RECONNAISSANCE BETWEEN SKEENA RIVER AND STEWART, BRITISH COLUMBIA

By George Hanson

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1923 the writer continued a geological reconnaissance which was begun the previous season in the area between Skeena river and Stewart, B.C.

The southern part of the area lies in the drainage basin of Tseax and Kitsumgallum rivers, and the northern part embraces Alice Arm and Portland Canal districts. Portland Canal district has been dealt with rather fully in previous reports (*See* Bibliography below) and will, therefore, be referred to in a cursory way only.

Previous investigations in the area by the Geological Survey consist of detailed work in Portland Canal and Alice Arm districts, and of reconnaissance in Portland Canal district, along Nass and Skeena rivers, and at Alice Arm. The mineral properties are described in the Annual Reports of the Minister of Mines, British Columbia, 1884-1887, 1898-1923.

R. H. B. Jones and H. C. Gunning rendered able assistance in the field. The writer wishes to express his appreciation to the various prospectors met with during the course of the work, for their interest and helpful suggestions.

BIBLIOGRAPHY

Dawson, G. M.—"Report on an Exploration from Port Simpson on the Pacific Coast to Edmonton on the Saskatchewan," Geol. Surv., Can., Rept. of Prog., 1879-80, pp. 1 B-177 B.

McEvoy, James.—Geol. Surv., Can., Ann. Rept., vol. 6, 1893, pp. 13 A-16 A.

McConnell, R. G.—"Portland Canal District," Geol. Surv., Can., Sum. Rept., 1910, pp. 59-90.

"Salmon River District," Geol. Surv., Can., Sum. Rept., 1911, pp. 41-71.

"Geological Section along the Grand Trunk Pacific Railway from Prince Rupert to Aldermere," Geol. Surv., Can., Sum. Rept., 1912, pp. 55-62.

"Prince Rupert and Skeena River," Geol. Surv., Can., Guide Book 10, 1913, pp. 6-35.

"Portland Canal and Skeena Mining Divisions," Geol. Surv., Can., Mem. 32, 1914.

O'Neill, J. J.—"Salmon River District, B.C.," Geol. Surv., Can., Sum. Rept., 1919, pt. B, pp. 7-11.
Schofield, S. J., and Hanson, George.—"Salmon River District, B.C.", Geol. Surv., Can., 1920, pt. A, pp. 6-11.
Hanson, George.—"Upper Kitsault Valley, B.C.", Geol. Surv., Can., Sum. Rept., 1921, pt. A, pp. 7-21.
Schofield, S. J., and Hanson, George.—"Salmon River District, B.C.", Geol. Surv., Can., Mem. 132, 1922.
Hanson, George.—"Reconnaissance Between Kitsault River and Skeena River, B.C.," Geol. Surv., Can., Sum. Rept., 1922, pt. A, pp. 35-50.
Minister of Mines Reports, B.C., for the years 1884-1887, 1898-1923.

GENERAL CHARACTER OF THE AREA

Location. Kitsumgallum district lies in the southern part of the area, and can be reached by a road extending northward from Terrace, a small town on the Canadian National railway.

Nass River district lies in the central part of the area and can be reached by river boats plying between Aiyansh and the canneries at the mouth of the Nass. A telegraph line and trail passes through Terrace, Aiyansh, and Alice Arm. The trail is suitable for pack horses between Aiyansh and Terrace.

Alice Arm district lies in the northern part of the area and is reached by steamer from Vancouver.

Climate. The mean annual temperature at Alice Arm, Stewart, Terrace, Prince Rupert, and Vancouver, is approximately the same. The temperature rarely rises above 90 degrees F. or falls below zero. The extremes are a few degrees greater at Alice Arm, Stewart, and especially at Terrace, as these places are farther from the influence of the ocean than Prince Rupert or Vancouver.

The rainfall is greater at Stewart and Alice Arm than at Vancouver, but less than at Prince Rupert. The snowfall at Stewart and Alice Arm is 10 to 15 feet a year, but in the mountains near these places snow may accumulate to a depth of 40 feet. At Terrace and along Kitsumgallum valley, precipitation is less than along the coast, the yearly rainfall being about 40 inches and the snowfall about 4 feet.

Physical Features. The area can be divided topographically into two sub-areas, Alice Arm district, and Nass and Kitsumgallum district. Alice Arm district has the youthful topography typical of the Pacific system of the western belt of the Canadian Cordillera, whereas Nass and Kitsumgallum district is characterized by more mature topography and in this respect resembles the belt of Interior plateaus rather than the Pacific system of mountains.

Alice Arm district lies in the drainage basin of the streams flowing into the head of Alice arm. The Kitsault, the largest of these streams, is a river with a steep grade, whose tributaries head in glaciers. This part of the area has mountain peaks extending up to 6,000 feet above sea-level and is somewhat more subdued than the central parts of the Pacific system. A permanent ice and snow cover conceals almost all the rocks between Portland Canal and Alice Arm districts. Illiance river heads in the low divide between Nass river and Alice arm. The area between Illiance and Kitsault rivers is also covered largely by permanent snow caps. The country east of the Illiance is a plateau with no glaciers and no high mountain peaks.

Kitsumgallum district lies on the eastern border of the Pacific system and is characterized by high mountain peaks and deeply incised valleys. The grade of the streams here is not great, although peaks rise to heights of 7,500 feet. Glaciers are present on the northern slopes of the higher mountains, but their lower limit is higher than that in Alice Arm district.

A large valley, now occupied by relatively small streams, extends southward from Nass river at Aiyansh to Kitimat arm. Tseax river flows north into Nass river, and Cedar and Kitsumgallum rivers south into the Skeena. Lakelse river flows north into Skeena river and Kitimat river south into Kitimat arm. The divide between Tseax and Kitsumgallum rivers is only 300 feet higher than Skeena river at Terrace, and the divide between Lakelse and Kitimat rivers is also low. This large valley is wider than the lower Skeena and lower Nass rivers. McConnell believes that it represents an old, partly abandoned valley of erosion, possibly robbed by the Skeena.[1] It is probable that formerly the upper Nass and upper Skeena waters flowed through the valley to Kitimat arm and that subsequently the lower Nass robbed the northern part and the lower Skeena the central part of the valley. A tilting of the area, the southern part being elevated more than the northern, would slow up drainage through the valley and speed up drainage westward to the coast.

Several lakes lie in the valley. Lava lake, 7 miles long and 180 feet deep, was formed in large part a few hundred years ago through the damming of Tseax river by a lava flow (*See* page 39). It is probable that a small lake existed there before the advent of the lava. Sand lake was formed by damming of Tseax river by detritus brought into the valley by Poupard river. Kitsumgallum lake fills a rock-scoured basin and is 450 feet deep. It is interesting to note that the bottom of the lake is approximately at sea-level, although the lake is 100 miles from the ocean. The two small lakes below Kitsumgallum lake have been separated from the main lake by detritus deposited by streams entering the valley from east and west.

A noteworthy feature pertaining to erosion in Kitsumgallum district is apparent in the tributary streams. Although the normal tributary drainage is west into Kitsumgallum river and east into Skeena river, near the head of the creeks there is a sharp bend and the headwaters flow north for 1 or 2 miles before joining the main tributary valley. This is particularly noticeable on Hall, Douglas, and Clear creeks, which flow west into Kitsumgallum lake, and on Fiddler and Lorne creeks, which flow east into the Skeena. The explanation lies in the fact that glaciers are larger and endure longer on the northern slopes than on the southern slopes of mountains and, consequently, have cut short northerly-trending valleys on the north side of the higher mountains. Evidently the main tributary valleys were eroded in pre-Pleistocene time, and the upper part of the valleys where the streams flow north represents erosion in Pleistocene and Recent time.

---

[1]McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1912, p. 55.

GENERAL GEOLOGY

GENERAL STATEMENT

The rocks of the area are in the main of Jurassic age. In Alice Arm district a series of fragmental and massive volcanic rocks is overlain by a

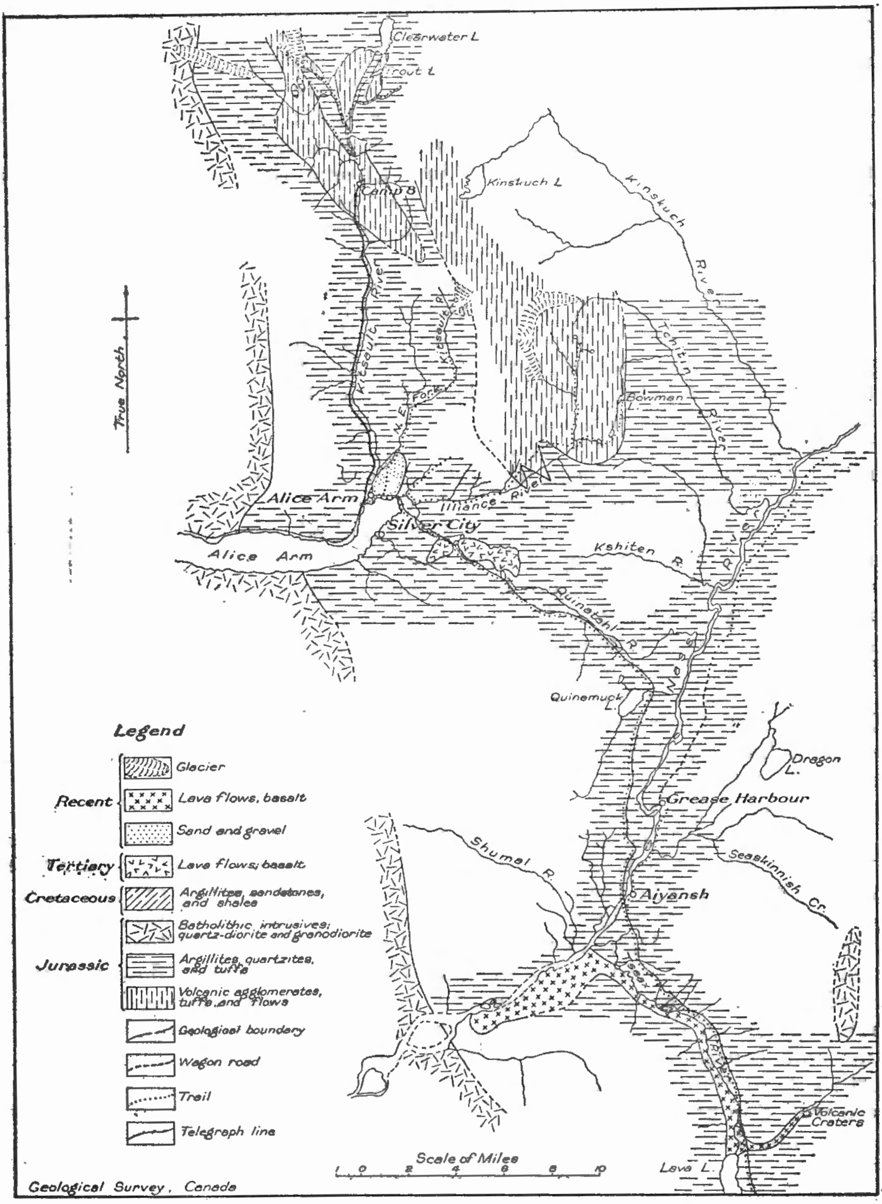


FIGURE 7. Geology between upper Kitsault valley and Lava lake, Cassiar district, B.C.

series of argillites. In the adjacent area to the north, the rocks are of the same type as those at Alice arm. Along Nass river, south of Alice arm, the rocks consist almost entirely of argillites. Farther south the argillites are either underlain by, or change gradually into, a series of quartzites, argillites, and hard, tuffaceous sandstones. South of Kitsumgallum district, at Skeena river, the sediments are underlain by a series of fragmental and massive volcanic rocks. The whole area is bordered on the west by the Coast Range batholith. At the south end of the area the batholith contact

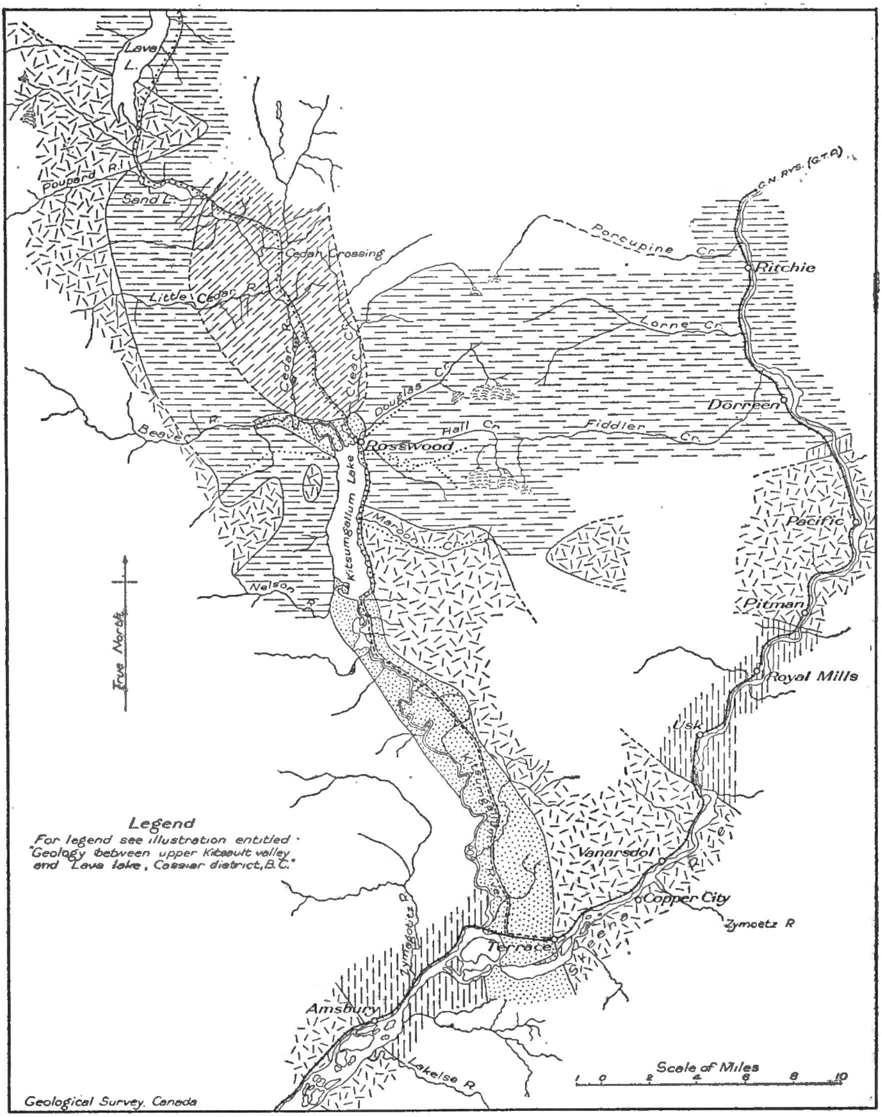


FIGURE 8. Geology between Lava lake and Skeena river, Coast district, B.C.

swings around to the east in a series of apophyses which bound Kitsumgallum district on the south and southeast. The argillites of Alice arm extend eastward across Nass river, where they are the most abundant rocks. The sedimentary rocks of Kitsumgallum district extend eastward and northeastward past Hazelton. The structure of the area is that of a synclinorium plunging slightly to the northeast.

Table of Formations

Period	Formation	Lithology
Recent	Tseax River lava flow Stream deposits	Basaltic lava, scoria, and cinders Gravel, sand, and clay
Pleistocene	Glacial deposits	Morainal material, boulder clay
Tertiary	Sedimentary rocks Lava flows and dyke rocks	Poorly consolidated sandstone and shale Basaltic lava flows and dykes
Post-Lower Cretaceous	Dykes	Quartz diorite and granodiorite dykes
Lower Cretaceous	Skeena formation	Argillites, sandstone, conglomerate (graphitic coal seams)
Upper Jurassic	Coast Range batholith	Granodiorite, quartz diorite
Jurassic	Hazelton group	Argillites, quartzites, and tuffaceous sandstones Fragmental and massive volcanic rocks

CORRELATION

The name "Hazelton group" was proposed in 1909 by Leach for a series of rocks in Telkwa-Hazelton district.[1] The lower part of the group consists of fragmental and massive volcanic rocks, and the upper part of argillites, quartzites, etc., containing a good deal of tuffaceous material. In later geological work in Portland canal, Upper Kitsault valley, and Skeena district, local names were proposed for rocks apparently of the same age, but it is now possible to correlate over the whole area from Portland canal to Skeena river and the local formation names can be dropped.

[1] Leach, W. W., Geol. Surv., Can., Sum. Rept., 1909, p. 63.

The name "Hazelton group" is preferable to the name "Bear River formation" which was proposed by McConnell in 1910. The name "Bear River formation" is undesirable, even though it is fairly well established in the geological literature of British Columbia, because the names "Bear River formation", "Bear River group", "Bear River beds", etc., had been used previously to designate formations of different ages.[1]

On Skeena river, between Terrace and Hazelton, a series of fragmental and massive volcanic rocks underlie the upper part of the Hazelton group.[2] In Upper Kitsault valley[3] and in Portland Canal district similar volcanic rocks underlie a series of sedimentary rocks.[4] The sedimentary series in Upper Kitsault valley is continuous from Kitsault river to Skeena river, where it becomes the upper Hazelton group. There is an area 12 miles wide between Portland Canal and Upper Kitsault districts not covered by the two map-sheets, and which the writer has not yet explored: but, Clothier, of the British Columbia Department of Mines, made a traverse across this area and found that the sedimentary series is continuous.[5] The overlying sedimentary series is, then, continuous over the whole area, and the volcanic complex which underlies the sediments conformably in Portland canal and Alice arm can be correlated with the lower Hazelton group which underlies the sediments conformably near Hazelton.

Fossils collected from the base of the upper Hazelton group in Portland canal and Alice arm proved to be of probable Jurassic age. Fossils from the upper Hazelton group at Telkwa, Hazelton, and in Groundhog district, are also of probable Jurassic age. The fossil collection consists of poorly-preserved specimens containing several new species, so it is not practicable to correlate with outside formations of known age.

HAZELTON GROUP

Rocks representing the lower part of the group are abundant and widespread in Alice Arm district. In Upper Kitsault valley the series, formerly known as the Dolly Varden formation,[6] consists of volcanic rocks several thousand feet thick. Most of the rocks of the series are green or grey, but large areas and bands of the rock have a reddish or purplish tinge. Tuffs, breccias, agglomerates, and flows occur, but contacts between the massive and fragmental members of the series are rarely discernible, and the series is in general devoid of apparent structure.

On upper Illiance river the rocks are mostly well-bedded, water-sorted tuffs. Northwest from the upper Illiance the formation becomes coarser in grain and the structure is not so readily seen.

South of Illiance river the volcanic rocks are overlain by argillites and do not appear again until Skeena river is reached. Along the Skeena occurs a series of massive, purple and green volcanic rocks named by

---

1 Hayden, F. V., U.S. Geol. Surv., Col. and New Mexico, 1869, p. 9.
Bowman, A., Geol. Surv., Can., vol. I, pt. C, 1887-88, p. 16 C.
McConnell, R. G., Geol. Surv., Can., vol. IV, pt. D, 1888-89, pp. 95-103.
White, C. A., Amer. Jour. Sci., vol. 43, 1892, pp. 91-97.
2 McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1912, p. 58.
3 Hanson, George, Geol. Surv., Can., Sum. Rept., pt. A, 1921, pp. 7-21.
4 McConnell, R. G., Geol. Surv., Can., Mem. 32, 1914.
5 Ann. Rept. of Minister of Mines, B.C., 1922, p. 64.
6 Hanson, George, Geol. Surv., Can., Sum. Rept., 1921, pt. A, pp. 7-21.

McConnell, the "Kitsalas formation."[1] McConnell placed these rocks tentatively in the Triassic, but on lithological and structural grounds the writer believes they are part of the Hazelton group. Narrow bands of argillite are present in the upper part of the lower Hazelton group along Illiance river and in the eastern part of Kitsault district.

From study of thin sections of the rocks it is evident that the crystalline rocks are andesites and that the fragments making up the tuffs and breccias also consist chiefly of andesite.

In Alice Arm district mineral deposits occur in the volcanic part of the Hazelton group. In Upper Kitsault valley the deposits are confined to the green members of the series, but along Illiance river they are present in both green and purple rocks. The mineral deposits are, in general, large quartz veins and replacement zones, and the principal metals are silver, copper, zinc, and lead.

The upper part of the Hazelton group overlies the volcanic part of the series conformably. In Alice Arm district the upper series consists chiefly of argillites with some sandstone, quartzite, and tuffaceous beds. The series is present in the central part and on the eastern and western flanks of Upper Kitsault valley. The sediments along the western flank continue southward in a broadening belt, embracing Alice Arm, Nass River, and Kitsumgallum districts. East of the Illiance the same series continues across Nass river.

In Upper Kitsault valley the rocks are argillites containing, near the base of the series, some quartzite and tuffaceous beds. Near Alice Arm to the south and east, quartzites and hard sandstones predominate. Along Nass river and southward to Lava lake argillites predominate, but farther south quartzite is more abundant.

The thickness of the series is difficult to estimate at Alice arm or along Nass river, but in Kitsumgallum district it is over 5,000 feet, and consists of quartzites and argillites with minor amounts of tuffaceous sandstones, tuffs, and conglomerates. Chert pebble conglomerates are present near the top of the series here, but are much harder and better consolidated than somewhat similar conglomerates found at the base of the Skeena formation in the same district. The argillites are commonly laminated, but the quartzite and sandstone beds are mostly devoid of internal structure.

This series is important in that it contains deposits of rich silver and gold ore. In Alice Arm district the deposits in this series are few and small and all occur within 6 miles of the Coast Range batholith. In Kitsumgallum district the mineral deposits are larger and exhibit more promise of permanence.

Fossils found at the base of the upper part of the Hazelton group in Upper Kitsault valley were examined by the Palæontological Division, Geological Survey, which reported as follows:

"*Gryphœa* sp.
Oxytoma sp.
Belemnites sp.
Rhynchonella sp.

The above fauna is certainly either Jurassic or Cretaceous and most probably Jurassic." No fossils have been found in the lower Hazelton group. These rocks are believed to be of Jurassic age, but they may be in part Triassic.

[1] McConnell, R. G., Geol. Surv., Can., Sum. Rept., 1912, pp. 55-62.

COAST RANGE BATHOLITH

The eastern contact of the Coast Range batholith extends southward from Portland canal and crosses Alice arm 4 miles west of the head of the arm. The contact then swings to the south-southeast and crosses Nass river below Aiyansh. So far the contact is approximately straight, but from Nass river southward it becomes irregular through the presence of granite tongues or apophyses projecting to the north and east, and also through the presence of outlying stocks of granite which are probably apophyses connected underground with the main body of the Coast Range batholith. In the southern part of Kitsumgallum district the contact swings abruptly to the east, northeast, and north, due to the presence of large apophyses of granodiorite.

The contact of the Coast Range batholith conforms in general to the line of strike of the formation flanking the batholith. Where apophyses of granite project into the older rocks, they extend as a rule in the direction of the strike of the intruded rock.

Thin sections of the Coast Range batholith at Alice arm, Lava lake, and Kitsumgallum lake, show that the rock varies from granite to quartz diorite.

Mineral deposits are present in the large apophyses of the batholith in Kitsumgallum district. These are quartz veins containing abundant pyrite and moderate to small quantities of gold.

In the area under discussion the Coast Range batholith intrudes the Hazelton group, but does not intrude the Skeena series. It is, therefore, probably mainly of Upper Jurassic age, but parts of the batholith may be of later age.

SKEENA FORMATION

The extent of the rocks of Lower Cretaceous age in the area is not known. The rocks are argillites which are similar to those of the older argillite formation and, as fossils are scarce, the boundaries of the series are difficult to trace. The formation is known to occur at Cedar River crossing and in the area between this crossing and Kitsumgallum lake. Similar rocks are found on Clear creek and on the lower part of Little Cedar river. Here the formation is faulted, intruded by granite dykes, and, locally, is rather severely folded. Graphitic coal seams are present and for this reason the formation is of economic interest.

On a hurried trip from Illiance river across the mountains to Kitsault river the writer found, about 3 miles east of Camp 8, outcrops of argillites that closely resemble rocks of the Skeena formation. There may be a small area of Cretaceous rocks here extending across the headwaters of East and Goat creeks.

Sandstones and conglomerates outcrop in Cedar River valley north of Kitsumgallum lake and appear to underlie the possible coal measures at Cedar River crossing. No place was found where the thickness of the Skeena formation could be measured; however, the basal sandstones and conglomerates may be not more than 100 feet thick and the overlying argillites not more than 300 feet thick.

The formation is known only in the valley and apparently overlies the Hazelton group unconformably. Heavy vegetation and a scarcity of outcrops rendered information in the Cretaceous area difficult to obtain.

The conglomerates contain pebbles of chert, quartz, and quartzite, cemented by calcite. The grains in the sandstone consist of quartz, feldspar, and chert, and the cement is calcite.

Poorly-preserved fossil leaves, etc., of probable Kootenay age, as determined by the Palæontological Division, Geological Survey, were obtained from the argillites.

DYKE ROCKS

Narrow lamprophyre dykes are numerous in Alice Arm district. They penetrate Jurassic sediments, so are of Upper Jurassic age or younger. South of Alice arm, lamprophyre dykes are rare, but dykes and sills of granodiorite and quartz diorite porphyry are plentiful. Some of these granite dykes intrude rocks of the Skeena formation and are consequently younger than Lower Cretaceous.

TERTIARY

Horizontally-lying lava flows of pre-Pleistocene age occur on the plateau southeast of Alice arm. Smaller flows are present on Tseax river, a few miles above its junction with the Nass, and also about a mile northeast of Lava lake. The flows near Alice arm are several hundred feet thick and have been split up into vertical hexagonal columns by joints. The lava is amygdaloidal and contains phenocrysts of plagioclase $\frac{1}{4}$ to $\frac{1}{2}$-inch in length. The rock is a basalt containing labradorite, augite, enstatite, olivine, magnetite, and apatite.

The small area of Tertiary lava northeast of Lava lake is overlain by poorly consolidated sandstones, shales, and conglomerate, several hundred feet thick. The lower beds of these sediments consist of conglomerate containing pebbles of granite, basalt, argillite, and quartz. The formation dips gently to the north.

PLEISTOCENE AND RECENT

Morainal debris is present at the snouts of all the glaciers, and boulder clay is found in many of the valleys. The boulder clay deposit on Kitsault river and its northeast fork is at least 50 feet thick. In the upper part of Douglas creek it is over 100 feet thick. In the placer creeks boulder clay may conceal gold-bearing gravels of Tertiary age.

Gravel terraces are present on the major streams. Those found along Kitsumgallum and Tseax rivers were formed probably during the wane of the Ice age and in Recent time through extensive deposition by overloaded streams and by deepening of the river channels. The terrace-like deltas along Kitsumgallum lake may have been formed in part along the edge of the main valley glacier by debris carried down by tributary streams. The gravel terraces at Terrace contain 2 or 3 beds of clay up to 3 feet thick. The top of each clay bed is a water horizon, and water for domestic purposes can be obtained in wells that reach the clay.

Post-glacial clays of marine origin are present along Bear river at an elevation of 400 feet above sea-level. Similar clays occur on Salmon, Kitsault, and Northeast fork, Kitsault rivers, at the same elevation above sea-level, but on these streams fossils were not found. The clays are suitable for the making of bricks.

Tseax River Lava Flow

The youngest solid rock in the area occurs along the valley between Nass river and Lava lake. This is a basaltic lava flow 20 miles long, covering an area of 10 to 15 square miles and having an estimated volume of one-eighth of a cubic mile. The Indians on Nass river believe that the flow took place about one hundred and fifty years ago, but it is clearly older than this as trees one hundred and seventy years old have been found growing on the lava. The flow is probably not older than three hundred years. Associated with the lava eruption are several cinder and scoria cones.

The first explosion resulted in a crater about 400 yards in diameter. There is very little evidence now of the material that was thrown out of the crater. The crater is in argillite on the banks of a creek flowing into Tseax river and situated 3 miles northeast and 1,100 feet above Lava lake. After a period of quiescence of sufficient duration to permit the formation of a flat floor to the crater, there was a second eruption of scoria and cinders building up a cone 300 feet high within the earlier crater. The crater in this second cone is 250 feet in diameter and 75 feet deep. The cone is built up of scoria and bombs, but a bed of cinders up to 10 feet thick is present as far as a quarter of a mile from the cone. There are also at least four other cinder cones within a quarter of a mile of the large crater, the largest of which is approximately 100 feet high.

The lava issued from or near the base of the large cone, filled up the creek valley, and dammed back the water to form a lake a mile long. The flow continued down the creek valley in a stream 300 yards wide to Tseax river, a distance of 3 miles, damming this stream and forming Lava lake. It is likely that a lake existed here before the lava was erupted. Apparently the lava flowed into the foot of the lake, and through damming made it longer than it was originally. The lava flow continued down Tseax valley in a stream approximately 2,000 feet wide, to Nass river, a distance of 14 miles, whence it spread out in a broader sheet and continued down Nass valley for a farther 6 miles. On reaching Nass valley the flow was only 10 feet thick, and although it probably crossed the river the lava was not of sufficient volume or thickness to make a dam. Falls were formed, however, and Nass river now flows along the northern margin of the lava.

The gradient of the lava stream is steep in its upper part for a distance of 100 yards. From this point to Tseax river the gradient conforms to that of the creek valley, approximately 300 feet per mile. From Lava lake to Nass river the gradient is only 30 feet a mile.

The creek, above Lava lake, down which the lava poured, now flows below the surface of the lava. Tseax river, especially in low water, also flows in some places under the surface of the lava. The lava flow is almost devoid of vegetation. Mosses and lichens grow, but afford no protection against the scoriated surface. Trees grow only along streams where the lava is very thin.

The lava, in the Tseax and the higher creek valley, is broken into irregular blocks varying in size up to 20 feet in diameter. In Nass valley the flow is more nearly level, and larger areas of unbroken surface are found. The lava blocks have jagged surfaces made so by broken vesicles and by glassy stalactites of lava. The grain is in general fine, but specimens can be obtained which are completely crystalline and have phenocrysts up to one-third inch in length.

Along the creek valley above Tseax river and on the upper part of that river, the original cooling crust of the lava has been in large part destroyed through collapse, partial remelting, and mixing with the lava below. Near Nass river the original cooling crust is seen in many places. As a rule this crust is 4 inches thick, is very fine-grained, and contains fewer and much smaller vesicles than the main body of the lava. The under surfaces of the crusts are commonly covered with stalactitic spikes and prongs of lava. In places where the lava has not flowed away from under the rapidly cooled surface the crust is thicker. In these instances, the crust, consisting of 6 inches or so of fine-grained lava with few small vesicles, changes gradually downward into fine-grained lava with large vesicles.

The breaking of the lava flow into blocks was due in large part to the rapid flow of the lava stream permitted by the steep gradient of the valley causing a progressive breaking of the cooling crust. In some places the crust would slump and in others the lava would break through from below. The process would continue until the lava was too viscous to flow. The physical reaction between the molten lava and the flowing water would also cause fragmentation of the lava. Later, atmospheric changes of temperature have also played a small part in breaking up the lava.

The rock is basalt consisting of labradorite, augite, enstatite, olivine, apatite, and magnetite. Labradorite makes up about 50 per cent of the rock, augite, enstatite, and olivine about 35 to 40 per cent, and apatite and magnetite the remaining 10 to 15 per cent. Phenocrysts of labradorite are commonly present.

The following is an analysis of a single specimen of a holocrystalline phase of the basalt:

SiO_2	46·24
Al_2O_3	15·79
Fe_2O_3	2·86
FeO	11·81
MgO	4·43
CaO	7·94
Na_2O	2·40
K_2O	3·90
TiO_2	3·00
Cl	trace
P_2O_5	1·00
SO_3	0·09
S (sulphides)	0·035
MnO	0·15
H_2O	0·10
	99·74[1]

[1] Analysis by M. F. Connor, Dept. of Mines, Ottawa.

STRUCTURE

In Alice Arm district the formations have a northerly and northwesterly trend. The rocks are steeply folded. The rocks along Kitsault valley are not as a rule sheared, but along Illiance river very pronounced shear zones have been developed.

South of Illiance river the volcanic rocks of the lower Hazelton group are overlain by argillites and do not appear again until Skeena river is reached. The formations between Alice arm and Skeena river lie in a broad synclinorium which plunges gently to the northeast and in which the incompetent rocks, especially the argillites, are folded into numerous tightly compressed folds. The strata in Kitsumgallum district have an easterly strike conforming in general to the eastward swing in the contact of the Coast Range batholith. Over the remaining part of the synclinorium the strike is northeast. Shearing is very prominent in Kitsumgallum district, but between that district and Illiance river the rocks are not as a rule sheared.

The volcanic rocks of the lower Hazelton group at Illiance river are overlain to the south by sedimentary rocks; along the Skeena they are overlain to the north by the same series of sediments: it is not likely that the volcanic series continues the whole way underneath the sediments, as no exposures of the volcanic rocks were observed in the intervening area. It is probable that the volcanic rocks are replaced in the central area by contemporaneously formed sediments.

ECONOMIC GEOLOGY

DEVELOPMENT AND PRODUCTION

Silver is the principal valuable metal in Alice Arm district, although in a few properties copper is the chief metal and, in one or two others, zinc. Along Nass river no mineral deposits have been discovered. In the northern and western parts of Kitsumgallum district a few properties are of the silver-lead type, but most of the mineral deposits are gold quartz veins. In this district placer gold was mined forty years ago and these operations have been continued on a small scale. Coal-bearing Cretaceous rocks are present here as well, but no tonnage of workable coal has been outlined.

Notwithstanding the fact that prospectors entered the area many years ago and have opened up several very good prospects the production of the metals to date has been small. Complete figures as to the production are not available. In 1884, Lorne creek yielded placer gold worth $17,000, and to date has probably yielded over $70,000. Douglas and Fiddler creeks have also been worked, but the quantity of gold taken from these creeks is less.

Lode mining has been confined to Alice Arm district. From this district there has been a production of 1,340,000 ounces of silver and 30 ounces of gold. Of this total production the Dolly Varden mine contributed 1,300,000 ounces of silver. The Esperanza mine which has been worked on a small scale for a number of years had yielded 25,000 ounces of silver by the end of 1922. The La Rose and North Star properties have made small shipments. The gold came from the Esperanza and La Rose properties.

A molybdenite deposit near Alice Arm was operated in 1916 by the Molybdenum Mining and Reduction Company and produced 15,000 pounds of molybdenite.[1]

ALICE ARM DISTRICT

The mineral deposits of this district have been described in previous reports (*See* Bibliography) and will not be discussed here. Development has been continued on most of the properties and new finds have been made. The owners of the Vanguard group have been successful in exposing a good body of chalcopyrite in their crosscut and this property is one of several that have good surface outcrops of ore.

KITSUMGALLUM DISTRICT

Development was continued on most of the mineral deposits and a few new veins were prospected.

Mr. Smith has opened up a narrow quartz vein outcropping on the west shore near the south end of Kitsumgallum lake. The vein lies in argillite near a large dyke of granodiorite and the whole has been cut by later lamprophyre dykes. The vein is a foot wide, but has not been traced far on the surface because of a heavy covering of drift. An average sample of vein matter weighing 500 pounds contained 3½ ounces in gold per ton, 3 ounces of which were present as free gold. Other properties visited during the past field season were described in the Summary Report for 1922 and in the Report of the Minister of Mines, British Columbia.

Placer gold is present in Douglas, Lorne, and Fiddler creeks. These creeks all head in the mountains east of Kitsumgallum lake and as no gold-quartz veins had been found which could be the source of the gold in the placers, the writer endeavoured to obtain some information regarding the source of the gold. A map (Figure 9) was prepared to show the structure and the probable source of the placer gold, but insufficient time prevented the structure on Lorne and Fiddler creeks being traced out in detail.

A number of claims have been staked on gold quartz veins on Hall creek on the Maroon Mountain slope. These properties are at timber-line or above it, so that the structure of the rocks and veins is readily discernible. The veins here lie with the bedding of the sediments 100 feet or less structurally below a 50-foot bed of conglomerate. The conglomerate and underlying beds were mapped in detail for the purpose of showing the structure of the rocks and of ascertaining whether the horizon below the conglomerate was mineralized over any extensive area. It was found that this horizon carried all the gold quartz veins that had been staked in this part of the district and also other quartz veins that had not been staked. The horizon was then located approximately on Fiddler creek and Douglas creek, and less accurately, on Lorne creek, the crossing in all cases lying

[1] Figures of production taken from Minister of Mines Reports, B.C.

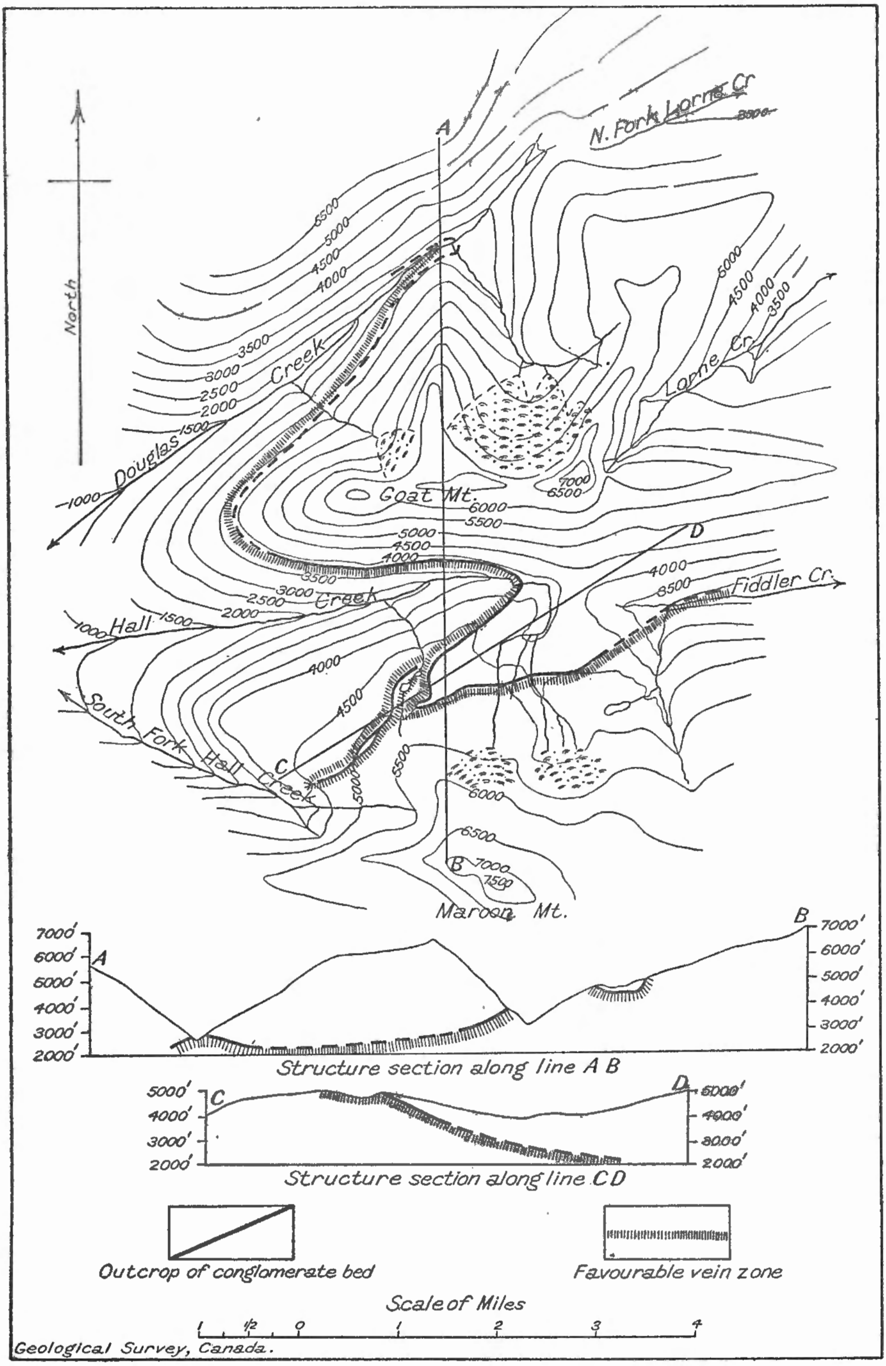


FIGURE 9. Sketch map of part of Kitsumgallum district, B.C., showing location of zone of gold-bearing veins from which the local placer deposits may have been derived.

below timber-line where the rocks were not well exposed. It was found that on Douglas creek the old placer workings extended practically up to the point where the horizon crossed the creek and this relation may hold true on Lorne and Fiddler creeks, although no definite proof of such was obtained.

It seems highly probable that this horizon, or horizons near it, contain the gold quartz veins from which the gold in the three placer creeks was derived. As the horizon crosses the placer creeks below timber-line, and further, as the structure of this area has not been previously described, it is fairly certain that the horizon has not been prospected to any extent.

If veins are found in this favourable horizon, they will probably be narrow, but may carry commercial quantities of gold.

ORIGIN OF THE ORE DEPOSITS

The area lies along the eastern contact of the Coast Range batholith and is a part of the great mineral belt which flanks the batholith throughout its length. Theoretically, the eastern contact is a promising mineral field and it has proved its worth through the presence of metal mines.

Although the mineral deposits along the interior mineral belt have a general similarity, the valuable metals are restricted to certain areas in the belt. The localization of certain metals into definite areas is of interest and it would be of great importance to discover the explanation for such concentrations. The source of the metals is considered as all important in this connexion. If the source contains metals, mineral deposits may form. It is not certain that ore deposits will result, as other conditions may prevent the deposition and concentration of the metals into ore-bodies. The main source of the mineral deposits of the Interior belt is believed to be the magma of the Coast Range batholith. It is probable that there are valuable metals in one part of the batholith which are lacking in another part. By very careful discrimination between rock types in the batholith in areas of known mineral deposits, some general rules may be established which can be applied to other parts of the Interior belt.

The country rock in which the ore-bodies occur is also of importance, but the influence of the country rock pertains chiefly to the size and persistence of veins and to the presence of ore-shoots in the vein. The rock in which the ores are found has probably not had much influence on the localization of metals into areas within a mineral belt. The physical nature of the country rock, which has a bearing on the size of fracture, and the chemical nature, which influences replacement of the rock and precipitation of the metals, are here the two main factors. The depth at which the ore was formed is also important, but will not explain the localization of certain metals into areas in one mineral belt.

Along the Interior belt in this area the chief rocks containing ore-bodies are fragmental volcanic rocks, quartzite, and argillites. The ore-bodies in the volcanic rocks are as a rule of moderate to large size compared with those in the sedimentary rocks. Those in the quartzites are larger and better defined than the lenticular stringers in the argillites. Fracturing and ease of replacement of the country rock were the main factors in determining the size of the ore-bodies.

FUTURE OF THE AREA

In Alice Arm district mining on a small scale has developed narrow veins containing workable silver ores, and this mining is likely to continue. The veins are not sufficently large to be attractive for company operation.

There are good possibilities for mining some of the copper or zinc deposits on a moderate scale. These properties have not been sufficiently developed to prove their value, but further development work on them is justified.

There are also possibilities for mining low-grade silver ores. Six or seven properties lie close together and if these were controlled by one company there would be sufficient ore to warrant a concentrator. Individually the properties have not sufficient merit, for mining must be restricted to shallow depths.

New finds are being made in the northern part of the district and there gold seems to be more plentiful. It is interesting to note that pre-Pleistocene lava flows are present south of Alice arm, and that these lava flows served as a cover which protected underlying deposits from glacial erosion. Consequently any mineral deposit which was enriched in Tertiary time and covered by the lava will still have its enriched secondary ore.

In Nass River district no mineral deposits have been found. There is a considerable thickness of argillite in this part of the area, and as veins are not very persistent in thick formations of this rock prospecting should be confined to areas near the contact of the Coast Range batholith or near outlying stocks of the batholith. If ore deposits are found here it is expected that they will be narrow quartz veins in which silver is the most valuable product.

In Kitsumgallum district opportunities for lode mining pertain to small-scale operations on gold quartz veins. The chances are very good of discovering gold quartz veins likely to contain shoots of rich gold ore. In regard to placer gold, the benches of gravel at the head of Kitsumgallum lake might be tested, but they are probably of low grade.

RECONNAISSANCE OF SILVER CREEK, SKAGIT AND SIMILKAMEEN RIVERS, YALE DISTRICT, B.C.

By C. E. Cairnes

CONTENTS

Illustrations

INTRODUCTION

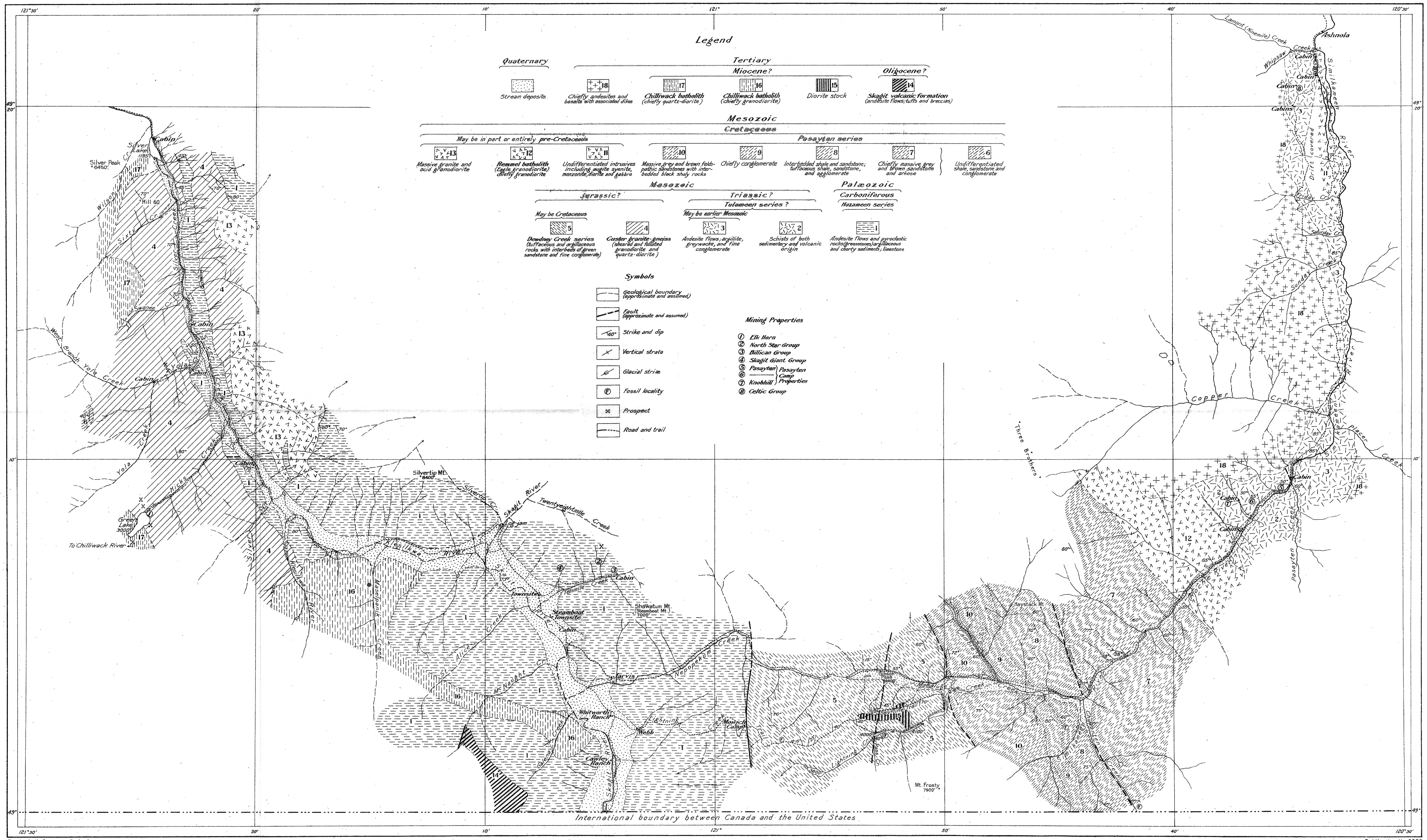
During the field season of 1923 the writer continued a geological reconnaissance survey in southwestern British Columbia. This work, begun in the previous year, has resulted in obtaining a fairly comprehensive idea of both general and economic geology between the towns of Hope and Princeton in Yale and Similkameen mining divisions.

In the field work the writer was most ably assisted by Messrs. Carl Tolman and R. A. Shatford.

The area explored (Figure 10) forms a strip of territory averaging 6 miles in width and extending from Silver lake, an expansion of Silver creek, 7 miles from Hope, to the mouth of Lamont (Ninemile) creek, 9 miles south of Princeton. Except for a digression over the Skyline trail and up the valley of Lightning creek, the route followed coincides with the line of the Cleveland survey made by the provincial government in an effort to discover a favourable site for a transprovincial highway across this southern section of British Columbia. The territory explored overlaps, or falls between, a number of areas (Figure 10) which have already been reported upon and these investigations have been of much assistance in the field work and in the preparation of the present report.

ROUTE FOLLOWED

The route followed leads from Silver lake up Silver creek and down Klesilkwa and Skagit rivers to Whitworth ranch, 3 miles north of the International Boundary. From Whitworth ranch the main line of the survey was extended eastward over the Skyline trail onto the divide between



Geological Survey, Canada.

Publication No. 2023

Reconnaissance geological map of portions of the drainage areas of **Silver creek** and **Skagit** and **Similkameen rivers**, Yale district, British Columbia.

To accompany report by C.E. Cairnes, in Summary Report, Part A, 1923.

Scale of Miles

Surveys and geology by C.E. Cairnes, 1923.

the valleys of Lightning and Nepopekum (Muddy) creeks. Following a steep descent from this divide into the valley of Lightning creek, the survey was continued up that creek to the junction of Mamaluse creek which comes in from the west. There, the line of the Cleveland survey from Skagit valley was encountered and followed down Mamaluse and Cambie creeks to the junction of Roche[1] river. From this junction an excellent trail was followed down Similkameen valley to the mouth of Lamont (Ninemile) creek where the survey ended.

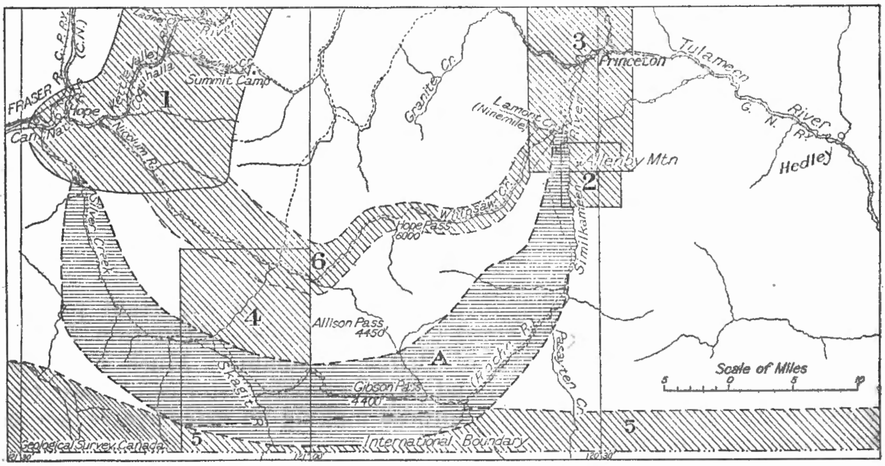


FIGURE 10. Index map of a part of southwestern British Columbia showing area A (in horizontal shading) dealt with in this report, and other areas previously mapped (in oblique shading) as follows: 1, Coquihalla; 2, Allenby mountain (report not yet published); 3, Similkameen; 4, Skagit valley; 5, International Boundary; 6, Dewdney trail.

PREVIOUS WORK

Prior to 1923 a considerable amount of exploratory work had been done in neighbouring areas, as well as across certain sections of the present area, and some geological work of a more or less detailed character had also been done.

In the years 1859-61, Bauerman, geologist to the North American Boundary Commission, made an examination of the country near the Forty-ninth parallel west of Rocky mountains. His report, illustrated by geological sections, was published by the Geological Survey, Canada, in the Report of Progress for 1882-3-4.

In 1877, Dawson made a geological reconnaissance of a large section of southern British Columbia,[2] including the area under present consideration.

During the years 1901-06 inclusive, Daly was engaged by the International Boundary Commission in making a more detailed geological

[1] Namely, the southern part of Similkameen river.
[2] Geol. Surv., Can., Rept. of Prog., 1877-78.

exploration across the Cordillera on both sides of the boundary line. The results of his work are embodied in a memoir[1] which has been of very great assistance in the present investigation.

In 1906, Camsell made preliminary investigations in Similkameen mining division and a report covering the work was published in the following year.[2]

In 1911, Camsell made a geological reconnaissance of Skagit River basin for 15 miles north of the United States boundary. The area included in this exploration crosses the routes followed by the present writer in 1922 and 1923.

During the field seasons of 1920-21 the writer was engaged in a geological examination of Coquihalla map-area adjoining the western end of the area here described and extending northward to the headwaters of Coquihalla river; and in 1922 made a rapid geological reconnaissance of a strip of territory traversed by the trail between Hope and Princeton over Hope Summit (Figure 10). This route crosses much the same series of formations as those under consideration in the present report.

TOPOGRAPHY

The area under discussion includes parts of two important physiographic provinces generally referred to as the Cascade Mountain system and the Interior Plateau region of British Columbia. Much has been written on the distinctive features and physiographic histories of these two provinces and the writer does not purpose making an extensive review of the subject at this time.

The valley of Silver creek and Klesilkwa river cuts across the unit of the Cascade system known as the Skagit range. To the east of this unit, and separated from it at the International Boundary by the broad valley of Skagit river, lies the Hozameen range. These mountains extend eastward to the valley of Pasayten river, beyond which rises the Okanagan range, the third, and most easterly, of the component units of the Cascade Mountain system at the International Boundary.

Within the area under consideration, the basin of Similkameen river forms a bay of the Interior Plateau region, flanked by the two main subdivisions of the northern Cascades; namely, Hozameen and Skagit ranges to the west and Okanagan mountains to the east.

A striking view of both mountain and plateau provinces is obtained from the divide between Lightning and Nepopekum creeks. To the south, and extending east and west along the International Boundary, is the mass of snow-covered peaks composing Hozameen range, some of which rise 9,000 feet. To the north, on the other hand, stretches the uniform, almost monotonous expanse of the plateau country, cut by deep valleys and exhibiting a remarkable uniformity of sky-line and a gentle regional slope which gradually rises toward the south until at its higher elevations it falls very little below the crest-line of the more rugged mountain province adjoining. A first casual survey seems to indicate a radical difference in

[1] Daly, R. A., Geol. Surv., Can., Mem. 38.

[2] Camsell, Chas., Geol. Surv., Can., "Preliminary Report on a Part of the Similkameen District, B.C.," Pub. No. 986.

the physiography of the two provinces, but more detailed study reveals important points of similarity. With the exception of an occasional prominent peak, the mountains to the south exhibit a certain uniformity of crest-line from which there is more or less gradual transition northward into the plateau country. This points to the origin of the mountains as a dissected plateau. The present, more rugged topography of the mountains has been occasioned by an initial greater elevation, inducing greater activity in mountain glaciation and other erosional forces.

Glaciation of both regional and alpine types has done much to modify the topography of this area. In the Cascades the summits of the hills have been scoured off up to about 6,500 feet, above which they have, apparently, escaped ice erosion. The movement of the regional ice down the main valleys and their tributaries fashioned the U-shaped contours of these channels and established hanging valleys at their junctures. Alpine glaciation still persists in the higher peaks and its effects are largely responsible for the extremely rugged and picturesque character of this mountainous region (Plate II A). By reason of its lower relief and elevation the plateau province was, doubtless, covered by a more persistent ice cap than the higher mountainous area to the south, where a ready exit to the sea was furnished by such master valleys as that now occupied by Klesilkwa and Skagit rivers.

The drainage of the area presents some interesting problems. Hozameen range may be said to separate the waters of the Skagit and Similkameen. The lowest point on this interstream divide lies at the head of Nepopekum creek and is sometimes referred to as Gibson pass. It has an elevation of about 4,400 feet and falls nearly 2,000 feet below the crest-line of the summits on either side. The hills to the north and northeast merge into the plateau region; those to the northwest form part of the Hozameen range. This low pass forms part of a well-marked through valley trending east and west and forming a connecting link between the basins of Skagit and Similkameen rivers. It probably antedates the regional uplift of plateau in relatively late Tertiary time. The gradient to the east, down the broad valleys of Mamaluse and Cambie creeks, is gentle, whereas the westward descent down Nepopekum creek is abrupt and the creek follows a series of canyons which have been cut below the level of the older valley bottom as a result of comparatively recent uplift or tilting in that section. This movement involved, to a variable degree, the main valley of Skagit river and has been partly responsible for certain changes in drainage in the valley occupied by Klesilkwa river and Silver creek.

These latter streams now flow in opposite directions in a master valley (Plate II B) which, below the mouth of Klesilkwa river, is occupied by the Skagit. This valley is remarkable in that it cuts deeply across the heart of Skagit range and, like the through valley occupied by Nepopekum and Mamaluse creeks, probably antedates the uplift of the Cascade peneplain. The walls rise abruptly on either side for heights of from 3,000 to 5,000 feet. Above this elevation they encounter the more gentle upland slopes and are carried back to the summits of the main interstream divides. The streams tributary to this main valley are consequently, with few exceptions, tumultuous in their lower courses. It is noticeable (Map 2023) that the width of the main valley bottom gradually increases from Silver lake to the International Boundary. Below Silver lake, and beyond the limits of the area, Silver creek drops rapidly to Fraser river.

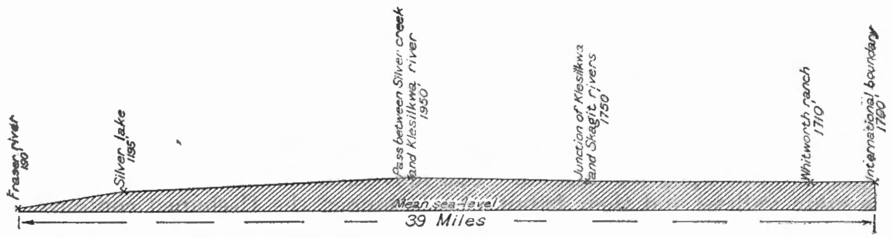


FIGURE 11. Cross-section of valley occupied by Silver creek and Klesilkwa and Skagit rivers, showing the gentle stream gradients between Silver lake and the International Boundary as compared with the more abrupt descent from Silver lake to Fraser river. Vertical exaggeration 4 times.

A profile of the present stream grades of Silver creek and Klesilkwa and Skagit rivers between Fraser river and the International Boundary is given above (Figure 11). Taken in conjunction with the increasing width of valley bottom between Silver lake and the boundary it suggests that Silver creek above Silver lake was, at one time, tributary to Skagit river, but that owing to more recent tilting of a differential character the Silver Creek drainage has been diverted entirely into the Fraser.

FLORA AND FAUNA

Vegetation is particularly heavy in the more westerly sections of the area. Heavy forests clothe the valleys up to about 4,000 feet above the stream beds. Some magnificent forests of red cedar and fir were observed in the valleys of Silver creek and Klesilkwa river. Below the mouth of the Klesilkwa, Skagit valley, trees become less abundant and their place is taken chiefly by an abundance of lodgepole pine (*Pinus murrayana*). A transition zone between the more characteristic vegetation of the moist coastal areas of British Columbia and that native to the semi-arid interior, was apparent over that part of the route extending between the mouths of Klesilkwa river and Chuwanten creek. An extended discussion of the flora in this zone of transition, as well as in adjoining sections of the basins of Skagit and Similkameen rivers, is given in a report[1] by Professor J. Davidson, of the University of British Columbia.

The more common of the larger wild animals in the area include black, brown, and occasional grizzly bear; mountain-lions; mule deer; and mountain goat. A variety of smaller fur-bearing animals are found and trapped during open season. They include wolverine, beaver, muskrat, fisher, mink, otter, and weasel. Coyotes are more or less numerous in the upper basin of Similkameen river. Grouse and ptarmigan are the commoner game birds. Trout are particularly plentiful in Skagit river and Lightning Creek lakes.

[1] Third Ann. Rept., Botanical Office of the province of British Columbia.

GENERAL GEOLOGY

The rocks in the area range in age from Carboniferous to Quaternary. The Mesozoic is represented by Cretaceous, Jurassic, and, probably, Triassic rocks. The bulk of the Tertiary rocks are of post-Eocene age, but the Oligocene period may be represented by the Skagit Volcanic formation exposed along the International Boundary west of Skagit river.

Table of Formations

Quaternary	Pleistocene and Recent	Stream and glacial deposits
Tertiary	Post-Eocene; probably post-Oligocene	Andesites and basalts with associated dykes
	Miocene?	*Chilliwack batholith* Quartz diorite, Granodiorite
	(?)	Diorite stock
	Oligocene or (and) Eocene; (probably Cretaceous)	*Skagit Volcanic formation*—chiefly andesite flows, tuffs, and breccias
Mesozoic	Cretaceous?	Granite and granodiorite *Remmel batholith* (*Eagle granodiorite*) chiefly granodiorite—may be pre-Cretaceous. Undifferentiated intrusions—augite syenite, monzonite, diorite, and gabbro.
	Cretaceous	*Pasayten series:* conglomerate, arkose, feldspathic sandstone, shale, and tuffaceous beds.
	Jurassic? (may be in part or entirely Cretaceous)	*Dewdney Creek series:* tuffaceous and argillaceous sediments with interbeds of green sandstone and fine conglomerate.
	Jurassic?	*Custer granite gneiss:* sheared and foliated granodiorite and quartz diorite.
	Triassic?	*Tulameen series?* Andesite flows, argillite, greywacke, and fine conglomerate. Schists.
Palæozoic	Carboniferous	*Hozameen series:* andesite flows and pyroclastic rocks commonly schistose (greenstones); argillaceous and cherty sediments, limestone.

CARBONIFEROUS

Hozameen Series[1]

The Hozameen series include the oldest rocks in the area and, except for the Tertiary volcanic rocks in Similkameen basin, have the greatest areal distribution. They have been traced continuously from the International Boundary northwestward to Fraser river, where they have been correlated on lithological and structural grounds with Dawson's Cache

[1] For a more detailed description of the members of the Hozameen series the reader is referred to the following reports: Daly, R. A., Geol. Surv., Can. Mem. 38, pp. 500-504. Smith, G. O., and Calkins, F. C., Bull. 235, U.S.G.S., 1904, p. 22.

Creek series of Carboniferous, and probably Pennsylvanian age. No fossils were discovered in these rocks within the limits of the present area. The series is composed of both sedimentary and volcanic members. The former are represented chiefly by bedded chert and by cherty and argillaceous sediments. Narrow limestone beds were occasionally encountered and are of some importance in connexion with the ore deposits at Green lake. The chert, in this series, is regarded as a chemical precipitate and is thought to have been derived from a magmatic source connected with the extrusion of the volcanic members of the series. The volcanic members are, on the whole, greatly altered lavas of intermediate and basic composition and are commonly referred to as greenstones.

Little information of value could be obtained relative to the thickness of the series, owing to its excessive deformation and to the faulted or intrusive character of its contacts with later formations. In the present area the series, as a whole, has a general trend of north 35 degrees west and dips at an average angle of 73 degrees to the northeast. This structure, however, is complicated by faulting and thrusting and by the development of slaty and schistose structures. The long and comparatively narrow strip of these rocks following a zone of shearing down Silver Creek valley, has, apparently, afforded a favourable zone for stream erosion as compared with the more resistant intrusive bodies on either side.

The members of the series show, near intrusive rocks, a varying degree of metamorphism. The limestone beds are especially susceptible to alteration and ore deposits have been found associated with them. The volcanic and sedimentary members have also been impregnated with ore minerals in certain sections of the area, notably in the basin of Tenmile creek. A discussion of these mineral deposits is given in a subsequent section of the report.

TRIASSIC

Tulameen Series

Those rocks which have been assigned a Triassic age are easily separable into two groups which may, in reality, represent more than one geological period. One of these groups is composed almost entirely of schistose rocks of both sedimentary and volcanic origin. These form a belt nearly 3 miles wide extending across the valley of Roche river above the junction of Pasayten creek. They are intruded to the south by the Remmel granodiorite which is held responsible for important ore mineralization in the schists. To the north these schists are, apparently, faulted against members of the other group of rocks included in the series. Elsewhere the schists are unconformably overlain by Tertiary volcanic rocks or by Quaternary stream deposits. The schists appear to be dominantly of sedimentary origin and, where least altered, have preserved distinct traces of bedding and clastic texture. More commonly, however, the original sediments have been altered to thinly laminated, light-coloured, quartz sericite schists which in many places show impregnation by pyrite and other ore minerals. Other abundant varieties of schist include greenish talcose and chloritic rocks, commonly thinly laminated and slickensided and some containing conspicuous acicular crystals of dark green hornblende. More rarely, and close to the granodiorite contact, this hornblende may compose 75 per cent or more of the rock. The general trend of schistosity is about north 15 degrees west, with dips averaging from 55 degrees to 60 degrees to the southwest. This group of schistose rocks is apparently faulted against the other group of rocks included in the Triassic, for there is an abrupt change both in the attitude and lithology of the two groups on either side of their contact.

The second group, like the first, includes members of both volcanic and sedimentary origin and, within the zone of metamorphism of such a large intrusive body as the Remmel batholith, such rocks might suffer alteration into types similar to those encountered in the belt of schists already described. On the other hand, the fault which separates the two groups may mark a contact between geological formations of quite different age. The group represented below the mouth of Pasayten creek forms a long series of outcrops extending down the valley of Similkameen river as far north as Whipsaw creek. Outcrops, chiefly of sedimentary rocks, are exposed in a series of rocky box canyons cut out by the river. The most abundant member is a fine-grained, black or dark grey argillite, but interbedded with it are coarser types including tuffaceous greywackes and fine conglomerate. The pebbles in the latter are subangular and were derived from fine-gained, cherty sedimentary and volcanic rocks. Along the bed of the river, however, and a mile or so below the mouth of Copper creek, a number of huge, angular blocks of coarse conglomerate were observed. These contain many cobbles and boulders of intrusive rocks, chiefly massive granodiorite or quartz diorite types. It seemed not unlikely that these blocks were derived from some horizon in the underlying sediments and, if so, there is a striking resemblance between this horizon and certain conglomerate strata in the Pasayten series. The argillaceous sediments in this group also show points of resemblance to members of both the Pasayten and Dewdney Creek series. In their association, on the other hand, with great thicknesses of volcanic flows; in their position and attitude on the eastern flank of the Remmel granodiorite, and also in many of their lithological characteristics, these sediments are regarded as more closely allied with members of the Tulameen series[1] exposed farther to the north in the basin of Tulameen river and on Whipsaw creek[2], and are consequently correlated tentatively with that series and referred in age to the Triassic. No fossils were found in these sediments in the present area.

In addition to the sedimentary members this group includes an even greater proportion of volcanic rocks. They are exposed over a wide area east of Similkameen river below the mouth of Pasayten creek. West of the river they outcrop at a number of points along and east of the trail between Pasayten and Copper creeks. They are prominently exposed in the canyon of Whipsaw creek; on the northeastern slopes of Kennedy mountain; and along Similkameen river near the mouth of Saturday creek.

Lithologically, these volcanic rocks include both flow and fragmental types with the former greatly in excess. The lavas are andesitic in composition, but vary considerably in habit and mineralogy. The most abun-

[1] Camsell, C., Geol. Surv., Can., Mem. 26, p. 37.
[2] Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1922, pt. A, p. 110.

dant type is a massive, dark green, vesicular lava in which the vesicles are commonly filled with calcite and the rocks intersected by numerous veins and veinlets of quartz or quartz and calcite. Other types are quite schistose and lack the vesicular structure. All types are metamorphosed and impregnated with ore minerals near that intrusive complex which crosses Similkameen river between Saturday and Whipsaw creeks. The copper ore on the Celtic claims on Kennedy mountain, referred to in a subsequent section of this report, occur in a vesicular andesite and probably owe their mineral content to these intrusives.

JURASSIC

Custer Granite Gneiss[1]

The Custer granite gneiss is continuous to the south of the area as far as Custer ridge, from which it received its name. A discussion of its field relations has been given by Daly and corresponds closely with observations made by the writer in the area under present consideration.

This intrusive is remarkable for its crushed and banded appearance and for its variability in texture and composition across the prevailing trend of foliation which runs approximately north 55 degrees west and dips about 65 degrees northeast.

This formation definitely intrudes the Hozameen series and seems as certainly to underlie unconformably those Cretaceous sediments which outcrop near the summit of the high ridge between the main forks of Yola creek. The gneiss is intruded by members of the Chilliwack batholith and by a massive granite or granodiorite which has been referred to a late Cretaceous period of intrusion. The gneiss may, accordingly, be regarded as Mesozoic in age and, probably, pre-Cretaceous. It has been assigned, tentatively, to the Jurassic and correlated with intrusives of that age which constitute the bulk of the Coast Range batholith.

A prominent zone of shearing follows along, and on either side of, Silver Creek valley, and has a width of about a mile. Within this zone is included a long, and comparatively narrow, strip of the older Hozameen rocks which appear to owe their position to folding preceding or accompanying their period of intrusion by the gneiss. The latter exhibits remarkable variations in composition within this zone of shearing, and, in particular, near its contact with these older rocks. This variability is attributed in part to some original differences in composition at the time of intrusion; in part to intense shearing and granulation; and, in part, to some assimilation of the older rocks by this intrusive.

Although this gneiss everywhere exhibits more or less banding and foliation, these structures are more prominent within certain limited zones of shearing such as that mentioned above. Between these zones the rock is more massive in appearance, more uniform in composition, and, probably, more nearly approaches the mineral and chemical composition of the original intrusive than elsewhere. A very similar type was encountered on either side of Silver Creek valley well back from the central zone of

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 523-26.

shearing. It was found to be, typically, a somewhat foliated biotite granodiorite containing little or no hornblende.

Within the zone of shearing down Silver Creek valley a cataclastic structure is very pronounced and the gneiss varies greatly in appearance and composition. Dark-coloured belts of quartz diorite, in which quartz, plagioclase, hornblende, and biotite are the essential minerals, lie between wider zones of a light-coloured granite composed almost entirely of quartz and orthoclase and showing extreme granulation.

Dewdney Creek Series

The rocks included in this series were placed by Daly at the top of the Pasayten series and regarded as probably Upper Cretaceous in age. It is, accordingly, with some hesitation, that they are here referred to an older period, and the present classification must be regarded as subject to correction in the light, chiefly, of palæontological research on the fauna of the Mesozoic rocks of southern British Columbia.

The series forms a belt over 6½ miles wide extending in a general northerly direction across the divide between the headwaters of Skagit and Similkameen rivers. It is faulted, to the west, against the older rocks of the Hozameen series and, to the east, against a belt of coarse-grained, feldspathic sediments forming part of the Pasayten series. The probability of a fault along this eastern contact is based, in part, on the recognition of an abrupt change in the character of the sediments and, in part, on the occurrence of opposing dips on either side of the contact. Although this change in attitude may be only local and consequently of no great stratigraphic significance, a similar structure has been observed by the writer farther to the north on either side of Skagit river[1] and at the headwaters of Tulameen river.[2] In both these localities the occurrence of these contrary dips was interpreted as the result of faulting along the eastern contact of the Dewdney Creek series with later Cretaceous sediments.

The separation of the Dewdney Creek series from the members of the Pasayten series has, however, not been based on structural evidence alone. The rocks of this belt are continuous across Skagit river and from there still farther north into Coquihalla area. In these localities, marine fossils were found in the series, and these fossils were assigned tentatively to the Jurassic.[3] In the Coquihalla area the bulk of the Dewdney Creek series is composed of volcanic tuffs. In Skagit valley this tuffaceous character is still pronounced, but the series includes a considerable thickness of black, shaly rocks and coarser, feldspathic sediments which have a more normal clastic appearance. In the present area the members of this series are very similar to those occurring on Skagit river. From one of the coarser beds a small collection of fossils was obtained, but was not found to be of present significance in fixing the age of the enclosing rocks.

Under the microscope the bulk of both coarse and fine-grained members have a decidedly tuffaceous appearance. They show very little quartz,

[1] Cairnes, C. E., Geol. Surv., Can., Sum. Rept. 1922, pt. A, p. 113 A.
[2] Cairnes, C. E., Geol. Surv., Can., Sum. Rept. 1922, pt. A, p. 97.
[3] McLearn, F. H., Geol. Surv., Can., Preliminary determination.

a large proportion of clear angular feldspar, and a considerable percentage of lava fragments. The groundmass is abundant and has an ashy appearance. Scattered through the rock are shards of partly devitrified glass, as well as lunar and cuspate fragments of feldspar. There is as a rule considerable secondary calcite in the slides of these rocks. Interbedded with these tuffaceous rocks are more normal clastic sediments, including beds of arkose, composed of angular grains of quartz and feldspar, and other beds of fine conglomerate with well-rounded pebbles. These pebbles do not include the plutonic types, so characteristic of the conglomerate strata in the Pasayten series, but were derived from fine-grained cherty sedimentary and volcanic rocks.

Over the greater width of the belt the dip is to the east, but varies considerably from point to point and is, in general, lower than that observed in the members of the Pasayten series farther to the east.

The lower member of the series is in faulted contact with the Hozameen rocks. It is moderately coarse grained and distinctly tuffaceous, and is overlain by finer-grained sediments in which black, shaly types predominate. These, in turn, were covered by a composite series of sediments, including both fine-grained, argillaceous rocks and coarser beds. The fine conglomerate, mentioned above, occurs in this section.

Not far from the eastern contact of this series there is a change in dip and the beds from this point to their contact with the Pasayten series dip to the west. This change in dip is abrupt and has probably resulted from faulting along a line running nearly, if not quite, parallel with the general trend of the series.

The Dewdney Creek series is intruded by numerous dykes and one small diorite stock. The latter only is shown on the map and is described in a later section of this report. The dykes are chiefly diorite-porphyry types. They vary somewhat in composition, but are commonly rich in plagioclase and contain hornblende as the chief mafic constituent; quartz is either absent, or present in very small proportions. These smaller intrusive bodies are probably related to the larger stocks of diorite and granodiorite which intrude the Dewdney Creek series within, and to the south of, the present area.

CRETACEOUS

Pasayten Series

The name Pasayten series as adopted by Daly[1] is a modification of the original Pasayten formation employed by Smith and Calkins, and refers to a great thickness of Cretaceous strata extending northward across the International Boundary west of Pasayten creek. The series, as defined by Daly, includes the Dewdney Creek series of the present writer, but, for reasons already given, the latter has been referred, tentatively, to the Jurassic, and the name Pasayten series is here restricted to those sediments which appear to be definitely of Cretaceous age.

The series, thus defined, includes a great thickness of sediments, dominantly coarse grained, and, except near their western contact, dipping

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 480.

to the west at angles which are rarely less than 20 degrees and as a rule exceed 35 degrees. The average strike is very nearly north 30 degrees west. These rocks are in faulted contact on the west with members of the Dewdney Creek series which trend north and south and, consequently, lie at a considerable angle to the Pasayten strata. On their eastern flank the Pasayten rocks are in contact with the Remmel granodiorite batholith. The relations are here a matter of doubt as, at all points examined, the contact was obscured by surface debris for a distance of several yards, at least, on either side. At the International Boundary the relation between the basal member of the Pasayten series, known as the Pasayten Volcanic formation, and the Remmel batholith was interpreted as unconformable,[1] but in the present area there are reasons for believing that the Pasayten series has been intruded by the batholith. The absence of the Pasayten Volcanic formation from the base of the Pasayten series in the present area is regarded as due probably to its having been cut off by the batholithic intrusive. For other considerations, too, which will be referred to later, the batholith is regarded, tentatively, as younger than the sediments.

The prevailing dip of the Pasayten series is to the west. This structure is complicated by a series of strike faults and by easterly dips near the contact of the Dewdney Creek series. The total thickness of sediments exposed is very great,[1] but is difficult to estimate as strike faulting has complicated the structure and the amount of reduplication, due to this faulting, could not be determined because of the lack of definite evidence of repetition of recognizable strata. One important horizon-marker exists in the thick belt of conglomerate—member No. 9 (Map 2023)—and its appearance only once in the section may mean that faulting has not caused any great reduplication of strata. On the other hand, and as seems more probable to the writer, the faulting may have been on a sufficient scale to throw this conglomerate below the present surface exposures or, possibly, one or other of the narrower conglomerate beds encountered east of the main belt may represent a part of the larger belt, the remainder of which has been faulted off. A suggestion that important reduplication may have occurred is supported by the occurrence of a belt of andesite, andesite agglomerate, and tuffaceous rocks lying immediately above, or to the west, of the fault running up Chuwanten and Hampton creeks on either side of Roche river. This belt, included with member 8 (Map 2023), is particularly well exposed on the high peak known as Haystack mountain at the head of Hampton creek. Judging from description alone, these volcanic rocks are very similar to members of the Pasayten Volcanic formation lying at the base of the Pasayten series at the International Boundary. Should such an identity be established it would involve the assumption of important reduplication between Chuwanten creek and the base of the Pasayten series at the contact of the Remmel batholith.

The Pasayten series is here subdivided into four members (*See* Map 2023). The most easterly, and largest, member 7, extends from the Remmel batholith to the fault up Chuwanten and Hampton creeks; the second, member 8, includes the rocks west of this fault and between it and the

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 481.

coarse conglomerate member 9; member 10 lies between this conglomerate belt and the western contact of the Pasayten with the Dewdney Creek series.

Member 7, as well as being the thickest member, is also probably the most uniform in character. The strata composing it dip everywhere to the west at angles varying from 20 to 60 degrees. It is probable that there has been reduplication by faulting, although the actual positions of important fault-planes were not determined. It seems likely that a fault of some significance crosses Roche river a little over 2 miles below the mouth of Chuwanten creek, where there is a rather abrupt change in the character of the sediments. Below this point the dominant rock is an exceedingly massive and well-cemented arkose whose attitude can be determined only by the presence of thin interbeds of shale. This arkose is typically light grey in colour and so crystalline in appearance as to be easily mistaken for an intrusive rock. It is composed chiefly of angular grains of quartz and feldspar and its igneous appearance is increased by the presence of abundant small black flakes of biotite or fragments of other rock. Small flakes of colourless muscovite are also present. Within half a mile or so of the contact of this member with the Remmel granodiorite the sediments are more feldspathic in appearance and are deeply weathered to shades of brown. Farther up the river, and above the more typical arkose beds, the sediments are more variable in composition, ranging from shale to fine conglomerate. Those beds of intermediate texture are feldspathic sandstones resembling those near the base of this member. Two collections of fossil plants were obtained by Daly from this member south of the present area. One collection was made about 2 miles west of the Remmel batholith and 2 miles north of the International Boundary. This collection was referred by Professor Penhallow to the Lower Cretaceous (Shasta series). The other collection was obtained at the 4,200-foot contour about 400 yards north of the Boundary slash and on the east side of Chuwanten Creek canyon. This locality is close to the east of the fault running up Chuwanten valley. The fossils obtained here were regarded by Professor Penhallow as representing horizons in both Lower and Upper Cretaceous (Shasta-Chico series).

Member 8 is much smaller than member 7 and is composed, in part, of rocks entirely unlike any of those occurring elsewhere in the series within the limits of the map-area. It is cut off from member 7 on the east by a fault running up Chuwanten and Hampton creeks and, on the west, grades rapidly into the coarse conglomerate beds of member 9. To the south of the area this member is intruded by a chonolith of syenite porphyry[1] regarded as Tertiary, and probably Miocene, in age. As in member 7 the strata dip to the east, but at a somewhat steeper angle. The change in dip on either side of the fault is abrupt and very noticeable in those outcrops exposed along the trail down Similkameen river, as well as on the hills to the north and south of this trail.

The greater part of member 8 is composed of rocks which are either of volcanic origin or are associated with the extrusion of pyroclastic material. This character is best exhibited on Haystack mountain at the head of Hampton creek. This peak is made up of coarse agglomeratic

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 499.

material showing little evidence of bedding and composed of an assortment of rounded, as well as angular, blocks of andesite cemented together by lava and well consolidated ashy materials. Under the microscope the andesite shows a marked porphyritic texture with phenocrysts of both feldspar and pyroxene. The feldspar is commonly zoned and of intermediate composition. The pyroxene is probably augite. The coarsest agglomerate is apparently confined to Haystack mountain, but some moderately coarse materials of very similar character were also observed within 2 miles of the International Boundary on the ridge west of the main valley of Chuwanten creek. Elsewhere these pyroclastic rocks appear to be finer in character and are commonly greenish in colour, although varying in the finer and more shaly beds to almost black. A thin section of the greenish tuff, obtained from an outcrop along the Roche River trail less than a mile above the mouth of Chuwanten creek, was examined under the microscope and found to be composed chiefly of fragments of andesite and partly devitrified glass. A few grains of augite and feldspar were present as well as considerable secondary calcite. Towards the west these pyroclastic rocks appear to grade into arenaceous and shaly sediments more clastic in appearance and composition, and in which both plant and animal remains have been found. Collections of the fauna[1] were studied by Dr. Stanton who reports the horizon to be " clearly Cretaceous and apparently within the limits of the Horsetown formation."

Member 9 is the most important stratigraphic member of the series. It is composed chiefly of coarse conglomerate, except toward the flanks, where it is finer in character. This member extends in an apparently regular manner across the area. It has a trend of about north 20 to 25 degrees west and dips at an average angle of 60 to 65 degrees west. To the south it extends across the International Boundary. To the north, it is, probably, represented by the belt of conglomerate which crosses Skaist river a short distance below where the trail from Hope Summit first crosses to the left bank of the river.[2] Still farther north a couple of similar coarse conglomerate members were observed at the headwaters of Tulameen river[3] and still another crosses Coquihalla river below Romeo.[4] In its more northern exposures there is a very considerable variation in the attitude and thickness of this conglomerate, but there seems little doubt of its representing the same horizon in the series and for this reason, and because of its ready identification, it becomes an exceedingly important horizon-marker in interpreting the structure of these Cretaceous rocks.

Lithologically, this conglomerate is distinguished by its coarseness and thickness; by the well-rounded character of its constitutent pebbles, cobbles, and boulders; and by the variety of rock types represented. The boulders commonly reach a diameter of from 1 to 2 feet and whether large or small, are mostly remarkably well rounded. Intrusive rocks are abundantly represented, particularly the more acid types such as granite and granodiorite. These are, in general, massive in structure and fresh in appearance. A large proportion of the pebbles are from cherty sediments

1 Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 487-488.
2 Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1922, pt. A, p. 112.
3 Cairnes, C. E., Geol. Surv., Can., Sum. Rept., pt. A, p. 97.
4 Cairnes, C. E., Geol. Surv., Can., Mem. 139, "Coquihalla Area, B.C."

and fine-grained volcanic rocks. Pebbles of porphyritic volcanic and dyke rocks are less plentiful, and fragments of slaty and arenaceous sediments are relatively scarce. No limestone pebbles were observed.

The thickness of member 9 has been estimated by Daly at 1,400 feet in the vicinity of the International Boundary. This corresponds closely with its calculated minimum thickness in the present area.

Member 10 is the most eastern member of the Pasayten series as defined in the present report. It is composed largely of greenish-grey, brown-weathering feldspathic sandstones interbedded with a considerable proportion of black or dark grey, shaly rocks. Although this member appears to lie conformably above member 9 there is a rather abrupt transition, at those points examined, from fine conglomerate to shale. The attitude of member 10 shows considerable irregularity. The prevailing dip is toward the west, but, near the contact of the Dewdney Creek series, a number of high easterly dips were observed.

Under the microscope, sections from different coarse feldspathic strata in member 10 were found to be composed largely of angular grains of quartz and feldspar, with the latter mineral always in excess. Remnants of biotite flakes and occasional lithic fragments were observed. Secondary minerals include sericite, chlorite, epidote, and calcite.

Undifferentiated Cretaceous. An area of sediments, very similar lithologically to members of the Pasayten series, is exposed on the summit of the high ridge between the main forks of Yola creek in Silver Creek basin. Their areal extent was not investigated, but it appears probable, from such observations as were taken, that they cover a considerable area farther to the south and along the summit of the ridge overlooking the south fork of Yola creek. Several miles farther north, and about 2 miles west of Silver lake, a very similar group of sediments composes the upper 1,500 feet or so of Silver peak and has been referred in an earlier report to the Lower Cretaceous.[1]

Structurally, these sediments have an exposed thickness of over 1,000 feet. They strike about north 10 degrees east and dip to the west at an average angle of about 40 degrees. They overlie unconformably, the Custer granite gneiss, which has been referred to the Jurassic, and, although no fossils were obtained in them, they so much resemble members of the Pasayten series that the writer has little hesitation in correlating them with these Cretaceous rocks. Lithologically, they range from shales to coarse conglomerate, and conglomerate forms the bulk of the sediments exposed at this locality (Plate III A).

Undifferentiated Intrusives

These intrusives are well exposed in the canyon of Similkameen river between the mouths of Saturday and Whipsaw creeks. Farther west, their contact with a series of sedimentary and volcanic rocks is obscured by a mantle of drift and its position on the map is assumed. Within the western limits of the Allenby (Copper) Mountain area these intrusives have been studied in detail by Dolmage of the Geological Survey, who has kindly

[1] Cairnes, C. E., Geol. Surv., Can., Mem. 139, "Coquihalla Area, B.C."

supplied the writer with information concerning their petrographic characteristics and field relations.

No attempt has been made by the writer to differentiate this intrusive complex into its separate members. Sufficient only was done to prove its variability in mineral composition. Dolmage recognizes several rock types, among which the most abundant include augite syenite, monzonite, diorite, and gabbro. As a whole the complex is characterized by the presence of augite. In the more acid members orthoclase is a prominent constituent and may be present almost to the exclusion of other minerals. Pegmatite dykes and dykelets of this character are locally abundant.

In places these rocks show a great deal of fracturing, but there does not appear to be evidence of important shearing or granulation. Foliated structures were observed, but are not common, and, where recognized, appear to have developed during, rather than subsequent to, consolidation.

On the west and south these intrusives cut through a series of andesite volcanic rocks and black, argillaceous sediments which have been grouped together and referred, tentatively, to the Triassic. They may, however, belong to a later period in the Mesozoic and in certain lithological features are not dissimilar to members of both the Pasayten and Dewdney series. The intrusives are not likely to be pre-Jurassic in age and almost certainly represent a late, and possibly a later, period of intrusion than the Remmel batholiths farther to the south. They are consequently referred, tentatively, to the Cretaceous period.

These intrusives are held responsible for important ore mineralization on both Allenby and Kennedy mountains. The ore occurs not only in the intrusive members themselves, but, to a more important extent, in the zone of older metamorphosed rocks encircling them. The ore mineralization on the Celtic group of claims, Kennedy mountain, is discussed on page 79.

Remmel Batholith

Eagle Granodiorite. The Pasayten series is in contact on the east with a belt of intrusives forming part of what has been called the western phase of the Remmel batholith.[1] In the present area it forms a belt about 4 miles wide extending in a northwest-southeast direction across Roche river above the mouth of Pasayten creek. On the west it is in contact with member 7 of the Pasayten series. On the east, it is intrusive into a belt of schists which are included with the Triassic rocks of the area. To the north, it is overlain unconformably by Tertiary volcanic rocks.

This intrusive varies considerably in both texture and composition, but may be generally described as a moderately coarse-grained hornblende biotite granodiorite. It shows evidence of foliation as a rule, but this structure is much more pronounced in some sections than others. Biotite is the more common of the mafic mineral constituents, but is locally subordinate in amount to the hornblende. Near the contact of this granodiorite with the Pasayten series on the right bank of Similkameen river, a coarse-grained basic border phase was observed. Horn-

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 443.

blende is here greatly in excess of biotite and has formed large prismatic crystals from one-half an inch to an inch in length.

The essential minerals in the more typical exposures of this granodiorite are quartz, plagioclase, orthoclase, biotite, and hornblende. Titanite, apatite, and magnetite are common accessory minerals. The percentage of alkali feldspar is in many cases a little low and the composition of the plagioclase too basic for granodiorite, so that the rock, in such cases, might be more closely classified as a quartz diorite. The plagioclase varies from oligoclase-andesine to andesine in composition.

Near the International Boundary the Remmel batholith forms a much wider belt than in the present area, and has been subdivided by Daly into an eastern and western phase. Both these phases are regarded as parts of the same intrusion which owes its present differences in structure and, to some extent, in composition, to subsequent metamorphic processes. The present area includes only a part of the western phase of this intrusive.

Some attention has already been given to the nature of the contact between the Remmel batholith and the Pasayten series. At the International Boundary there are, apparently, good indications of an unconformity, but this relation is much less certain in the present area where, in the writer's opinion, the evidence is rather in favour of an intrusive contact. This evidence, although not conclusive, is extremely suggestive and may be summarized as follows: (1) the Pasayten volcanic formation, which forms the base of the Pasayten series at the United States boundary and has an estimated thickness there of at least 1,400 feet, is missing at Similkameen river and may owe its absence to having been cut off by the granodiorite. (2))A number of dykes, not very different in composition from the granodiorite, were observed cutting the Pasayten strata at varying distances from the contact. These dykes are, probably, related to the same magmatic source as the granodiorite, but may, of course, belong to a considerably later period of intrusion. (3) At certain localities near the Pasayten contact the granodiorite is notably basic and both in texture and composition suggests the occurrence of a basic border phase of the granodiorite.

It might be expected that this batholithic intrusive would strongly metamorphose the adjoining Pasayten rocks, and the absence of definite evidence of such metamorphism in these sediments, favours the view of an unconformable relation at the contact. It must be remembered, however, that the extent of such metamorphism depends very largely on the character and composition of the rocks intruded. In this case the adjoining members of the Pasayten series are, generally speaking, massive types of arkose which would not be readily susceptible to alteration.

The "western phase" of the Remmel batholith is continuous to the northwest of the present area, and is probably represented by that intrusive which forms a belt about 5 miles wide on either side of Hope Summit at the head of Whipsaw creek and Skaist river.[1] Still farther to the northwest, and in line with the more southern exposures, this belt continues along the western side of Tulameen map-area into Coquihalla area. In these more northern localities it has much the same petrographic character-

[1] Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1922, pt. A, p. 114.

istics as farther south and has been referred to in previous reports as the "Eagle granodiorite," a name introduced by Camsell in his report on the Tulameen map-area.[1] Camsell assigned this granodiorite, tentatively, to the Jurassic. In the adjoining Coquihalla area,[2] however, the present writer was able to obtain what he considered good evidence that this granodiorite cut the Lower Cretaceous (Pasayten) rocks exposed there, and it is partly on the basis of this evidence that the age of the Remmel batholith in the present area is regarded as Cretaceous.

Granite and Acid Granodiorite

To the east of Silver Creek valley the Custer granite gneiss is intruded by a couple of bodies of a massive, pinkish, granitic rock which, although somewhat later in age than the gneiss, is probably genetically related to it.

In appearance this intrusive is a massive, moderately coarse-grained, pinkish rock containing an abundance of glassy quartz, white to pinkish feldspars, biotite, and a little hornblende. Acid plagioclase, albite-oligoclase in composition, is the most abundant feldspar. Orthoclase and microperthite are both present, the former in excess of the latter. Biotite is more abundant than hornblende. Under the microscope this intrusive shows evidence of strain and granulation comparable with the more massive members of the Custer granite gneiss; nor does the plagioclase show the zoned structure so characteristic of the so-called Tertiary intrusives of the area.

The exposures of this intrusive are continuous to the north into Coquihalla area where they were correlated with the later Cretaceous rocks. Their age cannot be more definitely fixed in the present area where they are in contact only with older formations.

TERTIARY

Skagit Volcanic Formation

Only a little time was spent in an examination of this formation as it lay somewhat beyond the limits of investigation and had already been reported on in considerable detail by Daly.[3] The formation comprises a thick group of volcanic rocks composed chiefly of andesite flows and pyroclastic rocks. Intercalated with these is a bed of conglomerate, 100 feet or more thick, and several thin lenses of argillite.

The formation is intruded to the south of the area by a stock of quartz-monzonite which has been referred tentatively to the Miocene. The Skagit volcanic formation is, consequently, older than this stock, but is probably post-Cretaceous. Daly postulates an Oligocene age for these rocks and thereby correlates them with the Oligocene andesite in the Midway district. It seems likely, too, that this formation is related to the Cedar Creek volcanic series of the Tulameen area[4] which is also of Oligocene age. There is a very remarkable resemblance between these

[1] Camsell, C., Geol. Surv., Can., Mem. 26.
[2] Cairnes, C. E., Geol. Surv., Can., Mem. 139.
[3] Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 528-531.
[4] Camsell, C., Geol. Surv., Can., Mem. 26, pp. 82-88.

two formations. Both comprise a heavy series of andesitic volcanic rocks including flow and fragmental types; both include a very minor proportion of intercalated sediments; and both are cut by Tertiary intrusive rocks referred tentatively to the Miocene period.

Hornblende Diorite

A small intrusive body of hornblende diorite is exposed on the northern slope of Lightning Creek valley above the chain of lakes lying near the head of this valley. The intrusive cuts members of the Dewdney Creek series and has the general form of a stock from the periphery of which many smaller dyke-like apophyses radiate into the adjoining sediments.

In appearance this is a massive, basic intrusive containing a varying but always high percentage of dark green hornblende. Plagioclase feldspar is the only other essential mineral. In some outcrops the proportion of these two constituents seems nearly equal, whereas in others the hornblende is considerably in excess. Under the microscope a thin section of an average specimen showed much alteration. Many of the hornblende crystals had almost colourless centres of pyroxene, and it is probable that much, at least, of the hornblende may be secondary after this pyroxene. The hornblende, in turn, is partly altered to chlorite and magnetite. The plagioclase approximates labradorite in composition.

This diorite is definitely late Mesozoic or Tertiary in age. It is probably related in age and origin to the Lightning Creek diorite and Castle Mountain stocks which are exposed to the south of Lightning Creek valley and have been regarded tentatively as Miocene in age.[1]

Chilliwack Batholith

The Chilliwack batholith is typically exposed about Chilliwack lake which lies beyond the map-area and near the International Boundary, a few miles to the southwest of the high divide at the head of Silver creek and Klesilkwa river. In the basin of the lake and its outlet, Chilliwack river, and on either side of the boundary, this batholith is widely exposed and is remarkable in the field for its general uniformity in colour, texture, and massive structure. Under the microscope, however, Daly was able to recognize three main phases, of which the most abundant was a biotite-hornblende granodiorite verging in composition to quartz diorite. The other phases included a biotite soda granite containing an abundance of quartz and orthoclase with some microperthite and no hornblende. A third, and most basic, phase is a quartz diorite characterized by basic plagioclase feldspar and an abundance of hornblende and quartz. Daly's studies led him to conclude, tentatively at least, that all three phases belong to one period of intrusion occurring at a relatively late date and probably in Miocene time.[2]

In the northern extension of this batholithic complex across and to the north of the present area, the writer has been able to recognize intrusive bodies corresponding very closely to all three of the aforementioned phases

[1] Daly, R. A., Geol. Surv., Can., Mem. 38, pp. 490-499.
[2] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 535.

of the Chilliwack batholith, but is of the opinion that the time of intrusion dates from the Cretaceous and that, in a still broader sense, the term Chilliwack batholith may be extended to include even late pre-Cretaceous intrusives. It seems likely, following the extraordinary bulk of intrusions in the late Jurassic, to which date is assigned the greater part of the Coast Range batholith, that irruption did not entirely cease, but continued on a less magnificent scale into mid-Tertiary time when there was a marked renewal of both orogenic and batholithic activity.

In the present report, however, only the later intrusives, including a granodiorite and a quartz diorite phase, will be included under the term Chilliwack batholith. These have been placed, tentatively, in the Tertiary, although it is not improbable that they belong, in part at least, to late Cretaceous time.

Granodiorite. The granodiorite occupies two areas to the south and southwest of the main valleys of Klesilkwa and Skagit rivers. Although the long and comparatively narrow belt of intrusive cutting across the Hozameen rocks to the southwest of Skagit river was not traced directly into the larger area south of Klesilkwa river, there seems little doubt that they form parts of the same body. Both have the same mineral composition and show similar relations toward those formations with which they come in contact. Both are comparatively fresh, unsheared rocks, and are consequently referred to a similar late period of intrusion. Both intrude members of the Hozameen series and the larger body intersects the Custer granite gneiss and is consequently younger. The smaller dyke-like body has been mapped and described by Camsell and referred to by Daly, and the larger body is continuous into the main body of the Chilliwack batholith. Both these writers refer the position of this granodiorite, tentatively, to the Tertiary, and Daly regards it as probably representing the most abundant phase of the batholith.

In appearance this granodiorite is a light grey to pinkish rock composed essentially of quartz, plagioclase feldspar approximating andesine in composition, orthoclase, biotite, and hornblende with accessory magnetite and apatite. Hornblende appears to be in excess of biotite in some of the specimens examined. The proportion of orthoclase is also variable and the granodiorite tends, on the average, to the composition of a quartz diorite.

Quartz Diorite. The quartz diorite phase of the Chilliwack batholith occupies a large area in the present sheet to the west of Silver Creek valley and is closely related in mineral composition to the granodiorite phase. In it, however, orthoclase is not an essential constituent and hornblende is commonly much in excess of biotite. This quartz diorite is continuous to the north into Coquihalla area and has been held responsible for the silver ores of the Eureka-Victoria mines on Silver peak.[1] The quartz diorite exposed at the southern end of Green lake has been included with this member of the Chilliwack batholith. It is more fully discussed in a subsequent section of this report dealing with the occurrence of certain ore mineralization.

[1] Cairnes, C. E., Geol. Surv., Can., Mem. 139.

TERTIARY VOLCANIC ROCKS

A large section of the present area north of the mouth of Pasayten creek is covered by a series of volcanic flows of Tertiary age. These have a vertical range, over the area examined, of about 3,000 feet, but their actual thickness is probably considerably less.

Structurally, these rocks overlie the older rocks with marked angular unconformity and form a basin-shaped body in Similkameen valley. It is likely that this valley antedated the extrusion of the lavas and that prior to their eruption the river occupied much the same course that it does at present. Subsequent stream erosion has cut steeply through these Tertiary flows into the older rocks beneath. West of the present area these volcanic rocks occupy a somewhat similarly shaped basin in the valley of Whipsaw creek.[1] Between the two basins areas of older rocks have been exposed on the divide between Whipsaw creek and Similkameen river.

A variety of types is represented in this series. They range in composition from andesite to basalt; in texture from aphanitic to coarsely porphyritic; and in colour from white to black through intermediate shades of grey, green, pink, red, purple, and brown.

The basal member or members of the series, as determined both from the lower outcrops above the bed of Similkameeen river and the higher ones on the divide between this river and Whipsaw creek, are, in general, dark grey to black, fine-grained, basaltic types. Above these lie a series of more porphyritic types showing a wide range in colour and mineral composition. The lower members are pink to reddish in colour with phenocrysts of basaltic hornblende which, in some cases, have been pseudomorphed by limonite. Above these is another pinkish type containing phenocrysts of both feldspar and hornblende, but in which the crystals of plagioclase are larger and more abundant. The feldspar has the composition of labradorite and is commonly zoned. Still higher in the series lie a variety of porphyritic types whose order of extrusion is less certain, but which tend to become more basic toward the top of the series. Shades of purple and dark grey are common in this section and a bright greenish weathering is in particular so pronounced as to have attracted considerable attention from prospectors who were convinced that the colour indicated the presence of copper. Cliffs of this character, overlooking the lower basin of Copper creek from the north, were responsible, originally, for the name which this creek bears. The green colour has resulted from the alteration of the hornblende and pyroxene minerals to chlorite and, when tested chemically, gives no trace of either copper or nickel.

Although the bulk of these rocks is undoubtedly of volcanic origin, a more detailed study may reveal the presence of associated intrusive types. A number of dykes, with very similar lithologic characters, intrude the older rocks of the area near the exposures of the volcanic flows, but no dykes of similar character were actually observed to cut the lavas themselves. Again, some of the coarse-grained outcrops, included with the volcanic rocks, may form part of stocks, sills, or volcanic necks and, as such, represent important outlets for the lava flows. The absence of pyroclastic deposits associated

[1] Cairnes, C. E., Geol. Surv., Can., Sum. Rept., 1922, pt. A.

with the lavas suggests that the extrusion may have been accomplished without particular violence and more after the fashion of fissure than crater eruptions.

In the valleys of Whipsaw and Lamont creeks these volcanic rocks overlie fossiliferous sediments of presumably Oligocene age[1] and their age is, consequently, referred to late or post-Oligocene time. Except for the Quaternary deposits, they represent the youngest rocks in the area.

QUATERNARY

The Quaternary deposits include those which accumulated during and following the Glacial period. They are represented on Map 2023 only by the stream deposits which occupy the bottoms of the larger valleys or occur as remnants of bench lands at elevations up to 1,000 feet or more above the present stream beds. The material for these deposits accumulated largely during the period or periods of retreat of the valley glaciers following the disappearance of the regional ice cap. In addition to these modified deposits, the greater part of the area is covered by a mantle of glacial debris which up to an elevation of about 7,000 feet supports an abundant vegetation. Many large glacial erratics are encountered and are of some value in following the course of Cordilleran ice-movements.

Only in the major valleys occupied by Klesilkwa, Skagit, and Similkameen rivers have stream deposits of importance accumulated. The tributary streams are, in general, and particularly in the Cascade Mountain province, short, and descend rapidly into the main valleys, offering, thereby very little opportunity for the accumulation of the eroded materials. During the retreat of valley glaciers up the main valleys an accumulation of poorly assorted debris would be left behind and subsequently reassorted by the action of the streams occupying the valleys. Temporary damming of these streams, such as might occur through the accumulation of debris at the mouths of tributary valleys, or through rapid elevation or tilting of the valley floors, would result in the formation of terraces at various elevations above the present stream beds. Remnants of a number of such terraces fringe the valley walls of Skagit, Klesilkwa, and Similkameen rivers.

On the probability that at the close of the period of valley glaciation the basin of Silver creek, above Silver lake, drained southward into Klesilkwa and Skagit valleys, it would appear that (Figure 11) there has been a differential upward tilting of these latter valleys of from 500 to 800 feet with the maximum elevation in the vicinity of the divide between Klesilkwa river and Silver creek. What depth of glacial material was present in Klesilkwa and Skagit valleys at the close of the glacial period is uncertain, but it was doubtlessly greater in the lower reaches of the valley than farther upstream. At no point in this major valley has the underlying rock been exposed and the streams now meander widely across a valley bottom which, below the mouth of the Klesilkwa, has an average width of over a mile. Remnants of what appear to be gravel benches were observed on the slopes of Klesilkwa and Skagit rivers up to an elevation of 1,000 feet above the present stream bed, and it seems safe to assume this for a

---

[1] Camsell, C., Geol. Surv., Can., Rept. 986, p. 81.

minimum thickness of glacial materials originally occupying the valley of these streams.

Somewhat different conditions obtain in the valley of Similkameen river. The basin occupied by this stream forms a bay of the Interior plateau extending southward almost to the International Boundary. Component ranges of the northern Cascades fork around this bay. During the retreat of Cordilleran ice from the plateau region a great accumulation of glacial debris was left in Similkameen valley. Following a post-glacial uplift, this material has been entirely cut through by the river. Between the mouths of Pasayten and Whipsaw creeks the stream has carved a deep and narrow canyon for a distance of about 18 miles (Plate III B). Above the mouth of the Pasayten the bedrock is not exposed and the valley is wide and flat with many terraces on either side (Plate IV A).

A number of observations were taken on the altitude of terrace remnants in Similkameen valley. These were found to range up to an elevation of about 1,100 feet above the present stream bed and indicate that at different stages in post-glacial history the river occupied those levels. That there has been comparatively recent uplift and tilting of the basin is indicated by the rock-cut valley below the junction of Pasayten creek. The gradient in this part of the stream bed is comparatively steep.

Above the left bank of Cambie creek, near the junction of the trail down Mamaluse valley with that from Allison pass, is a stream-cut terrace of partly modified glacial materials standing about 325 feet above the present stream bed. A couple of miles farther up Cambie creek, and on the same side of the valley, is a well-marked terrace remnant about 75 feet higher than the other. Below the junction of the two trails is a more recent and wider bench 50 feet above the stream bed. In the valley of Chuwanten creek three well-marked benches were observed within 2 miles of the mouth of Cambie creek, and at elevations of 100, 170, and 600 feet respectively above this mouth. Between the mouths of Chuwanten and Pasayten creeks a number of bench remnants were noted up to an elevation of about 250 feet above the present stream bed of Roche river. Farther down the river, and on the east side of it, a well-marked flat or bench was observed immediately below the mouth of Placer creek and at an elevation of about 200 feet above the river. On the opposite side of the river and on either side of Copper creek, a series of terraces occur at elevations of 280, 160, and 60 feet above the mouth of the creek. Still farther down Similkameen river, and on the southern rim of Sunday Creek basin, terraces were observed at elevations of about 1,000 and 1,100 feet above the river. These correspond in position and elevation very closely with the higher benches above the bed of Cambie creek.

ECONOMIC GEOLOGY

The area includes a variety of sedimentary, volcanic, and intrusive formations and, as might be expected, affords a promising field for mineral deposits.

Placer gold occurs in the valley of Similkameen river and some of its tributaries as far up as the mouth of Pasayten creek. The most productive bars were found on Whipsaw and Lamont creeks and on Similkameen river below the mouth of Whipsaw creek. These bars have been exhausted and no placer mining has been done on them for several years.

Two attempts at hydraulic mining were made on the west side of Similkameen river near the mouth of Whipsaw and Friday creeks.[1] Neither attempt proved successful.

Prospecting for lode properties began with the discovery of placer deposits and has been more or less active in different localities ever since. The earliest records are concerned with discoveries made in the Similkameen valley and date back to the early eighties. Some rich gold ore was obtained then from properties located near the mouth of Pasayten creek. Subsequent development work in this section has also been concerned with the copper content of the ores. Copper ores, carrying gold and silver, were discovered about 1887 near the mouth of Friday creek and much prospecting and development work has been done there since. From the old Victoria claim a little high-grade bornite was carried out on pack-horses and shipped to a smelter. Some attention was also given at about that time to discoveries on Allenby (Copper) mountain, but active prospecting did not begin there until 1895. Interest in Kennedy mountain, on the west side of the river, arose coincidently with the boom on Allenby mountain and a great deal of money was spent in prospecting and development.

Beyond the limits of Similkameen basin there is little record of active prospecting in the area until 1910, when ill-advised reports of the discovery of rich gold ores on Shawatum (Steamboat) mountain in Skagit valley started a stampede.[2] As the claims on which the discoveries were reported carried no ore at all the district was soon almost deserted. The boom had the advantage, however, of opening up the country and of drawing the attention of prospectors to ores less spectacular in character, but, nevertheless, deserving of some attention. In the valley of Tenmile creek several bodies of low-grade sulphide ores were discovered (*See* page 73). They are very similar in character to a number of properties at Twentythreemile camp near the junction of Sumallo and Skagit rivers, beyond the limits of the present area.

Within the past couple of years some attention has been directed to properties at Green lake, about 22 miles by trail south of Hope. These properties are still in the prospect stage, but include at least one showing of silver-lead and zinc ore which in spite of its comparative inaccessibility may prove to be of commercial value.

The following discussion of the mineral properties of the area has been arranged, for convenience, in the order of the localities in which they occur. An alternative classification based on the genesis of the ores might have been adopted, but as the localities are widely separated and the mineralization has occurred under very different geological associations, it seems better to refer the question of origin to the particular discussion of the locality in which the ores occur. They are all regarded as essentially primary in character, and deposited from ascending magmas, solutions, and gases related to contemporaneous intrusions. Superficial agencies have, in certain instances, effected some modification of the primary deposits.

---

[1] Camsell, C., Geol. Surv., Can., "Preliminary Report on a Part of the Similkameen District, B.C.," pp. 15-16.

[2] Camsell, C., Geol. Surv., Can., Sum. Rept., 1911, p. 116.

GREEN LAKE

A number of mineral prospects have been discovered in the vicinity of Green lake 22 miles south of Hope via the trail up Silver and Hicks creeks. A wagon road has been constructed as far as Silver lake, 7 miles from, and 1,000 feet above, the town of Hope. Above the lake a trail leads at a gentle grade up the broad, U-shaped valley of Silver creek to the mouth of Hicks creek, a distance of 10½ miles. The branch trail up Hicks creek is a little over 4½ miles long and rises from about 1,800 feet in the valley of Silver creek to the approximate elevation of Green lake 3,000 feet above the sea.

Green lake has no apparent outlet but it is likely there is underground drainage from its southern end into the basin of Chilliwack river. Elsewhere its shores are rocky and precipitous.

A general discussion of those geological formations represented at Green lake has been given in an earlier section of this report. Broadly speaking, the northern half of the lake is underlain by sheared and foliated crystalline rocks correlated with the Custer granite gneiss. This gneiss is intruded to the south by more massive rocks varying in composition from granite to quartz diorite. Prospects have been located in both the older and later intrusives, but have not yet revealed any significant ore-bodies except on the Elkhorn claim at the northern end of the lake.

The Elkhorn mineral claim has one important showing in the face of the steep cliff at the extreme head of the lake and about 35 feet above lake-level. The ore occupies a fracture zone in the older intrusive rock and has a width of about 11 feet. Within this mineralized zone the ore is concentrated chiefly in a series of veins and stringers whose dip and strike correspond in a general way with that of the zone of fracture which appears to trend nearly north and south and pitch steeply to the northeast. The chief ore minerals are the lead and zinc sulphides, galena and sphalerite. Their relative proportions are exceedingly variable in the different veins and stringers, but the zinc blende is most generally abundant. Pyrite is also a common ore mineral and is closely associated with the other sulphides. Assays across the face of the mineralized zone were reported to average 1 ounce in silver. A sample obtained by the writer from a 4-inch ore vein near the hanging-wall of the ore zone was assayed by the Department of Mines, Ottawa, and ran 4·68 ounces in silver, 13·76 per cent lead, 6·72 per cent iron, and 20·69 per cent zinc. The gangue is chiefly a fractured and leached equivalent of the wall-rock. Calcite and quartz occur as vein minerals closely associated with the sulphides.

The wall-rock on either side of the main ore-body is a coarse-grained intrusive and is remarkable for its variability in mineral composition. This peculiarity has resulted chiefly from its intrusion into, and subsequent digestion, in part, of, an original bed or pod of limestone. The latter probably formed part of an older series of sediments of which but little trace now remains. The limestone is represented either by small, irregular bands or lenses of lime silicate rock, or its original presence is inferred from the composition of the intrusive which itself shows evidence of recrystallization and the formation through assimilation of such lime silicate minerals as titanite and pyroxene (diopside). A specimen obtained a few feet east of the ore zone was examined microscopically. The essential minerals were found to be quartz, oligoclase, feldspar, pyroxene, titanite, and hornblende. Apatite is a common accessory. To the west of, and closely adjoining, the main ore-body a more acid rock type was found to be composed chiefly of quartz and orthoclase. A few feet farther west the intrusive changes to a type of lime silicate rock composed chiefly of green epidote, massive pink garnet, and calcite. Tiny pods of pure recrystallized limestone are associated with this type. This lime silicate rock has a width of only 3 or 4 feet. It is very irregular in outline and appears to show gradation on the west into an intrusive type of more normal granodiorite. A couple of small dykes cut nearly vertically across the older rocks a few yards on either side of the ore zone, but appear to have no significance in the ore mineralization.

A very similar association of ore, limestone, and intrusive rock occurs at the upper end of Green lake south of the showing on the Elkhorn claim and about 2,000 feet from it. Here, the metamorphosed lime-silicate rock is closely associated with an intrusive containing such calcium-rich minerals as pyroxene (diopside) and epidote. Ore mineralization is scanty, but includes a very similar association of sulphide minerals to that occurring on the Elkhorn claim. It seems not unlikely that there is a connexion between these two ore deposits below the bottom of the lake.

Within a mile to the north of the ore-showing on the Elkhorn claim, and on the Hilton No. 1 and No. 2 claims, some surface stripping and open-cut work has exposed a little ore mineralization associated with a narrow belt of lime silicate rock containing limestone pods. The showings on these claims occur at elevations of 500 and 1,200 feet, respectively, above the level of the lake and coincide with the general trend of the country rock, whose foliation has an average strike of about north 30 degrees west. Ore mineralization is rather scanty. The chief ore mineral is pyrrhotite, but chalcopyrite and pyrite are associated with it in minor and variable proportions. No galena or zinc blende was observed. The sulphides form small lenses in, or are disseminated through, the country rock which is clearly a product of the metamorphosis and digestion of an original limestone bed by the intrusive gneiss. A sample of solid pyrrhotite ore from Hilton No. 2 claim was assayed by the Department of Mines, Ottawa, and gave a trace of gold and 0·05 per cent nickel. Lime silicate minerals include an abundance of red garnet (andradite), green epidote, and, in one specimen examined, anorthite feldspar.

At the southern end of Green lake different geological conditions prevail. The country rock is here a more massive intrusive, fresher in appearance, finer and more uniform in grain, and later in age. It varies considerably in composition, but the prevailing type is a biotite quartz diorite in which the essential minerals are quartz, oligoclase feldspar, biotite, and, more rarely, hornblende. A little orthoclase is commonly present and in the more acid but less abundant types, may be an essential constituent. Chlorite is a common secondary mineral. The plagioclase shows zonary banding and the rock, as a whole, is very similar to that in other parts of the area included with the Chilliwack batholith and regarded as of Tertiary age. To the east and southeast of the southern end of Green lake this intrusive is extensively mineralized with pyrite and the exposed surfaces are everywhere stained red as a consequence of its oxidation.

A few claims have been staked in this formation to the east of Green lake and some mineral showings were observed above the right bank of the large tributary to Chilliwack river, which flows to the southwest around the southern end of the lake. Here, the quartz diorite shows rather minute jointing running south 55 degrees west and dipping about 30 degrees to the northwest. Lines of fracture or jointing also occur at various angles, and along these fracture planes narrow veins and stringers of ore minerals, including galena, sphalerite, and pyrite, have formed. Pyrite is also disseminated through the body of the wall-rock. Assays on the pyrite were said to give no gold values, but samples across several feet of country rock, including a number of narrow stringers of ore, gave from $1 to $1.50 in gold. The galena was said to assay about seven ounces in silver.

Genesis of the Ores. It seems likely that the ore mineralization at the southern, and probably, in part at least, at the northern end of Green lake is related to the younger intrusive quartz diorite. The wide dissemination of pyrite and the occurrence of this, together with other sulphides in fractures in the quartz diorite, point to this relation of ore minerals to the intrusive at the southern end of the lake. At the northern end the origin of the ore is not as clearly defined. Here, the country rock is an older intrusive having the average mineral composition and structure of a granodiorite gneiss and, except at certain mineralized zones or belts, does not carry ore minerals. These mineralized zones are peculiar in that they are coincident with the position of inclusions of limestone and its metamorphosed and assimilated products. These inclusions have, apparently, in certain instances, furnished lines of weakness along which shearing and fracturing have occurred. Along these fracture zones mineralizing solutions have found a comparatively easy access and the deposition of ore minerals has been facilitated by the limy character of the wall-rock. The mineralizing solutions may be all related to a comparatively late stage in the consolidation of the older intrusive. In this case the fracturing must have occurred prior to the complete consolidation of the magma. On the other hand, the fracturing may have occurred subsequent to consolidation and the mineralizing solutions be related, at least in part, to the younger quartz diorite intrusive exposed at the southern end of the lake.

In accepting the latter view as the most probable the writer does not exclude the possibility of some of the mineralization being due to the older intrusive as well. In fact there seem to be two types of ore mineralization in this northern section. The one is represented by the important showing on the Elkhorn claim, where fracturing is much in evidence and where the principal ore minerals are galena, zinc blende, and pyrite. The other is typified by the showings on the Hilton No. 1 and No. 2 claims north of Green lake, and by very similar prospects on Yola creek (Map 2023), where similar rocks are encountered and where fracturing is not pronounced. In these showings pyrrhotite and chalcopyrite are the common ore minerals, and little or no lead or zinc sulphides are present. The latter type of mineralization may well be related to the adjacent intrusive country rock, whereas the former is probably connected with the later quartz diorite, which, as has already been observed, shows a similar suite of ore minerals at the southern end of Green lake.

TENMILE CREEK

A number of claims have been staked on the northern slope of the valley of Tenmile creek. This creek enters the valley flat of Skagit river at Townsite 2 miles below the mouth of the Klesilkwa and 33 miles from Hope, from which it is reached by an excellent trail up Skagit and Sumallo rivers. A trail suitable for pack horses has been constructed for 2 miles up Tenmile creek to the uppermost or Billican group of claims.

On Map 2023, accompanying this report, four small tributaries are shown draining the northern slope of Tenmile creek. These, named in order from the most easterly, are Mineral, Pyrrhotite, Antimony, and Dry Gulch creeks. The ore-bodies on the Billican group of four claims lie to the east of the valley of Mineral creek. The North Star group of five claims extends in a northeasterly direction from the lower valley of Pyrrhotite creek to the head of Mineral creek. The latter creek has two branches which come together around an important centre of mineralization known as Gold Pan point. West of the North Star group, and in the basin of Dry Gulch creek, are a couple of claims forming the Skagit Giant group. The ore-bodies on each of these three groups of claims will be considered in turn.

Billican Group

The more important showings on the Billican group lie east of Mineral creek and between elevations of 500 and 800 feet above the bed of Tenmile creek. Development work includes a great deal of surface stripping and open-cut work and the driving of an adit to a length of 45 feet. The country rock includes hard, cherty sediments and fine-grained andesitic flows. Both rock types are provisionally included as members of the Hozameen series and regarded as Carboniferous in age. The ore minerals favour the greenstone, but are not confined to it. A contact between the two rocks follows up the hill above the portal of the adit and appears to coincide nearly with the general trend of the ore veins.

The ore forms a series of nearly parallel veins and stringers and also occurs in less regular and more lens-shaped bodies. The veins are coincident with a series of joint-planes or fractures which strike north 30 degrees west and dip about 75 degrees to the northeast. This attitude is closely parallel to the trend of deformation of the Hozameen series as a whole. The ore minerals include a variety of admixed sulphides of which pyrrhotite is the most abundant. Others present include zinc blende, pyrite, chalcopyrite, stibnite, and arsenopyrite.

The metallic constituents of the veins are commonly associated with a varying and, frequently, large proportion of white crystalline quartz. The more lenticular bodies may be composed of almost solid sulphide ore mixed with a little granular quartz, and are commonly surrounded by a zone of heavily impregnated country rock. The solid ore has much the appearance of having been introduced in a molten or plastic condition and the ore veins, at least in part, probably represent offshoots or "dykes" from such an ore magma.[1] As the distance from the source increased

[1] The theory of ore-magmas as developed by Spurr finds a particularly happy application in accounting for the genesis of such massive bodies of sulphide ore as occur on these properties.

and the temperature of the injected material fell there would be a change to a more mobile liquid phase which could penetrate along the fractures in the intruded rocks and deposit ore and gangue minerals in its passage. The smaller ore veins or stringers commonly show more or less distinct zoning from the walls of the fracture inward. The more common sulphides in these ore stringers include pyrite, sphalerite, and arsenopyrite, with, in a few cases, small proportions of galena. The common gangue is clear crystalline quartz. Accompanying both plastic and liquid phases there would doubtless be considerable gaseous activity and this is held responsible for the heavy mineral impregnation of the country rock around the larger ore-bodies, as well as either side of and between the ore veins. The great mobility of these gases would enable them to penetrate minute fractures and take advantage of the slightest porosity in the rock traversed, and their high temperature and chemical characters would assist in their work of metamorphism and replacement.

No attempt was made, in the short time allotted to the examination of this property, to estimate either the bulk or average tenor of the ore. The aggregate bulk of the different ore-bodies, as exposed by surface work, is large, but the ore is consistently low grade in values of gold and copper. Galena, where present, carries good values in silver, but is a comparatively scarce sulphide. One specimen of solid sulphide ore, composed chiefly of pyrrhotite and sphalerite, but containing some stibnite and a little galena, was assayed by the Department of Mines, Ottawa, and gave 0·05 ounce gold, 9·43 ounces silver, 40·30 per cent iron, 10·66 per cent lead, 2·66 per cent antimony, 7·15 per cent zinc, and no arsenic.

North Star Group

The mineral showings on this group are, with the exception of a couple of small bodies of magnetite ore, very similar in character to those encountered on the Billican group of claims. A great deal of surface work has been done between elevations of about 4,550 and 4,900 feet in the basins of both Mineral and Pyrrhotite creeks. Large lenses of solid sulphide ore were uncovered at almost the same elevation in both basins, and are associated with heavily impregnated zones of country rock and with many veins and stringers of ore minerals. The largest ore-body is exposed at what is known as the "Glory Hole," a hundred yards or so east of the junction of the two branches of Mineral creek. Here, a number of shallow pits and considerable surface stripping have exposed solid or nearly solid sulphide ore over an area of several hundred square feet. The depth of this ore has not been proved and it is uncertain whether there are a number of shallow pods of ore or one or more large lenses represented. The general appearance of the ore exposed seems to favour the latter view. The principal ore minerals are pyrrhotite and sphalerite. Associated with these is a variable proportion of white crystalline quartz. The ore-body is capped by a reddish, decomposed, porous material composed largely of granular quartz, stained with iron oxide.

An ore-body has also been exposed on Gold Pan point between the forks of Mineral creek. The country rock is here chiefly a moderately coarse-grained diorite which cuts the older volcanic rocks on either side and probably has an important bearing on the genesis of the ore in this locality. With the exception of this diorite, no other intrusive rocks were observed near the ore-bodies so far described. The ore minerals include a considerable proportion of galena and arsenopyrite, as well as sphalerite and pyrrhotite. Assays on picked samples have given as much as 23 ounces in silver. A number of small veins and stringers were observed running down Gold Pan point toward the creek bottom at a bearing of north 45 degrees west and a dip of about 60 degrees to 70 degrees to the northeast.

Ore has been exposed at four localities in the basin of Pyrrhotite creek. Three of these localities lie at about the same elevation and within a few yards of each other. Further development may establish a connexion between them. The ore is of a very similar type to that occurring at the Glory Hole and on the Billican group of claims. Two of the showings have exposed large bodies of nearly solid sulphide ore. A specimen of such solid ore was obtained from the middle of the three showings and assayed by the Department of Mines, Ottawa. It was composed chiefly of pyrrhotite, but contained a little chalcopyrite. It showed a trace of gold, 0·19 per cent copper, and 40·48 per cent iron. Ore of a somewhat different character occurs in the bed of Pyrrhotite creek about 300 feet below the other showings. The ore here occupies a fissured zone 6 feet wide, in a fine-grained, greyish-green volcanic rock of doubtful composition. The mineralized zone trends nearly north and south and dips about 70 degrees southwest. The bulk of the vein material is clear, coarsely crystalline quartz. The chief ore mineral is pyrrhotite, but chalcopyrite, pyrite, and a little stibnite were observed.

Two interesting occurrences of magnetite ore were observed near the headwaters of the west fork of Mineral creek. The lower showing lies at an elevation of about 5,600 feet and the upper one occurs on the summit of the divide at the head of the west fork and overlooking the valley of Twentyeightmile creek. Both deposits occur in a dark green andesite and are similar in mineral association. The lower showing is poorly exposed and but little idea could be gained of its size or probable origin. The upper showing appears on the surface as a somewhat lens-shaped body composed largely of magnetite and crystalline quartz, the latter of which makes up the bulk of the rock. The adjoining andesitic country rock has the appearance of having been intruded by this quartz body and is intersected by many veinlets of the ore which are relatively rich in magnetite. A small area of intrusive diorite porphyry is exposed within a hundred yards to the west of the ore-body on the crest of the divide, and may have some genetic bearing on the mineralization. A thin section of the ore, examined under the microscope, was seen to be composed largely of interlocking crystals of quartz and magnetite. Associated with these minerals are a very few altered grains of a mineral resembling feldspar. The magnetite shows inclusions of apatite and is commonly bordered by small crystals of a greenish spinel. The whole has much the appearance of an intrusive rock. It is interesting to observe that the crystalline quartz which forms the bulk of these deposits is very similar in character to that associated with the larger bodies of sulphide ore already described and which have been assigned a magmatic origin. The texture of the ore is somewhat miarolitic and suggests that gaseous activity may have been pronounced during the period of injection and consolidation of the ore. It is probable that the two showings are related in origin as well as in mineral composition. They may even be connected at depth or at the surface, but as the intervening ground is largely covered with soil and talus debris, no such continuity has been established.

Skagit Giant Group

The principal showing on this group of claims is located in the basin of Dry Gulch creek at an elevation of about 3,600 feet, or over 1,700 feet above Skagit valley at Townsite. Here, a large lens of sulphide ore is exposed and forms a bluff about 30 feet high and from 70 to 100 feet wide (Plate IV B). No development work has yet been done on this ore-body, so that its dimensions below the surface can not be estimated.

The country rock is a more or less massive, dark green, andesitic, volcanic rock showing considerable fracturing and impregnation by sulphide minerals. The ore-body is composed chiefly of a dark bronze-coloured pyrrhotite, intersected, along the exposed face, by a number of narrow veins and stringers of pyrite. The body of the pyrrhotite ore contains many well-developed crystals of pyrite which are commonly surrounded by an irregular zone of chalcopyrite. Chalcopyrite is also disseminated through the body of the pyrrhotite. The ore has much the appearance of having been injected as a melt of sulphide minerals and the great body of it contains little or no gangue mineral. A specimen of typical solid sulphide ore was assayed by the Department of Mines, Ottawa, and showed a trace of gold, 0·71 per cent copper, and 43·41 per cent iron. Some narrow veins of limonite were observed along minute fractures in the sulphide ore, which is, no doubt, of secondary origin. The surface of the ore-body is partly coated with a whitish deposit of iron sulphate.

PASAYTEN CAMP

On the western slope of Roche valley, above the mouth of Pasayten creek, some important ore mineralization occurs in that belt of schists lying to the northwest of, and intruded by, the Remmel granodiorite. A great deal of development work has been done in this locality, but except on the Pasayten and Knobhill claims the workings have fallen in and prevented underground examination of the ore-bodies.

The country rock in this mineralized section is, with the exception of occasional small dykes, represented by one or more varieties of schist which have already been described in an earlier section of this report. They have been so greatly altered by dynamic and igneous metamorphism that their original characters are in many places a matter of doubt. A more particular reference to these schists will be given in discussing the several mineral deposits occurring in them.

Pasayten Mineral Claim

This claim is located on the western slope of Similkameen valley nearly opposite the mouth of Pasayten creek. The principal workings lie between 250 and 350 feet above the river bed. They include, besides some surface stripping, a 15-foot shaft and a lower and upper adit 50 feet and 115 feet long respectively. The country rock includes greenish to greenish-grey schists weathering in shades of green, grey, and brown, and apparently all of a very similar type. The planes of schistosity are commonly spotted with innumerable small metacrystals of a ferruginous carbonate averaging a millimetre or so in diameter. The average trend of schistosity is about north 10 degrees east, with a dip of from 55 degrees to 60 degrees southwest.

The ore minerals occur in quartz veins which cut across the planes of schistosity at different angles and average only a few inches in width. Except for a little chalcopyrite and pyrite, and their secondary carbonates and oxides, no ore minerals of importance were recognized, although high values in gold are reported to have been extracted from the shaft where an irregular lens or vein of quartz, about 4 inches wide, was observed. These high values were said to have occurred as native gold and gold tellurides, but these minerals were not seen at the time the examination was made by the writer.

Knobhill Claim

The principal working on the Knobhill claim is located on the western slope of the valley about 2 miles above the junction of Pasayten creek and at an elevation of 1,000 feet above Roche river. A trail one mile in length leads from the main Roche River trail to these workings. An excellent cabin has been built beside this trail about 450 feet below and 1,000 feet from the workings.

Development work has consisted chiefly in driving an adit for 75 feet at right angles to a series of schists which strike nearly north and south and dip from 40 degrees to 50 degrees west.

Near the face of this tunnel the schists are soft, thinly laminated, and slickensided. They have a dark greenish colour, contain a considerable percentage of granular quartz, and are heavily impregnated with pyrite. Some chalcopyrite is also present. Mineralized schists of similar character are also exposed in an open-cut on the surface above the tunnel.

The larger showing of ore, however, is exposed about half-way along the adit which cuts across a heavily mineralized belt about 10 feet wide striking parallel with the schists and, apparently, representing a replacement of these rocks above a more than usually massive member of the series. The chief ore minerals include pyrite and chalcopyrite. A bluish band about 6 inches wide occurs near the centre of the mineralized belt. Below this band is a heavy concentration of pyrite ore containing a little chalcopyrite. Similar but less concentrated mineralization occurs above the band. The band itself carries the same minerals, but these have been coated over with a bluish sulphide mineral, probably chalcocite, and the rock is also stained with copper carbonate. The whole mineralized belt is peculiar in that the sulphide minerals occur as a more or less close assemblage of separate crystals or grains associated with granular quartz, and the whole is very loosely cemented together. Under a blow from the hammer, specimens of the ore fall into a granular heap of sulphide and quartz crystals.

Assays from the heavy pyrite zone underlying the "blue" band were said to have given 4 per cent copper. An assay made by the Department of Mines, Ottawa, of a specimen from the band itself showed no gold, 4·20 per cent copper, and 23·57 per cent iron.

The mineralization on this property seems to have resulted from replacement of the schistose country rock by magmatic solutions and vapours originating with the Remmel granodiorite batholith whose contact is only a few hundred feet distant. The quartz in the schists seems to have best resisted the replacement and some additional silica has probably been added.

Other Properties

A number of workings occur about a mile above the mouth of Pasayten creek on the west slope of Roche valley. Here, a series of five adits at elevations of 10, 275, 435, 500, and 600 feet, respectively, above the valley bottom, have been driven into the sidehill in directions more or less at right angles to the schists which trend north and south and dip at an average angle of about 55 degrees to the west or into the hill. Unfortunately, all but the lowest and most recently constructed adit have caved in and prevented an examination underground. The country rock is, in great part, represented by thinly laminated and slickensided sericitic and chloritic schists which, when exposed to the atmosphere by the underground workings, tend to swell and force themselves out into the passages. The lowest adit was driven with the intention of intersecting the ore-bodies crossed by the different upper workings. Although 650 feet long it has not yet reached any of these. A rough calculation was made, based on barometric elevations and angles of elevation on the portals of the different adits taken from a fixed point on the valley flat. On the assumption that the ore-bodies cut by these adits pitch into the hill more or less parallel with the schists, as is the case on the Knobhill claim, it was estimated that this lower adit would have to be projected about 80 feet farther to tap an ore-body occurring near the portal of the lowest of the upper adits, and something like 930 feet beyond the present face to catch an ore-body from the portal of the highest adit. The several distances from the portals of the different adits to the ore-bodies must be added to the above calculated projections.

Although the lowest adit does not apparently intersect any of the ore-bodies from the upper adits, it does cut through some schists which show a certain amount of mineralization. This is most noticeable near the face of the adit. Here, the schists are thinly laminated, slickensided, and very soft and talcose in appearance. They are intersected by a number of quartz stringers and both quartz and schist impregnated with a considerable amount of pyrite. The country rock and mineralization at this point are very similar to that encountered near and at the face of the adit on the Knobhill claim and have probably originated in much the same way.

Going up the hill from this lowest adit, the first important evidence of ore was encountered at the portal of the third adit about 435 feet above the valley floor. Above the portal of this adit is a thickness of several feet of a richly oxidized iron cap or gossan, testifying to the original presence of iron sulphides and to the probable concentration of sulphide ore below the zone of surface oxidation.

At the portal of the next highest adit, 500 feet above the valley, is a large dump on which about a carload of ore is stacked. The country rock, judging from materials on this dump, is a much slickensided, talcose schist and the principal ore minerals are chalcopyrite, pyrite, and sphalerite. A specimen of solid sulphide ore, composed chiefly of chalcopyrite and containing a little sphalerite, was assayed by the Department of Mines, Ottawa. It showed 0·07 ounce gold, 25·55 per cent copper, and 22·14 per cent iron.

The highest adit, 600 feet above the valley, was, however, the one from which the most ore had been extracted. Some ten or twelve carloads of ore, the writer was informed, had been stacked on the dump at the portal of the adit, but most of it had slid away. The ore remaining included a great deal of high-grade material. Large chunks, several inches across, of nearly solid chalcopyrite, were observed. Some of the specimens included a considerable proportion of sphalerite and pyrite. The country rock is, apparently, similar to that in the adit 100 feet lower down.

A peculiar feature connected with the discovery of these ore-bodies is the inconspicuous nature of their outcrops. About the only clue to the position of underlying ore is the presence of a reddish oxidation product in the country rock due to the weathering of the iron sulphides, and even this is commonly obscured by a mantle of soil. It is not improbable, therefore, that other ore-bodies are still to be found in this belt of schists. This section is regarded by the writer as a particularly promising one, although, at present, somewhat remote from rail transportation and accessible only by pack animals.

CELTIC GROUP

The Celtic group of six claims is located on Kennedy mountain. The principal showings are on the Celtic claim and are distant, by trail, about 1½ miles from the main road along Whipsaw creek. This road leads north to Princeton, an additional distance of about 10 miles.

The country rock, where the ore occurs, is a vesicular green volcanic rock about andesite in composition. The vesicles are commonly filled with calcite. This andesite is in contact, approximately along the centre line of the claim, with a belt of argillaceous sediments which are regarded as forming part of the same series as the volcanic rock.

The ore occurs in the andesite within a short distance of the argillaceous sediments. Development work, consisting of surface stripping and open-cuts, has exposed a zone of potential mineralization, following more or less in line with the sedimentary contact, and having a width of from 100 to 200 feet. Only here and there, however, in this zone, is there any appreciable concentration of ore minerals. The occurrence of the ore seems to be influenced chiefly by the amount of fracturing which the volcanic rock has suffered. At such localities the rock is commonly penetrated by veins and veinlets of quartz or of quartz and calcite. These minerals fill fractures and, to some extent, replace the wall-rock and appear to have been introduced at about the same time as, or possibly a little earlier than, the ore minerals with which they are associated.

The chief ore minerals are chalcopyrite and bornite. Either may be in excess at different points and both appear to be primary minerals. They occur either in irregular quartz veins following fractures in the volcanic rock, or else replacing the more limp parts of this andesite. The outcrops near these ore minerals are commonly stained with copper carbonate solutions.

The source of the ore on this property is referred to the complex of undifferentiated intrusives outcropping along Similkameen river and mentioned in an earlier section of this report.

HILLSBAR GOLD CLAIMS, YALE DISTRICT, B.C.

By C. E. Cairnes

Considerable local excitement was caused in the summer of 1921 by the discovery of rich gold quartz on Hillsbar creek about 14 miles north of Hope, B.C., on the east side of Fraser river, and resulted in a large number of claims being staked around the original discovery. It was recalled that, in the early days of placer mining in the province, Hills bar at the mouth of this creek had proved to be the richest of a series of bars along Fraser river below Yale[1]; and, consequently, it was suspected that an important source of this great placer wealth had been discovered.

In company with John Viken, one of the original locators of the claims, the writer visited the property in early October, 1923. The examination was conducted in very wet and foggy weather, so that, unfortunately, no general view of the surrounding country could be obtained, and attention was confined to the immediate vicinity of the principal showings.

The gold-bearing veins are located in the bed of Hillsbar creek at an elevation of approximately 2,475 feet above sea-level, or about 2,200 feet above the Canadian National railway which follows the east bank of Fraser river. The distance by rail from Hope to the foot of the trail is about 12 miles. Squeah, 11 miles from Hope, is the nearest station. It requires about two hours of energetic climbing to reach the cabin near the principal showings.

The claims are eight in number, arranged in two parallel and adjoining rows of four claims each. They have been staked approximately in line with a series of quartz veins which occur in a belt of slates near the contact of an intrusive granodiorite. The general trend of these quartz veins appears to be about north 35 degrees to 55 degrees west and follows more or less along the middle line separating the two rows of claims. As a consequence, the claims to the northeast of the dividing line fall entirely in the slate belt, whereas those to the southwest lie chiefly within the area occupied by the granodiorite. Hillsbar creek cuts across the centre of this group nearly at right angles to this contact.

The rocks represented on the gold claims include slate, granodiorite, and occasional porphyritic dykes. The slates form part of a heavy sedimentary and volcanic series which has been correlated with the Cache Creek rocks of southwestern British Columbia and is regarded as Carboniferous in age. The placer gold obtained in the late fifties from the rich bars along Fraser river below Yale, is regarded as having been obtained chiefly from the rocks of this series. The slaty structure of the members represented here coincides with the general direction of deformation of the series as a whole and, in this section, is, approximately, parallel with the bedding planes which dip to the northeast at an angle of about 60 degrees. The granodiorite intrudes these slates and it is likely that their mineralization is associated with this intrusion. The granodiorite is a light-coloured

[1] Bancroft, H. H., "History of British Columbia," p. 441.

rock composed chiefly of quartz, orthoclase, acid plagioclase, a colourless mica (probably muscovite), and a little altered hornblende. It shows evidence of considerable shearing and granulation and is very similar in appearance to members of the Jurassic intrusives of this section of Fraser valley. A larger area of more foliated granite and granodiorite is exposed along the line of the Canadian National railway, and outcrops over the greater part of the distance along the trail between the railway and the group of claims. The granodiorite exposed on the property is probably an apophysis from this larger body and, in the vicinity of the workings, has a width of about a quarter of a mile. It was observed to be sparsely mineralized with iron sulphides near the slate contact.

A small outcrop of a feldspar diorite porphyry sill or dyke was observed on the right bank of Hillsbar creek nearly opposite the portal of the adit. It shows evidence of considerable deformation and is slightly mineralized by an iron sulphide resembling pyrrhotite. This rock is probably of about the same age as the granodiorite, but is not thought to have any direct bearing on the genesis of the ore minerals. It could not be traced for any distance on either side of Hillsbar creek.

The principal showings are represented by a series of quartz veins crossing Hillsbar creek near the centre of the group of claims and between distances of 100 and 200 feet of the granodiorite contact. These quartz veins follow more or less parallel with the enclosing slates and vary in width from a few inches to about 3 feet. The individual veins pinch and swell in an irregular manner and the impression is conveyed that although no single vein may be depended upon to persist for any distance either laterally or in depth, yet there is probably a zone of slaty rocks, a couple of hundred feet or so in width, following the granodiorite contact, in which quartz veins may be expected to occur. This vein quartz has doubtless all been introduced at about the same time, and is connected with the granodiorite intrusion. The aggregate width of vein quartz can only be estimated from the one section exposed on Hillsbar creek where a series of three veins shows a total average width of about 4 feet. Other quartz veins were said to have been observed at different points on either side of Hillsbar creek; some of these were reported to be wider than those occurring in the bed of the creek, but their aggregate width, as far as is known, does not exceed 10 feet and is likely to be less. No free gold was observed in any of the vein quartz except at the principal showings on Hillsbar creek.

The ore minerals are associated with the vein quartz which is commonly somewhat banded in appearance, due, apparently, to the inclusion of thin laminæ of slate. The bands are, as a rule, only a small fraction of an inch in width and, in general, are closely in line with the schistosity of the slaty wall-rock. Here and there they swell out to include small lenses of slate that have been caught up by the siliceous vein matter. These dark bands and lenses of included slaty material are important in that they are the common sites for the deposition of the ore minerals.

Ore mineralization is, on the whole, very scanty in these quartz veins and is represented chiefly by free gold and arsenopyrite. A very little iron sulphide is present in some places. These minerals are commonly associated with the dark bands in the vein quartz, particularly where fracturing has occurred along these bands or where drusy cavities occur in the quartz. Specimens of free gold were also seen in the body of the more massive quartz.

Free gold is, however, very irregularly distributed in these quartz veins, and in the greater part of the veins exposed no gold could be seen, although a little arsenopyrite and pyrite might be observed. Where locally concentrated the gold has formed some rich pockets from which fine specimens have been obtained. Good assays have also been reported from samples in which no free gold could be seen. A sample was taken across a width of 3 feet of quartz and included slaty material from the vein near the face of the only adit on this property. This sample, in which no free gold was observed, was assayed by the Mines Branch, Ottawa, and gave 0·13 ounce in gold. A general sample taken across a series of three veins exposed along the creek near this adit, and aggregating about 4 feet in width, is said to have assayed \$109. This sample included some quartz showing free gold.

Very little development work has been done on this property. An adit 27 feet long, driven through slate rock on the left bank of Hillsbar creek, exposed a lens of quartz having a maximum width of 3 feet, across which the sample referred to above was taken. Some surface stripping has been done on the quartz veins exposed on either side of the creek near this adit. About 150 feet below the adit Hillsbar creek goes over a 60-foot falls and it has been proposed to drive an adit from near the base of the falls to cut the quartz veins at this depth. Such an adit could be driven at relatively small expense, and if the grade and quantity of ore encountered at this depth proved satisfactory, Hillsbar creek could supply power for mining on a more ambitious scale.

PLATINIFEROUS ROCKS FROM TULAMEEN MAP-AREA, YALE DISTRICT, BRITISH COLUMBIA, AND URAL MOUNTAINS, RUSSIA

By Eugène Poitevin

CONTENTS

Illustrations

INTRODUCTION

During the field season of 1918 the writer spent two months in British Columbia investigating several areas of ultrabasic irruptives from which the platinum placers of Tulameen map-area are derived. The purpose of the study was to compare these irruptives with similar ones which form the parent rock of the famous Russian platinum deposits.

The geology of the area has been well described by Charles Camsell in "The Geology and Mineral Deposits of the Tulameen District, B.C.[1]", hence the present paper deals only with the ultrabasic rocks, chiefly the dunite and pyroxenite.

Information concerning the Ural Mountain platinum deposits was gathered from the works of Professor Louis Duparc of Geneva University[2] and of Dr. N. Wyssotsky.[3]

---

[1] Geol. Surv., Can., Mem. 26, 1913.

[2] Le Platine et les Gites Platinifères de l'Oural et du Monde par Louis Dupare et Marguerite-N. Tikonowitch, Genève, 1920.

[3] Die Platinseifengebiete Von Iss-Und Nischny-Tagil Im Ural, Mémoires du Comité Géologique. Nouvelle Série. Livraison 62. St. Petersbourg, 1913.

CHEMICAL COMPOSITION OF PLATINUM

Native platinum found in dunite, pyroxenite, and placer deposits is not pure metal. It is essentially a solid solution of platinum and iron, or of platinum and palladium, to which iridium, rhodium, osmium, copper, gold, silver, nickel, cobalt, manganese, are commonly added. The best classification of the various alloys of the metals of the platinum group was proposed by Moukhine[1] and may be summarized as follows:

—	Pt%	Fe%	Ir%	Pd%
Platinum	100	0	0	0
Iridium	20	0	77	0
α—Ferro-platinum	73–78	16–20	1–15	0·2–0·3
α—Polyxene	80–90	6–10	1–3	0–2·5
β—Ferro-platinum	73–78	16–20	0	2
β—Polyxene	80–90	6–10	0	2
α—Palladium-bearing platinum	73–74	0	0·1–0·9	21–8
β—Palladium-bearing platinum	83–84	0	1·3–3·6	3·0–3·7

During the past century a large number of Uralian platinum samples have been analysed and apart from a few local variations these analyses show that each primary dunite occurrence is in some measure characterized by the chemical composition of its platinum. This is clearly shown in the following table prepared by Professor Louis Duparc.[2] For comparison the writer has added the last analysis which was made by Hoffmann on crude platinum from Tulameen map-area, B.C.

—	Osmiridium	Pt	Ir	Rh	Pd	Cu	Fe
Taguil	1·37	77·93	2·46	0·50	0·24	2·30	14·21
Weressowy-Ouwal	1·68	84·60	1·88		0·45	1·02	9·84
Swetli-Bor	4·86	81·93	2·19		0·21	0·50	9·08
Iss	4·68	84·17	1·37	0·57	0·40	0·55	7·95
Kamenouchky	4·99	82·46	1·79	0·69	0·18	0·54	9·49
Koswinsky-Kitlin	0·79	83·50	2·74	0·62	0·28	1·14	11·05
Id. Tilai	5·22	78·58	1·22	0·58	0·22	1·83	12·20
Kanjakowsky-Jow	20·21	60·39	6·80	0·80	0·19	0·49	11·16
Solwa	3·10	81·87	3·35		....	....	11·31
Omoutnaia	10·44	77·60	6·40	0·42	0·32	1·93	2·48
Tulameen, B.C.	14·62	68·19	1·21	3·10	0·26	3·09	7·87

The most important platinum deposits of Ural mountains are those of Daneskin-Kamen, Travianka, Jow, Koswinsky, Kamenouchky, Iss, Taguil, and Omoutnaia. The basic irruptives from which these deposits are derived always outcrop showing a more or less elliptical area of dunite surrounded by a continuous zone of pyroxenite, which in turn is bordered by paler

[1] Moukhine-Analyse chimique de différents spécimens de platine de l'Oural. Soc. Minéral de St. Petersbourg, part II, p. 101, 1842.

[2] The figures given for each locality represent the average of a large number of analyses.

rocks, such as gabbro, gabbro-diorite, and diorite. All these rocks are cut by numerous dykes—some light, others dark—some confined to the dunite, whereas other varieties are found either in dunite, pyroxenite, or gabbro.

The accompaning sketch (Figure 12) was drawn from Dr. N. Wyssotsky's geological map of Taguil and serves to illustrate the above description of rock relationship.

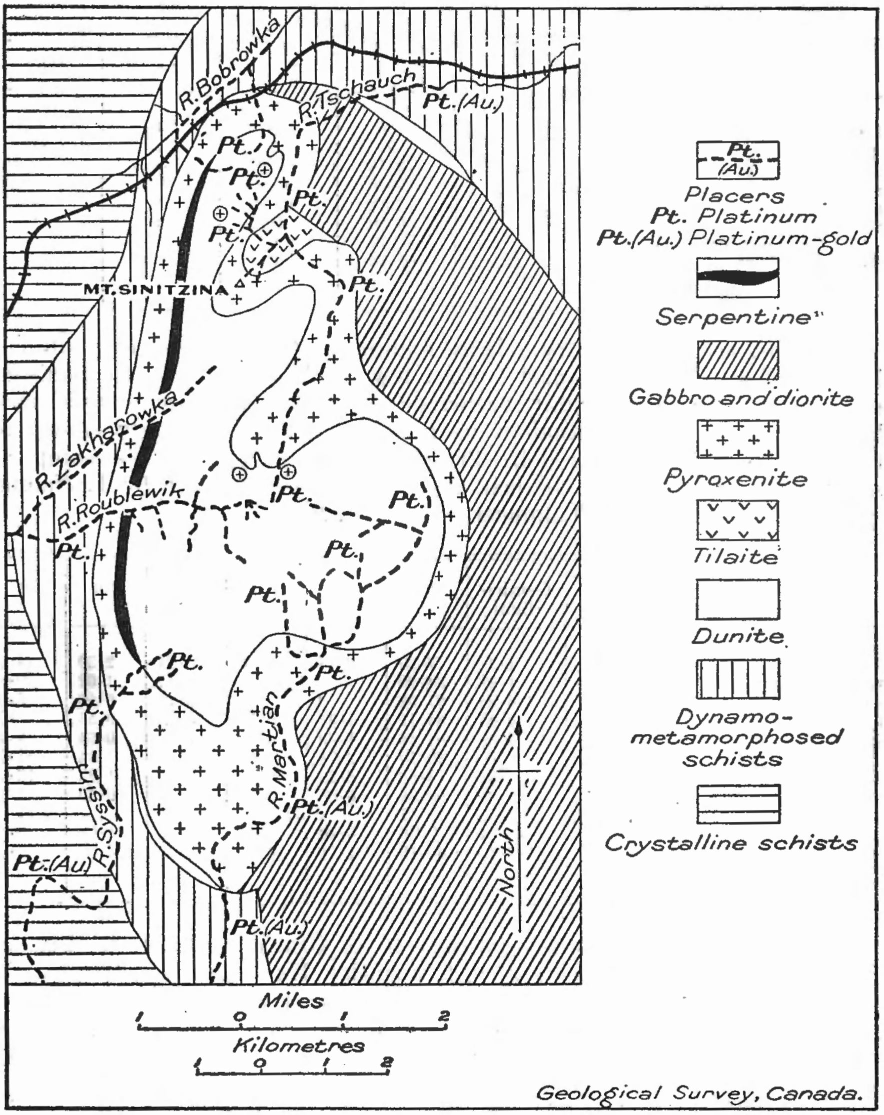


FIGURE 12. Part of geological map of Taguil, Ural mountains, Russia, showing differentiation of basic igneous rocks and distribution of platinum placer deposits (after Dr. N. Wyssotsky).

The platinum placer deposits of Tulameen map-area are derived from similar basic rocks. Their association is shown in Figure 13, which is a part of Camsell's geological map (No. 46A) of Tulameen district, slightly modified. The numbers 1, 2, 3, 4, and 5 indicate exact localities from which rock specimens were collected for microscopic examination.

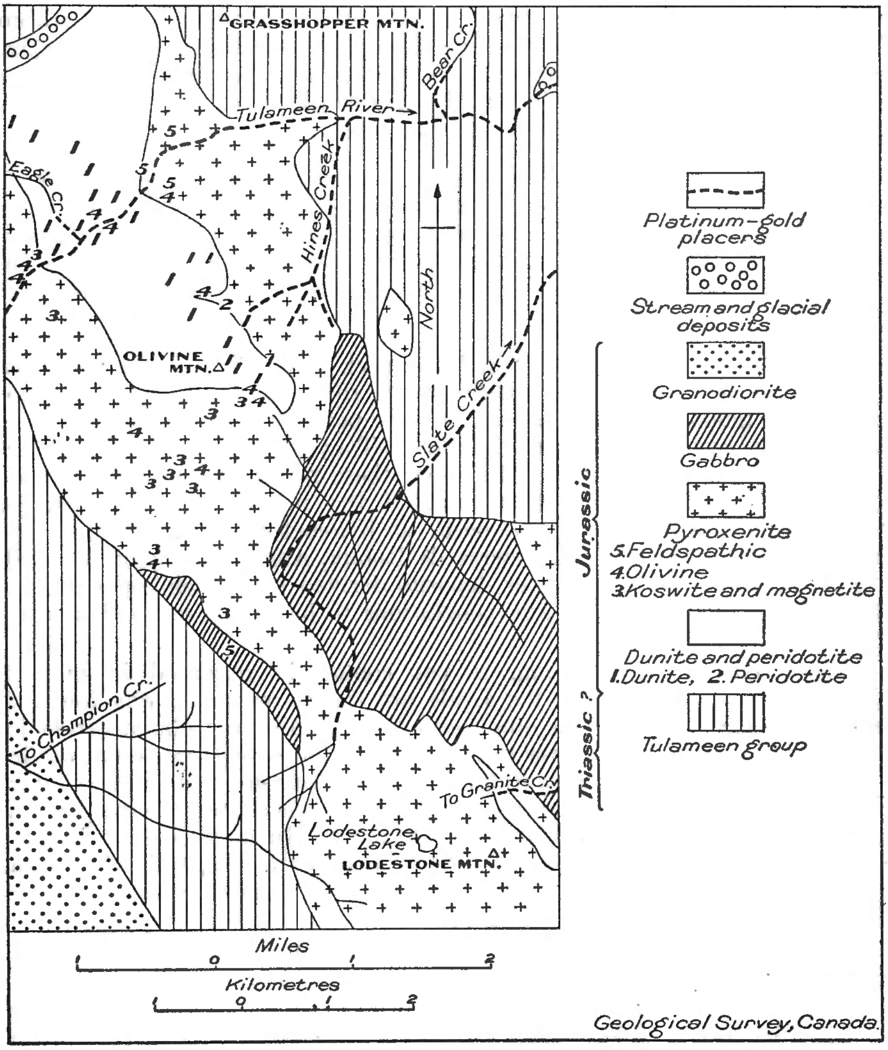


FIGURE 13. Part of Tulameen geological map (No. 46A), Yale district, B.C., slightly modified, showing differentiation of basic igneous rocks and distribution of platinum placer deposits.

PRIMARY PLATINUM DEPOSITS

After studying the Uralian and other platiniferous areas for more than twenty years Professor Duparc[1] concluded that three typical primary deposits may be distinguished.

(1) *A dunite type* in which the mother rock of platinum is dunite surrounded by successive zones of koswite, pyroxenite, and gabbro. This is the classic type, and wherever dunite is observed with its marginal zones of pyroxenite and gabbro it is always more or less platiniferous. The great placer deposits of Taguil, Iss, Koswinsky, etc., were derived from such type of rocks and so were the Tulameen placers.

(2) *A pyroxenite type* in which the mother rock of platinum is practically a koswite. This pyroxenite may be associated with gabbro but never with dunite. Even in the Urals such occurrence is rare. Placer deposits derived from this type of primary ground are always poorer than the dunite type and their occurrence does not necessarily mean the presence of platinum.

(3) *A peridotite type* in which the rock is in all places a peridotite carrying more or less large quantities of rhombic pyroxenes, and some accessory monoclinic pyroxenes. These peridotites pass laterally to dunite, but rarely to true pyroxenites. They mostly contain brownish spinels and chromite grains. Moreover, these peridotites may be serpentinized to such an extent that none of the primary minerals can be recognized. Rocks of this type occur at Khrebet-Salatim, northern Ural mountains, Russia; and at la sierra de Ronda, Andalusia, Spain. According to Professor Duparc, placer deposits derived from such rocks are not sufficiently known to allow any conclusions to be drawn as to their commercial value.

Although native platinum is not commonly observed in massive dunite, several localities in the Urals are known where it was found in place. In some cases it was observed either as minute, isolated octahedra 1 to 3½ millimetres in diameter that are associated with more recent olivine crystals, or as minute segregations. Native platinum may also occur in dunite as large, compact masses older than the associated olivine. It has also been recognized as inclusions in chromite. In many cases when the chromite is removed by a bisulphate or carbonate fusion the remaining platinum forms a spongy mass. Platinum is a product of magmatic crystallization formed later than chromite.

Dr. Wyssotsky gathered a large number of dunite and chromite specimens from the primary outcrops of Taguil, Weressowy, Kamenouchky, etc., from which twenty-five samples of all descriptions were prepared and submitted for assay. Twenty-two of them gave negative results and the remaining three revealed very small quantities of platinum. Similar results were obtained in assaying the Tulameen dunites.

---

[1] Etude Comparée des Gisements Platinifères de la sierra de Ronda et de l'Oural, par Louis Duparc et Augustin Grosset, Mémoires de la Société Physique et d'Histoire Naturelle de Genève, vol. 38, fascicule 5, p. 290.

When searching for native platinum in dunite or serpentinized areas, it should be remembered that this alloy has an erratic distribution and that negative assay results may be the rule in either rich or poor primary platiniferous ground.

About twenty primary platinum deposits are known in Ural mountains. Most of them are located in chromite schlieren; a few are in dunite. Although small bonanzas were found at times, experience showed that systematic mining of primary ground was impracticable.

No primary platinum deposits have yet been recorded from Tulameen map-area. This is probably due to the removal in Pleistocene time of preglacial dunitic debris from the gulches.

PLACER DEPOSITS

The richness of platiniferous placers derived from dunite and its associated rocks is governed by several factors, such as the area of primary rocks exposed (especially the dunite), the length of time during which the rocks were submitted to destructive agencies, and, to a certain degree, to the abundance and volume of chromite segregations (since platinum is associated with chromite). The preservation of accumulated gravels, sand, and pay dirt from subsequent disturbances such as glacial action is a factor among others that may influence the economic value of placer grounds.

During post-Tertiary time special climate conditions favoured the erosion of the Ural rugged mountain system—hence the rapid disintegration of ultrabasic rocks and the formation of huge platinum placers. Continental ice which invaded European Russia never developed in the Urals and the placers already formed were not disturbed.

In the Urals, to each primary dunite outcrop corresponds a large volume of platiniferous river gravels.

From the primary dunite outcrop of Taguil 65 miles of workable platiniferous gravels are distributed along the valleys of the Martian, Wyssim, and Tschauch rivers, Taguil area, Russia.

From the primary outcrops of Weressowy and Swelti-Bor were derived 125 miles of platiniferous gravels distributed along Iss river and its tributaries; from the primary outcrops of Kamenouchky, 30 miles of river gravels; from the Sosnowsky, 28 miles of river gravels; from Koswinsky-Kamen, 28 miles of river gravels.

The above list does not include all the smaller placers and yet more than 276 miles of platiniferous gravels along the rivers in the Urals have been actually exploited or are being worked.

The topography of Tulameen map-area is distinctly of the plateau type. With the exception of Tulameen river, which divides the main dunite exposure into two parts, the drainage is limited to a few creeks. The disintegration of basic rocks was accordingly not so extensive as in the Urals. Tulameen valley was overrun by local glaciers and thus certain parts of the valley, which probably at one time contained the richest platiniferous deposits of the district, were severely glaciated and the platiniferous gravels left behind greatly impoverished.

Before glaciation Tulameen river and its tributaries probably had more than 30 miles of platiniferous gravels, but whereas the gravels of the Urals were spread in broad valleys those of Tulameen were deposited in narrow, almost canyon-like channels.

From 1824 to 1915 (ninety-two years) the total platinum production of the Urals is officially given at 14,479 poods, corresponding to 231,664 kilos or approximately 8,120,000 troy ounces. According to Professor Duparc these figures are low because they do not include the large amount of platinum stolen by the labourres or the professional thieves. At Taguil alone it has been proved that only half the output of the placers reached the owners.

The total platinum production of Tulameen map-area is officially given as 10,000 ounces, but it is generally conceded that the output of the placers was more likely to have been 20,000 ounces.

The above notes will explain why the placers of Tulameen are smaller, poorer, and cannot be compared with the Uralian placers, although the primary dunite outcrop of Tulameen was as rich in platinum as any of the Uralian dunite exposures of the same size.

CONCLUSIONS

The following detailed study of Olivine and Grasshopper mountains, Tulameen map-area, shows that the primary platiniferous rocks of Tulameen are of the Uralian type. The area of dunite and pyroxenite exposed is smaller than at Taguil, but is quite comparable in size and otherwise with several other Uralian occurrences. This petrographic comparison adds strength to Duparc's statement that placer deposits derived from rocks of the Uralian type are always platiniferous. The present investigation does not change any conclusions arrived at by Camsell as to the economic future of Tulameen. The placers of that district were fairly prospected and up to date probably 20,000 ounces of platinum has been recovered from them, but unfortunately the greater part of this output was disposed of when platinum was at its lowest price.

The basic rocks from which the platinum placers of Russia are derived were proved by Professor Duparc to constitute thick sills. These sills were in many places sufficiently truncated by erosion to expose the dunite and its consanguine associates. Thus, for 300 miles along the east flank of the Urals, dunite is to be found outcropping at intervals. If, as there is every reason to believe, the Tulameen irruptives are similar in form, it is to be expected that they are distributed along a line somewhat parallel to the Coast range. Olivine and Lodestone mountains are the only two separate dunite outcrops of the same age known to exist in that part of British Columbia, but it is most probable that other exposures are likely to be found, especially south of Tulameen map-area where the country is not so heavily covered by younger volcanics as it is north of Olivine mountain.

Although southern British Columbia is in no way an ideal territory to look for placer deposits, prospecting for primary platiniferous dunite in that direction may nevertheless lead to a possible discovery, similar to that of Tulameen, which when at its best would have been a good business proposition had native platinum then been worth $122[1] an ounce instead of $2 or $3.

[1] Quotation, January, 1924.

Briefly summarized the following suggestions may be of value and assistance to those interested in prospecting for native platinum.

Prospecting should first be carried on preferably in an unglaciated area, to locate basic irruptives having the petrographic characters outlined in the following pages.

When such an area is located, the gravels of those parts of old or recent streams traversing it should be very carefully examined. Native platinum in many cases is extremely fine and it may be overlooked by expert panners. This will occur, especially if the platinum is magnetic, as the metal will then adhere and be carried by magnetite which generally forms a good percentage of the heavy concentrates.

No dunite or serpentinized area should be abandoned as being non-platiniferous because an assay of some specimens failed to give positive results.

DETAILED PETROGRAPHIC AND MINERALOGICAL COMPARISON OF PLATINUM-BEARING ROCKS OF URAL MOUNTAINS, RUSSIA, AND OF TULAMEEN[1] MAP-AREA, B.C.

DUNITE

The Uralian and the Tulameen dunites, when unaltered, are fine-grained, pale green, or olive green rocks of little mineralogical interest, since chromite and olivine are the only minerals to be seen under the microscope. Chromite may be observed as small octahedra enclosed in olivine crystals or as "schlieren" irregularly dispersed in the rock. Olivine is present as idiomorphic crystals more or less rounded. The crystals vary in diameter from ½ mm. to 2 mm. according to the locality.

The following table gives the optical constants of olivine from the Uralian and the Tulameen dunites, all measurements being for sodium light.

—	α	β	γ	$\gamma-\alpha$	$\gamma-\beta$	$\beta-\alpha$	2V
Dunite from Koswinsky (Duparc)	1·6543	1·6707	1·6896	0·0353	0·0188	0·0165	83° Measured 86° Calculated
Dunite from Taguil by M. Zawaritzsky	....	....	....	0·050 to 0·038	....	0·0175 to 0·025	80° to 90°
Average of other figures by Zawaritzky	....	....	....	0·042	....	0·021	87°
Dunite from Weressowy-Ouwal (M. Wyssotsky)	....	....	....	0·0309	....	....	
Dunite from Kamenouchky (M. Wyssotsky)	....	....	....	0·031	....	....	86°–87°
Dunite from Taguil-Awrorinsky (M. Wyssotsky)	....	....	....	....	....	....	87°
Dunite from Tulameen (Poitevin)	....	....	....	0·036	0·020 to 0·021	0·0168	83° to 89°

1 The optical constants of the Tulameen dunite and other rock-forming minerals were determined on the Universal Stage, using the methods of Von Fedoroff.

The chemical composition, according to Duparc, of olivine from the Uralian dunite, may be represented by the following formula:

$$Fe_2SiO_4 + 8\ Mg_2SiO_4$$

The chemical composition of olivine from the Tulameen dunite, calculated from analysis No. 5 (page 93), is represented by the following figures and formula.

	—	Theoretical	Calculated	Difference
Fe_2SiO_4	SiO_2	40·79	41·02	+0·23
+	FeO	10·87	10·45	−0·42
$8\ Mg_2SiO_4$	MgO	48·34	48·43	+0·09

As was to be expected from their optical constants the chemical composition of olivine from Tulameen is identical with that of the Uralian orthosilicate.

By fixation of water the olivine of the dunites is transformed partly or totally to antigorite (Plate V A). Examination of a large number of dunite specimens from Tulameen map-area reveals only a slight serpentinization. Advanced serpentinization is commonly limited to the joints in the dunites. As a rule the Uralian dunite is highly weathered on surface exposures, but otherwise it is, like that of Tulameen, in a good state of preservation. Other rocks closely related to dunite, such as magnetite, olivinite, diallage, peridotite, diallage-amphibole, peridotite, and amphibole-peridotite occur only as small apophyses, or as a marginal phase of the dunite, and will not be dealt with here.

The following analyses of dunite are taken from the reports of Camsell and Wyssotsky. For comparison the magmatic ratios of the Canadian rocks are calculated by the method of F. Loewinson-Lessing[1] used by Wyssotsky.

[1] $R_2O_3 = Al_2O_3, Fe_2O_3, Cr_2O_3$
$RO = FeO, MnO, NiO, CaO, MgO$
$R_2O = K_2O, Na_2O$
$\overline{RO} = RO + R_2O$
$MO = \overline{RO} + R_2O_3$
$n\ \overline{RO} : R_2O_3 : mSiO_2$
$\alpha = \frac{m \times 2}{n + 3};\quad \beta = \frac{(n+1)\,100}{m};\quad \gamma = SiO_2 : MO$

—	1	2	3	4	5	6	7	8
SiO_2	33·48	36·54	33·96	35·98	38·40	35·85	35·60	38·26
TiO_2	....	....	....	....	....	....	....	....
Al_2O_3	1·50	1·20	trace	0·08	0·29	....	0·24	0·48
Cr_2O_3	....	trace	0·60	0·40	0·07	1·46	trace	0·60
Fe_2O_3	7·27	2·15	3·32	3·76	3·42	1·62	2·07	5·37
FeO	1·36	5·62	4·43	4·73	6·69	6·82	2·36	1·47
MnO	0·06	0·60	0·24	0·29	0·24	....	....	0·14
NiO	....	0·25	0·10	0·03	0·10	1·31	trace	0·11
CaO	0·02	0·84	trace	0·88	0·35	trace	0·28	trace
MgO	42·02	44·94	43·10	43·34	45·23	41·48	44·07	37·08
K_2O	0·29	trace	0·13	....	0·08	....	0·14	0·14
Na_2O	....	trace	0·18	....	....	....	0·22	0·06
H_2O	13·86	7·22	12·87	10·40	4·34	10·07	14·40	16·13
CO_2	....	0·18	0·75	....	1·10	0·75	0·25	....
S	....	....	....	....	0·06	....	....	....
	99·86	99·54	99·68	99·89	99·99	100·52	99·63	99·84

No. 1. Camsell, C., near summit of Olivine mountain, Tulameen map-area, B.C.
2. Wyssotsky, N., 399, 1902, Iss river, Ural mountains, Russia
3. Wyssotsky, N., 943, 1904, N. Taguil, Ural mountains, Russia
4. Wyssotsky, N., N. Taguil, Ural mountains, Russia
5. Kemp, J. F., mouth of Eagle creek, Tulameen map-area, B.C.
6. Wyssotsky, N., N. Taguil, Ural mountains, Russia
7. Wyssotsky, N., 958, 1904, N. Taguil, Ural mountains, Russia
8. Wyssotsky, N., 993, 1904, N. Taguil, Ural mountains, Russia

The ratios calculated from the above analyses, water free, are as follows:

No.	α	β	γ	RO	R_2O_3	SiO_2
(1)	0·89	202·8	0·49	18·07	1	9·40
2	0·94	203·3	0·49	47·14	1	23·68
3	0·95	202·5	0·49	45·28	1	22·86
4	0·97	197·8	0·51	43·17	1	22·33
(5)	0·98	196·3	0·50	52·00	1	27·00
6	1·03	186·7	0·54	57·41	1	31·27
7	1·01	192·6	0·52	74·00	1	38·94
8	1·19	154·9	0·65	22·12	1	14·94

On Figure 13 dunite is represented by No. 1.

PYROXENITE

The pyroxenites of Ural mountains are dark, medium-grained rocks. They are very much alike from one locality to another and can be distinguished from each other only by very careful observation. The size of the pyroxene crystals, and a smaller or greater proportion of olivine are the only differences to be observed between pyroxenites of different Uralian localities. Professor Duparc has distinguished two types of pyroxenite. One he has named "koswite," whereas the other is true pyroxenite. Dr. Wyssotsky in his Memoir describes the rock type koswite as magnetite-olivine-diallagite and the true pyroxenite of Duparc as olivine-diallagite.

The pyroxenites of Tulameen map-area are of the Uralian type. They occur as a broad, continuous zone surrounding the dunite of Olivine mountain. Although not commonly observed, thin sections of this rock from certain spots of the outcrop duplicate sections made from koswite collected from Koswinsky mountain (Plate V B). Olivine-diallagite can be seen on Olivine mountain as a phase of the magnetite-diallagite.

KOSWITE OR MAGNETITE-OLIVINE-DIALLAGITE

These melanocratic rocks are mostly fine or medium grained and are essentially composed of a special pyroxene intermediate in composition between diopside and diallage, and of olivine and magnetite. The structure of this association is typical and has been named "sideronitic" by

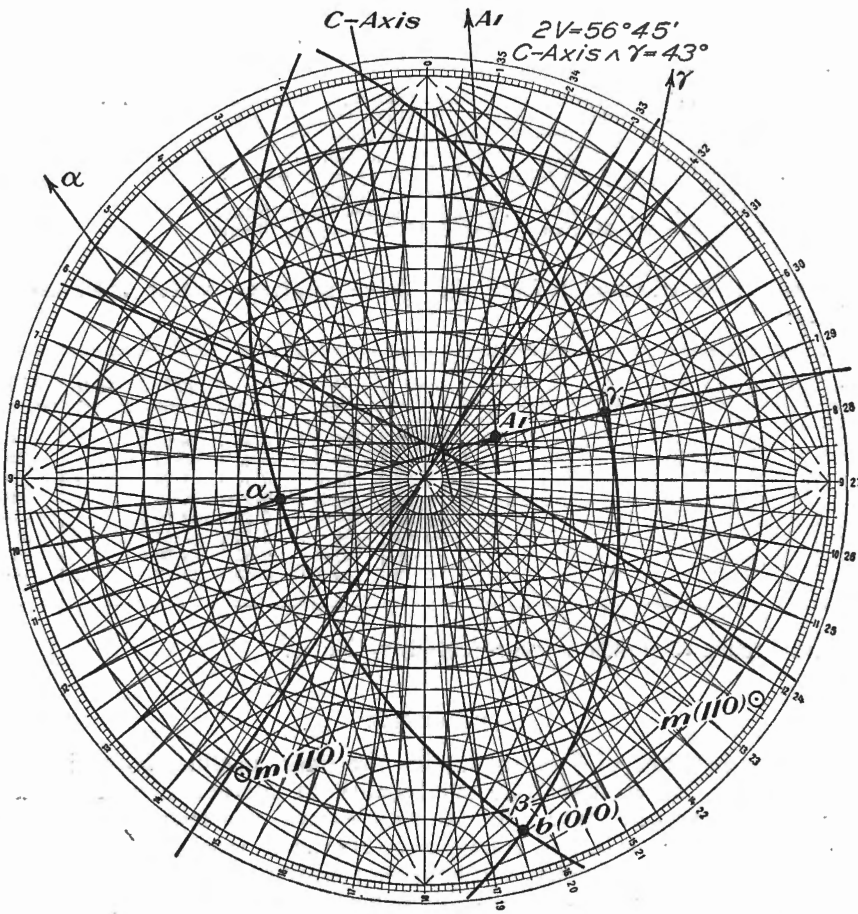


FIGURE 14. Stereographic projection of the optical properties of pyroxene from koswite, Olivine mountain, Tulameen area, Yale district, B.C.

Duparc. The olivine and the pyroxene, as a rule idiomorphic, are moulded by magnetite which acts like an interstitial cement. This structure characterizes many meteorites.

Olivine was in all cases the first to crystallize, and appears as rounded grains. Its physical and optical properties do not differ appreciably from the dunite olivine. Olivine from the Uralian koswite has the following optical constants:

$$(\gamma-\alpha)=0\cdot036-0\cdot037 : (\gamma-\beta)=0\cdot019-0\cdot023 :$$ *(Duparc)*
$$(\beta-\alpha)=0\cdot016-0\cdot018 : {}_2V_{na}=86°-89°$$

whereas the most common figures obtained upon measuring olivine from the Tulameen koswite are as follows:

$$(\gamma-\alpha)=0\cdot036 : (\gamma-\beta)=0\cdot0205$$ *(Poitevin)*
$$(\beta-\alpha)=0\cdot017 : {}_2V_{na}=87°$$

The pyroxene of this rock belongs to a group intermediate between diopside and diallage, although differing in many characters. The pyroxenes are characteristically short and stout, m(110) is the prominent cleavage. The cleavage b(010) is commonly observed, whereas a(100) is rare, and so is twinning along that plane. These pyroxenes examined in ordinary light when fresh, are colourless or greenish. The axial plane is || to b(010), and Bx_a V C-axis varies from 37 degrees to 43 degrees. The acute bisectric γ is always positive and the axial angle varies from 54 degrees to 59 degrees.

The following tables were prepared to show the remarkable similarity between the optical properties of pyroxene from the Uralian koswite and the optical properties of pyroxene from the Tulameen koswite.

Optical Properties of Pyroxene from Koswite

No.	Locality	α	β	γ	$2V_{na}$ Measured
8	Koswite from mount Koswinsky (Duparc)........................	1·6800	1·6861	1·7074	56°·28′
10	" " "	1·6825	1·6889	1·7087	57° 00′
139 ML	Koswite, Olivine mountain, Tulameen map-area, B.C. (Poitevin)...	1·680	1·687	1·707	56° 45′

Optical Properties of Pyroxene from Koswite

Specimen No.	Locality	γ–α	γ–β	β–α	$Bx_a \wedge c$	2 V Measured	Cleavages
1129	Koswite from Poloudmewaia Tilai (Duparc)...............	0·027	0·020	....	38°	....	Bad
9	Koswite from Koswinsky (Duparc).......	0·0274	0·0213	0·0061	....	56° 19′	
10	" "	0·0262	0·0198	0·0064	....	57 00	
139 ML	Koswite from Olivine mountain, Tulameen map-area, B.C. (Poitevin)..........	0·0296	0·0230	0·0066	43°	56 45	m (110) b (010) (Fig. 14)
130	" "	0·0296	Measured 0·0234	0·0062	....	54 15	m (110) : b (010)
1075	Koswite from Tilai (Duparc)...........	0·0300	0·0220	....	40°	....	
1066	" "	0·0280	0·0220	....	43°	....	
2	Koswite from Koswinsky (Duparc).......	0·0266	0·0212	0·0054	....	53 30	
3	" "	0·0253	0·0202	0·0052	....	....	
31	" "	....	....	....	....	59 00	

Hornblende is only present in small quantities and in some cases is totally absent.

Magnetite is observed as filling spaces either between olivine and pyroxene grains or between pyroxene crystals. It constitutes also schlieren of small sizes in the rock. Emerald green chromiferous spinels are found in the centre or at the margin of magnetite grains. In Tulameen map-area these spinels are small, but quite abundant in the magnetite schlierens of the koswite.

Alteration. The Uralian koswite when altered or weathered commonly shows the olivine to be serpentinized, whereas the pyroxenes have changed to bastite. The Tulameen koswite in certain zones was submitted to hydrothermal action. The olivine is now serpentine, and the pyroxene is partly transformed to chlorite or bastite. A certain number of pyroxene crystals are uralized and appear dark green in colour. Where this rock passes to a gabbro, epidote is also found as an alteration product.

The chemical composition of some Uralian and Tulameen koswites is given on page 97 for comparison:

—	1	2	3	4	5
Cr_2O_3	....	....	0·58	trace	trace
SiO_2	36·92	37·33	40·15	39·50	40·56
Al_2O_3	8·55	7·27	4·60	5·94	4·54
Fe_2O_3	17·46	13·41	12·24	13·66	13·65
FeO	8·02	9·24	10·87	8·10	8·77
CaO	18·20	16·50	17·26	19·50	19·06
MgO	11·87	12·27	15·01	12·15	13·07
H_2O	0·15	1·13	0·40	....	1·04
MnO	....	0·07	....	0·16	0·02
K_2O	....	0·30	....	....	0·09
Na_2O	....	0·45	....	0·32	0·25
TiO_2	....	1·66	....	0·50	0·33
Total	101·17	99·63	101·11	99·83	101·38

No. 1. Beautiful koswite, poor in olivine, Tilai near Poloudniewai. L. Duparc et F. Pamfil, Sur la composition chimique et l'Uniformité pétrographique des roches qui accompagnent la dunite dans les gisements platinifères, Bulletin de la Soc. Minéral. de France t XXXII, p. 351, 1910.

No. 2. Koswite, Olivine mountain, Tulameen map-area, B.C., C. Camsell, Mem. 26, Geol. Surv., Can., Dept. of Mines, 1913, p. 61.

No. 3. Typical koswite from mount Koswinsky, Mémoires de la Société de Physique et d'Histoire Naturelle de Genève, vol. 34, 1902–1905, page 119. Recherches pétrographiques sur l'Oural par Louis Duparc.

No. 4. Magnetite-olivine-diallage, Katchkanar mountain, Iss.

No. 5. Koswite, Katchkanar, Iss.

Nos. 4 and 5. N. Wyssotsky, Die Platimseifengebiete Von Iss-und Nischny-Tagil Im Ural—Mémoires du Comité Géologique. Nouvelle série, Livraison 62, table 24. St. Petersbourg, 1913.

The magmatic ratios obtained from the above analyses, recalculated water free, are as follows:

No.	α	β	γ	R_2O	RO	$\overline{RO}$	R_2O_3	SiO_2
1	0·94	150·0	0·66	....	....	3·8	1	3·2
(2)	1·03	143·4	0·70	1	75	4·7	1	4·0
3	1·10	143·8	0·70	....	....	6·8	1	5·4
4	1·10	138·7	0·72	1	135·8	5·3	1	4·5
5	1·15	157·2	0·73	1	157·2	6·0	1	5·2

From the above table it is clear that the Tulameen koswite is as closely related to the typical Koswinsky koswite as any from other Uralian occurrences.

TRUE PYROXENITE

This type of rock is mostly coarse grained, and under the naked eye appears to be entirely composed of greenish lamellar pyroxene. The Russian rock is composed of magnetite as a rule observed as octahedra, of olivine, monoclinic pyroxene, hornblende, hypersthene, and mica.

The texture of this combination is holocrystalline. Between a koswite rock and a *true pyroxenite* all the intermediate types may be observed.

In Tulameen map-area true pyroxenite is not common. The predominant type is a koswite poor or without olivine (Plate VI). True pyroxenite appears to be found only as dykes, or as a marginal phase of magnetite diallagite.

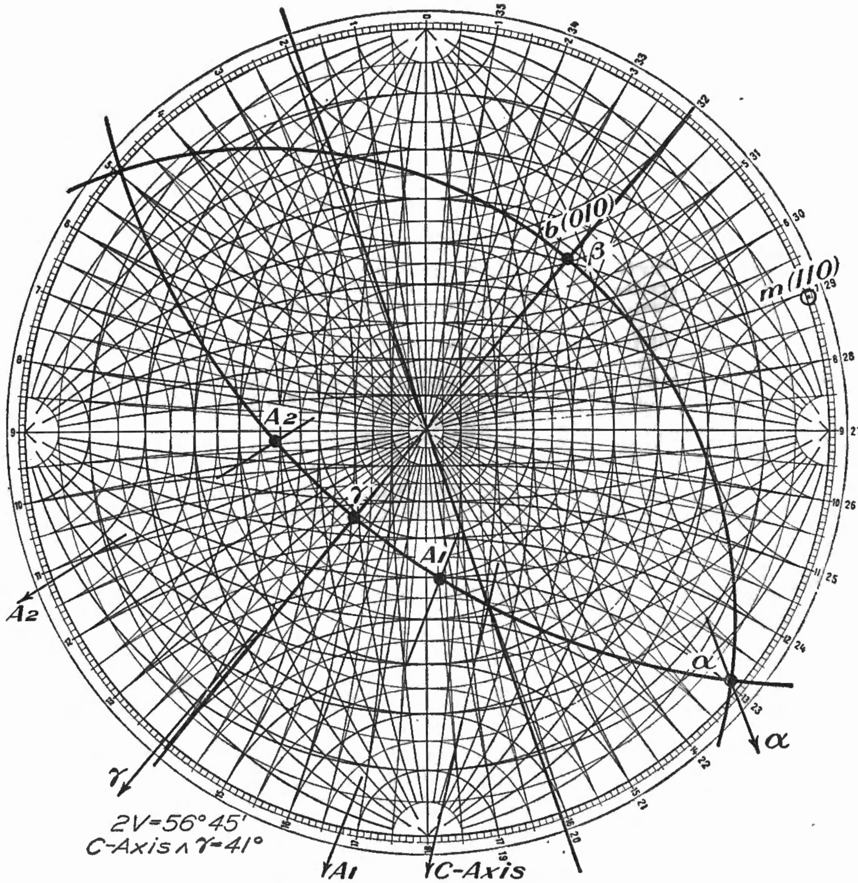


FIGURE 15. Stereographic projection of the optical properties of pyroxene from olivine-diallagite, Olivine mountain, Tulameen area, Yale district, B.C.

The most interesting mineral of this rock type is the monoclinic pyroxene. In the Russian rocks the pyroxene crystals are large and shapeless. The cleavage m(110) is in all cases observed, and a(100) is common. Twinning along a(100) is simple and not common. $Bx_a \wedge$ C-axis=37°—41°. Axial plane || b(010): γ = acute bisectric and $2V_{Na}$=52° to 56°. In Tulameen map-area the pyroxenes of the true pyroxenite have optical properties extremely close to those of the koswite. The following table shows that the pyroxene of the true pyroxenite is identical with the special pyroxene of the koswite.

Pyroxenite (True Pyroxenite), Olivine Mountain, Tulameen Map-area, B.C.

—	Opt.	$Bx_a \wedge C$	2 V	$\gamma-\alpha$	$\gamma-\beta$	$\beta-\alpha$	Cleavages
115 ML Olivine-diallagite Figure 15—Poitevin...........	+	41° 00	56° 45	0·0295	0·0225	0·007	b(010) m(110)
148 ML Olivine-diallagite with spinels Figure 16—Poitevin...........	+	42 00	58 00	....	....	0·008	m(110) a(100)
158 ML " "	+	42 00	56 00	....	....	0·006	m(110)

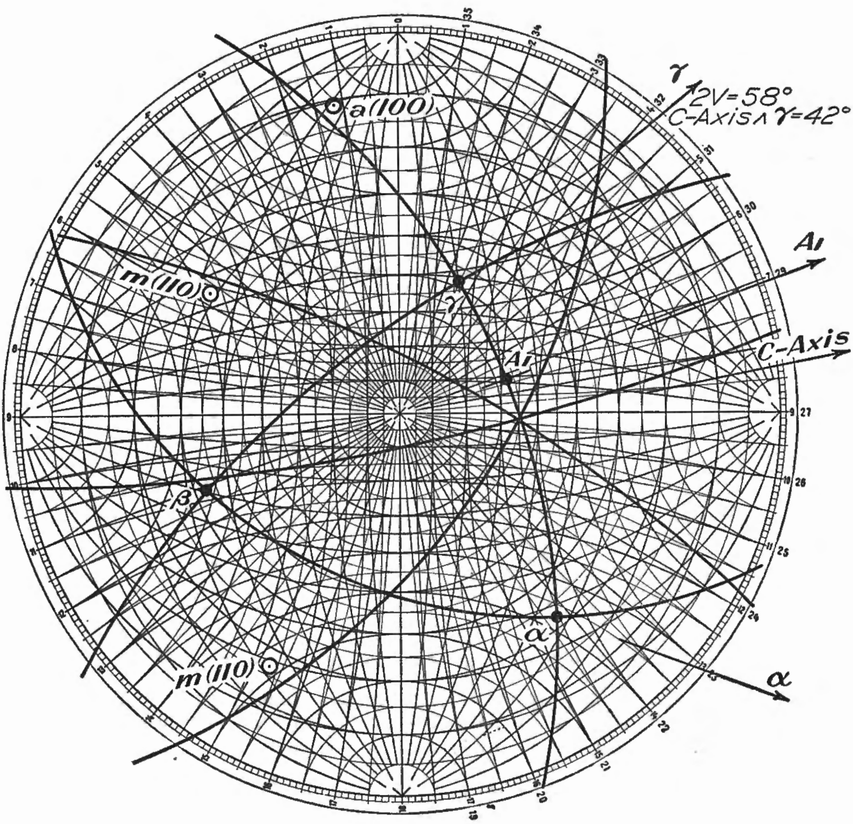


FIGURE 16. Stereographic projection of the optical properties of pyroxene from olivine-pyroxenite (with spinels), Olivine mountain, Tulameen area, Yale district, B.C.

A rock intermediate in composition between pyroxenite and gabbro was named tilaite by Duparc. This rock is found in many of the platinum deposits of Russia. It is very melanocratic and differs from pyroxenite through the presence of feldspar. The rock is composed of monoclinic pyroxene, some orthorhombic individuals in addition, a little olivine, magnetite, green spinels, and finally a feldspar of the labrador-bytownite group. It is quite possible that this marginal phase of the pyroxenite exists in Tulameen, but up to the present time, owing to the small amount of detail work done there, it has not been recognized.

GABBRO

The gabbro zones bordering the pyroxenites in the primary platinum deposits of the Urals contain a great variety of rocks. Briefly stated they include melanocratic olivine gabbros, uralized gabbros, saussuritized gabbros and gabbro-diorites.

The gabbro zone of Tulameen is not very well known because it is covered with a heavy timber growth as a rule. It commonly outcrops as detached areas, some of which resemble apophyses or dykes. This zone was not examined in detail by the writer, because most of it was covered with snow when the district was visited. According to Camsell it shows divergence in composition from one point to another. The name augite-syenite was given by Kemp to this complex.

The only analysis made of this rock indicates that it has the composition of a gabbro.

The chemical composition of this Tulameen gabbro is given below, together with two analyses of Uralian gabbros for comparison.

—	1	2	3
SiO_2	49·41	50·24	50·47
TiO_2	0·95	....	0·12
Al_2O_3	18·08	19·48	18·98
Fe_2O_3	5·93	5·45	4·22
FeO	4·08	5·02	6·16
MnO	0·09	....	0·12
CaO	10·10	11·02	11·72
MgO	4·61	4·84	5·62
K_2O	1·01	0·77	0·56
Na_2O	3·48	3·33	2·75
H_2O	1·59 }	0·55	1·06
H_2O	0·04 }		
	99·37	100·70	101·78

No. 1. Gabbro, Olivine mountain, Tulameen map-area, B.C. C. Camsell, Geol. Surv., Can., Mem. 26, p. 71.

No. 2. Hypersthene gabbro, S. E. Cerebriansky–Duparc, Le Platine et les Gites Platinifères de l'Oural et du monde, par Louis Duparc et Marguerite—N. Takonowitch, p. 105.

No. 3. Norite gabbro, O. Cerebriansky–Duparc (loc. cit.) p. 105.

The magmatic ratios obtained from analysis No. 1, recalculated water free, are given below with those of the average figures of analyses 2 and 3 also recalculated water free.

Nos.	SiO_2	R_2O_3	$\overline{RO}$	α	β	γ	R_2O	RO
1	3·86	1	1·95	1·56	76·4	1·30	1	5·28
2} 3}	3·80	1	2·10	1·49	81·5	1·33	1	7·10

The Ural Mountain dunite, pyroxenite, and gabbro are cut by numerous dykes which were classified in two groups by Duparc; a melanocratic series including issites, anorthic diorites, wehrlites, micro-gabbros, olivine berbachites, garewaites, and possibly gladkaites; and a leucocratic one including albitites, plagioclase granulites, and plagiaplites. Many dykes are mentioned by Camsell as traversing the rocks of Tulameen, but the descriptions are general and they cannot for the present be compared with those of the Russian field.

OTHER FIELD WORK

W. E. Cockfield and A. H. Bell. Mr. Bell continued the geographical and geological mapping of a 4,500 square-mile sheet in southern Yukon lying between latitudes 60 degrees and 61 degrees and longitudes 134 degrees and 136 degrees, which was begun in 1922 by Mr. W. E. Cockfield. This sheet when completed will include Conrad, Whitehorse, and Wheaton districts, which form part of the eastern margin of the Coast batholith and which contain important silver, gold, and copper deposits and other evidences of mineralization. The western half of the sheet was completed in 1922, but there still remains unfinished a small part of the eastern half. The results of the investigation will be published as a memoir, accompanied by a map on a scale of 1 inch to 4 miles, now in course of preparation.

G. A. Young. Mr. Young continued a detailed investigation of the iron ore resources of the province, which was begun in 1922, with a view to ascertaining whether they would warrant the establishment in the province of an iron and steel-making industry. It is expected that the general investigation will be completed in 1924, and that a report embodying the information collected will be published the following year. During 1923 the following deposits were examined, mapped, and otherwise studied in such detail as circumstances warranted:

Queen Charlotte Mining Division:
- Claims near Ikeda bay, Jedway, Houston bay, Collison bay, on Moresby island; and on Lyell, Burnaby, and Louise islands.

Skeena Mining Division:
- Claims on Porcher and Pitt islands.

Bella Coola Mining Division:
- Claims on Dean channel and Seymour inlet.

Nanaimo Mining Division:
- Claims on West Redonda and Texada islands, Phillips arm; and Vancouver island at Quinsam lake, Iron river, Bacon lake, and Nimpkish river.

New Westminster Mining Division:
- Claims near Harrison lake.

Kamloops Mining Division:
- Claims near Kamloops.

T. B. Williams. In 1921 the late J. D. MacKenzie commenced an investigation of the geology and coal deposits of the northern part of the Nanaimo coal basin, on the east side of Vancouver island. The field work was completed by Mr. MacKenzie in 1922, but owing to his sudden death on December 15 of that year, the maps and report which were already in course of preparation could not be completed. Accordingly, Mr. Williams was entrusted with the task of finishing the investigation. For the purpose of acquainting himself with the geology of the coal basin he spent the field season of 1923 in reviewing the part of the basin previously examined by Mr. MacKenzie.

W. A. Johnston. Mr. Johnston completed the investigation of the placers of the Barkerville area, Cariboo district. The results of the work will be published in a joint memoir with W. L. Uglow who did the bedrock geology of the area in 1922. A few creeks, including parts of lower Lightning, Peters, and Swift rivers, adjacent to the Barkerville area, were also examined and will be described in the memoir. About twenty-five detailed topographical and geological maps of the creeks have been made and will be included in the report, mostly as page illustrations. Keithley creek and a few other gold-producing creeks in other parts of Cariboo were also examined, but not in sufficient detail to warrant publishing a report on them.

V. Dolmage. Mr. Dolmage undertook and completed a detailed investigation of, the Allenby Mountain ore deposits near Allenby, B.C. A memoir, accompanied by a detailed geological map of the area, which comprises 20 square miles, is now in course of preparation.

Mr. Dolmage also examined two deposits of talc near mileage 175 on the Pacific and Great Eastern railway. The information obtained is being embodied in a report upon the talc and soapstone resources of Canada, which is being compiled by Mr. M. E. Wilson.

M. F. Bancroft and J. F. Walker. Messrs. Bancroft and Walker continued a systematic geological survey of Windermere map-area in southeastern British Columbia. The area, which comprises 700 square miles, is situated at Invermere on the Kootenay Central branch of the Canadian Pacific railway, between Golden and Cranbrook. It contains deposits of gold and its geology is an essential link in the geological study of southeastern British Columbia. It is expected that the field work will be completed by Mr. Walker in 1924.

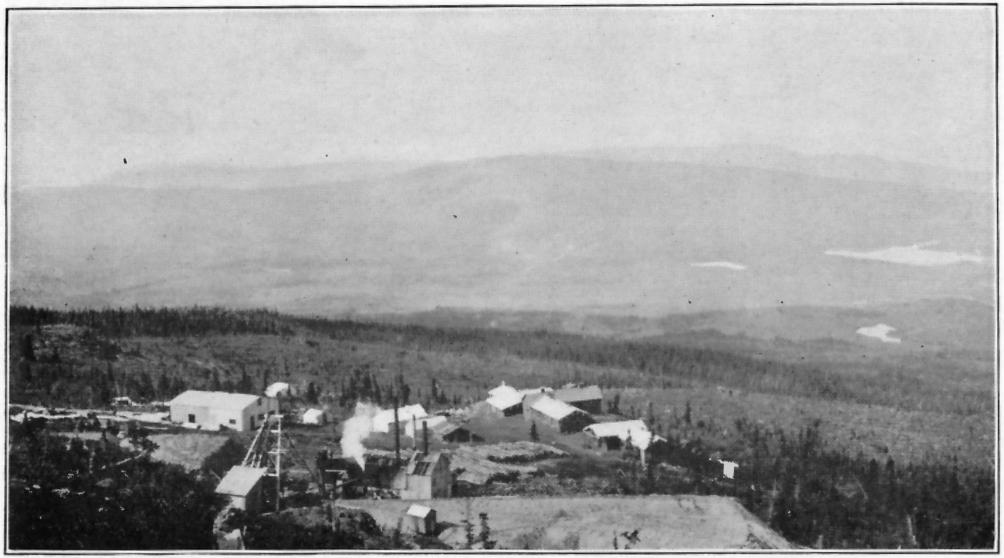
A. C. T. Sheppard. Mr. Sheppard carried out a secondary triangulation control and topographically mapped an area of 125 square miles embracing Kokanee park and adjoining area to the north. This area lies in West Kootenay, B.C., and is bounded approximately by latitudes 49° 43′ and 49° 54′ and longitudes 117° 02′ and 117° 16′. The map is on a scale of 2,000 feet to 1 inch, with a contour interval of 100 feet. The area contains numerous important deposits of silver-lead and gold, and the map is to serve as a base for future geological investigation.

W. H. Miller. Mr. Miller topographically mapped an area of approximately 200 square miles in Babine mountains, B.C., lying between latitudes 54° 45′ and 55° 00′ and longitudes 126° 45′ and 127° 00′. The area was mapped on a scale of 3,000 feet = 1 inch, with a 100-foot contour interval, the low-lying parts of the area being mapped by plane-table traverses and the uplands by phototopography. The area has numerous prospects and deposits of silver-lead and gold and the map is to serve as a base for geological investigations now under way.

E. M. Kindle. Mr. Kindle spent six weeks of the field season in the Rocky mountains of southeastern British Columbia and Alberta, studying representative sections for the purpose of assisting in determining the geological succession in the Windermere, Banff, and Kananaskis map-areas which were being surveyed respectively by M. F. Bancroft, P. S. Warren, and J. R. Marshall.

J. R. Marshall. Mr. Marshall completed the areal structural and statigraphic mapping of the Palliser-Kananaskis map-area. The major part of the season was devoted to the Palæozoic section in the valleys of Spray, Palliser, and Kananaskis rivers. Examinations were made of the Ing coal mines on Evans-Thomas (Porcupine) creek; MacKay Dippie coal claims, Pocaterra creek; P. Burns coal claims near the head of Sheep creek; and some claims now in process of development on Sheep creek near the eastern boundary of the map-area. The final report covering the entire area, accompanied by a geological map on a scale of 2 miles to 1 inch, is now in process of compilation.

PLATE I

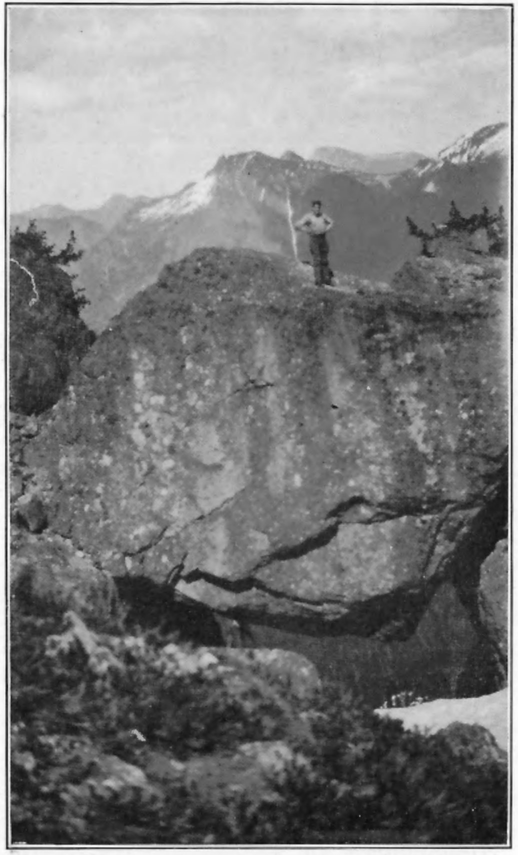


Treadwell Yukon property on the western slope of Keno hill, Mayo district, Yukon. (Page 15.)

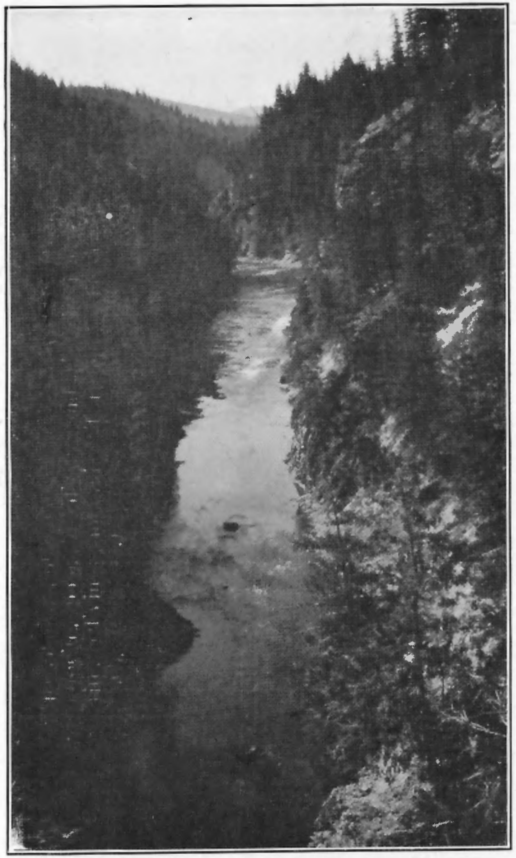
PLATE II

A. Looking east over a rugged section of Skagit mountains north of Klesilkwa valley, Silvertip mountain in left middle background—showing the influence of alpine glaciation on the upland topography of these mountains. (Page 49.)

B. Looking east across the valley of Silver creek from hills north of Green lake. Silvertip mountain in right middle background. View shows a section of Skagit mountains and the character of Silver Creek valley near the pass between that stream and Klesilkwa river. (Page 49.)

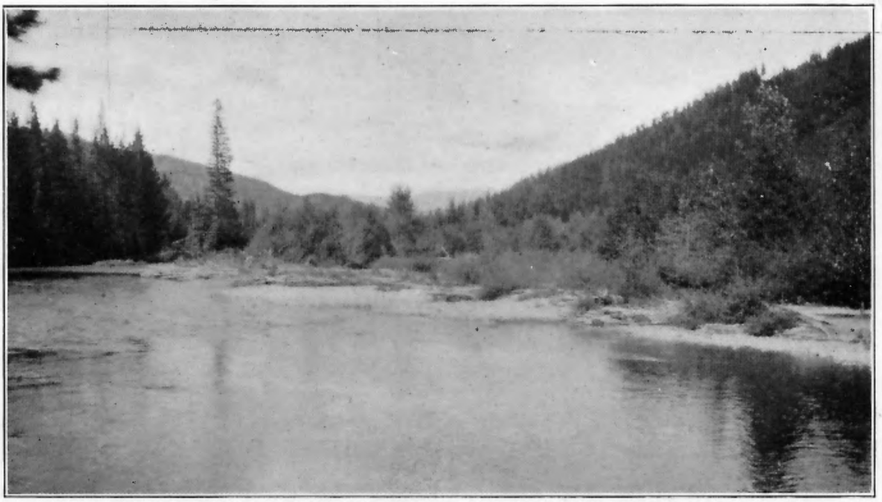


A. Block of conglomerate from exposures of Cretaceous sediments near the summit of high ridge between main forks of Yola creek, Silver Creek drainage. (Page 60.)

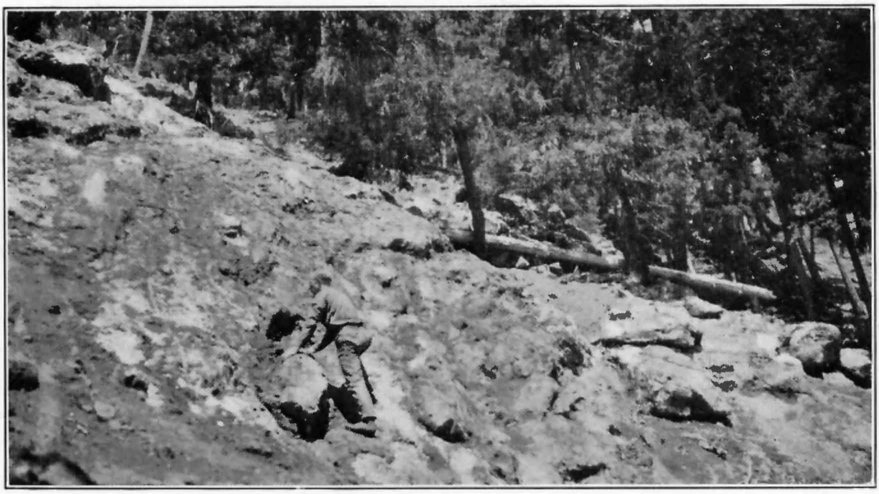


B. Canyon of Similkameen river below mouth of Pasayten river—a result of post-glacial uplift and stream erosion. (Page 68.)

PLATE IV

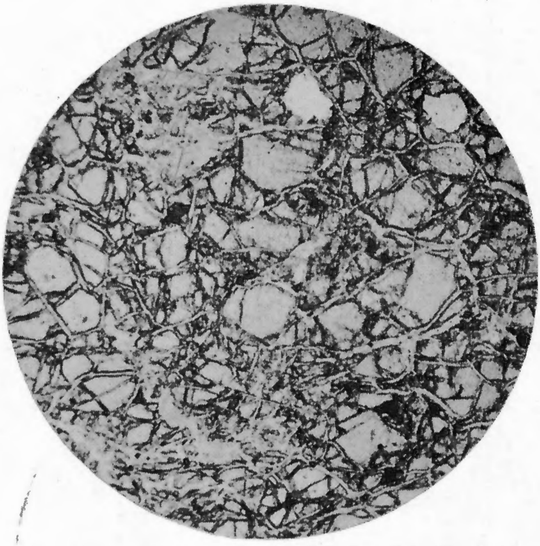


A. Looking down Roche river about 3 miles above the junction of Pasayten river —showing the broad undissected character of the valley floor above the junction of these streams. (Page 68.)



B. Bluff of solid sulphide (chiefly pyrrhotite) ore on Skagit Giant group of claims, valley of Dry Gulch creek, tributary to Tenmile creek, near Townsite on Skagit river. Ore deposit coated with white iron sulphate. (Page 76.)

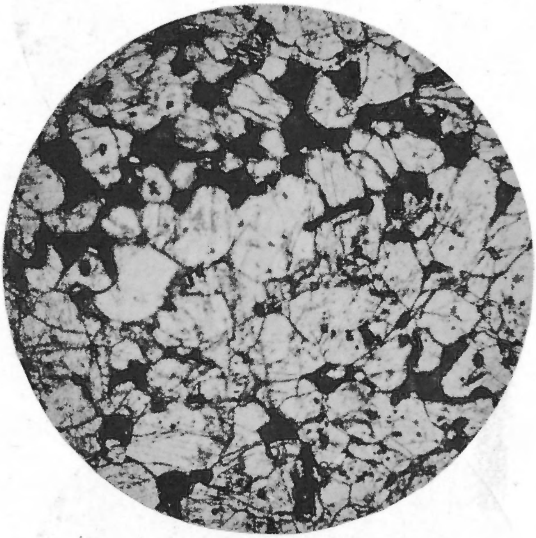
PLATE V



A. Microphotograph of slightly altered dunite, showing ribbons of antigorite, Olivine mountain, Tulameen map-area, B.C. (Page 92.)

B. Microphotograph of koswite from Olivine mountain, Tulameen map-area, B.C. (Page 94.)

PLATE VI



Microphotograph of magnetite pyroxenite or koswite, poor in olivine and rich in magnetite, Olivine mountain, Tulameen map-area, B.C. (Page 98.)

INDEX