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MINERALOGICAL STUDY OF A LOW-GRADE NICKEL ORE FROM THE RED LAKE AREA IN ONTARIO FOR W.D. SUTHERLAND OF BLIND RIVER, ONTARIO

by

W. PETRUK, D.C. HARRIS, R.W. BUCKMASTER,

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MINERAL SCIENCES DIVISION

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SUMMARY OF RESULTS

A mineralogical investigation was made of a low-grade nickel ore from the Red Lake area in Ontario, and on samples of a nickel concentrate and tailing prepared from this ore in the Mineral Processing Division. The results show that the ore contains disseminated grains of pyrite, violarite-polydymite, pentlandite, sphalerite, magnetite, chalcopyrite, and galena in a fine-grained rock composed of feldspar, chlorite, calcite, ankerite, quartz and serpentine. The tailing contains 0.13 per cent Ni, 0.11 per cent Zn, 0.008 per cent Cu, and 0.064 per cent S. The high nickel content of the tailing can be attributed, at least in part, to minute inclusions of nickel sulphides (violarite-polydymite and pentlandite) in the gangue minerals. The low sulphur: metal ratio in the tailing suggest, in addition, that some nickel is present in a non-sulphide form, probably as a trace element in some of the gangue minerals. The amounts, however, are too low to be detectable by the methods employed. Tests on the tailing sample show that there is no appreciable variation of nickel values with respect to grain size, and the nickel in the tailing cannot be concentrated by gravitational and magnetic methods.

*Research Scientists, Mineralogy Section, ** Scientific Officers and Technician, respectively, Analytical Chemistry Sub-division, Mineral Sciences Division, Department of Energy, Mines and Resources, Ottawa, Canada.

INTRODUCTION

A low-grade nickel ore from the Red Lake area in Ontario was received by the Mines Branch from W. D. Sutherland, Mining Exploration Consultant, P.O. Box 128, Blind River, Ontario in January, 1967. Beneficiation tests, made on the ore in the Mineral Processing Division, gave a nickel recovery of about 50 per cent and produced tailings containing 0.12 to 0.13 per cent nickel and 0.07 to 0.08 per cent sulphur (personal communication, G. Mathieu). The low sulphur contents suggest that some of the nickel is present in a non-sulphide form. Preliminary mineralogical studies of the ore and tailings indicated that only some of the nickel losses in the tailings could be attributed to minute grains of ore minerals (References 1 and 2). An intensive study was, therefore, undertaken to find the nickel-bearing minerals in the tailing by a re-examination of the ore, a nickel concentrate, and a tailing sample.

METHOD OF INVESTIGATION

Polished and thin sections of the ore were re-examined under the ore and petrographic microscopes. The nickel concentrate was studied by means of the X-ray diffractometer and the ore microscope.

The tailing sample was split and one quarter was used for the polished sections, oil immersion, and electron microprobe studies.

Another quarter of the sample was separated into float and sink fractions by means of a centifruge using a liquid with a specific gravity of 2.96. The resulting fractions were studied microscopically, and the float fraction was analysed chemically for nickel.

The remaining half of the sample was sized into -100+400 mesh, and -400 mesh portions. The -100+400 mesh portion was separated into a series of fractions by means of liquids having specific gravities of 2.65, 2.70, 2.80, 2.90 and 2.96. The resulting fractions were split and one-half of each was analysed for nickel. The other half was separated into magnetic fractions by means of a Frantz isodynamic separator and the magnetic fractions obtained from the "2.80 float/2.70 sink" fractions were analysed for nickel to determine if the magnetite is nickeliferous. All the gravity and magnetic fractions were studied microscopically, and the "2.96 float/2.90 sink" fraction was studied by means of an electron probe microanalyzer and by X-ray diffraction. The carbonate in this fraction was also analysed for nickel by subjecting the fraction to successively stronger acid attack and analysing the filtrates for nickel. The -400 mesh fraction was analysed for nickel, zinc, copper and sulphur, and studied microscopically. The sulphur was analysed in duplicate by the combustion and gravimetric methods by use of closely-spaced standards. The results are, therefore, deemed to be accurate and reliable.

W. Petruk conducted the investigation and did some of the microscopical work, D. C. Harris performed the electron probe microanalysis in the Physical Metallurgy Division, and also some microscopical work. R. W. Buckmaster, H. R. Lauder and R. S. Kobus undertook the chemical analyses.

RESULTS OF INVESTIGATION

Ore Samples

The ore consists of a fine-grained rock composed of feldspar, chlorite, calcite, dolomite, ankerite and quartz with a minor amount of serpentine, and it contains disseminated grains of pyrite, violarite-polydymite, pentlandite, sphalerite, hematite, ilmenite, chalcopyrite and cobaltite (1). The chlorite has a refractive index of 1.64 - 1.65 and an X-ray diffraction intensity ratio $\frac{I_{002} + I_{004}}{I_{003}}$ of about 10, both of which indicate that the chlorite is an iron-rich variety (3 and 4). Violarite $(Ni\,Fe)_3S_4$ and polydymite (Ni_3S_4) have very similar X-ray diffraction patterns, and the pattern of the mineral from this ore has some of the characteristics of both; therefore it will be referred to as violarite-polydymite in this report. The ore minerals are present as variously sized grains scattered throughout the rock: pyrite as large cubic crystals and small grains, violarite-polydymite, pentlandite, sphalerite, chalcopyrite, and cobaltite as small grains (Figure 1), and magnetite as small irregular grains and rims around limonite. The grains of pentlandite and violarite-polydymite vary from about less than one to about 200 microns in size.

Nickel Concentrate

A nickel concentrate prepared by G. Mathieu in February, 1967 was studied. It was reported to contain about 15 per cent nickel to represent about 50 per cent of the nickel in the ore. It contained about equal quantities of violarite-polydymite, pentlandite, pyrite, chlorite and quartz, with additional small amounts of mica, talc, feldspar, sphalerite, galena, chalcopyrite and magnetite.

Nickel Tailing

A sample of nickel tailings, prepared by G. Mathieu and submitted to the Mineral Sciences Division on March 3, 1967, was studied in detail. This sample contained 0.13% nickel, and consisted largely of chlorite, feldspar, calcite, dolomite, ankerite and quartz. These minerals were found to

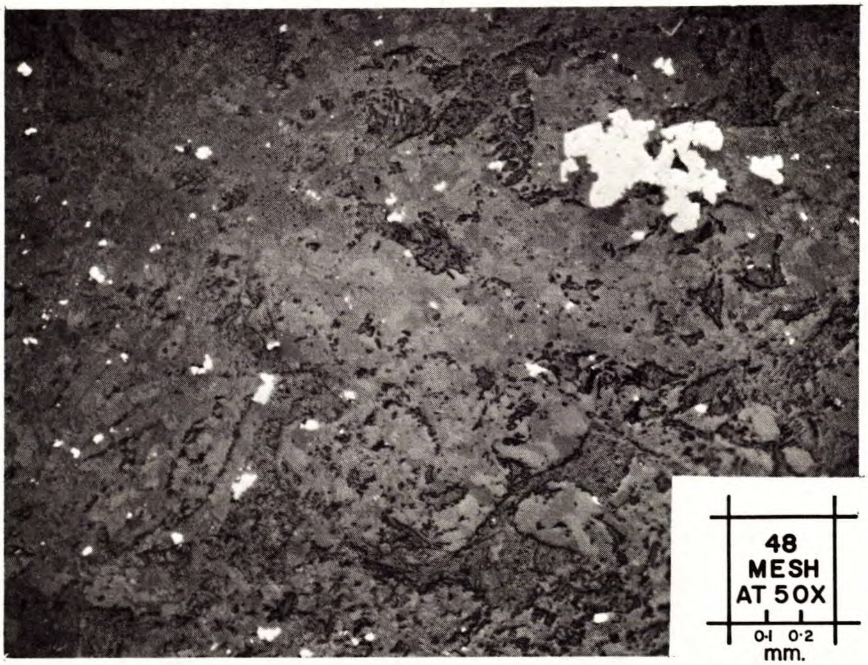

Figure 1, Photomicrograph of a polished section of the ore showing one large pyrite grain (white) and a number of minute inclusions of pyrite, violarite-polydymite, pentlandite and chalcopyrite (white) in gangue. The individual minerals cannot be differentiated in this photograph.

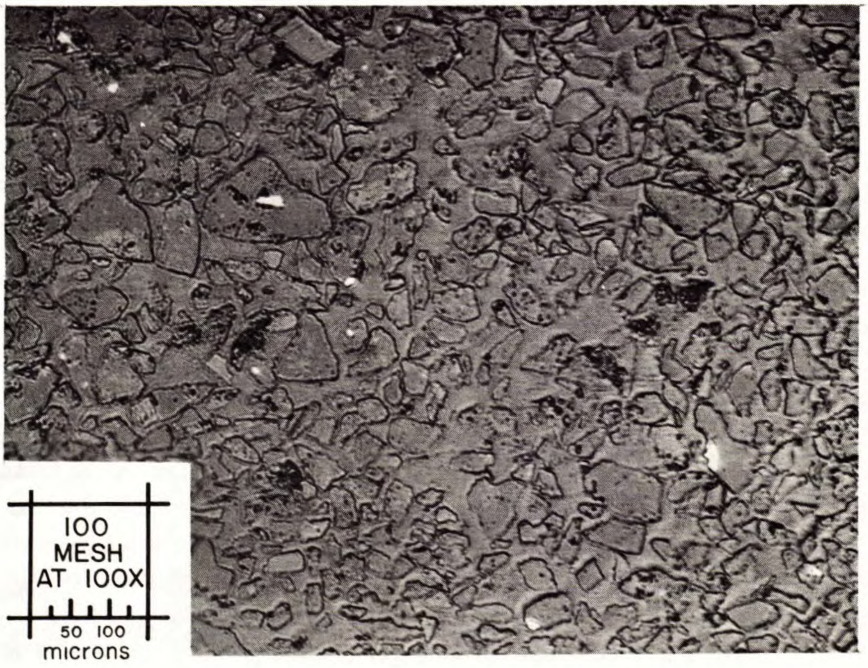

Figure 2, Photomicrograph of a polished section of the -100+400 mesh "2.80 float-2.70 sink" fraction, showing inclusions of ore minerals (white) in gangue (grey).

contain minute inclusions of magnetite, limonite, sphalerite, violarite-polydymite, pentlandite (?), pyrite (?), and chalcopyrite (Figure 2). Microprobe traverses showed that the gangue minerals are not nickeliferous, but that a few contain inclusions, about 5 microns in size, of nickel-bearing minerals.

Chemical analyses of the unsized tailing sample and the -400 mesh fraction, given in Table 1, show that there is no appreciable variation of nickel with respect to grain size.

Analyses of the -400 mesh fraction (Table 1) confirm that the tailing does not contain enough sulphur to account for all the nickel, zinc and copper as sulphide minerals.

TABLE 1

Chemical Analyses of a -100 Mesh Tailing Sample

Sample	Weight % of sample	Nickel %	Zinc %	Copper %	Sulphur %
Tailing	100	0.130			
-100+400 mesh	44.3	0.135 (calc)			
-400 mesh	55.7	0.125	0.110	0.008	0.064*

* This value is the average of results obtained by two different methods: 0.061 by gravimetric analysis and 0.068 by the combustion method.

Chemical analyses of the tailing fractionated by heavy liquids show that, although a small proportion of the nickel was concentrated in the heaviest fraction, most of the nickel remained in the lighter ones (Table 2). The nickel in the tailing, therefore, cannot be concentrated by gravitational methods. The various fractions consist of gangue minerals with the heavier ones containing more chlorite and ankerite, and the lighter ones containing more feldspar, calcite and quartz. Microprobe traverses across the "-100 +400 mesh, 2.96 float/ 2.90 sink" fraction show that the gangue minerals do not contain detectable amounts of nickel (less than 0.05%), but a few contain minute inclusions of nickel-bearing minerals. Microscopical and X-ray diffraction studies show that the gangue minerals contain minute inclusions of violarite-polydymite, magnetite, limonite, pyrite (?), pentlandite (?), sphalerite, and chalcopyrite (Figure 2). These inclusions vary from less than one to about 20 microns in size, but most are about 5 microns. They are most abundant in chlorite.

TABLE 2

Chemical Analyses of Gravity Fractions Obtained from the Tailing Sample

Sample	Weight % of sample	Nickel %	Distribution of Nickel
Unsized tailing			
2.96 sink	3.5	0.69 (calc)	18
2.96 float	96.5	0.11	82
Composite	100.0	0.13	100
-100+ 400 mesh			
2.96 sink	0.95	1.06	7
*2.96 float - 2.90 sink	9.63	0.15	11
2.90 float - 2.80 sink	6.75	0.13	7
2.80 float - 2.70 sink	23.80	0.11	20
2.70 float - 2.65 sink	0.07	not analysed	
2.65 float	3.10	0.03	1
Composite	44.3	0.135 (calc)	46
-400 mesh	55.7	0.125	54
	100.0		100

* Subjected to electron probe microanalysis.

Tests were conducted to determine whether the carbonate minerals and magnetite in the ore contain nickel. The test on the carbonates was done by treating the "-100+400 mesh, 2.90 float/2.80 sink" fraction with successively stronger acids. A treatment with 50% acetic acid, which normally dissolves all carbonate minerals, did not reduce the nickel content in the ore (Table 3). This suggests that the carbonate is not nickel-bearing.

TABLE 3

Analyses of Filtrates Obtained by Treating the -100+400 Mesh "2.90 Float - 2.80 Sink" Fraction with Successively Stronger Acids

Treatment	Nickel %
50% acetic acid	0.001
5% H_2SO_4	0.008
HCl, HNO_3 and $HClO_4$	0.129
Total	0.138

The test for nickeliferous magnetite was conducted by analysing magnetic fractions obtained from the "2.80 float/2.70 sink" fraction (Table 4). The results show that the fraction containing the most magnetite (0.2 amp) was not enriched in nickel, and indicates that the magnetite is not nickeliferous. The tests further show that the nickel in the tailing cannot be concentrated by magnetic methods.

TABLE 4

Results of Magnetic Separations and Chemical Analyses of Fractions

Magnetic Fraction	2.80 float/2.70 sink Wt %	Ni %
0.2 amp	1.8	0.12
0.3 amp	-	-
0.4 amp	14.2	0.14
0.5 amp	51.5	0.11
non-magnetic	32.5	0.10

CONCLUSIONS

The nickel-bearing minerals identified in the tailing are violarite-polydymite and pentlandite. They are present as minute inclusions in gangue, and attribute, at least in part, to the high nickel content of the tailing. The low sulphur:nickel ratio in the tailing indicates that some nickel is also present in a non-sulphide form. However, experiments aimed at determining whether the magnetite, carbonate minerals, and other gangue constituents contain significant amounts of nickel gave negative results. It is inferred, therefore, that the non-sulphide nickel is present as a trace element in gangue minerals (most likely chlorite) in concentrations too low to be detected by the electron probe microanalyser.

Because of the difficulty of liberating minute sulphide grains and the possibility of some nickel being present in the non-sulphide form, it is unlikely that high nickel recoveries can be achieved by conventional ore-dressing procedures.

REFERENCES

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