A MICROSCOPIC STUDY OF A SUITE OF ORE SPECIMENS

FROM THE

B.C. NICKEL MINES LTD., CHOATE, B.C.

Submitted by

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to Mr. Robert Thompson, who prepared the sections and guided
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Purpose of the study.

1. To identify the minerals, and particularly to try to find and identify the mineral or minerals responsible for the presence of minor amounts of cobalt in the ore.

2. To determine the relationships of the minerals, one with the other.

3. To note anything which would be of interest in solving the metallurgy of these ores; such as grain-size of the pentlandite and chalcopyrite; intergrowth of these two ore minerals; and, particularly, their intimacy of intergrowth with the uneconomic pyrrhotite.

Introduction.

One interesting feature of the B.C.Nickel ore is that it seems to be the only well-studied mineral occurrence of the Cu — Fe — Ni —S series in which the pentlandite is considered to have been the first mineral of the series to crystallize. In all other cases of such deposits it has been fairly well established that pyrrhotite was the first mineral of the series to form.[i]

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i. Hawley, J.E., Colgrove, G.L., and Zurbrigg, H.F., The Fe — Ni — S system, Economic geology, Vol.XXXVlll, No.5 August '43 p.347

Further information on this point would be of real interest.

In the course of investigations previously reported on this mineral occurrence small amounts of unidentified minerals have been considered responsible for the cobalt content of the ores. In no case, however, has the cobalt mineral been definitely identified. H.C.Horwood,[2] in a report of the Canadian Geological survey, found "a hard, white mineral with variable anistrophism" which he believed "to be the cobalt mineral linnaeite." Mr.M.Haycock, of the Mineragraphic Laboratory, Department of Mines, Ottawa, reported (in a mineragraphic report to B.C.Nickel Mines, Ltd.) a white, hard, strongly anistropic mineral which reacted negatively to everything except $H N O_3$. For this reagent M.Haycock reports a weak action with some areas etched differently grey. Considerable effort was made in carrying out this investigation to find and identify any minor mineral which may be responsible for the cobalt content of these ores.

Location of the property.

The property of B.C.Nickel Mines Ltd. is located on the ridge between Stulkawhits and Emory Creeks. It may be reached by a 7-mile road up Stulkawhits Creek from Choate on the Canadian Pacific Railways, or by pack trail up Emory Creek. Choate is six miles above Hope on the Fraser River and ninety-five miles by rail from Vancouver.

2. Horwood, H.C. Geology and mineral deposits at the mine of B.C. Nickel Mines Ltd., Yale, B.C. Memoir 190, Canadian Geol.Survey, 1936, p.12

The area is within the Coast Range system of mountains and has the rugged topography so characteristic of their southern and eastern borders. Rainfall and snowfall is moderate to heavy. The area is heavily wooded.

General geology[3]

The area contains late Palaeozoic schists, early Mesozoic intrusives, Cretaceous (?) conglomerates, and late Mesozoic hornblendites, diorites, and quartz-diorites. The hornblendite mass that contains the nickeliferous sulphides occupies an irregular area of approximately one and a half square miles and is intrusive into the late Palaeozoic schists.

Most of the intrusives is hornblendite, but masses of pyroxenite, believed to have segregated from the hornblendite, are common, and it is to these segregations of pyroxenite that the nickeliferous bodies are related. The hornblendite-pyroxenite mass is surrounded by diorites and quartz diorites which, it is thought, are the more acid phases of the magma from which the hornblendite segregated. All these earlier rocks have been fractured and intruded, first by acidic and basic dyke rocks, and later by siliceous vein materials and sulphides. Post-mineral faulting and jointing are mentioned.

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3. Ibid. p.2.

Mineral deposits[4]

"The mineral deposits are masses of sulphides irregularly
distributed in the hornblendite. They occur as massive bodies
that have up to fifty to sixty per cent sulphides and contain over
one percent nickel, and as disseminations of no economic value.
Small sulphide veinlets cut both types of deposits but are of
importance only where they enrich the massive sukphide bodies."
The sulphide veinlets do not contain pentlandite.

These deposits have been opened up by surface and under-
ground workings, and diamond drilling. The main workings are in
the No.1 tunnel, which has been driven from Stulkawhits to Emory
Creek at an elevation of 3,530 feet. The sulphide bodies were
explored from this level by crosscuts at 1,600, 1,900, 3,400, and
3,800 feet from the portal on Stulkawhits Creek.

Ore specimens.

The suite of ores used for this mineralogical study were
selected from sacks of ore sent in to the Mining Department of the
University for metallurgical investigations. The sacks of ore
were more or less representative of the orebodies listed below:

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( 1.  1,600-1
( 2.  1,600-2
( 3.  1,900
( 4.  3,400
( 5.  3,800-1
( 6.  3,800-2
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4. Loc. cit.

Two sections (A and B) were cut from the specimens from each orebody, and were then mounted and polished by hand for microscope study.

Metallic minerals occurring in the specimens.

The metallic minerals found in the specimens are:

Pyrrhotite $Fe_x S_y$

Pentlandite $(Ni, Fe) S$

Chalcopyrite $Cu Fe S_2$

Pyrite $Fe S_2$

Magnetite $Fe_3 O_4$

(or Chromite) $Fe Cr_2 O_4$

An unidentified mineral occurring as a distinct crystal in pyrrhotite and having the following properties was found:

Colour – White

Hardness – unknown, but its surface was much smoother than the surrounding pyrrhotite.

Crossed nicols – strong anistropism.

Etch tests (incomplete) – negative to $Hg Cl_2$, $Fe Cl_3$, K C N and K O H.

The above minerals were identified by etch tests and crossed nicols, and confirmed by microchemical analyses.

Microscopic study.

Since the general relationship of the minerals present in all sections examined was quite similar, only differences will be emphasized in the descriptions of the specimens which follow.

In many of the specimens the sulphides were too disseminated to be of value in determining the paragenesis, consequently most of the evidence regarding the genetic relationships of the minerals was gleaned from sections 1600-1, 1600-2, and 3400. In these sections the sulphides were quite massive. Furthermore, in all cases in the following descriptions mention of magnetite will be understood to mean either magnetite or chromite.

Descriptions of the sections.

Sections 1600-1. These sections showed an abundance of pyrrhotite, pentlandite, and chalcopyrite occurring as intergranular filling of the silicate minerals, and as vein-filling in fine, hair-like fractures in the silicates. The sulphide particles were nearly always aggregates of intergrown pyrrhotite, pentlandite, and chalco-pyrite, although grains of unmixed sulphides do occur uncommonly. The sulphide particles were quite irregular in outline and ranged in size from about 500 microns in diameter down to extremely fine grains, the greater number being in the range of 100 to 500 microns. The section as a whole could be designated as showing medium to fine grain size. Many of the sulphide-filled fractures were in the order of only a few microns in thickness. Magnetite was not particularly abundant, but was found veining all three major sulphides.

Sections 1600-2. These sections showed sulphide relation-ships similar to those in the section above, but contained coarser

grains.   Particles of mixed sulphides up to several millimeters in diameter were abundant in one of these sections. Veins of pyrite in the sulphides were common. Magnetite occurred as small, distinct crystals irregularly and sparsely distributed through both gangue and sulphides, and as vein-filling accompanying silicates in fractures cutting pyrrhotite and pentlandite.

Sections 1900.   These sections showed the presence of pyrrhotite, pentlandite, and chalcopyrite in this as in the other orebodies.   A fair amount of magnetite was seen, but no pyrite. Intergrowth of sulphides was not so complex as elsewhere. Much of the sulphide occurred as filling in very fine fractures in the gangue. Grain size was fine to extremely fine.

Sections 3400.   These sections showed all of the minerals mentioned in this study. The sulphides were intergrown in a complex manner in aggregates measuring more than a centimeter in length by several millimeters in width. These masses occurred as coarse, irregular patches intergranular to the silicates. Detailed relationships of the sulphides were largely based on evidence seen in these sections and will be considered later. One notable feature, however, was the round, corroded appearance of the silicates associated with the sulphides. A band of soft alteration product was always found between the hard silicates and the sulphides. Pyrite was rare in these specimens.

Sections 3800-1. Pyrrhotite, pentlandite, and chalcopyrite were present along with a fair amount of magnetite. Pyrite was not seen. Considerable evidence of chalcopyrite occurring as exsolution bands and lenses in pyrrhotite was seen. The gangue in these sections was quite solid and unaltered. Grain size could be described as fine to very fine.

Sections 3800-2. Pyrrhotite, pentlandite, and chalcopyrite occurred in these specimens in unusually irregular intergranular masses. A notable feature of these specimens was the relatively high percentage of magnetite occurring both in the gangue and sulphides but found much more abundantly in the sulphides than in the silicates. Most of these grains of magnetite were distinct, well-shaped, unaltered crystals although some were fractured and others were irregular and definitely later than some of the silicates. No pyrite was found. The grain-size was medium to coarse.

Relationships of the metallic minerals.

The evidence indicates that the sulphide minerals are generally distinctly later than the silicates and magnetite. The fact that trapped particles of sulphides and magnetite in the silicates, of silicates and sulphides in the magnetite, and of magnetite in the sulphides do occur, however, shows that there was an overlap in the period of crystallization of these minerals. The occurrence of magnetite and silicates as vein-filling in fractures in pentlandite and pyrrhotite shows that at least some of this

phase of the magma was quite late in solidifying and was fairly mobile.

Relationships between the sulphides are confused, but it is probable that overlaps in the periods of crystallization of each of the major constituents has caused much of this apparently contradictory evidence. The general picture is suggestive of segregation origin. The fact that most of the individual grains of sulphides consist of all three minerals - pentlandite, pyrrhotite, and chalcopyrite - filling the interstices between the silicates, and have internal structures suggesting that the chalcopyrite and pentlandite exsolved from the sulphide aggregate in situ, indicates that much of the sulphide moved into place as a solid solution of Cu -Ni -Fe sulphides which later separated on cooling. Evidence of this type of mineralization appeared in almost all the sections examined, and was best seen where the sulphides were not too massive. Plate 2 shows what the author believes to be lenses of chalcopyrite exsolved from pyrrhotite. The pentlandite formed similar much smaller lenses in some cases, but more often appeared as blebs, which were obviously not of replacement origin, around the margins of exsolved chalcopyrite lenses and between contemporaneous adjacent pyrrhotite crystals.

The pentlandite appears in several relationships to the rest of the sulphides. As seen in one place it seems to have segregated from the main sulphide mass and crystallized before the pyrrhotite and chalcopyrite. This age of pentlandite was highly

fractured and invaded by silicates and magnetite, and later was replaced by pyrrhotite (see Plate 1). That this pentlandite was earlier than the chalcopyrite is proved by the fact that the same crystal of pyrrhotite which replaced the pentlandite was itself replaced by chalcopyrite. That the pyrrhotite was later than the period of fracturing which shattered the pentlandite is shown by the lack of similar fracturing in the pyrrhotite. In other places, as mentioned above, the pentlandite and chalcopyrite occurs in a manner suggesting exsolution origin. The volume of pentlandite occurring in this manner, however, seems to be relatively small. Furthermore, pentlandite was found to have replaced pyrrhotite to a considerable extent in some areas (Plate 4) and to have completely enclosed fragments of it without disturbing their crystal orientation. It was also found around the margins of exsolution lenses of chalcopyrite in pyrrhotite where it replaced both these latter minerals. Probably of the same age is the pentlandite which is found as small, ragged, finger-like intrusions extending out from irregular fractures in the pyrrhotite (Plate 7). The fractures themselves appear to be filled with silicates (?) and, occasionally, magnetite. Minute specks of pentlandite are found in these fractures. This later phase of pentlandite seems to have crystallized from solutions. Plate 3 shows pentlandite veining pyrrhotite.

Pyrrhotite, which is by far the most abundant sulphide, replaced one age of pentlandite, but was veined and replaced by others as mentioned above. It was contemporaneous with some

chalcopyrite, but earlier than another variety (Plates 2 and 4.)
It was also veined by pyrite (Plate 6). The unknown mineral
apparently crystallised before the pyrrhotite, since it was com-
pletely enclosed in it.

Chalcopyrite occurs as exsolved lenses and veins in
pyrrhotite with blebs of pentlandite scattered around the margins
of these lenses. It also occurs as intruding masses which have
veined and replaced pyrrhotite (Plate 4) and pentlandite (Plate 5).
Most of the chalcopyrite seems to be of the exsolved variety in
pyrrhotite.

Pyrite was found veining pyrrhotite and pentlandite (Plate 6).
In almost all cases where pentlandite was cut by a pyrite vein the
vein was surrounded by an aureole of alteration which, although soft,
polished roughly. Under the high powerthis material looked like
masses of dendrites, of hard material scattered throughout the pent-
landite. The structure seemed to follow a pattern and decreased in
intensity with distance from the pyrite vein until unaltered pentlan-
dite was reached. No evidence could be found to definitely corre-
late the ages of the pyrite and the late chalcopyrite.

Paragenesis.

The above criterion seems to indicate the following
paragenesis:
1. Pentlandite
2. Pyrrhotite, chalcopyrite and pentlandite.
3. Chalcopyrite and pentlandite
4. Chalcopyrite.
5. Pyrite.
6. Pentlandite (solutions)

Actually this sequence means that the pentlandite began to crystallize before, and persisted to crystallize until a short time after the complete solidication of the pyrrhotite. The chalcopyrite apparently started to separate out with the pyrrhotite and persisted to crystallize some time after the last of the pyrrhotite and even after the pentlandite. The pyrite is somewhat difficult to place definitely but it is believed to be quite late in the series, probably after the chalcopyrite. Also rather difficult to place is the solution type of pentlandite, but it is believed to be later than the pyrite because it was found along the margins of fractures which cut the pyrite.

Mineralogical conclusions.

The evidence found by the author confirms the views of others who have worked on this ore; that is, that at least some of the pentlandite formed before the pyrrhotite. The opinions of Horwood and Haycock that the pyrite formed first in the series could not, however, be agreed with in the face of evidence seen in these sections. Evidence to show that pyrite was probably the last formed mineral has been previously discussed.

The unknown mineral found by the author seems to be the same   one found by Haycock and mentioned in his report to the B.C.Nickel Company. It may or may not be the cobalt mineral for which the author was looking.

Metallurgical conclusions.

Study of these sections indicates that any attempt to selectively float the sulphides present could not meet with a high degree of success because of the intimate intergrowth of the sulphides. During flotation test work done on the ores at the University of British Columbia and at Ottawa it was found practically impossible to increase the recovery of nickel above eighty-five per cent without making a bulk float of all sulphides.[5] This would indicate that about 15% of the pentlandite was tied up with the pyrrhotite too intimately to be freed at the grind used. It is probable that most of this 15% loss is represented by the small exsolution lenses, veins, and replacement particles mentioned previously which certainly could not be liberated without grinding to minus twenty or thirty microns. Similar results were obtained when a copper concentrate was made from this ore.[6] Such results could be predicted from inspection of these sections.

5. Morrison, B., Metallurgical Department, University of British Columbia, personal communication.
6. Lyle, A.G., personal communication.

Plate 1.   (from section 3400 B)
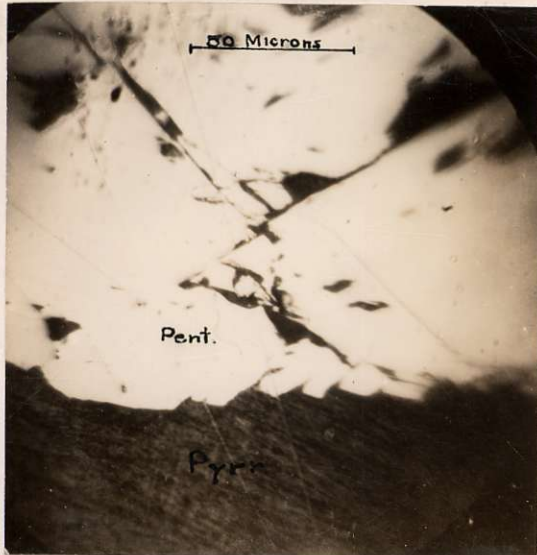
Pyrrhotite invading and
replacing pentlandite.
(Pyrrhotite stained with
chromic acid for photo-
graphic purposes.)

Magnification x 430.

Plate 2.   (from section 1600-2 B)

Chalcopyrite exsolution
lenses in pyrrhotite.
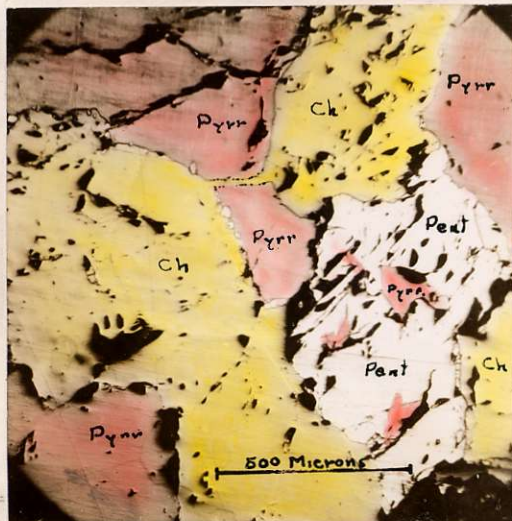Dark area is gangue.

Magnification x 40.

Plate 3.   (from section 3400 B)

Pentlandite veining pyrrhotite.
Black area is gangue.
(Pyrrhotite stained with
chromic acid for photographic
purposes.)

Magnification x 50

Plate 4.   (from section 3400 B)

Pentlandite replacing pyrrhotite
showing remnants of pyrrhotite
completely enclosed in the
pentlandite. All the pyrrhotite
showing in the picture has
the same crystal orientation.
Chalcopyrite is shown replac-
ing the pyrrhotite and possibly
the pentlandite.

Magnification x 50

Plate 5   (from section 3400 B)

Chalcopyrite is shown veining
a particle of pentlandite at
the contact of chalcopyrite
and pyrrhotite. (Pyrrhotite
stained with chromic acid
for photographic purposes.)

Magnification x 50.

Plate 6   (from section 1600-2 B)

Section shows pyrite veining
pentlandite and pyrrhotite.

Magnification x 20

Plate 7   (from section 3400 B)

Section shows pentlandite
projecting from ragged,
gangue-filled fractures
into pyrrhotite, replacing
the latter. (Pyrrhotite stained
with chromic acid for photo-
graphic purposes.)

Magnification x 60

BIBLIOGRAPHY

"Mineral Deposits" by Waldemar Lindgren.

"Geology and Mineral Deposits at the Mine of B.C.Nickel
Mines Ltd., Yale District, B.C." by H.C.Horwood.

"The "e- Ni- S System," by J.E.Hawley, G.L.Colgrove,
and H.F.Zurbrigg.

"Microscopic Examination of Samples from Choate, B.C."
by Haycock   . A report of the Mineragraphic
Laboratory, Division of Ore Dressing and Metallurgy,
Depsrtment of Mines, Ottawa.