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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 64-100

**CONCENTRATION TESTS ON A
COPPER-NICKEL ORE FROM THE
ROTTENSTONE LAKE AREA IN
NORTHERN SASKATCHEWAN**

IR 64-100
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by

G. I. MATHIEU

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MINERAL PROCESSING DIVISION

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CONCENTRATION TESTS ON A COPPER-NICKEL ORE FROM THE ROTTENSTONE LAKE AREA IN NORTHERN SASKATCHEWAN

by

G. I. Mathieu*

- - -

SUMMARY OF RESULTS

Analysis of the Rottenstone Lake head sample showed 1.39% Cu, 4.24% Ni and 0.22 oz Pt/ton. Principal minerals included chalcopyrite, violarite, pentlandite and sperrylite intimately associated with pyrrhotite.

The copper and nickel minerals were concentrated by flotation followed by magnetic separation to remove the pyrrhotite from the nickel concentrates. The range of the results in the main tests are summarized in the following table:

	Cu (%)	Grade Ni (%)	Pt (oz/ton)
Cu conc	29.6 - 31.5	0.8 - 1.4	0.04 - 0.08
Ni conc	0.9 - 1.4	10.2 - 12.1	0.48 - 0.64
Cu + Ni conc (calcd)	4.1 - 4.3	9.2 - 10.4	0.43 - 0.59
Total Recovery (%)	77 - 85	73 - 76	79 - 85

An additional nickel recovery of about 5% was obtained by roasting and leaching of a nickeliferous pyrrhotite concentrate.

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INTRODUCTION

The sample submitted was from a small copper-nickel property located on the south east shore of the Rottenstone Lake, about 80 miles north of La Ronge, Northern Saskatchewan. The orebody, which also contains important values of platinum and palladium, was estimated at 50,000 tons by diamond drilling.

A new company will be formed to put the property into production. It intends to build a small mill and start processing next summer at a rate of about 125 tons per day.

Shipment

A 200 lb sample of ore was received at the Mines Branch on January 29, 1964, from Mr. B.R. Richards, geologist for Pre-Cam Exploration and Development Ltd.

Purpose of Investigation

Mr. Richards requested an investigation to find a method to concentrate the copper and nickel minerals with a good recovery of the precious metals. He wanted a high ratio of concentration to reduce the freight costs because of the remote location of the deposit.

A method of dry concentration was said to be preferred. However, the poor results obtained by electrostatic and electromagnetic separations precluded the use of these methods and prompted an investigation of flotation techniques.

Sampling and Analysis

All the material received was crushed to minus 1 in. A few selected pieces were picked out for mineralogical examination. The remainder was crushed to -10 m for testing purpose. A head sample was riffled out by conventional methods for chemical analysis and microscopic examination.

The chemical analysis of the head sample gave the following results.

TABLE 1

Chemical Analysis* of Head Sample

Copper (Cu)	-	1.39%	Platinum (Pt)	-	0.22 oz/ton
Nickel (Ni)	-	4.24"	Palladium (Pd)	-	0.14 "
Iron (Fe)	-	23.68"	Rhodium (Rh)	-	0.008 "
Sulphur (S)	-	16.24"	Gold (Au)	-	0.035 "
Insoluble	-	28.06"	Silver (Ag)	-	0.27 "

A spectrographic analysis on a portion of the head sample indicated the presence of the following elements in their approximate order of decreasing abundance.

TABLE 2

Spectrographic Analysis** of Head Sample

I	-	Fe, Si
II	-	Mg, Ni, Cu
III	-	Ca, Cr, Al
IV	-	Co, Ti.

MINERALOGICAL EXAMINATION***

A few hand specimens and a portion of the -10 m head sample were submitted to the Mineralogy Section of the Mineral Sciences Division for mineralogical examination.

Summary of Results

The copper-nickel ore from the Rottenstone Lake consists essentially of disseminated pyrrhotite, violarite in a serpentine-rich rock, and chalcopyrite. The pyrrhotite contains minute grains of pentlandite and sperrylite, and the violarite is frequently intergrown with pentlandite and sperrylite. Other metallic minerals in the ore are sphalerite, cubanite, magnetite and graphite.

* From Internal Report MS-AC-64-686.

** From Internal Report MS-AC-64-73.

*** From Investigation Report IR 64-42 by W. Petruk, April 8, 1964.

Method of Examination

The head sample was screened and the -65 + 200 m fraction was separated into sub-fractions by means of heavy liquids. Polished sections were prepared from the sub-fractions and also from rock chips and the minerals were identified by means of microscope and X-ray diffraction methods.

Mineralogical Description

The ore consists of disseminated metallic minerals in a serpentine-rich rock. The metallic minerals are pyrrhotite (FeS), violarite (Ni_2FeS_4), chalcopyrite (CuFeS_2), sphalerite (ZnS), cubanite (CuFe_2S_3), pentlandite ($(\text{Fe}, \text{Ni})\text{S}$), sperrylite (PtAs_2), magnetite (Fe_3O_4) and graphite (C).

Pyrrhotite is the most abundant metallic mineral; it is present as relatively large grains and contains flame-like grains of pentlandite and sperrylite (see Figures 1 and 2). Violarite is also an abundant mineral and it occurs as relatively large grains (see Figure 2). It is frequently intergrown with fine sperrylite (see Figure 3) and pentlandite, and contains sphalerite and cubanite veinlets.

Chalcopyrite is present as small irregular masses and frequently is intergrown with pyrrhotite and violarite (see Figure 4).

The sphalerite and cubanite were found only as veinlets in violarite, gangue and pyrrhotite.

The magnetite occurs as elongated grains in serpentine (see Figure 5), and graphite is present as irregular grains in serpentine.

The gangue minerals are serpentine, olivine, pyroxene and chlorite.

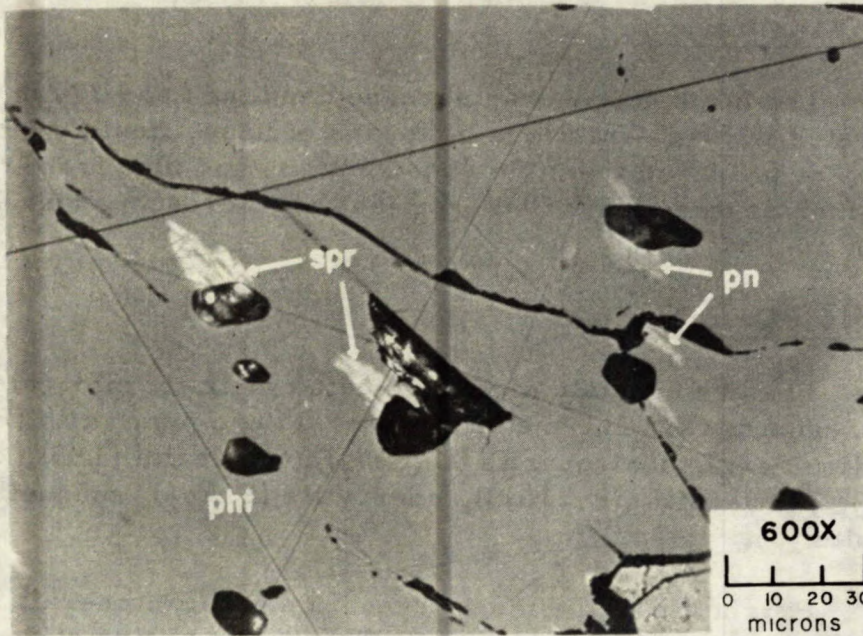


Figure 1. Photomicrograph of a polished section showing flame-shaped grains of sperrylite (spr) and pentlandite (pn) in pyrrhotite (pht). The black areas represent gangue.

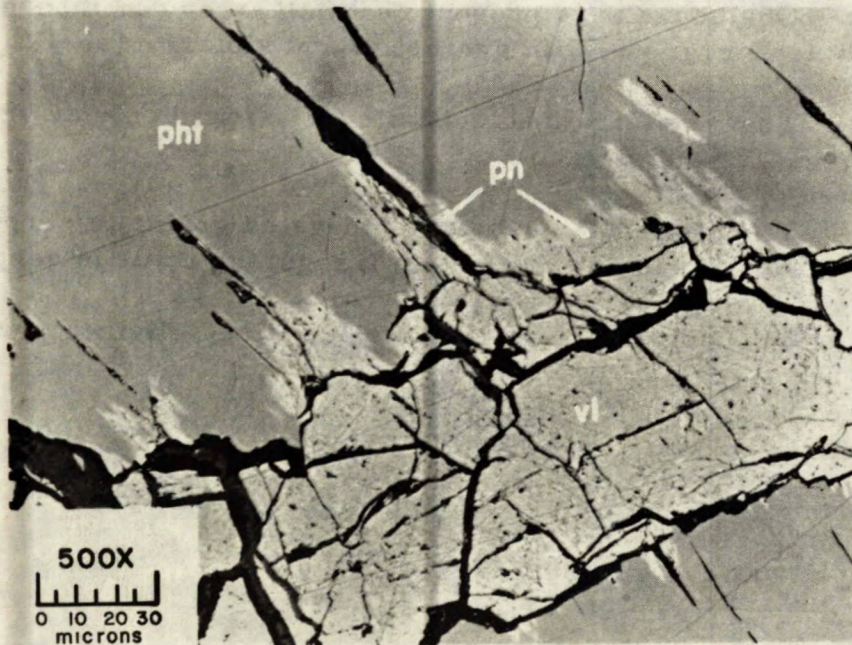


Figure 2. Photomicrograph of a polished section showing violarite (vl), pyrrhotite (pht) and pentlandite (pn).

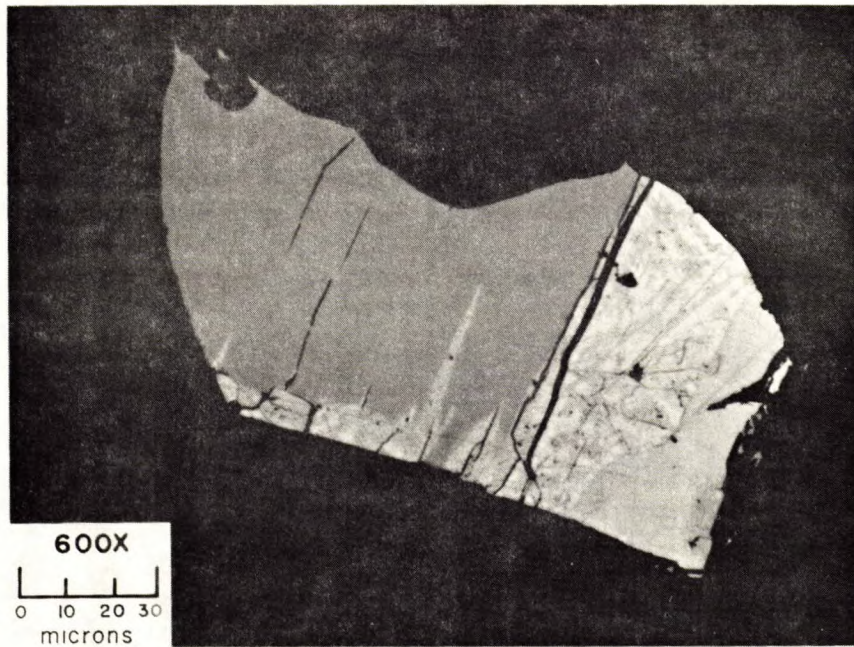


Figure 3. Photomicrograph of a polished section showing the complex intergrowth of sperrylite (white) and violarite (light grey). The dark grey area to the left of the violarite-sperrylite assemblage represents pyrrhotite, and the light grey area to the right represents chalcopyrite.

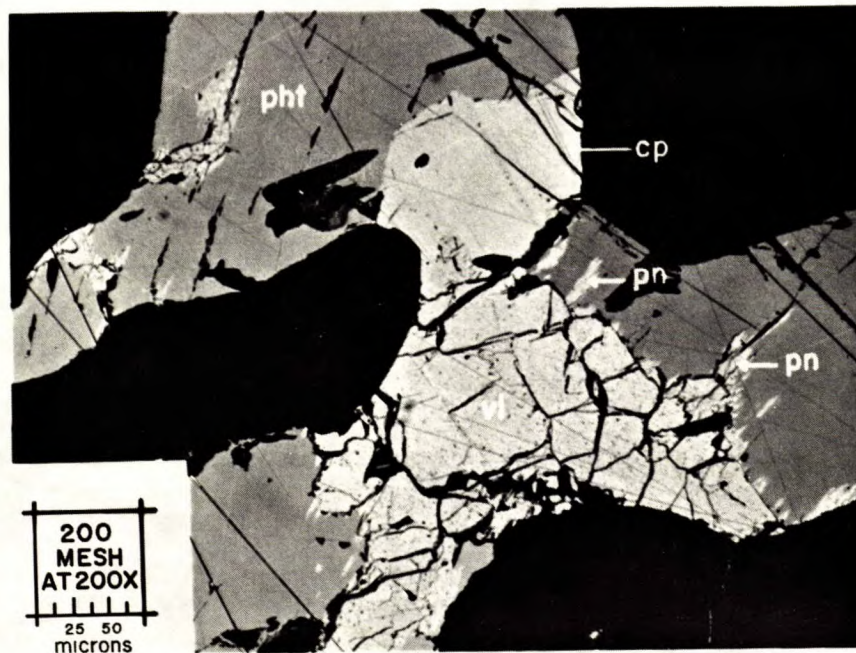


Figure 4. Photomicrograph of a polished section showing chalcopyrite (cp), violarite (vl), pyrrhotite (pht) and pentlandite (pn).

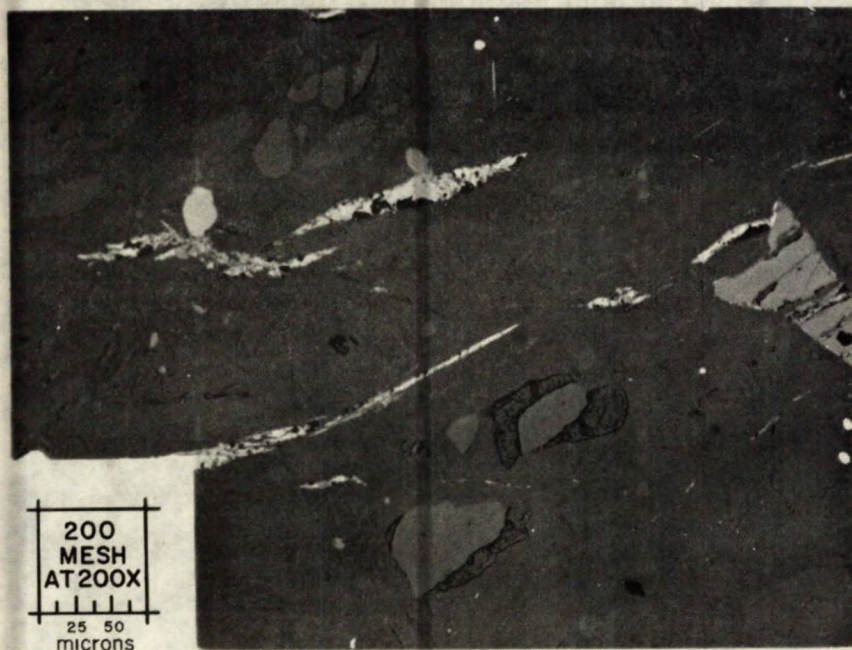


Figure 5. Photomicrograph of a polished section showing elongated magnetite grains (light grey) in serpentine (dark grey). The medium grey area at the right represents sphalerite.

OUTLINE OF INVESTIGATION

The investigation of the Rottenstone Lake ore was carried out under five main procedures:

1 - Concentration of the sulphides by electrostatic separation and removal of the pyrrhotite from the copper and nickel minerals by magnetic separation.

2 - Bulk flotation of a copper-nickel concentrate followed by flotation of a nickel concentrate. Pyrrhotite removal from the nickel concentrate by magnetic separation.

3 - Flotation of a bulk copper-nickel concentrate and separation of the copper from the nickel minerals. Flotation of a nickel concentrate and removal of its pyrrhotite content by magnetic separation.

4 - Selective flotation of a copper concentrate and stage flotation of nickel concentrates. Removal of the pyrrhotite from some of the nickel concentrates by magnetic separation.

5 - Roasting and leaching of a nickeliferous pyrrhotite concentrate.

Note: The copper and nickel concentrates obtained by procedures 2, 3 and 4 were upgraded by cleaning flotation stages when necessary.

DETAILS OF INVESTIGATION

Electrostatic and Magnetic Separation

This procedure was tried at the request of Mr. Richards to determine if it was possible to produce a copper-nickel concentrate by dry methods.

Test 1

A 1000 g sample of ore crushed to -10 m was reduced to -48 m with a disc pulverizer. The -48 m material was then sized into three fractions, -48+65 m, -65+100 m and -100 m. Each fraction was fed to an electrostatic separator with the following results.

TABLE 3

Results of Electrostatic Separation

Fraction	Product	Weight %		Analysis %		Distribution %			
		In Fraction	In Feed	Cu	Ni	In Fraction		In Feed	
						Cu	Ni	Cu	Ni
-48 + 65 m	Conc	78.4	15.2	1.36	2.65	92.1	86.8	16.1	10.0
	Tailing	21.6	4.2	0.41	1.46	7.9	13.2	1.3	1.5
-65 + 100 m	Conc	65.2	12.0	1.52	3.40	85.9	77.5	14.1	10.1
	Tailing	34.8	6.4	0.47	1.85	14.1	22.5	2.3	2.9
-100 m	Conc	2.3	1.4	3.02	6.04	5.0	2.8	3.3	2.1
	Tailing	97.7	60.8	1.33	4.86	95.0	97.2	62.9	73.4
Feed (calcd)		-	100.0	1.29	4.03	-	-	100.0	100.0

These results indicate the doubtful value of electrostatic separation to concentrate the copper and nickel minerals in the ore. However, as a final stage in this test, the three concentrates were combined and treated by dry magnetic separation in an attempt to remove pyrrhotite from the copper and nickel minerals.

TABLE 4

Results of Magnetic Separation

Product	Weight %	Analysis %		Distribution %	
		Cu	Ni	Cu	Ni
Conc	35.0	1.43	3.87	36.9	42.3
Tailing	65.0	1.32	2.84	63.1	57.7
Feed (calcd)	100.0	1.36	3.20	100.0	100.0

No appreciable concentration of either chalcopyrite or nickel minerals was obtained probably due to their intimate association with pyrrhotite. A high intensity wet magnetic separation, on the ore ground to -150 m, confirmed this close association. Because of the mineralogical characteristics of the ore and the limitations of an electrostatic separator, further testwork on this procedure seemed unwarranted.

Bulk Copper-Nickel Flotation

Test 2

A 2000 g sample of ore, crushed to -10 m, was ground for 30 minutes to 83% -200 m. A copper-nickel concentrate and a nickel concentrate were successively floated. The nickel concentrate was re-ground to 95% -325 m and treated on a Crockett wet magnetic separator to produce a nickel-rich non-magnetic product and a nickeliferous pyrrhotite concentrate. The nickel-rich product was then upgraded by a cleaning flotation stage to remove the gangue impurities.

The flotation procedure is shown in Table 5, and the results of the test are shown in Table 6.

TABLE 5

Reagents and Conditions

Operation	Time min	Reagents	lb/ton	pH
Cu-Ni flotation: Conditioning	3	Xanthate Z-6*	0.10	6.7
		Dowfroth 250	0.04	
Rougher flotation	10	Xanthate Z-6	0.10	
		Dowfroth 250	0.04	
Ni flotation: Conditioning	5	Sulphuric acid	4.00	3.3
		Xanthate Z-6	0.10	
		Dowfroth 250	0.03	
Rougher flotation	15	Xanthate Z-6	0.05	
		Dowfroth 250	0.03	
		After 8 min Copper sulphate	1.00	
Cleaner flotation	5	Xanthate Z-6	0.02	6.1
		Dowfroth 250	0.02	
		TSPP**	0.05	

* Potassium amyl xanthate

** Tetrasodium pyrophosphate

TABLE 6

Results of Flotation and Magnetic Separation

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu-Ni conc	28.3	4.04	9.34	85.5	71.2
Ni cl conc	2.7	0.80	9.40	1.6	6.9
Ni cl tailing	2.3	0.62	4.68	1.0	2.9
Ni-pyrrhotite	12.2	0.27	1.86	2.5	6.1
Flot tailing	54.5	0.23	0.88	9.4	12.9
Feed (calcd)	100.0	1.34	3.72	100.0	100.0
Cu + Ni conc**	31.0	3.76	9.35	87.1	78.1

* From Internal Report MS-AC-64-1006.

** Combined Cu-Ni conc and Ni cl conc.

Test 3, Flowsheet I

This test was carried out using the procedure illustrated by the following flowsheet.

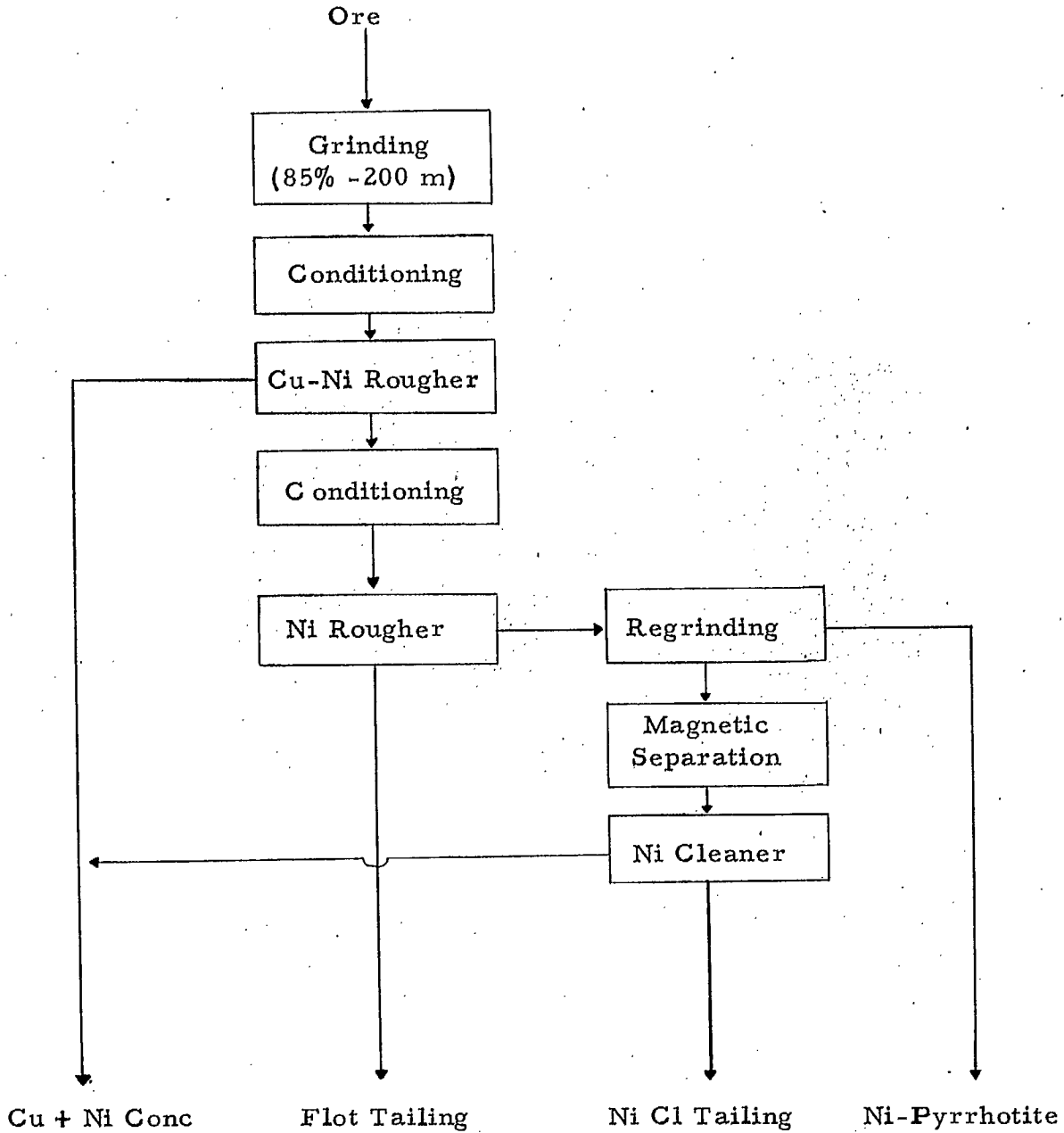


Figure 6. Flowsheet I

Table 7 gives the flotation data, and the results obtained are shown in Table 8.

TABLE 7

Reagents and Conditions for Flowsheet I

Operation	Time min	Reagents	lb/ton	pH
Cu-Ni flotation:				
Conditioning	3	Xanthate Z-6	0.10	6.8
		Dowfroth 250	0.04	
Rougher flotation	10	Xanthate Z-6	0.10	
		Dowfroth 250	0.04	
Ni flotation:				
Conditioning	5	Sulphuric acid	4.00	3.2
		Xanthate Z-6	0.10	
		Dowfroth 250	0.03	
Rougher flotation	15	Xanthate Z-6	0.05	
		Dowfroth 250	0.03	
		After 8 min Copper sulphate	1.00	
Cleaner flotation	5	Xanthate Z-6	0.02	6.2
		Dowfroth 250	0.02	
		TSPF	0.05	

Copper-Nickel Separation from a Bulk Concentrate

To separate the copper and nickel minerals from a bulk concentrate, flotation techniques with lime and sodium cyanide were used under two sets of conditions:

- (1) after conditioning in warm water
- (2) after aeration at ordinary temperature.

Test 4, Warm Water Conditioning

A 2000 g sample of ore was ground for 30 minutes to 83% -200 m and floated using the procedure shown in Table 9.

TABLE 9

Reagents and Conditions of Rougher Flotation and Separation

Operation	Time min	Reagents	lb/ton	pH
Cu-Ni flotation:				
Conditioning	3	Xanthate Z-6	0.10	6.7
		Dowfroth 250	0.04	
Rougher flotation	10	Xanthate Z-6	0.10	
		Dowfroth 250	0.04	
Cu-Ni separation:				
Conditioning	15	Lime	1.50	11.5
		Sodium cyanide	0.20	
		Reagent Z-200	0.01	
		Temperature 35°C		
Cu flotation	4	Reagent Z-200	0.01	
Ni flotation:				
Conditioning	5	Copper sulphate	1.00	4.5
		Xanthate Z-6	0.10	
		Dowfroth 250	0.03	
Rougher flotation	15	Xanthate Z-6	0.05	
		Dowfroth 250	0.03	

The nickel flotation concentrate was reground to 95% -325 m and treated on a Crockett wet magnetic separator to produce a nickel-rich, non-magnetic concentrate, and nickeliferous pyrrhotite.

TABLE 10

Results with Separation in Warm Water

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	5.0	18.37	6.18	65.7	7.3
Ni sep. conc	21.8	0.79	11.19	12.3	57.6
Ni conc	10.6	1.22	6.81	9.2	17.1
Ni-pyrrhotite	14.7	0.28	1.96	2.9	6.8
Flot tailing	47.9	0.29	0.99	9.9	11.2
Feed (calcd)	100.0	1.40	4.23	100.0	100.0

* From Internal Report MS-AC-64-656.

Test 5, Aeration Treatment

This test was similar to Test 4 except that the Cu-Ni conditioning stage was replaced by a 15 minute aeration with 3.0 lb of lime/ton and 0.2 lb of sodium cyanide/ton.

TABLE 11

Results with Separation After Aeration

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	5.1	20.34	5.72	69.9	6.8
Ni sep. conc	23.5	0.61	11.52	9.7	63.4
Ni conc	10.7	1.06	5.12	7.6	12.8
Ni-pyrrhotite	12.1	0.28	1.94	2.3	5.5
Flot tailing	48.6	0.32	1.01	10.5	11.5
Feed (calcd)	100.0	1.48	4.27	100.0	100.0

* From Internal Report MS-AC-64-679.

Because the aeration gave better results than the conditioning with warm water, aeration was used in all subsequent tests to separate the copper and nickel minerals.

Test 6, Cleaning Stages

In this test, the same basic procedure was used as in Test 5 except that both the copper and nickel concentrates were cleaned using the following procedure.

TABLE 12

Reagents and Conditions in Cleaning Flotation

Operation	Time min	Reagents	lb/ton	pH
Cu cleaner flotation	3	Reagent Z-200 TSP	0.01 0.05	11.2
Ni cleaner flotation	5	Xanthate Z-6 Dowfroth 250 TSP	0.02 0.02 0.05	6.0

The results obtained are shown in Table 13.

TABLE 13

Results with Cleaning Stages

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu cl conc	3.2	28.17	2.08	62.3	1.6
Cu cl tailing	1.5	7.57	11.25	7.9	4.1
Ni sep. conc	20.9	0.83	12.10	12.0	61.8
Ni cl conc	4.7	0.83	8.10	2.7	9.3
Ni cl tailing	4.8	0.84	3.65	2.8	4.3
Ni-pyrrhotite	14.2	0.22	1.77	2.1	6.1
Flot tailing	50.7	0.29	1.03	10.2	12.8
Feed (calcd)	100.0	1.44	4.09	100.0	100.0
Ni conc** (calcd)	25.6	0.83	11.37	14.7	71.1

* From Internal Report MS-AC-64-712 and 741.

** Combined Ni sep. conc and Ni cl conc.

Test 7, Effect of Sulphuric Acid

This test was similar to Test 6, except that 4.0 lb of sulphuric acid per ton was added to the nickel conditioning stage and the copper sulphate addition was made during the flotation stage. The acid addition decreased the pH from 4.5 to 3.2.

TABLE 14

Results with Sulphuric Acid

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu cl conc	3.0	26.31	1.54	57.5	1.1
Cu cl tailing	2.1	5.18	7.15	7.9	3.8
Ni sep. conc	21.7	1.09	11.19	17.2	61.4
Ni cl conc	3.2	1.52	14.40	3.6	11.7
Ni cl tailing	3.5	0.76	5.67	2.0	5.0
Ni-pyrrhotite	12.7	0.27	1.88	2.4	6.1
Flot tailing	53.8	0.24	0.80	9.4	10.9
Feed (calcd)	100.0	1.35	3.95	100.0	100.0
Ni conc**(calcd)	24.9	1.14	11.60	20.8	73.1

* From Internal Report MS-AC-64-1006.

** Combined Ni sep. conc and Ni cl conc.

Test 8, Flowsheet II

The changes made in the basic flowsheet are illustrated in Figure 7. A confirmatory test was done following the new flowsheet. The details of the reagents and conditions are shown in Table 15 and the results obtained are shown in Table 16.

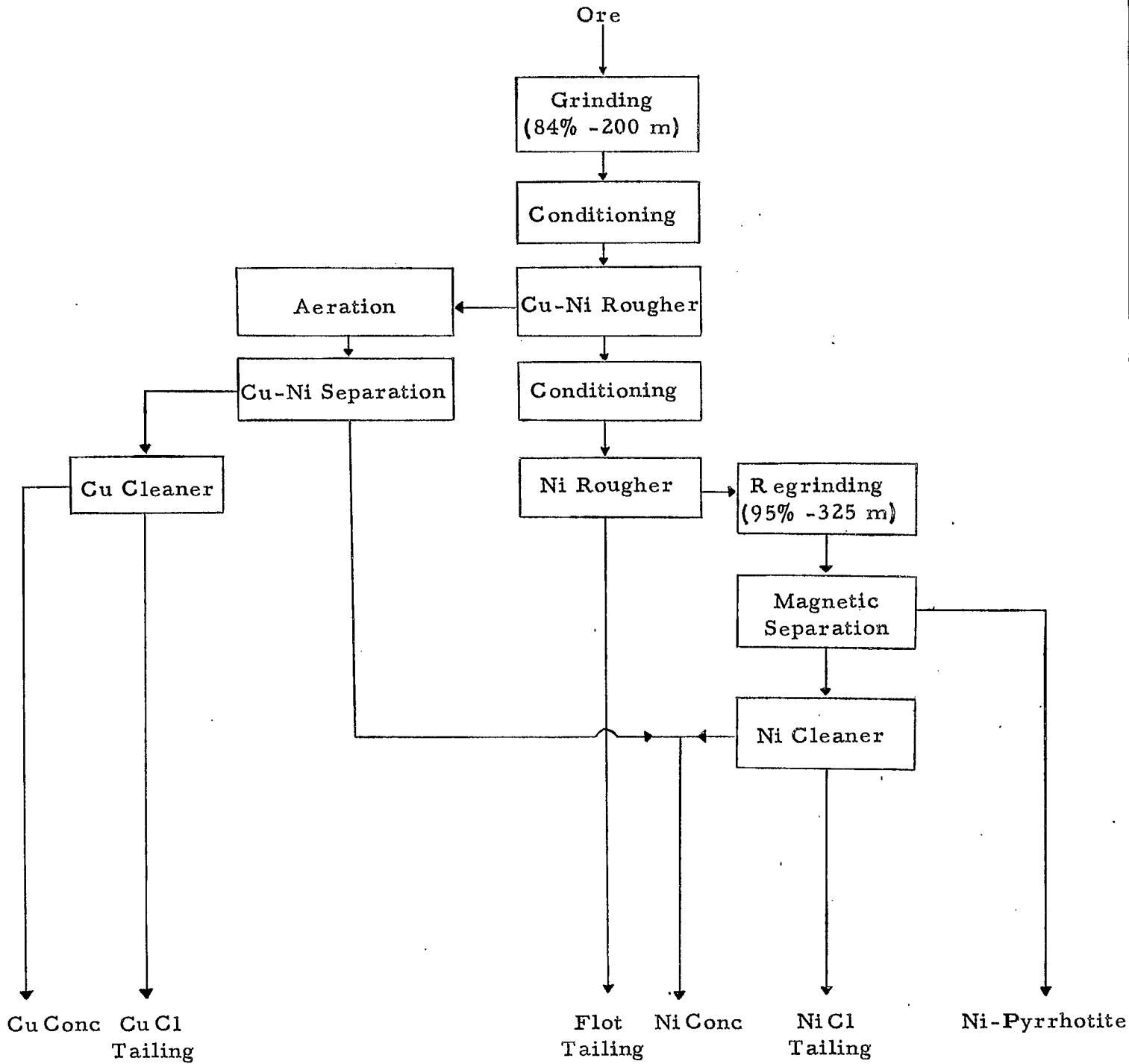


Figure 7. Flowsheet II

TABLE 15

Reagents and Conditions for Flowsheet II

Operation	Time min	Reagents	lb/ton	pH
Cu-Ni flotation:				
Conditioning	3	Xanthate Z-6 Dowfroth 250	0.10 0.04	6.8
Rougher flotation	10	Xanthate Z-6 Dowfroth 250	0.10 0.04	
Cu-Ni separation:				
Aeration	15	Lime Sodium cyanide	3.00 0.20	11.9
Cu rougher flotation	4	Reagent Z-200	0.01	11.4
Cu cleaner flotation (twice)	3	TSP Reagent Z-200	0.05 0.01	11.2
		TSP	0.05	
Ni flotation:				
Conditioning	5	Sulphuric acid Xanthate Z-6 Dowfroth 250	4.00 0.10 0.03	3.3
Rougher flotation	15	Xanthate Z-6 Dowfroth 250 After 8 min Copper sulphate	0.05 0.03 1.00	
Cleaner flotation	5	Xanthate Z-6 Dowfroth 250 TSP	0.02 0.02 0.05	6.7

Selective Flotation of Copper and Nickel

A series of tests, each consisting of selectively floating a copper concentrate followed by stage flotation of the nickel was done to study the effect on selectivity of different reagents and treatments. Using the best combination of reagents, a few tests were then made in which magnetic separations and cleaning stages were added to the basic procedure to upgrade the concentrates.

Test 10, Rougher Flotation

A 2000 g sample of ore was ground for 30 minutes to 83% -200 m and floated as in Table 18. The results of this test are shown in Table 19.

TABLE 18

Reagents and Conditions of Rougher Flotation

Operation	Time min	Reagents	lb/ton	pH
Cu flotation:				
Conditioning	5	Xanthate Z-6	0.12	7.1
Rougher flotation	6	Dowfroth 250	0.04	
Ni flotation (1st stage):				
Conditioning	3	Xanthate Z-6	0.08	6.2
Rougher flotation	9	Dowfroth 250	0.04	
Ni flotation (2nd stage):				
Rougher flotation	12	Copper sulphate	1.00	5.5
		Xanthate Z-6	0.10	
		Dowfroth 250	0.04	

TABLE 19

Results of Rougher Flotation

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	4.3	9.57	4.62	27.6	5.1
Ni conc (1st stage)	25.1	3.28	10.60	55.2	68.4
Ni conc (2nd stage)	18.6	0.54	2.74	6.7	13.1
Flot tailing	52.0	0.30	1.00	10.5	13.4
Feed (calcd)	100.0	1.49	3.89	100.0	100.0

* From Internal Report MS-AC-64-417.

Test 11, Increased Copper Conditioning Time

In this test, the copper conditioning period was increased to 30 minutes while allowing pH to drop from 7.0 to 5.2.

TABLE 20

Flotation Results with Increased Copper Conditioning Time

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	6.3	10.80	6.94	47.8	10.3
Ni conc (1st stage)	24.6	2.02	9.40	34.9	54.6
Ni conc (2nd stage)	16.0	0.60	5.52	6.8	20.9
Flot tailing	53.1	0.28	1.13	10.5	14.2
Feed (calcd)	100.0	1.42	4.23	100.0	100.0

* From Internal Report MS-AC-64-488.

Test 12, Reagent Z-200

In this test, the xanthate Z-6 was replaced by the same quantity of reagent Z-200 in the 30 minutes copper conditioning. The remainder of the test was made using the procedure described in Table 18.

TABLE 21

Flotation Results with Reagent Z-200

Product	Weight %	Analysis % *		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	5.0	15.21	5.40	57.4	6.4
Ni conc (1st stage)	24.8	1.26	9.48	23.6	55.3
Ni conc (2nd stage)	17.2	0.60	6.20	7.8	25.1
Flot tailing	53.0	0.28	1.06	11.2	13.2
Feed (calcd)	100.0	1.32	4.25	100.0	100.0

* From Internal Report MS-AC-64-488.

A few tests were done using the same basic procedure but with lime or soda ash and gave inferior results to those obtained without an alkali.

Test 13, Lower Concentration of Reagent Z-200 and Xanthate Z-6

This test was similar to Test 12, except that the amount of the reagents Z-200 and Z-6 were decreased to 0.08 and 0.05 lb/ton of ore in the copper and nickel conditioning stage respectively.

TABLE 22

Flotation Results with Lower Concentration of Reagent Z-200 and Xanthate Z-6

Product	Weight %	Analysis % *		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	4.2	17.35	5.18	54.7	5.6
Ni conc (1st stage)	21.4	1.73	10.22	27.8	56.4
Ni conc (2nd stage)	19.6	0.41	4.67	6.0	23.6
Flot tailing	54.8	0.28	1.02	11.5	14.4
Feed (calcd)	100.0	1.33	3.88	100.0	100.0

* From Internal Report MS-AC-64-362.

Test 14, Pre-Aeration

In this test, the copper conditioning stage was replaced by a 20 minute aeration period while allowing the pH to drop from 7.1 to 5.0.

TABLE 23

Flotation Results with Pre-Aeration

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	4.7	18.21	4.91	59.1	5.9
Ni conc (1st stage)	22.0	1.52	9.79	23.1	55.1
Ni conc (2nd stage)	19.2	0.53	4.96	7.0	24.3
Flot tailing	54.1	0.29	1.06	10.8	14.7
Feed (calcd)	100.0	1.45	3.91	100.0	100.0

*From Internal Report MS-AC-64-517.

Test 15, Effect of Sulphuric Acid

This test was similar to Test 14, except that sulphuric acid in ratio of 5.0 lb/ton of ore was added to the pulp prior to the aeration period. The pH decreased to 3.5 during the aeration with sulphuric acid.

TABLE 24

Flotation Results After Aeration with Sulphuric Acid

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	4.8	16.34	3.68	57.6	4.3
Ni conc (1st stage)	21.6	1.47	11.52	23.3	60.7
Ni conc (2nd stage)	22.0	0.55	4.54	8.9	24.4
Flot tailing	51.6	0.27	0.84	10.2	10.6
Feed (calcd)	100.0	1.36	4.10	100.0	100.0

*From Internal Report MS-AC-64-517.

As the sulphuric acid addition was found beneficial for both the copper and nickel flotation, several tests were done in which this reagent was added to copper conditioning and/or to nickel conditioning. In each case, the addition improved the selectivity and the nickel recovery. However, the best overall results were obtained when the acid was added to the pre-aeration stage.

Test 16, Nickel Floated in Three Stages

This test was carried out using pre-aeration with sulphuric acid as in Test 15, but the nickel was floated in three stages as shown by Table 25.

TABLE 25

Reagents and Conditions of Nickel Flotation in Three Stages

Operation	Time min	Reagents	lb/ton	pH
Conditioning	3	Xanthate Z-6	0.05	3.8
Rougher flotation (1st stage)	6	Dowfroth 250	0.02	3.7
Rougher flotation (2nd stage)	4	Xanthate Z-6 Dowfroth 250	0.02 0.02	3.6
Rougher flotation (3rd stage)	12	Copper sulphate Xanthate Z-6 Dowfroth 250	1.00 0.10 0.04	3.6

TABLE 26

Flotation Results with Nickel Floated in Three Stages

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	5.0	16.16	4.50	57.6	5.5
Ni conc (1st stage)	20.6	1.63	11.66	24.0	58.7
Ni conc (2nd stage)	13.0	0.45	4.79	4.1	15.2
Ni conc (3rd stage)	10.9	0.59	3.82	4.6	10.2
Flot tailing	50.5	0.27	0.84	9.7	10.4
Feed (calcd)	100.0	1.40	4.09	100.0	100.0

*From Internal Report MS-AC-64-635.

Test 17, Flotation and Magnetic Separation

This test was similar to Test 16, except that each nickel concentrate was reground and treated on a Crockett magnetic separator to remove the nickeliferous pyrrhotite from the free nickel minerals.

TABLE 27

Results of Flotation and Magnetic Separation

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu conc	4.5	17.61	3.52	56.9	4.2
Ni conc (1st stage)	13.6	2.01	15.28	19.6	55.0
Ni-pyrrhotite (1st stage)	4.9	0.55	3.47	1.9	4.5
Ni conc (2nd stage)	4.6	1.24	8.92	4.1	10.9
Ni-pyrrhotite (2nd stage)	9.5	0.19	1.60	1.3	4.0
Ni conc (3rd stage)	5.6	1.20	5.20	4.8	7.7
Ni-pyrrhotite (3rd stage)	6.3	0.25	1.40	1.1	2.3
Flot tailing	51.0	0.28	0.84	10.3	11.4
Feed (calcd)	100.0	1.39	3.78	100.0	100.0

* From Internal Report MS-AC-64-635 and 644.

Test 18, Cleaning Stages

This test was similar to the preceding test except that the copper concentrate was cleaned twice with lime. Also, the first nickel concentrate was cleaned with the cleaner tailing going to magnetic separation, and the third nickel concentrate was cleaned after magnetic separation. The details of the cleaning procedure are shown in Table 28, and the results obtained in Table 29.

TABLE 28

Reagents and Conditions of Cleaner Flotation

Operation	Time min	Reagents	lb/ton	pH
Cu cleaner flotation	3	Lime Reagent Z-200 Dowfroth 250 TSP	1.50 0.01 0.01	12.2
Cu recleaner flotation (twice)	2	-		11.4
Ni cleaner flotation (1st stage)	4	Xanthate Z-6 Dowfroth 250 TSP	0.05 0.02 0.20	5.6
Ni cleaner flotation (3rd stage)	5	Xanthate Z-6 Dowfroth 250 TSP	0.02 0.02 0.05	6.4

TABLE 29

Results of Flotation and Magnetic Separation with Cleaning Stages

Product	Weight %	Analysis %*		Distribution %	
		Cu	Ni	Cu	Ni
Cu recl conc	2.4	31.35	0.75	51.8	0.4
Cu recl tail	0.4	11.17	5.58	3.1	0.5
Cu cl tail	2.0	3.36	12.30	4.6	6.1
Ni cl conc (1st stage)	11.8	2.40	17.30	19.5	50.2
Ni conc (1st stage)	2.2	1.05	7.32	1.6	4.0
Ni-pyrrhotite (1st stage)	1.7	0.24	1.66	0.3	0.7
Ni conc (2nd stage)	4.5	0.98	10.92	3.0	12.1
Ni-pyrrhotite (2nd stage)	8.1	0.17	1.52	1.0	3.0
Ni cl conc (3rd stage)	3.2	1.26	8.94	2.8	7.0
Ni cl tail (3rd stage)	3.1	0.48	3.06	1.0	2.3
Ni-pyrrhotite (3rd stage)	4.7	0.29	1.72	0.9	2.0
Flot tailing	55.9	0.27	0.85	10.4	11.7
Feed (calcd)	100.0	1.45	4.03	100.0	100.0
Ni conc** (calcd)	23.7	1.94	13.50	31.5	79.4
Ni-pyrrhotite*** (calcd)	14.5	0.22	1.58	2.2	5.7

* From Internal Report MS-AC-64-723 and 729.

** Combined Ni cl conc (1st stage), Ni conc (1st, 2nd and 3rd stages) and Cu cl tail.

*** Combined Ni-pyrrhotite (1st, 2nd and 3rd stages).

Test 19, Flowsheet III

The changes made in Flowsheet II are illustrated in Figure 8.
A confirmatory test was then done following the new flowsheet.

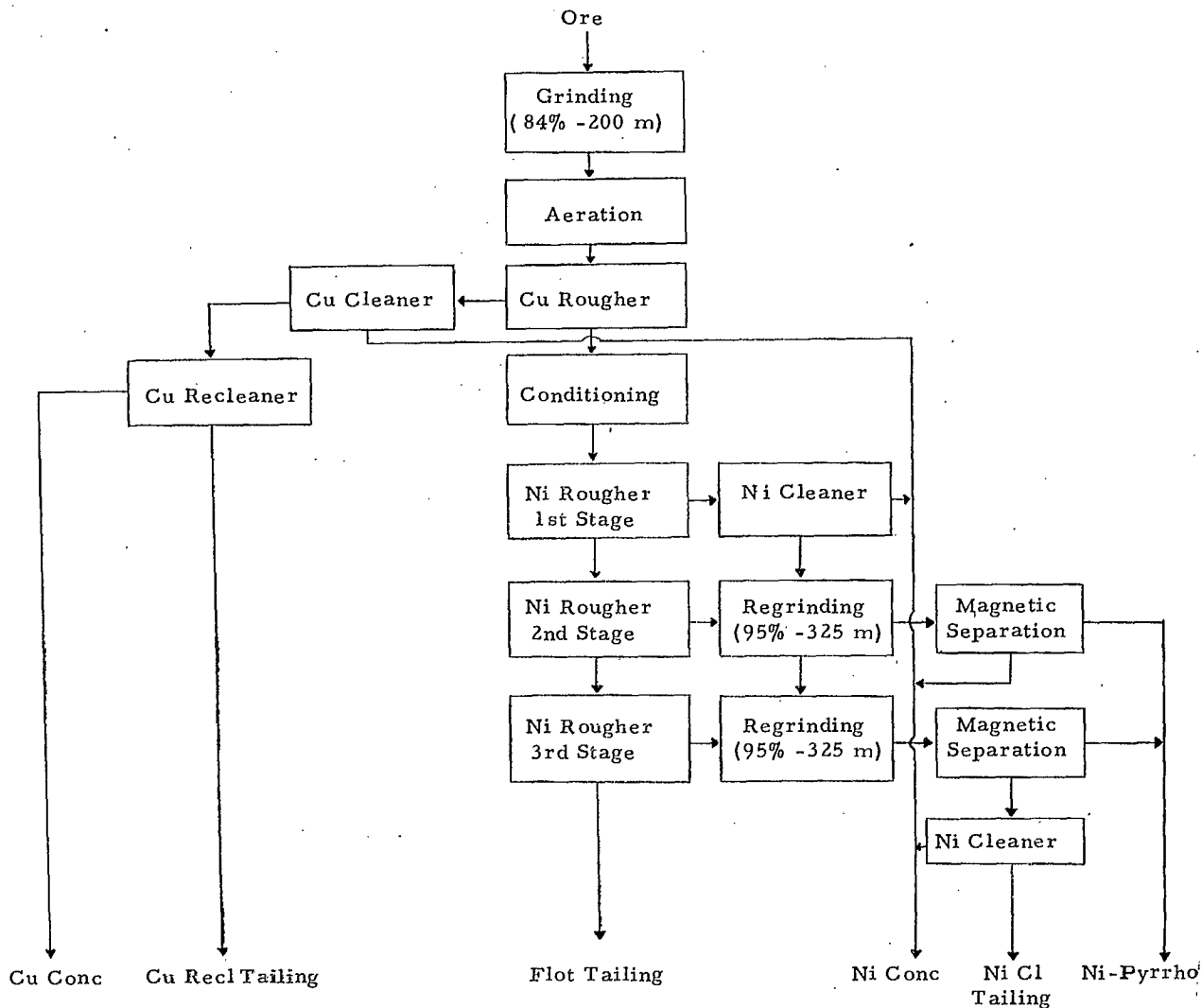


Figure 8. Flowsheet III

In this test, the magnetic separations were carried out on a Jones separator set at 1 ampere. The reagents used and the results of the test are shown in Tables 30 and 31.

TABLE 30

Reagents and Conditions for Flowsheet III

Operation	Time min	Reagents	lb/ton	pH
Cu flotation:				
Aeration	20	Sulphuric acid	5.00	7.1 - 3.8
Rougher flotation	4	Reagent Z-200	0.06	3.7
		Dowfroth 250	0.02	
		TSPP		
Cleaner flotation	3	Lime	1.50	11.9
		Reagent Z-200	0.01	
		Dowfroth 250	0.01	
		TSPP	0.05	
Recleaner flotation (twice)	2	-	-	11.0
Ni flotation (1st stage):				
Conditioning	3	Xanthate Z-6	0.05	3.7
Rougher flotation	6	Dowfroth 250	0.02	3.6
		TSPP	0.20	
Cleaner flotation	4	Xanthate Z-6	0.02	5.5
		Dowfroth 250	0.02	
		TSPP	0.10	
Ni flotation (2nd stage):				
Rougher flotation	4	Xanthate Z-6	0.02	3.6
		Dowfroth 250	0.02	
		TSPP	0.20	
Ni flotation (3rd stage):				
Rougher flotation	12	Copper sulphate	1.00	3.5
		Xanthate Z-6	0.10	
		Dowfroth 250	0.04	
		TSPP	0.20	
Cleaner flotation	5	Xanthate Z-6	0.02	6.5
		Dowfroth 250	0.02	
		TSPP	0.05	

To determine the cause of the high nickel flotation tailing in Test 19, a representative sample was sent to the Mineral Sciences Division for microscopic examination. The mineralogical examination revealed that most of the nickel contained in the flotation tailing appeared as garnierite, genthite and other silicates which are not recoverable by ordinary flotation techniques.

Roasting and Leaching of Nickeliferous Pyrrhotite

A 50 g sample of a mixed nickeliferous pyrrhotite concentrate assaying 0.20% Cu and 1.80% Ni was pulped in 75 cc water containing 30 g Na₂SO₄. The pulp was filtered and the filter cake was dried. Approximately 2 g of salt remained in the sample. This procedure was used to insure a homogeneous distribution of salt through the pyrrhotite for the sulphating roast.

The material was then placed in a furnace and the temperature was gradually raised from 200°C to 650°C over a period of three hours. The temperature of the roasted product was lowered to 225°C and the calcine was leached in water at about 60°C for one hour. The residue was filtered, washed and analysed for copper, nickel and iron with the following results.

TABLE 32

Results of Roasting and Leaching of Nickeliferous Pyrrhotite

Weight Lost %	Analysis %*			Extraction %**	
	Cu	Ni	Fe	Cu	Ni
30	0.03	0.67	65.2	89.5	73.3

* From Internal Report MS-AC-64-956.

** Calculated by difference.

It is doubtful that a roast-leach treatment would be economical for a small tonnage. However, the pyrrhotite concentrate could be stockpiled for possible future treatment.

SUMMARY AND CONCLUSIONS

Head analysis of the ore sample submitted by Pre-Cam was as follows:

<u>Cu</u>	<u>Ni</u>	<u>Pt</u>	<u>Pd</u>	<u>Au</u>
1.39%	4.24%	0.22 oz/ton	0.14 oz/ton	0.035 oz/ton

The metallic minerals consisted essentially of pyrrhotite and violarite frequently intergrown with chalcopyrite, pentlandite and sperrylite.

At the request of Mr. B. R. Richards, concentration of copper and nickel was attempted by dry methods using electrostatic and magnetic separation. However, these methods gave poor results because of the intimate association of the copper and nickel minerals with pyrrhotite and the inefficiency of the dry separators for the treatment of fine material.

The testwork showed that flotation concentration was successful in producing copper and nickel concentrates from this ore. Wet magnetic separation was then used to remove the pyrrhotite from some of the lower grade nickel concentrates.

Three main procedures were investigated to recover the copper and nickel minerals.

The first procedure consisted essentially in the production of a bulk copper-nickel concentrate with pyrrhotite removal by magnetic separation (see Flowsheet I, page 10).

In the second procedure, flotation was used to separate the copper and the nickel from a bulk concentrate followed by magnetic separation on a nickel concentrate (see Flowsheet II, page 17). The following observations were made from this series of tests:

- 1 - Pre-aeration appeared better than conditioning in warm water to separate the copper and nickel minerals;
- 2 - Regrinding of the Cu-Ni concentrate prior to the separation did not give appreciable improvement;
- 3 - Addition of sulphuric acid to the nickel circuit improved nickel grade and recovery without a significant effect on the precious metals.

The third procedure included copper selective flotation, nickel stage flotation and magnetic separation (see Flowsheet III, page 28). In this series of tests, the following points were established:

1 - The selectivity of the copper flotation was significantly increased by longer conditioning time, use of reagent Z-200 and pre-aeration.

2 - The nickel grade and recovery were improved by staged flotation in conjunction with proper cleaning and magnetic treatment, and by sulphuric acid addition.

The results obtained by the three procedures are compared in the following table:

TABLE 33

Comparison of Treatment Procedures

		Cu (%)	Ni (%)	Pt oz/ton	Pd oz/ton	Au oz/ton
Flowsheet I (Bulk Flotation)	Cu-Ni conc	3.6	9.5	0.45	0.18	0.10
	Total Recovery (%)	85.4	77.8	82.6	61.7	58.6
Flowsheet II (Bulk Flotation and Separation)	Cu conc	29.6	1.0	0.04	0.22	0.11
	Ni conc	1.0	11.5	0.48	0.24	0.06
	Total Recovery (%)	76.9	74.8	78.7	60.0	41.3
Flowsheet III (Selective and Stage Flotation)	Cu conc	31.5	1.4	0.07	0.13	0.12
	Ni conc	1.4	11.1	0.64	0.26	0.07
	Total Recovery (%)	84.7	75.9	83.6	63.2	47.7

The feature of Flowsheet I is simplicity. This would be advantageous for a short-term operation, provided that a convenient market is available for a bulk concentrate.

Failing this, it may be necessary to produce separate copper and nickel concentrates using either Flowsheet II or III. The former has the advantage of simplicity, but the latter gives better overall recovery.

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