GEOLOGY 9. REPORT.

600318

COBALT IN THE NICKEL PLATE ORE.

April 1942.

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CONTENTS.

INTRODUCTION.

The work which is described in this paper, has been done as part of the Geology 9 course at the University of British Columbia, in the session 1941-1942.

The purpose of the work was to identify and estimate the distribution of inclusions of one or more cobalt-bearing minerals in arsenopyrite in six one samples from the Upper Purple and Lower Purple ore-bodies of Nickel Plate mine. Previous workers have fairly definitely identified inclusions in arsenopyrite as cobaltite, but a complete suite of the ore had not been available, and their investigations, therefore, did not give detailed information on the amount and distribution of cobaltite, or on the suspected existence of other cobalt-bearing minerals. The work has been continued because the present shortage of cobalt has made it a strategic metal and because a detailed knowledge of the occurrence of cobalt-bearing minerals in the Nickel Plate ore may prepare the way for production of cobalt as a by-product. Investigations on ore from other parts of the mine were carried on contemporaneously by three other students, and in addition, Dr. H.V. Warren kept apace, or ahead, of all these investigations by means of a reverse-duplicate controlling suite of specimens.

The author is indebted to the management of the Nickel Plate mine for the ore samples, and to Dr. H.V. Warren for guidance in the work. Acknowledgment is also due to

Mr. Cave-Brown-Cave, Chief Analyst, Provincial Department of Mines, for assays of the six samples, and to James Donnan and Robert M. Thompson for instruction and help in making the polished sections.

LOCATION AND HISTORY.

The headquarters and mill of Nickel Plate mine are at Hedley in the Similkameen Canyon of southern British Columbia. The mine itself is near the summit of Nickel Plate mountain in the Okanagan Range. A spur of the Great Northern Railway and the Southern Trans-Canada Highway provide good transportation.

Nickel Plate mountain was at one time Canada's largest gold producer. Small scale placer mines on the Similkameen River led to the discovery of ore in the mountain in 1898, and mining was pursued actively from 1904 until 1930. From 1930 to 1932, the Hedley Gold mining properties were closed down. In 1932 the properties were optioned to J.W. Mercer of New York and in 1934 production was resumed at the mine under the Kelowna Exploration Company. The total production from Nickel Plate ore-bodies is over two million tons of ore averaging one half ounce of gold per ton. The most recent publication on the ore deposits in Nickel Plate mountain is that by Paul Billingsley and C.B. Hume, published by the Canadian Institute of Mining and Metallurgy, Transactions Volume XLIV, 1941, pp.524-590, (or Bulletin October 1941, pp. 524-590.) Previous workers include C. Camsell and H.S. Bostock of the Geological Survey of Canada.

GENERAL GEOLOGY.

The Similkameen Canyon cross sections a belt of Triassic argillites, limestone and volcanics folded into many anticlines and synclines trending from northeast to southwest and south. The folds flank the Okanagan granitic mass to the north and butt against the Similkameen batholith to the south. Nickel Plate mountain is on the west flank of an anticline with beds dipping 25 to 30 degrees northwest. Here, as elsewhere in the group, the argillites are intruded by many sills, dykes and large igneous bodies, and at Nickel Plate mountain, the whole assemblage is floored by a granite mass.

The Nickel Plate orebodies lie mainly within the central part of the Nickel Plate formation which lies above the granite mass and below the "Climax" breccia. The formation consists of banded limey argillites which have been altered and recrystallized into marble, chert, "quartzite" and skarn. Under deformative stress the argillites were first highly crumpled, but with the introduction of sill-like sheets of hornblende-diorite-porphyry and porphyry dykes, and the consequent development of marble accompanied by a coarsening of the grain and followed by further alteration, the rocks became hard and brittle. Further deformation took place by thrusting and fracturing, so that channels were made, along which mineralizing solutions could come. The dominant control of ore in the Nickel Plate structure, however, is the so called "Hot Sill" believed to be identical with the "Midway dyke", a body of intrusive gabbro on the footwall of the ore, and cutting across the limestone beds at a sharp angle.

Billingsley says, "The orebodies consist of certain sulphides disseminated in the necessary amounts in special portions of the skarn and marble alteration complex". He does not use the term "Contact metamorphic", applied by earlier workers.

The Purple orebodies are in the trough north of Central fault and are the highest and most northerly of the Nickel Plate system. The Upper Purple "ore bed" is above the main Purple body and is separated from it, and the other ore bodies, by a "chert breccia" sheet.

THE INVESTIGATION, METHOD AND RESULTS.

The six samples examined, came from the top, middle and the bottom of the Upper Purple and Lower Purple orebodies. Etch reactions and microchemical tests were made on six hand-polished specimens, and the results were compared visually under very high power on super-polished sections.

The first step in the investigation was to become familiar with the ore, and to note the abundance of the arsenopyrite and any peculiarities in its occurrance. As a guide to this preliminary study, reference was made to the work by H.V. Warren and J.M. Cummings, "Mineralogy at Nickel Plate Mine", reprinted from the B.C. Miner, May 1936. These workers identified the following minerals:

Arsenopyrite
Lollingite
Cobaltite (?)
Unknown Grey Mineral
Pyrrhotite
Sphalerite
Chalcopyrite
Pyrite
Calcite
Garnet
Epidote
other silicates
Gold

Of arsenopyrite (FeAsS), they say, "This is the most important metallic mineral in the ore. It is predominantly massive and anhedral, although it occasionally develops crystal form when in contact with gangue minerals. It occasionally occurs with pyrrhotite, in which case it is found in tiny subhedral or rounded grains, often as clusters or small masses. Blebs of pyrrhotite in arsenopyrite grains are common. Arsenopyrite is the most common host mineral for native gold".

Lollingite ($FeAs_2$): Found to be very rare.

Cobaltite ($CoAsS$): "Under magnifications of 900 diameters, what are thought to be specks of this mineral were seen in one place enclosing "islands" of pyrrhotite, but usually as tiny inclusions in and completely surrounded by arsenopyrite."

Pyrrhotite ($Fe_x S_{x-1}$): Sometimes appears to be contemporaneous with arsenopyrite, but more often found to be younger.

Sphalerite (ZnS): Not abundant.

Chalcopyrite ($CuFeS_2$): Not abundant but usually close to pyrrhotite when present. "Chalcopyrite was not seen in high grade specimens and its presence may possibly be indicative of a relatively low gold content."

Pyrite ($FeSn$): "This mineral is rarely found at Nickel Plate mine".

Calcite ($CaCO_3$.): Occurs as coarsely crystalline masses, as tiny inclusions, and in minute cracks in the sulphides. "Possibly two generations of calcite are represented in the ore."

Silicate minerals "include enhedral garnets, epidote, pyroxene, and possibly axinite. All are older than the ore minerals and have been replaced by them in varying degrees."

Gold: Warren states, "There appears to be enough of this native gold in the ore to account for all the gold reported by the assays.

There is no evidence to suggest that any gold is chemically related to or in solid solution with the arsenopyrite or pyrrhotite, the two minerals with which the gold is most closely associated."

The inclusions of gold are commonly in or surrounded by arsenopyrite and probably average less than 7 microns.

"The following paragenesis is suggested.

(1) Formation of silicates.

(2) Introduction of arsenopyrite.

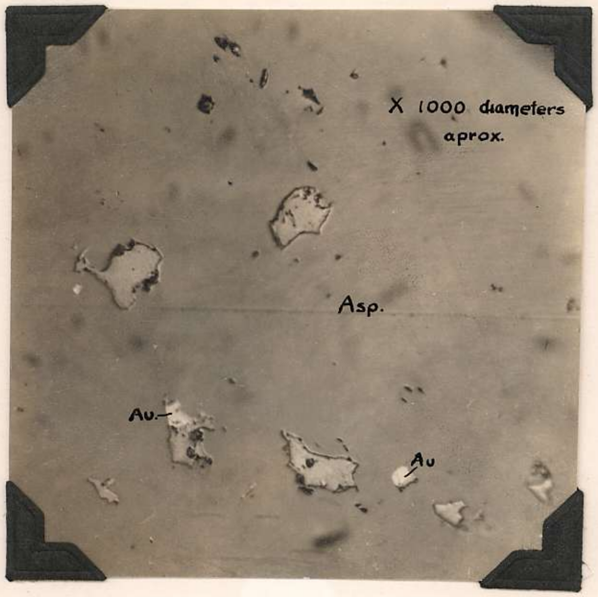
(3) Introduction of pyrrhotite, chalcopyrite and sphalerite.

(4) Fracturing and veining of ore by calcite stringers.

The gold appears to have been deposited in and contemporaneously with arsenopyrite."

The cursory examination of the main constituents of the six specimens from the Upper Purple and Lower Purple orebodies, revealed that the paragenesis of this ore was substantially that described by Warren.

On careful examination of the arsenopyrite under high magnification, tiny irregular inclusions of a white mineral almost indistinguishable from arsenopyrite, were found. As it is not possible to identify and distinguish between the several cobalt-bearing and associated minerals by the common etch reactions, the article, "A Qualitative and Quantitative Determination of the Ores of Cobalt, Ont." by Ellis Thompson, was consulted. In the section "Methods of



Inclusions associated with Gold

in

Arsenopyrite.

Analysis" Thompson describes the development and use of new etch reagents for the identification of the minerals, in the following table:-

		Conc HNO_3	Dil HNO_3	Pot. Perm.	$FeCl_3$ (Sat)	A.R. FeAsS	A.R. (Co,Ni)AsS.
Arsenopyrite	FeAsS	+	+	–	–	–	–
Chloanthite	N.As	+	+	–	–	+	+
Cobaltite	CoAsS	–	–	–	–	–	–
Gersdorffite	NiAsS	+	+	+	–	–	–
Loellingite	$FeAs_2$	+	+	–	+	–	–
Rammelsbergite	$NiAs_2$	+	+	–	+	+	–
Safflorite	$CoAs_2$	+	+	–	–	–	+
Skutterudite	$CoAs_3$	+	–	–	–	–	–
Smaltite	$CoAs_2$	+	+	–	–	–	+

The following assays of the six samples for gold, cobalt, arsenic, iron and surphur, were provided by the Provincial Department of Mines at Victoria.

	Au.	Co	As	Fe	S	Ratios As/Co	Ratios % arsenopyrite.	S needed for arsenopyrite.
Upper Purple:								
Top.	.32	.05	6.4	10.7	5.4	128	14.2	2.7
Middle	.47	.31.	12.2	14.9	6.2	39	27.0	5.2
Bottom.	.07	.13	6.5	15.6	5.1	50	14.4	2.8
Lower Purple:								
Top	.07	.26	2.3	7.1	2.6	9	5.1	9.8
Middle	.07	.32	8.9	14.0	3.4	28	19.7	3.8
Bottom	.16	.41	20.0	14.8	7.4	50	43.4	8.4

The last three columns are computed. % arsenopyrite represents the percentage of arsenopyrite which would be present if all the arsenic were in the form of arsenopyrite. S need for arsenopyrite is the sulphur which would have to be present if all the arsenic were in the form of arsenopyrite.

Compared with samples from other parts of the mine, these samples are rather low in gold and are not high in cobalt.

The relative abundance of the main minerals in sections, is shown by the following table:-

Upper Purple:

	Arsenopyrite	Pyrrhotite	Pyrite	Chalcopyrite	Inclusions.
Top.	over 90%	very little	+ 2% ±	very little in all. +	+ some with different appearance
Middle	about half	about a third.	–	+	+ few
Bottom.	about 90%	about 5%	about 5%	+	+ few also gold particles not associated with inclus.

Lower Purple:

Top	about 10%	abundant	+	+	none in original section, but abundant in second sections high in arsenopyrite.
Middle.	about half	about a third	about 10%	+	+ most & largest inclusions. some assoc. with gold.
Bottom.	over 90%	low	+	+	+ few.

One or two fairly large particles of gold, included in arsenopyrite were found in both hand-polished and super-polished sections from the bottom of the Upper Purple only. Small inclusions of gold associated with inclusions of the cobalt mineral (see microphotograph) were found in super-polished sections from the middle of the Lower Purple. In both cases the most abundant and largest inclusions were found in the middle of the Lower Purple.

In only two of the hand-polished sections, from the middle of the Lower Purple and the middle of the Upper Purple, were the inclusions large enough or definite enough to be identified by etch reactions. In both of these sections, the following reactions were obtained on the inclusions:

Potassium Permanganate - negative.

Fe Cl3 - Not a distinctly positive reaction, but on continued application the inclusions became more distinct.

FeAsS in Aqua Regia - negative.

(Co,Ni) AsS in Aqua Regia - positive - a light brown stain, which remains on gentle rubbing.

It is interesting to note that in one instance when (Co,Ni) AsS in Aqua Regia was applied to the inclusions and washed off before the application of potassium permanganate a distinct positive reaction was given by the potassium permanganate. This was, at first, taken as indication of the nickel bearing mineral gersdorffite. No confirmatory tests for nickel could be obtained, however, and the potassium permanganate reaction was not produced on freshly polished inclusions. This apparent incongruity is believed, by the author, to be a further indication that the (Co Ni) AsS in Aqua Regia did react with the inclusions, leaving, near the surface of the inclusion, a thin film of a nickel-arsenical sulphide compound.

The above reactions suggest that the inclusions examined, are safflorite. It has been suggested, however, that safflorite and lollingite form an isomorphous series, and as the inclusions show a slight reaction to $FeCl_3$, they may actually be a high cobalt-safflorite-lollingite compound.

A single microchemical test for cobalt was obtained from a speck of powder drilled from the surface of a section near a group of inclusions. The inclusions are so much smaller than the burr of the drill that the test cannot be taken in itself as a reliable indication that the inclusions do contain cobalt.

Inclusions were identified visually in all the superpolished sections under the oil immersion microscope. Their identity was not confirmed by etch reactions, or by microchemical tests by this author. Some of the inclusions, especially those in the Upper Purple, had a texture different from those characteristic ones found in the middle of the Lower Purple associated with gold. The largest inclusions found were about 60 microns in diameter.

The inclusions tend to be in groups, and often none, or only one or two groups, will be found in a fairly large piece of arsenopyrite. This would indicate that sampling is a serious problem and that a great many sections should be made from each ore body for a complete examination. The sampling problem is illustrated by the fact that one pair of polished specimens from the top of the Lower Purple contained very little arsenopyrite and no inclusions, whereas another pair from the same sample contained much arsenopyrite and abundant inclusions. Because of this difficulty, it is not felt that any conclusion can be derived from comparison of the assays and the abundance of the inclusions.

Attention has been drawn to the fact that neither safflorite nor lollingite contain sulphur, and that if all the arsenic was in the form of arsenopyrite, there would be a deficiency of sulphur in some of the samples. This suggests that some arsenide, such as safflorite or lollingite might be present. Of the six samples from the Purple orebodies, only those from the middle and the bottom of the Lower Purple show this surphur deficiency, and these samples show only average arsenic to cobalt ratios. These samples, therefore, may be high in some non-cobalt-bearing arsenide or possibly iron-rich member of the safflorite-lollingite series.

All the inclusions examined were in, and entirely surrounded by, arsenopyrite, and none of the specks of hard-white-mineral in the gangue, were examined microchemically to confirm the assumption that they were arsenopyrite.

SUMMARY AND CONCLUSIONS.

Inclusions of a cobalt-bearing mineral do occur in all parts of the Upper and Lower orebodies, included and entirely surrounded by arsenopyrite.

The inclusions, apparently, are in groups.

Specks of gold may be associated with the inclusions but the rule is net consistent, and inclusions may occur without gold, or gold without inclusions.

The inclusions are probably safflorite, or a member of the isomorphous series safflorite-lollingite.

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