THE DOLLY VARDEN MINE.

By George Hanson.

Annual General Meeting, British Columbian Division, Vancouver, February, 1922.

The Dolly Varden mine, controlled by the Taylor Engineering Company, has been for several years the outstanding property in the Alice Arm section of the Nass River mining division, British Columbia. More than 1,300,000 ounces of silver have been extracted from its ores and some of the ore shipped has yielded over 1,200 ounces to the ton.

The mine is located at an elevation of 1,700 feet above sea level in the Upper Kitsault River district, 16 miles north of the town of Alice Arm. A narrow-gauge railway, 17 miles long, connects Camp 8 with the wharf at Alice Arm. The district can be reached on boats of the Union Steamship Company, which call at Alice Arm. Grand Trunk boats call at Anyox. Alice Arm is 18 miles from Anyox, and a tri-weekly boat service is maintained between the two towns.

General Geology.

The Upper Kitsault River district lies a few miles east of the eastern margin of the Coast Range batholith, and the surrounding area is characterized by the rugged peaks and the steep sided valleys typical of Coast Range topography. The rocks of the area in general are folded into anticlines and synclines, which have a trend parallel to the eastern border of the batholith. Locally, folding transverse to these predominant structural lines has taken place.

The rocks can be classified into four main groups. Given in order of decreasing age, these are:

(1) A thick series of volcanic fragmental rocks;
(2) A series of argillites and other sedimentary rocks;
(3) Coast Range granitic rocks;
(4) Lamprophyre and diabase dyke rocks.

The oldest rocks exposed, the volcanic fragmental series of Triassic or Jurassic age, make up the country rock of the Dolly Varden mine, and of all the other silver properties in the district. The series includes some coarse agglomerates, but medium grained breccias predominate. The upper beds consist chiefly of finer grained tuffs. In general the rocks are green or grey in colour, but some members are purple or red. The breccias at the Dolly Varden mine dip in a northerly direction, and may be part of the northern limb of a small anticline transverse to the general structure.

Basic dykes are found in the mine workings, but as they do not appear to be related genetically to ore deposition they will not be discussed here.

Faulting has an important bearing on the ores. The faults are chiefly reverse faults and later than the primary mineralization. They strike roughly north and south, and dip 45-75 deg. to the west. The thrust has acted from west to east. These reverse faults are cut by normal faults having the same general strike and dip. The trace of a fault plane on the surface is marked usually by a narrow gully, but since the rocks are in general void of apparent structures, surface examination gives very little evidence regarding the nature of the fault, except where a vein or a dyke has been offset. Underground, there are other evidences, such as gouge, drag ore, striations, etc., which can be studied to throw light on the problem of determining the direction of movement of the fault blocks.

Discovery and Development of the Mine.

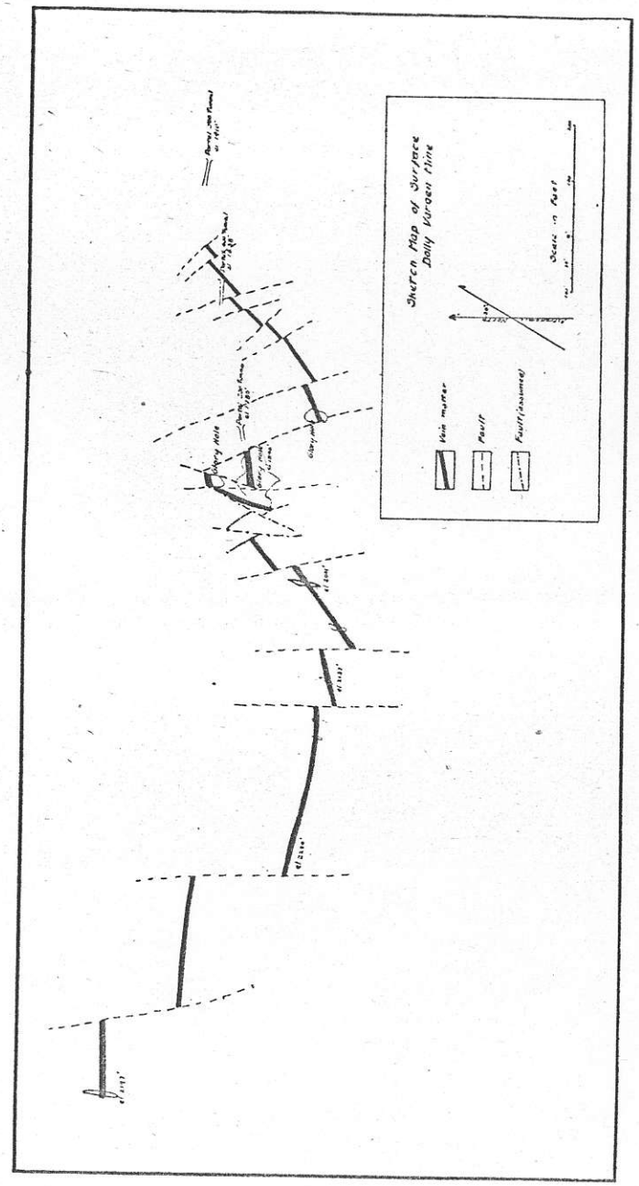
A prospector named Gus Pearson dreamed a dream. In his dream he found a mineral vein on a steep wooded hillside. The place was marked by a great white boulder. He staked the claim and named it the Dolly Varden, and eventually it became a big mine. Thus the dream. When Pearson and his partners were going up the Kitsault River valley later, they found the steep wooded hillside, found the big quartz boulder, staked a claim, and named it the Dolly Varden. This was the first mineral claim located on the upper waters of the Kitsault river.

The property was first described in the Annual Report of the Minister of Mines (B.C.) for 1913. There were then two open cuts showing a great deal of quartz, but carrying low values. The Dolly Varden was again mentioned in the Annual Report for 1915, and from that time to the present short descriptions have been given every year. In 1915 there were six claims in the group, and the property was under bond to R. B. McGinnis. By the end of the year a good deal of development work had been done, such as surface work, 550 feet of tunnelling, and 4,500 feet of diamond drilling. In 1916, work consisted of 800 feet of tunnelling and 4,000 feet of diamond drilling. A compressor was installed and a wharf built at Alice Arm. There were now eight claims in the group. Development, preparatory to shipping ore, was continued in 1917 and 1918. In 1919 the property came into the hands of the Taylor Engineering Company. In the same year, the railway was completed from Alice Arm to Camp 8. An aerial tram 1,900 feet long was also built from the 400-ft. level to Camp 8. To-day there are about 7,000 feet of tunnels, raises, drifts, etc. Production has been as follows:

Year	Ore, tons,	Total Silver, oz.	Silver, oz. per ton
1919	6,668	376,562	56
	42	50,562	1,202
1920	27,944	749,340	27
	93	82,298	884
1921	1,862	45,647	24
Total:	36,609	1,304,409	35⅔

THE ORE BODY.

The ore body is in the form of a vein, of which only one wall,. the hanging, is free. The footwall is gradational, ore merging gradually into country rock thoroughly impregnated with pyrite. In every place where ore has been extracted, the hanging wall consists of purple breccia and the footwall of green or grey breccia. The ore zone does not seem to be a pre-mineral fault, and consequently the vein is probably a bed vein. The ore material has formed along this contact, chiefly by replacement of the footwall rock. The hanging wall shows no replacement whatever. The vein east of the most easterly stope shows on the surface the same geological relations. It has not been developed underground. The westward extension of the vein is not a bed vein, but lies entirely in green breccia. The



Sketch Map of Surface, Dolly Varden Mine.

most westerly open cut, west of which the vein has not been traced, shows again the same geological condition as that of the stopes.

The vein has an east-west trend, and has been cut by transverse reverse faults into a number of sections, each about 100 feet long. The horizontal offset of the vein is more than 120 feet in some instances. (See accompanying plan.)

The ore is massive. Banding, crustification, etc., are absent. The vein material is highly silicious, with an average of 70% or more of quartz. Calcite and barite are other gangue minerals. The primary metallic minerals are pyrite, with a little chalcopyrite, sphalerite, galena, and tetrahedrite. Sphalerite and galena are more prominent than chalcopyrite, yet the combined percentage of lead and zinc in the ore shipped has been less than 2%. The primary vein, then, is really a silver bearing quartz-pyrite vein. The metal extracted is silver, and it has been taken from an ore composed chiefly of the minerals ruby silver, argentite, native silver, pyrite, and quartz.

MINERALOGY OF THE ORE.

The metallic minerals present in the vein are pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, argentite, pyrargyrite, proustite, pearceite, native silver, and limonite. The gangue minerals are quartz, calcite, barite, and jasper. Arsenopyrite[1], hornsilver and brittle silver[2], rhodochrosite or hodonite[3], have been recorded but were not identified by the present writer.

Pyrite is more plentiful than all the other primary metallic minerals together. It occurs, in the form of cubes, both in the footwall rock and in the vein itself, though in the vein-quartz it is commonly present as small stringers. The other primary sulphides are rare.

In the ore mined, native silver, argentite, and ruby silver were plentiful. Argentite is in part associated with galena, but, chiefly, it is present with the minerals which are distinctly later in time of deposition. Probably more silver was yielded by the native metal in the ore than by any other mineral. The native silver is present in the form of leaves and plates in small fractures in the vein matter; in the lower levels it is usually in wire form. With it are associated ruby silver, argentite and pearceite. The ruby silver minerals, particularly pyrargyrite, were important constituents in the ore. Limonite is found in the faults down to the lowest levels.

Quartz is by far the most abundant gangue mineral. It is milky white usually, but in much of the high-grade ore it is bluish to almost black. Barite is common in some parts of the vein, but is not associated with high silver values. These are in quartz gangue, here as elsewhere in the same district. Calcite in small quantities is found everywhere, associated with the other gangue minerals. It is more abundant in the wall rocks, as stringers of late deposition. Jasper, common in other veins in the district, is not plentiful in the Dolly Varden vein. The jasper contains a small amount of manganese.

The hanging wall rock has not been altered by ore solutions, but the footwall has been impregnated with pyrite. Some silicification and sericitisation has also taken place.

The group of minerals comprising pyrite, chalcopyrite, sphalerite, galena, and tetrahedrite, were deposited early in the process of vein formation. They are believed to be entirely primary. The ruby silver, argentite, pearceite, native silver group is of late formation, and of these, native silver was the last to deposit. The minerals of this second group are believed to belong to a second period of mineralization: that is, a period of secondary enrichment.

SECONDARY ENRICHMENT.

The terms "primary" and "secondary" have been used with different meanings by various writers on ore deposition. However, nearly all writers now use the term "primary" to describe ore bodies whose chemical and mineralogical composition has not been changed by superficial agencies, and the term "secondary" to designate those ore bodies which have resulted through the action of superficial agencies on primary ore.

When mineral deposits are exposed to weathering, the compounds which are unstable under these conditions are

[1] Forbes, Donald G., "Kitsaulte Copper Camp, Alice Arm, Observatory Inlet". Ann. Rept. Minister of Mines, B.C., p. K83, 1913.

[2] McMullin, J. H., "Skeena and Bella Coola Mining Divisions", Ann. Rept. Minister of Mines, B.C., p. K70, 1915.

[3] Turnbull, J.M., "Alice Arm District", Ann. Rept. Minister of Mines, B.C., p. K75, 1916.

decomposed, and soluble salts and stable secondary minerals are formed. The soluble salts may move downward, react with minerals below, and thus form other secondary minerals. In the change from oxidizing conditions at or near the surface to what are, relatively, reducing conditions below, solutions may deposit part or all of their metal content. Secondary minerals may result from other reactions. In general the process of secondary enrichment takes place in three steps.

(1) Decomposition of primary minerals;
(2) Transportation, usually in solution;
(3) Deposition in concentrated form.

It is believed that the ore of the Dolly Varden mine represents enrichment of lower grade primary vein material. The evidence favouring this view will be presented under three headings:

(1) Geological evidence
(2) Mineralogical evidence
(3) Textural evidence.

Geological evidence.— If a high-grade ore is related in position to the present surface, it is probably related thereto in origin also. Again, if there has been considerable erosion since the deposition of the primary ore, the ores now confined to the surface are probably not primary but secondary. This point was brought out by Ransome[1] in 1910.

The primary ore bodies in the neighbourhood of Observatory inlet, as well as the great majority of all the primary metallic deposits of British Columbia, were formed in late Jurassic or early Cretaceous time. Since that time, erosion has stripped off thousands of feet of rock. Consequently, it would be a curious coincidence if the ore deposited at that time should show any close relation to the present surface. At the Dolly Varden mine, good ore has been mined to a depth of 200 feet below the outcrop, and development has extended to a greater depth. Mining and development have shown a great change from high-grade to lower grade vein matter between 175 and 250 feet below the surface. This is a strong argument favouring the view that the ore is secondary.

[1] Ransome, F. L., "Criteria of Downward Sulphide Enrichment"; Econ. Geol., Vol. 5, pp. 205-220, 1910.

Further evidence is obtained from the relation between the high-grade ore and the numerous faults. The best ore was found near the faults, and near the hanging wall of the vein. Since the faults are later than primary mineralization, a second period of mineralization is postulated to explain the relation. The faults and fractures are water-courses, and the obvious source of the mineralization of this period was the primary vein. A second period of primary mineralization is unlikely. There are dykes cutting the ore and one of them is later than the faults; but the dykes do not appear to have any relation to the ore. If the period were primary, the whole fault plane should be mineralized. This is not the case. Only the original vein carries ore. It seems obvious that the faults and fractures were simply channels for the downward-moving enriching solutions. The hanging wall is free and in many places has a slab-like or sheeted structure parallel to the vein. Solutions could also move downward along this wall.

Mineralogical Evidence.— In the faults previously mentioned limonite is ever present. This proves that oxidizing solutions have moved down along the fractures. The ore minerals regarded as secondary are argentite, ruby silver, pearceite, and native silver. The secondary nature of these minerals has been investigated by various writers. Emmons states that, in sulphide deposits, native silver is generally or invariably secondary[1], and that argentite is one of the commonest secondary minerals, but that it is sometimes primary[2]. He also states that the ruby silvers are nearly everywhere secondary minerals, and that pearceite is secondary in most of its occurrences[3]. Some secondary action is necessary to produce the limonite. It is probable that the other common secondary minerals were deposited at the same time and by the same processes.

Textural evidence.— In the upper workings of the mine, native silver occurred as thick plates and leaves. Lower down,

[1] Emmons, W. H., "The Enrichment of Ore Deposits": U.S. Geol Survey, Bull. 625, p. 270, 1917.

[2] Emmons, W. H., idem. p. 274.

[3] Emmons, W. H., idem. p. 261.

the plates were thinner, and 200 feet below the surface very thin leaves and wires of the metal are found. All the native metal is found in small fractures in the primary vein material. In the lower workings, argentite and ruby silver are found only in the small fractures, but near the surface these minerals were more abundant, and occurred as well in large bunches and numerous small blebs. Near the surface, replacement has been more extensive than below and has gone beyond the fractures; in depth, however, replacement is confined to the fractures. It is not known whether all the fractures in which the secondary minerals are now found were previously occupied by primary sulphides. It is not likely that they were, however, as intermediate stages of this replacement are not common.

From a metallographic study of the ore, it is apparent that all the minerals believed to be secondary are later in time of deposition than the known primary minerals. It is also seen that argentite replaces galena in many places. Argentite areas show cores and remnants of galena. The argentite areas are in turn replaced around the edges by native silver.

CONCLUSIONS.

Although it is fully realized that general conclusions, such as are given below, may be misleading if taken as rules, particularly since they are drawn in part from only one mine, they are stated because even one mine may contribute a good deal toward the "law of the camp". The conclusions given here refer to the Kitsault River district:

(1) The Dolly Varden contact between red and green breccia is a favourable horizon for ore.

(2) Red breccia is an unfavourable country rock.

(3) Green or grey breccia is favourable country rock.

(4) The primary vein contains primary ore shoots.

(5) Very high-grade secondary silver ore cannot be expected to continue in depth for more than 250 feet below the outcrop.

(6) More extensive faulting and fracturing is accompanied by more intensive enrichment, in veins of equal primary value.

DISCUSSION.

MR. J. D. MACKENZIE: Two years ago last November there was a discussion about the Dolly Varden and other mines in the same district, and Dr. Dolmage was a protagonist at that time for the primary character of these ores. There is to some extent a tendency among geologists at the present time to believe that sulph-antimonides are more apt to be primary than secondary. Two years ago at this convention the tendency seemed to be to consider these minerals primary. I fail to see the justification of any interpretation other than that which has been put forward by Dr. Hanson, after a field study made in the mine. Materials were gathered on the ground, and, from these, facts, conclusions, and theories, are derived. Two years ago the discussion was based on small samples examined under the microscope. To-day we have the facts obtained in the examination of the mine itself, and there is no doubt Dr. Hanson has given us the correct solution. An important fact is the reduction in the grade of the ore. Finding the enrichment along the faults leads one to believe the enrichment has been connected with the surface water. Again, you have the limonite. These facts point to one conclusion, and one only: that is, that these ores are secondary.

MR. H. R. VAN WAGENEN: I am in accord with the views which have been expressed concerning the secondary enrichment of silver veins. So common is this action, because of the ease with which silver is dissolved by surface waters, that, in countries where the rate of erosion has not kept pace with the migration of the soluble metals, secondary minerals are invariably present. Small veins, of uncommercial grade where primary, have thus been made profitable near the surface. So high-grade are they, frequently, as to be a "poorman's proposition" and, as a result, in the arid "Silver States", such as Nevada, the name "chlorider" has long been the title given to the prospector or leaser who makes his living (and occasionally a "stake") from coyoting outcrops and shallow workings in which the chief valuable constituent is silver chloride. Even in a country like British Columbia, where erosion has been very rapid, secondary silver is to be expected; but it would be unreasonable to hope that the zone of that secondary en-

richment would extend deep — because, as stated, erosion has been rapid, rapid enough to have almost kept pace with the migration of silver.

DR. HANSON: In the Dolly Varden there is no gold. Although gold is present in neighbouring districts, there is very little in the Alice Arm district.

MR. F. W. GUERNSEY: Is there any evidence of a change of the water table at the Dolly Varden? I understand they get secondary minerals below the present water table. A good criterion we used to have was, that when the permanent water level was reached, we looked for any secondary enrichment to stop, or at least only to extend a comparatively slight distance below such level. It was always a question, however, where the original top of the water table was. I remember the case of a mine in Nevada, where one of our men reported that the shaft, although the property had not been worked for some time, was dry at the 500-foot level. A year or so afterwards he returned to make a further inspection, and found the water standing at the 400-foot level. Between the times of his visits an earthquake had occurred in the vicinity and evidently had changed the level of the water table over the whole district. The point I wish enlightenment on is, are these secondary minerals, mentioned by Dr. Hanson, deposited at any great depth below the present water level? Or is there any evidence of a change of this level?

DR. HANSON: In the Dolly Varden, the enrichment probably took place in Tertiary time, and you could not tell where the water table was at that time.

DR. S. J. SCHOFIELD: I am very much interested in the evidence of secondary enrichment of silver. There are geologists who hold that the native silver of the Dolly Varden is primary. Because they find evidence that some silver is primary, they conclude all silver is primary. Every case has to be decided on its own merits, and every mine studied by itself. In the Dolly Varden, the evidence is conclusive, and in the Premier it is conclusive. The manager of the Premier considers the high-grade silver values are secondary. There are high values in gold which will make the mine produce for

a long time. It looks as if the gold values are primary, and if so they will continue with depth. It is nice to have these high values in an ore-body, because they pay for the preliminary development work. If you have these enriched values it is easy to open them up, and of course this helps a lot in the development of the country. The ore-bodies occur at the contact between quartz-porphyry and tuff. In the Dolly Varden they occur at the contact of the purple and green tuff. If you examine the geology of the country you will see the greater portion is underlain by tuffs, and this enlarges the possibility for the occurrence of these high-grade silver ores.

MR. H. G. NICHOLS: I would like to ask Dr. Hanson if he can give us some further information regarding the structural conditions, especially the localization, intensity, and persistence of the fracture system. I raise the point in connection with the depth to which secondarily enriched ore may be expected to occur. Dr. Hanson has suggested a depth of 250 feet for the horizon of secondary enrichment, but if the process is to be associated with the function of the fracturing as affording channels for the downward passage of the mineral solutions, a knowledge of the conditions of fracturing is essential to an appreciation of the ore occurrence. I came across an interesting case recently in Mexico, where oxidation and secondary enrichment had been carried to varying depths in different sections of an ore-body as a result of a system of vertical fractures. A body of secondarily enriched ore was followed on one level to a point where a vertical line of demarcation between sulphide and oxidized ore was passed. Beyond this point, the ore was found at a horizon about 200 feet lower, for a certain distance, and then, an area of a more intense phase of the fracturing being entered, it dropped out of sight altogether, so far as development had gone when I was there. It occurs to me that similar fracturing conditions in the Dolly Varden area probably have a pertinent bearing upon the case, and to a similar extent.

DR. HANSON: The secondary enrichment gradually decreases to a limit of about 250 feet, but the fracturing goes further down. It contains no secondary enrichment, however, but there is limonite in the fractures below the enriched zone.

DR. W. L. UGLOW: I did not hear the first part of Dr. Hanson's paper, but I would like to ask if he has any evidence to present to show us whether there is a secondary sulphide zone in that northern portion of British Columbia? Why has it not been removed, as it has been in other parts?

DR. HANSON: In studying the Dolly Varden mine I came to the conclusion the ores are secondary. Whether or not these secondary ores should have been eroded, they were not eroded. The country has been glaciated, it is true, but in the valleys there is not the same evidence of erosion as you would expect if the ice had eroded deeply.

DR. UGLOW: Is the oxidized zone gone?

DR. HANSON: Yes.

THE PREMIER MINE.[1]

BY GEORGE HANSON.

Annual Western Meeting, Vancouver, November, 1922.

The Premier mine has been the subject of so much comment in mining circles that the writer felt that a short paper dealing with the geology and ore-bodies of the mine would be of interest. The statements which follow are of a general nature merely, being based on the results of a preliminary investigation.

LOCATION.

To reach the mine from Vancouver the journey is made by Grand Trunk steamer to the boat landing between Stewart, B.C., and Hyder, Alaska, — the landing is one and a half miles from the former town and one half mile from the latter. An automobile road extends from Stewart through Hyder to the mine, a distance of 17 miles. The road follows the Salmon river in Alaska to Eleven Mile, then ascends along Cascade creek for two miles, and finally zigzags up to an elevation of 2,000 feet above sea level on Bear River ridge. The road enters British Columbia 12½ miles from Hyder. The International Boundary at this point practically coincides with the coast Range batholith. The complex of pre-batholithic rocks extending to the north and south along the eastern border of the batholith is the great mineral belt of British Columbia.

GEOLOGICAL HISTORY.

On a surface which is not now exposed, there was accumulated, in the latter part of the Jurassic period, a thick series of volcanic fragmental rocks of intermediate chemical compo-

(1) Published by permission of the Director of the Canadian Geological Survey.