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FLOWSHEET DEVELOPMENT FOR PROCESSING A GOLD ORE FROM TULLY TOWNSHIP, ONTARIO, FOR McINTYRE PORCUPINE MINES LIMITED

by

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MINERAL PROCESSING DIVISION

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SUMMARY OF RESULTS

Head analysis of the four ore samples received for investigation gave the following results:

Elements	Offsets #1	Offsets #2	Offsets #3	Offsets #4
Au (oz/ton)	0.08	0.07	1.63	0.03
Ag (oz/ton)	0.05	1.06	0.23	0.06

Barrel amalgamation showed that, in all of the samples, more than half of the gold was free-milling at a coarse size (-20 mesh). Almost all the liberated gold was recovered by jigging.

Flotation recovered 91% to 99% of the gold, depending on the samples. The best recoveries were achieved on the high-grade ore sample, namely, Offsets #1 and #3.

Straight cyanidation also proved to be a very effective method for recovering the gold, as a contact period of only 24 hours was sufficient for dissolving more than 96% of the gold.

A confirmatory test was carried out on a composite sample from the four ore lots and involved jigging, amalgamation, flotation and cyanidation. It resulted in gold and silver overall recoveries of 96.5% and 91.5%, respectively.

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INTRODUCTION

Mr. A. Skrecky of the Exploration Department of McIntyre Porcupine Mines Limited, P.O. Box 970, Timmins, Ontario, stated in his letter of November 5, 1969, that the company has recently completed a diamond drilling program on its Nickel Offsets gold prospect located in Tully Township, Ontario, and had reached the stage where some information was needed concerning the milling characteristics of the gold-bearing rock. The assistance of the Mines Branch was requested for this purpose.

Shipment

Four samples representing various sections of the gold bearing zone were submitted for investigation. These were identified and described by Mr. Skrecky as follows:

"Nickel Offsets One - approximately 140 pounds averages 0.148 ounces gold per ton. Sample consists of silicified volcanic wallrock and 20% quartz mineralized with trace amounts of pyrite and a few grains of visible gold.

Nickel Offsets Two - approximately 140 pounds averages 0.030 ounces gold per ton. Sample consists of silicified volcanic wallrock and 30% quartz mineralized with trace amounts of pyrite and graphite.

Nickel Offsets Three - approximately 65 pounds averages 1.857 ounces gold per ton. Sample consists of 60% quartz, 30% silicified volcanic wallrock and 10% graphite schist mineralized with trace amounts of pyrite and scattered grains of visible gold.

Nickel Offsets Four - approximately 110 pounds averages 0.028 ounces gold per ton. Sample consists of quartz and 10% silicified volcanic wallrock mineralized with graphite and trace amounts of pyrite."

Sampling and Analysis

Each sample was crushed to minus one inch and a few representative samples were selected for mineralogical examination. The remainders were crushed separately to minus 10 mesh from which head samples were riffled for chemical analysis.

TABLE 1

Chemical Analyses* of Head Samples

Element	Sample			
	Offsets #1	Offsets #2	Offsets #3	Offsets #4
Gold (Au), oz/ton	0.08	0.07	1.63	0.03
Silver (Ag), "	0.05	1.06	0.23	0.06
Carbon**(C), %	2.60	2.89	1.40	0.78
Iron (Fe), "	7.61	7.32	3.80	1.54
Sulphur (S), "	2.16	1.79	0.58	0.06
Insoluble, "	64.6	64.9	81.9	91.2

*From Internal Reports MS-AC-70-135 and 155.
**In the form of graphite.

A spectrographic analysis was also carried out on a combined sample from the Nickel Offsets 1 to 4. This method indicated the presence of the following elements listed in their approximate order of decreasing abundance.

TABLE 2

Results of Spectrographic* Analysis

I - Si, Fe (1%)
II - Na, Mg, Al, Ba, Ti (1% - 0.1%)
III - Ni, Cr, Pb, Mn, Mo (0.1% - 0.01%)
IV - V, Cu, Zr, In, Au (0.01%)
V - Ag, As, Bi, Sn (none detected)

*From Internal Report MS-AC-70-211.

MINERALOGICAL EXAMINATION*

A portion of the head samples and selected rock chips from each ore were sent to the Mineralogy Section of the Mineral Sciences Division to identify the ore minerals and to determine their grain sizes and textural relationships.

Samples

Each of the four samples, as received, consisted of about 30 small hand specimens and about 100 grams of head sample, crushed to minus ten mesh. The hand specimens were all smaller than one inch in diameter, and were composed mainly of quartz, some feldspar and small amounts of carbonate minerals, graphite and chlorite. Dispersed throughout the gangue minerals were small masses and grains of pyrite and traces of native gold.

The four samples were labelled "Nickel Offsets, Nos. 1, 2, 3 and 4" and were reported to contain 0.148, 0.030, 1.857 and 0.028 ounces of gold, respectively.

Method of Investigation

The hand specimens were examined under the binocular microscope and representative pieces of each were selected for polished sections. Visible native gold was seen only in the hand specimens of Nickel Offset No. 3. The polished sections prepared from the hand specimens were examined microscopically to identify the ore minerals and to determine their grain sizes and textural relationships. The head samples were screened and the minus 48 to 325-mesh fractions were removed and separated into sink and float products by means of heavy liquids. Polished sections were prepared from the sink products and examined microscopically to permit a comparison of the minerals in the head sample with those in the hand specimens. The gangue minerals were identified by microscopical examination of oil immersion mounts of the float products, and by X-ray diffractometer analyses. The minerals in the ore were identified by the combined methods of microscopy, X-ray diffraction analysis and electron microprobe analysis.

Results of Investigation

The examination of the head samples shows that the hand specimens are not completely representative of the ore. This is shown by the presence of copper sulphides, iron oxides and some nickel-iron sulphides in the head samples, but not in the hand specimens.

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*From Mineral Sciences Division, Internal Report MS-70-42, "Mineralogical Examination of Four Samples of Gold Ore from Tully Township, Ontario on Behalf of McIntyre Porcupine Mines Limited, Timmins, Ontario" by D.R. Owens, April 14, 1970.

General Mineralogy of the Samples

Each of the samples consists largely of gangue minerals and, to a lesser degree, of pyrite. All were found to contain some goethite, magnetite, rutile, ilmenite, hematite, chalcopyrite, marcasite, native gold, chalcocite, digenite, covellite, sphalerite, galena and pyrrhotite. Two of the samples contain traces of bornite, altaite, and violarite; a third a trace of melonite; and a fourth a few grains of tetradymite(?). In all of the samples, traces of nickel were detected in some areas of the pyrite.

Detailed Mineralogy of the Samples

Native Gold

Native gold occurs in all of the head samples. Its presence in the hand specimens, however, was detected only in Nos. 3 and 4.

In all of the head samples the native gold occurs largely as free grains. Some native gold, however, is present as small inclusions in grains of gangue and pyrite. These inclusions vary in size from about 2 to 35 microns.

In the hand specimens of sample No. 3 all of the native gold occurs as inclusions in pyrite, and varies in size from 2 to about 125 microns. The word "size", as used in this report, refers to the greatest dimension of the mineral grain being described.

The native gold in the hand specimens of No. 4 is present entirely as inclusions in the gangue (Figure 1), although a few grains adhere to galena. These inclusions vary in size from a few microns to about 1.6 millimetres; most, however, vary from about 10 to 400 microns. A few of the grains of native gold contain inclusions of chalcopyrite and galena (Figure 2).

Other Ore Minerals

Pyrite

Pyrite is the most dominant ore mineral*, and is present in all of the samples. In the hand specimens it occurs as coarse grains and small masses in gangue, which vary in size from a few microns to about one centimetre. Inclusions of gangue, chalcopyrite, pyrrhotite, rutile and marcasite are present in the pyrite in all of the samples, while native gold, pentlandite, violarite and goethite are present in the pyrite of only a few of the samples. These inclusions vary from 2 to about 400 microns in size; all but the gangue inclusions, however, are smaller than 200 microns.

Electron microprobe analysis shows that traces of nickel occur in some areas of the pyrite in the samples. The amount, however, is variable and very low.

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*The term "ore mineral", as used in this report, does not necessarily have an economic connotation.

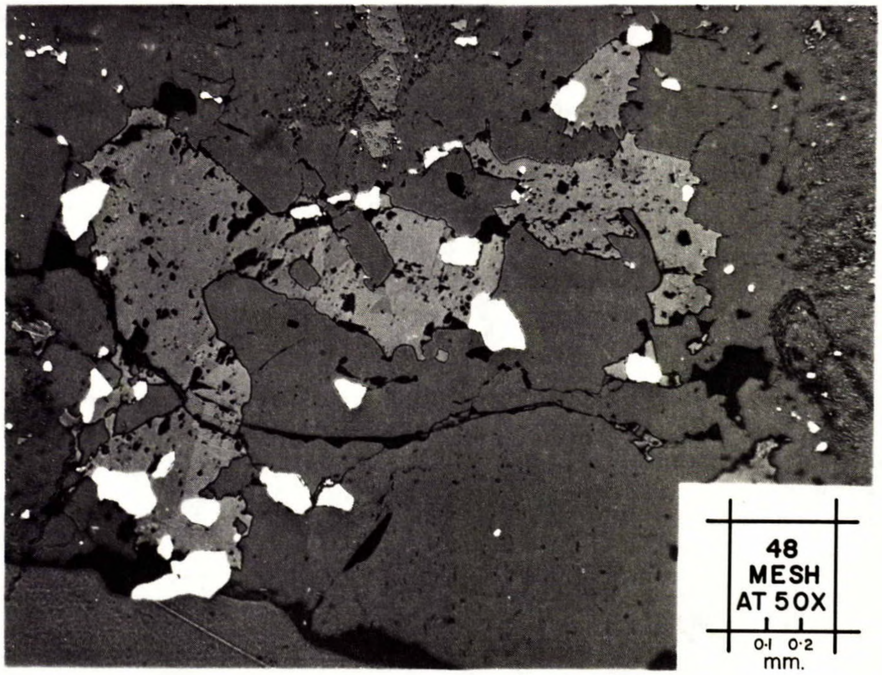

Figure 1. Photomicrograph of a polished section showing numerous grains of native gold (white) in gangue (grey).

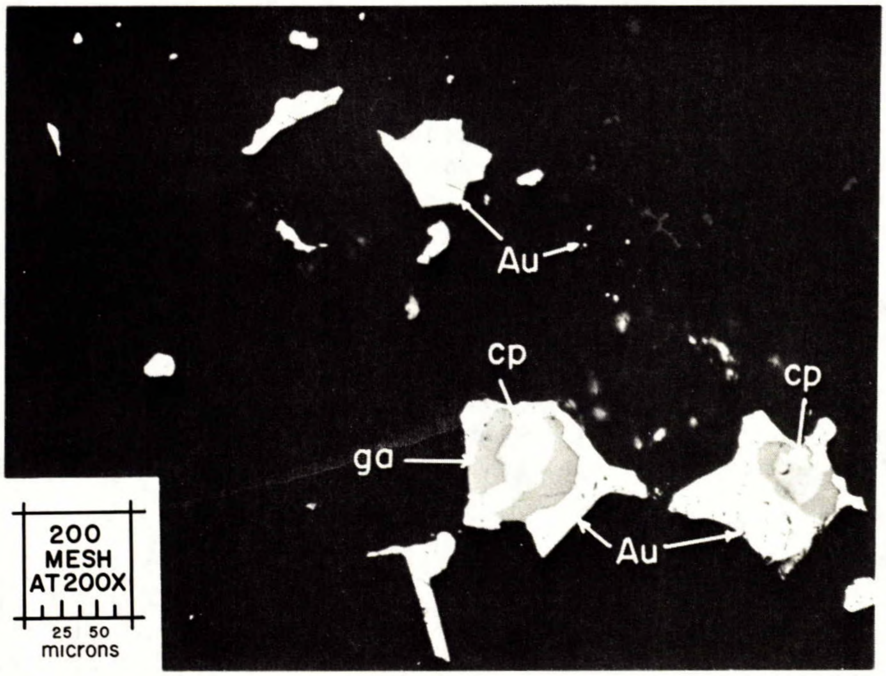

Figure 2. Photomicrograph (in oil immersion) of a polished section showing native gold (Au) in gangue (black) two grains of which contain inclusions of galena (ga) and chalcopyrite (cp).

Chalcopyrite, Pyrrhotite and Marcasite

These three minerals occur in all of the samples in small amounts. They each are present essentially as inclusions in the pyrite, although a few grains of chalcopyrite occur in the gangue and in the native gold. Although the grains of these minerals vary from about 2 to 200 microns in size, most of the chalcopyrite and pyrrhotite are smaller then 50 microns.

Rutile

Rutile occurs in all the hand specimens and head samples of the ore in small amounts. It is present as disseminations in the gangue and as a few inclusions in the pyrite. These grains usually are from 2 to 30 microns in size, although one cluster of rutile grains in pyrite reaches 1.5 millimetres in size.

Galena and Sphalerite

Both galena and spahlerite occur in very small and varying quantities in all four head samples. Galena was seen only in the hand specimens of sample No. 4, where it is present as a few grains in gangue. These grains vary from 10 to 800 microns in size, and contains a few small inclusions of altaite and a bismuth-tellurium sulphide believed to be tetradymite.

Goethite, Ilmenite, Hematite and Magnetite

Small amounts of goethite and traces of the other three minerals are present in each of the head samples. The only goethite seen in the hand specimens occurs in sample No. 4 as a border on some of the pyrite grains. Ilmenite, magnetite and hematite were not observed in any of the hand specimens.

Chalcocite, Digenite, Covellite and Bornite

Very small to trace amounts of the above four minerals are also present in each of the head samples, but were not observed in any of the hand specimens. Each occurs primarily as free grains in the head sample, or in combination with some of the chalcopyrite.

Altaite, Tetradymite(?) and Melonite

As noted above, a few very small grains of altaite (PbTe) are present as inclusions in the galena in sample No. 4. Altaite is also present in the head sample No. 3, where it occurs as a few free grains, and as inclusions in a grain of melonite ($NiTe_2$). This is the only occurrence of melonite seen in the ore samples.

The only tetradymite(?) in the ore occurs as a few minute inclusions in galena in sample No. 4. The grains were too small for an accurate electron microprobe analysis and the identification is therefore tentative.

Other Nickel-bearing Minerals

Small to trace amounts of the nickel sulphides - violarite, millerite and pentlandite - occur in a few of the samples. Violarite occurs in both the head samples of Nos. 3 and 4 and in the hand specimens of sample No. 3, while pentlandite occurs in the hand specimens of No. 3 and millerite in the head sample No. 3. Of these three minerals, violarite is the most prevalent. It occurs as inclusions in gangue and in pyrite, and varies from a few to about 100 microns in size. The pentlandite in hand specimen No. 3 is present as a few very small inclusions in pyrite, while the millerite consists only of a few free grains in the head sample of No. 3.

Gangue Minerals

The gangue minerals in each of the samples are the same. However, samples Nos. 1 and 2 differ from Nos. 3 and 4 in that they contain appreciable amounts of feldspar. In each sample the principal gangue mineral is quartz. Also present are smaller amounts of dolomite and chlorite as well as traces of clay and mica.

Conclusions

The only mineral of sufficient quantity to be of economic interest in the ore samples is native gold. Many of the grains are quite large and it is expected that a good degree of liberation can be effected.

Although small amounts of copper- and nickel-bearing minerals occur in some of the ore samples, they are not believed to be sufficiently abundant to be of interest.

OUTLINE OF INVESTIGATION

Preliminary amalgamation tests were carried out to determine the content of coarse free-milling gold in each ore sample. As appreciable free gold was present, attempts were made to recover it by jigging. The jig tailing was then reground and tabled for concentrating the remaining values associated with sulphide minerals. The latter treatment fell short of recovering all the residual gold, probably because some of it is associated with graphite. This led to investigation of flotation as a possible means to recover all the gold-bearing constituents. In a subsequent series of tests, the response of the ore to cyanidation under various conditions was investigated.

Since it was found in the preceding tests that the four ore samples, treated separately, gave almost identical results, these were combined for a final test using the best features found previously. The procedure incorporated jigging, amalgamation, flotation and cyanidation.

DETAILS OF INVESTIGATION

Amalgamation

A 1000-g sample was cut from each ore lot and crushed to minus 20 mesh. The resulting products were amalgamated separately for 1 hour using 10 ml of mercury and 1 g of lime. The results shown in Table 3 were obtained.

TABLE 3

Result of Amalgamation

Sample	Product	Assays* oz/ton Au	Distribution % Au
#1	Amalgam	0.04	50.0
	Residue	0.04	50.0
	Feed	0.08	100.0
#2	Amalgam	0.55	78.6
	Residue	0.015	21.4
	Feed	0.07	100.0
#3	Amalgam	1.16	71.2
	Residue	0.47	28.8
	Feed	1.63	100.0
#4	Amalgam	0.02	66.6
	Residue	0.01	33.3
	Feed	0.03	100.0

*From Internal Report MS-AC-70-211.
Note: Amalgam assays were calculated by difference and expressed in oz/ton of amalgamation feed.

Gravity Concentration

A 4,000-g sample was riffled out of each lot of crushed ore (minus 14 mesh) and fed to laboratory jig. After reducing the jig tailings to minus 65 mesh by stage grinding, these were tabled separately. The combined results of jigging and tabling are given in Table 4.

TABLE 4

Results of Gravity Concentration

Sample	Product	Weight %	Assays* oz/ton Au	Distribution % Au
#1	Jig conc	7.9	0.40	37.0
	Table conc	2.5	1.09	31.8
	Table tailing	89.6	0.03	31.2
	Feed (calcd)	100.0	0.09	100.0
#2	Jig conc	6.5	0.38	49.3
	Table conc	3.5	0.47	32.7
	Table tailing	90.0	0.01	18.0
	Feed (calcd)	100.0	0.05	100.0
#3	Jig conc	5.1	22.38	59.5
	Table conc	3.1	20.62	33.3
	Table tailing	91.8	0.15	7.2
	Feed (calcd)	100.0	1.92	100.0
#4	Jig conc	6.4	0.45	72.0
	Table conc	4.1	0.22	22.5
	Table tailing	89.5	0.0025	5.5
	Feed (calcd)	100.0	0.040	100.0

*From Internal Report MS-AC-70-211.

Flotation

2000-g samples from each lot of ore were ground for 30 minutes and floated using the following procedure.

TABLE 5

Reagents and Conditions of Flotation

Operation	Time min	Reagents*	lb/ton	pH
Conditioning	3	Xanthate 301	0.05	8.1
Rougher flotation	20	Xanthate 301** Dowfroth 250	0.15 0.10	8.2

*Added by stages at 5-minute intervals.
**Sodium Secondary Butyl Xanthate.

Both the flotation concentrate and tailing from each test were analyzed for gold, and screen tests were carried out on representative combined products. The results are summarized in Table 6.

TABLE 6

Results of Bulk Flotation

Sample	Product	Weight %	Assays* oz/ton Au	Distribution % Au
#1 (87% -200 m)	Au conc	21.5	0.28	90.5
	Flot tailing	78.5	0.008	9.5
	Feed (calcd)	100.0	0.067	100.0
#2 (86% -200 m)	Au conc	33.4	0.14	95.9
	Flot tailing	66.6	0.003	4.1
	Feed (calcd)	100.0	0.049	100.0
#3 (75% -200 m)	Au conc	28.3	5.48	99.2
	Flot tailing	71.7	0.017	0.8
	Feed (calcd)	100.0	1.56	100.0
#4 (70% -200 m)	Au conc	16.5	0.20	95.1
	Flot tailing	83.5	0.002	4.9
	Feed (calcd)	100.0	0.035	100.0

*From Internal Report MS-AC-70-163.

Additional flotation tests were made to determine if graphite, sufficiently low in gold content, could be eliminated by selective flotation using only kerosene and a frother (pine oil). However, gold loss in the graphite concentrates was too high, as shown by the following calculated collective results for the four ore lots.

TABLE 7

Results of Graphite Selective Flotation

Product	Weight %	Assays* oz/ton Au	Distribution % Au
Graphite conc	5.4	1.34	17.0
Cleaner tailing	5.1	0.10	1.2
Flot tailing	89.5	0.39	81.8
Feed (calcd)	100.0	0.43	100.0

*From Internal Report MS-AC-70-163.

Cyanidation

Three series of cyanidation tests were conducted on the ore samples. In every test, a 1000-g sample was cyanided in a solution maintained at a concentration of 1.5 lb NaCN/ton and 1.0 lb CaO/ton. The liquid to solids ratio was 2:1. The other conditions were varied as follows:

TABLE 8

Cyanidation Variables

Series	Grinding Time min	Agitation Period hr
I	30	48
II	30	24
III	20	24

The results of the cyanidation tests are shown in Table 8 along with the amounts of reagents consumed during the process.

TABLE 9

Results of Cyanidation

Test Series	Sample	Reagents Consumed lb/ton of ore		Residue Assay* oz/ton Au	Extraction** % Au
		NaCN	CaO		
I	#1	1.1	3.9	0.0025	96.9
	#2	0.6	3.6	0.0025	96.7
	#3	1.2	3.1	0.015	99.1
	#4	0.4	2.1	0.0020	93.3
II	#1	0.6	3.8	0.0025	96.9
	#2	0.6	3.3	0.0025	96.7
	#3	0.7	3.0	0.016	99.0
	#4	0.4	1.9	0.0025	91.7
III	#1	0.8	3.4	0.0025	96.9
	#2	0.7	3.4	0.0025	96.7
	#3	0.7	2.8	0.019	98.8
	#4	0.4	2.3	0.0012	96.0

*From Internal Report MS-AC-70-163.
**Calculated by difference.

Integrated Test on Combined Ore

This test was made on a 4,500-g sample composed of equal fractions from each of the four ore lots. The procedure included jigging, amalgamation and cyanidation stages, as illustrated in Figure 3.

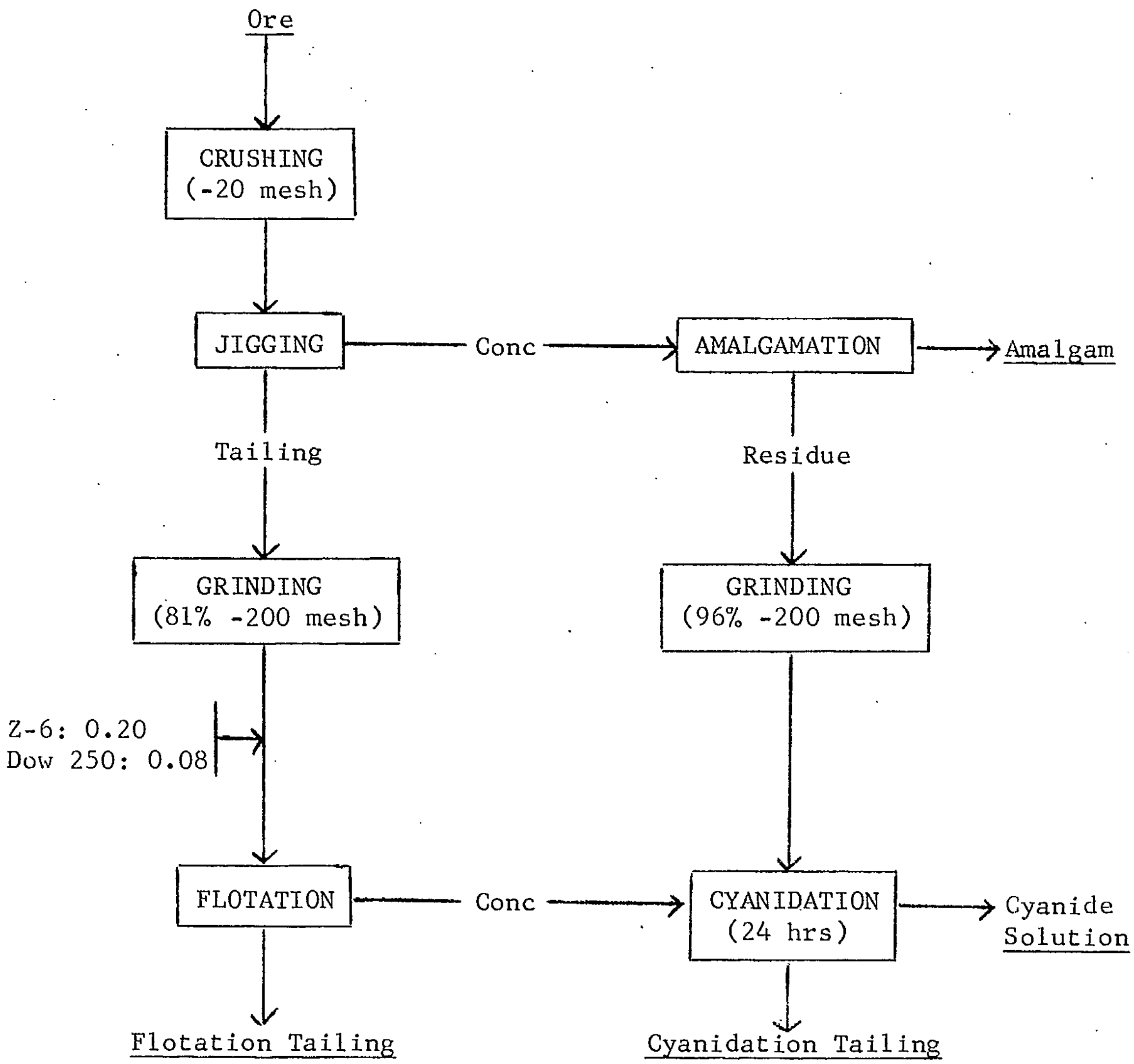

Figure 3 - Flowsheet I

In order to establish a metallurgical balance for each operation of the above test, samples were taken at various points in the circuit and assayed for gold and silver. The following metal distribution could then be calculated.

TABLE 10

Results of Jigging, Amalgamation, Flotation and Cyanidation

Operation	Product	Weight %	Assays* oz/ton		Distribution %		Recovery %	
			Au	Ag	Au	Ag	Au	Ag
Jigging	Conc Tailing	5.4 94.6	5.32 0.16	3.80 0.05	65.5 34.5	81.2 18.8	65.5 34.5	81.2 18.8
	Feed (calcd)	100.0	0.44	0.31	100.0	100.0	100.0	100.0
Amalgamation	Amalgam** Residue	- 5.4	5.26 0.06	3.60 0.20	98.9 1.1	94.7 5.3	64.8 0.7	77.7 3.5
	Feed (calcd)	5.4	5.32	3.80	100.0	100.0	65.5	81.2
Flotation	Conc Tailing	13.3 86.7	1.16 0.001	0.37 0.001	99.5 0.5	98.4 1.6	34.3 0.2	18.5 0.3
	Feed (calcd)	100.0	0.16	0.05	100.0	100.0	34.5	18.8
Cyanidation	Pregnant sol'n*** Residue	- 18.7	0.38 0.04	0.20 0.12	90.5 9.5	62.5 38.5	31.7 3.3	13.8 8.2
	Feed (calcd)	18.7	0.42	0.32	100.0	100.0	35.0	22.0
Total recovery (amalgam + cyanide solution)							96.5	91.5

*From Internal Report MS-AC-70-376.
**Amalgam assay expressed in oz/ton of amalgamation feed.
***Calculated and expressed in oz/ton of cyanidation feed.

CONCLUSIONS

Preliminary testwork carried out on each of four samples showed that they all responded similarly to the various methods of concentration investigated, namely, amalgamation, gravity, flotation and cyanidation. It was found that:

(1) an appreciable portion of the gold (50% to 70%) was free-milling;
(2) gravity concentration (jigging and tabling) succeeded in recovering these liberated values, but not the remaining attached gold (with final tailing containing from 6% to 31% of the total gold depending on the samples);
(3) both flotation and straight cyanidation resulted in excellent gold recoveries (91% to 99%).

A confirmatory test, on a composite sample prepared by mixing equal parts from the four samples, was done to simulate plant practice using the flowsheet developed from the investigative testwork. This included a jigging and amalgamation step to recovery free-milling values, supplemented by flotation for recovering the residual gold and silver which were then extracted by cyanidation. This procedure gave total recoveries of 96.5% for the gold and 91.5% for the silver. It has the advantage of greatly reducing the size of a cyanidation plant as only the flotation concentrate and amalgamation residue need to be cyanided.

ACKNOWLEDGEMENT

The writers wish to acknowledge the assistance received in this investigation from members of the Mineral Sciences Division, namely, D.R. Owens for the mineralogical examination, P. Palombo for the spectrographic analysis, P. Lanthier, B. Kobus, R. Sabourin, J. Graham and C. Derry for the chemical analyses.

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