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A MINERALOGICAL STUDY MADE WITH SPECIAL REFERENCE TO COBALT MINERALS ON A GOLD ORE FROM THE NICKEL PLATE-SUNNYSIDE MINE.

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OBJECT---

The purpose of this study was twofold; firstly, to determine the cobalt mineral in the specimens of Nickel Plate ore submitted for examination, and; secondly, to study the occurence and size of this cobalt mineral in relation to the other sulphide minerals in an effort to throw more light on the problem of making a cobalt concentrate by flotation.

SUMMARY OF CONCLUSIONS.

This study indicates that at least part of the cobalt in Nickel Plate ore occurs as small inclusions, ~~after~~ associated with gold, in arsenopyrite. These inclusions gave etch reactions which corresponded to those obtained by other investigators upon loëllingite and safflorite. The size of the inclusions was measured and was found to range between five and thirty microns.

SUMMARY OF PREVIOUS WORK.

Although the presence of cobalt in the ore deposits of Nickel Plate Mountain has been recognized for many years, it has been in recent years only that careful studies have been made of the sulphides to determine this cobalt mineral.

In the earliest of these studies, cobaltite was found as tiny inclusions in, and completely surrounded by, arsenopyrite. Further work done last year proved that the cobaltite can also occur as small inclusions associated with gold in the pyrrhotite.

ORES STUDIED.

The samples examined by the author were said to be representative specimens taken from the top, middle, and bottom of the Yellow ore body of the Kelowna Exploration Company's workings on Nickel Plate mountain. Two additional samples, one from the north side of the north dyke and the other from the north side of the south dyke, of the Sunnyside 4½ ore body belonging to the same company were also examined.

PREPARATION OF SPECIMENS.

The samples were received as single pieces of ore; each piece being representative of the section of the ore body from which it was taken. From each of these samples three adjacent specimens were cut with a diamond saw. The middle section of the three cut from each sample was sent to the laboratories of the Department of Mines, Victoria, B. C., where the cobalt, arsenic, iron, and sulphur assays were determined. The gold assays were made in the Department of Mining and Metallurgy at the University upon samples taken from the remainder of the piece of ore after the sections had been cut. Each of the remaining two sections from each sample was mounted and one was polished by hand and the other superpolished.

PRELIMINARY INVESTIGATION.

The major sulphide minerals in the polished sections were determined by etch tests and michrochemical analysis. Michrochemical tests for cobalt were also obtained for all the sections tested excepting section 22--from the top of the Yellow ore body. These important sulphide minerals were,

in the order of their abundance, arsenopyrite, pyrrhotite, chalcopyrite, pyrite, and marcasite. The proportions of each of the various sulphide minerals in each section were estimated and ~~ore~~ are shown in Table I.

Table I.

Location of Sample.	Arsenopyrite %	Pyrrhotite %	Chalcopyrite %	Pyrite. %
22-Top of Yellow.	5	-----	-----	-----
62-Middle of Yellow.	90	1-2	Trace.	
122-Bottom of Yellow.	5	5	Trace.	5
Sunnyside 4½ N450-A North side of north dyke.	15	-----	-----	
S450-A North side of south dyke.	10	-----	-----	

PARAGENISIS.

A study of the polished sections from the Yellow ore body seems to indicate that arsenopyrite was the first mineral deposited. It was followed by the chalcopyrite and pyrrhotite which were deposited more or less contemporaneously. In certain sections the pyrite seems to have a

colliform structure indicating that it has been converted to marcasite. In other sections the arsenopyrite seems to have been fractured and a subsequent deposition of calcite along these fractures has occurred. One crystal of arsenopyrite showed evidences of having been replaced in part by the gangue. (see PlateI.)

Table II.

Results of assays of sections.

Location.	Co %	As %	As/Co	Fe %	S %	Au oz/Ton.
22-Top of Yellow.	0.29	7.0	24	11.1	6.2	0.07
62-Middle of Yellow.	0.23	11.4	50	16.5	10.0	0.64
12-2-Bottom of Yellow.	0.15	1.3	8.7	12.1	6.7	1.10
Sunnyside 4½ N450-A North side of North dyke.	0.49	11.0	22.5	17.3	5.6	0.80
S450-A North side of south dyke.	0.46	15.6	34	15.8	6.1	2.30

DISCUSSION OF ASSAY RESULTS.

The cobalt and arsenic assays shown in Table II are much higher than those reported for the run of mine ore. This material is said

to assay about 0.05 to 0.10 percent cobalt and 2 to 3 percent arsenic. The average cobalt assay for all the specimens submitted for examination about was 0.26 percent and the average arsenic assay 10 percent. If this average arsenic assay is reduced to that of run of mine ore the cobalt would be about .05 percent. This would indicate that the samples examined were not representative of the ore mined but were probably representative of the sulphides in the ore body.

If an attempt is made to calculate the percentage arsenopyrite in the samples from the assay results it will be found in certain cases that there will be a deficiency of sulphur below the theoretical requirements of arsenopyrite. This would indicate that all the arsenic is not present in the form of arsenopyrite but is probably associated with the cobalt or iron to form arsenides of these elements.

This can best be illustrated by considering the analysis of the Sample S450-A.

	Co	As	Fe	S
S450-A-North side of south dyke.	%	%	%	%
	0.46	15.6	15.8	6.1

If all the arsenic existed as arsenopyrite it would theoretically require 6.7 percent sulphur in the analysis; but, there is only 6.1 percent sulphur shown. However, if it is assumed that all the sulphur shown in the analysis is combined in arsenopyrite, (it will be noted from Table I that neither pyrrhotite nor chalcopyrite were found in the polished section examined) 14.2 percent arsenic would theoretically be required. Assuming this figure to be substantially correct an excess of 15.6-14.2= 1.4 percent As over the requirements of arsenopyrite would be present.

The following are representative analyses of safflorite specimens as selected from Dana's--Textbook of Mineralogy.

Safflorite.

	As. %	S. %	Co. %	Ni. %	Fe. %
1.	69.53	0.32	22.11	1.58	4.63.
2.	70.37	0.66	13.95	1.79	11.71.
3.	66.02	0.49	21.21	----	11.60.

If the ratio of cobalt to arsenic in the first Safflorite analyses shown above is used the 1.4 percent arsenic over that theoretically required

for arsenopyrite in section S450-A should combine with 0.45 % Cobalt. The assay shows 0.46% Cobalt.

When this reasoning is applied to other samples that showed a sulphur deficiency or excess of arsenic the results are as follows:

Section 64-- Excess arsenic shown in analysis over requirements for arsenopyrite is 1.0 percent Cobalt to combine with this arsenic in ratio 69.53 As to 22.1 Co. is 0.30 percent. Cobalt shown in asay is 0.32 percent.

Section 11.6-- Excess arsenic 1.25 percent Cobalt to combine with this arsenic 0.40 percent, assay shows 0.33 percent cobalt.

These assumptions would lead one to conclude that the cobalt should exist as a mineral more nearly safflorite than loellingite. However, the weakness of the whole argument lies in the assumption that all the sulphur exists as arsenopyrite in the samples where there is apparently a shortage of sulphur. This assumption cannot be proven despite the fact that little or no pyrrhotite or chalcopyrite at all could be seen in these sections. If sulphur were to exist in these sections ~~elsewhere~~ other than with arsenopyrite it would force one to conclude that the

arsenic was distributed between safflorite and loëllingite.

IDENTIFICATION OF THE COBALT MINERAL.

The location of the mineral suspected of being cobalt required a thorough study of the sections under about 500 magnifications. Small inclusions of a hard grey mineral often associated with gold were observed in certain crystals of arsenopyrite. Upon testing these inclusions with etch reagents similar to those used by Thompson[1], reactions which corresponded to those the above author noted for safflorite and loëllingite were obtained. These reactions are shown in Table III.

Table III.

Etch Reactions for Safflorite--Loellingite.

	Conc. HNO_3	1-1 Nitric	3-10 Nitric	$FeCl_3$ Sat.	Aqua Regia (CoNi)AsS.
Loellingite	Gry. diff. remains	Gry.diff. remains	---	Ft. bn. remains of neg.	---
Safflorite	Dk.gry. remains	Dk. gry. remains	Lt. bn. remains	---	Lt. bn. diff. remains.

On certain inclusions the difference between safflorite and loëllingite could not be clearly distinguished by etch tests. This probably due to the inclusion being a mixture

[1] Thompson, Ellis; A Qualitative and Quantitative Determination of the Ores of Cobalt, Ont. Reprinted from Economic Geology, Vol. XXV, No. 5, August, 1939.

of safflorite and loëllingite and thus yielding inconclusive reactions. However, certain of the larger inclusions gave reactions for safflorite that were fairly certain while those associated with gold usually gave reactions more typical of loellingite.

One might conclude from these observations that loëllingite was more often associated with the gold and the larger inclusions that were nearer to being pure safflorite, usually stood alone. This is proposed merely as a working hypothesis and would require considerably more work to be definitely substantiated.

Pyrrhotite, chalcopyrite, and pyrite were all examined for the same type of inclusions but none was evident.

OCCURRENCE OF COBALT MINERAL.

Although all the inclusions thought to be safflorite-loëllingite were found in arsenopyrite not all the arsenopyrite contained inclusions. It seems that these inclusions are segregated into certain grains of arsenopyrite, but once located these grains were found to contain numerous inclusions. No relationship between the inclusion-bearing arsenopyrite and

the remainder of the sulphide minerals could be established.

Another significant feature of the occurrence of these safflorite-loëllingite inclusions is to be found in their frequent associtation with gold. The majority of the inclusions studied were found to be adjacent to a piece of gold or in the same arsenopyrite grain as were the specks of gold. This type of occurrence is illustrated in the attached photographs and drawings.

This juxtaposition of gold and safflorite--loëllingite is not as significant as it might seem for it will be noted from the assays in Table II that there is no apparent correlation between gold and cobalt assays. This lack of agreement is probably due to the occurrence of gold not associated with safflorite-loëllingite in the other sulphide minerals and in the gangue. Although gold was not found in either chalcopyrite or gangue in the sections examined it's occurrence unassociated with safflorite-loëllingite in these minerals has been observed by other investigators. One piece of gold not associated with safflorite-loëllingite was found

in pyrrhotite during the course of the study by the author. (See Plate II)

As a possible aid to ore dressing the author made a count of the size distribution of the gold and safflorite-loëllingite inclusions in the superpolished sections that were examined This information is presented in Table IV.

It will be noted from this table that the majority of the safflorite-loëllingite inclusions measured range in size from five to ten microns, with single pieces as large as 29 microns being found.

Table IV.

Size Distribution of Gold and Safflorite-Loëllingite Inclusions in Nickel Plate Ore.

22-Top of Yellow--no gold or inclusions observed.

62-Middle of Yellow--Gold-

1 piece--23u.

1 piece--26u X 8u.

Safflorite--Loëllingite.

1 inclusion 26 u.

2 " 16 u.

5 " 10 u.

9 " 5 u.

12-2 Bottom of Yellow

Gold-- 1 piece--37 u X 26 u.

2 pieces-- 10. u.

Safflorite--Loëllingite.

1 inclusion 29 u X 13 u.

10 inclusions---10 u.

S450 A-North Side
of South Dyke

Gold-- 1 piece 10 u.

1 piece 8 u.

1 piece 5 u.

Safflorite--Loëllingite.

1 inclusion 26 u X 16 u.

2 inclusions 26 u.

1 inclusions 24 u X 18 u.

2 inclusions 10 u.

1 inclusion 8 u.

3 inclusion 5 u.
Average Size 14 u.

N450-A North Side
of North Dyke.

No inclusions found.

Plate ~~VIII~~ I

Section 12 -2

Bottom of Yellow Ore Body

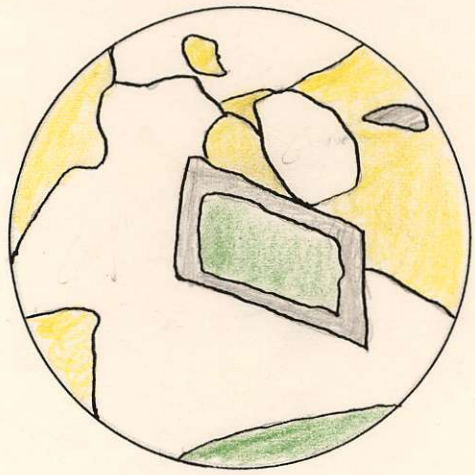
Arsenopyrite being

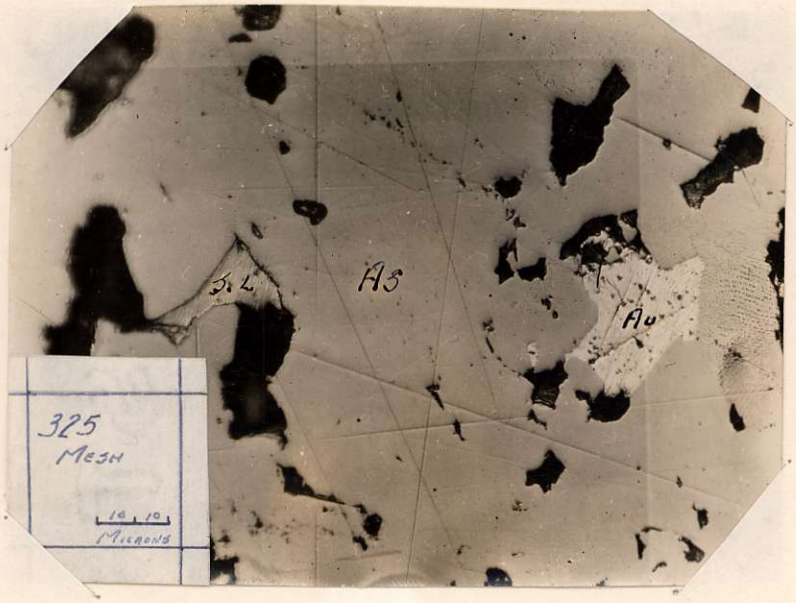
replaced by gangue

Yellow - Chalcopyrite

Green - Arsenopyrite

White and shaded - Gangue





Mag.- 480 X

Gold and Safflorite - Loëllingite in Arsenopyrite

Section 12 -2 Bottom of Yellow ore body

As - Arsenopyrite

S.L. - Safflorite-Loëllingite

Au - Gold

Mag. 1060 X

Gold Associated with Safflorite - Loëllingite in Arsenopyrite

Section 12 - 2 Bottom of Yellow ore body

As - Arsenopyrite

S - L Safflorite ± Loëllingite

Au - Gold

Plate II

Gold in Pyrrhotite

Section 62-2

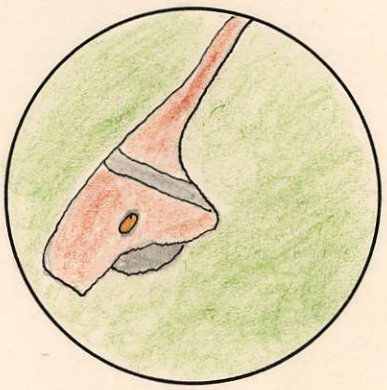
Middle of Yellow Ore Body

Green - Arsenopyrite

Brown - Pyrrhotite

Orange - Gold

Black - Gangue



X 500 (Approx.)

Plate III

Section 12-2

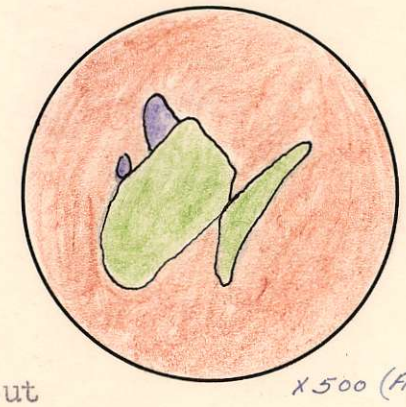
Bottom of Yellow Ore Body

Brown - Gangue

Green - Arsenopyrite

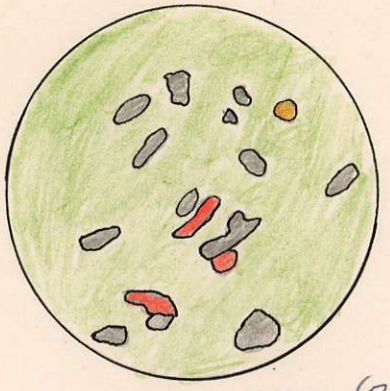
Purple - Unknown

Etch reactions of unknown correspond to those of galena, but could not get a michroochemical test for lead



X 500 (Approx)

Plate IV



x 500 (Approx.)

Section 12-2

Bottom of Yellow Ore Body

Safflorite-Loëllingite in

Arsenopyrite.

Green - Arsenopyrite

Red - Safflorite-Loëllingite

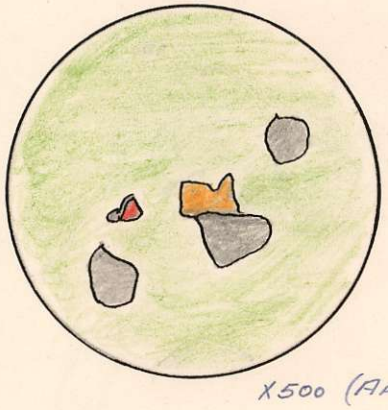
Orange - Gold

Black - Gangue

Inclusions etched black with $FeCl_3$ indicating composition

closer to loëllingite

Plate V



x 500 (Approx.)

Section 12-2

Bottom of Yellow Ore Body

Gold and Safflorite-

Loëllingite in Arsenopyrite

Green - Arsenopyrite

Black - Gangue

Orange - Gold

Red - Safflorite - Loëllingite

Plate VI

Section 12 - 2

Bottom of Yellow Ore Body

Safflorite -Loëllingite in

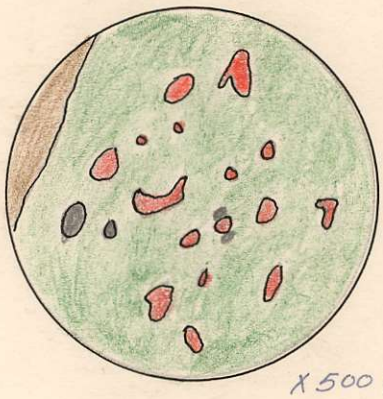
Arsenopyrite

Green - Arsenopyrite

Brown - Pyrrhotite

Red - Safflorite-Loëllingite

Black - Gangue



X 500 (APPROX)

Plate VII

Section 12 - 2

Bottom of Yellow Ore Body

Safflorite-Loëllingite in

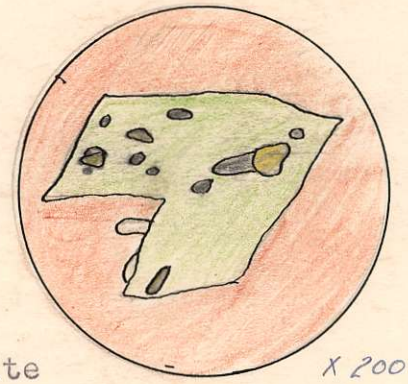
Arsenopyrite.

Green - Arsenopyrite

Yellow - Safflorite-Loëllingite

Brown - Gangue

White at border of arsenopyrite - unknown



X 200 (APPROX)

The leëllingite-safflorite inclusion shown in this plate was large enough to be readily seen under medium power magnification..It was unetched by $FeCl_3$ reagent but etched brown with Aqua regia plus(Co,Ni)AsS reagent.

Plate IX

Section S 450 A

North Side of South Dyke

Gold and Safflorite -

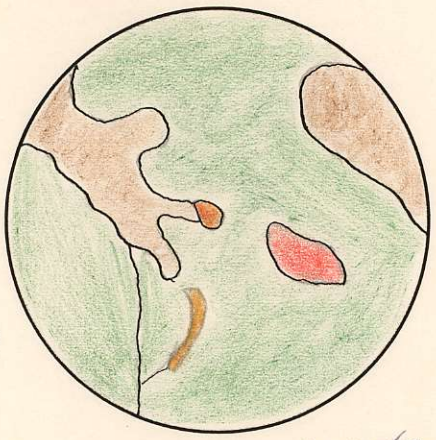
Loellingite in arsenopyrite

Green - Arsenopyrite

Red -, Safflorite - Loëllingite

Orange - Gold

Brown - Gangue



X 700 (Approx)