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O T T A W A June 14th, 1940.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 856.

Gold Ore from the McMarmac Red Lake
Gold Mines Limited, McKenzie Island,
Ontario.

J. F Kostash

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
—
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Shipment:

Three lots of gold ore were received on November 7th, 1939, from the McMarmac Red Lake Gold Mines Limited, McKenzie Island, Ontario. The shipment was submitted by M. F. Fairlie, Managing Director, McKenzie Red Lake Gold Mines Limited, 507 National Building, Bay Street, Toronto, Ontario.

The shipment consisted of the following lots of ore:

Lot No. 1, weight 404 pounds, is a representative sample taken from the ore dump. It is naturally somewhat diluted by development rock, but nevertheless may be more typical of actual mill feed than Lot No. 2.

Lot No. 2, weight 648 pounds, is a bulk sample taken exclusively from good oreshoots underground. This was done deliberately in order to ensure the inclusion of any minerals which might create trouble in metallurgical treatment.

Lot No. 3, weight 21½ pounds, is a special sample taken underground, containing a high percentage of arsenopyrite.

Characteristics of the Ore:

Six polished sections of each lot of ore were prepared and examined microscopically for the purpose of determining the character of the ore.

Lot No. 1.

Gangue Minerals -

The gangue consists essentially of siliceous, greenish-grey rock with abundant carbonate as fine disseminated grains and narrow stringers.

Metallic Minerals -

Metallic minerals are distributed unevenly and rather sparsely throughout gangue. Pyrite, which preponderates, is disseminated as medium to fine irregular grains and small masses containing occasional

inclusions of gangue. Pyrrhotite, the next most abundant ore mineral, occurs as irregular disseminated grains, medium to fine in size. A minor amount of arsenopyrite is sporadically distributed through gangue as medium to fine subhedral crystals and irregular grains, in some places intimately admixed with pyrite. Small quantities of sphalerite and chalcopyrite are present as medium to small irregular grains, often occurring together in gangue. Tiny irregular particles of two anisotropic grey minerals, which resemble ilmenite and hematite, are locally present.

Two tiny rounded grains of native gold are visible in the sections. Both occur alone in gangue and they are respectively 24 and 14 microns in size.

Lot No. 2.

Since the sections of this sample are essentially the same as those of Lot No. 1, both as to gangue and to metallic minerals, they will not be further described except as to gold content. Eight tiny grains of native gold, ranging from 30 microns down to 2 microns in size, were observed in the sections. All occur alone in gangue.

Lot No. 3.

The ore in these sections is also essentially the same as that in the previous two lots, with the following exceptions: (1) Arsenopyrite replaces pyrite as the predominant metallic mineral, the approximate order of decreasing abundance being: arsenopyrite, pyrite, pyrrhotite, sphalerite, chalcopyrite, and

native gold; (2) neither ilmenite nor hematite was visible; and (3) native gold is much more abundant, some 90 particles being observed and measured. The modes of occurrence and grain sizes of the native gold are shown in the following table:

Grain Sizes and Modes of Occurrence of the Native Gold.

MESH	Alone in gangue, per cent	Associated with arsenopyrite, per cent		Associated with pyrite, per cent		Associated with pyrrhotite, per cent		TOTALS, per cent
		Within	Against	Within	Against	Within	Ag'nst	
+ 400			5.3					5.3
- 400 + 560	8.8		4.1				1.8	14.7
- 560 + 800	14.9		5.8		3.1		1.3	25.1
- 800 +1100	14.5	1.9	6.5	1.0	2.2		1.6	27.7
-1100 +1600	15.6	0.7	4.4	0.8		1.6		23.1
-1600 +2300	1.0	1.4	0.5			0.9		3.8
-2300			0.3					0.3
Totals	54.8	4.0	26.9	1.8	5.3	2.5	4.7	100.0
		30.9		7.1		7.2		

Sampling and Assaying:

The ores were crushed and sampled by the standard methods. The assays were as follows:

	Lot No. 1.	Lot No. 2.	Lot No. 3.
Gold, oz./ton -	1.07	1.46	10.38
Silver, " -	0.11	0.09	0.12
Arsenic, per cent -	0.08	0.11	2.11
Iron, " -	4.52	4.32	4.51
Copper, " -	Trace.	Trace.	Trace.
Sulphur, " -	0.53	0.50	1.94

Results of Experimental Tests:

The research procedure on this ore consisted of:

(1) Straight cyanidation of the ore.

(2) Cyanidation of the ore, followed by flotation

and cyanidation of the roasted concentrates.

(3) Concentration of the ore by jig, flotation, and corduroy strakes; and cyanidation of the strake tailings.

While the investigations were being conducted along the second method of treatment, a request was received from J. L. Ramsell, the resident manager of the McKenzie Red Lake Gold Mines Limited, McKenzie Island, Ontario, to investigate the gold recovery by flotation and corduroy strakes, obtaining a high-grade concentrate for shipment to a smelter, and a reasonable tailing. The third method mentioned above comprises this work.

The ore is somewhat refractory in nature; 83 and 69 per cent of the gold in the ore in Lots Nos. 1 and 2, respectively, were extracted by straight cyanidation.

Treating the ore by the method (2) above, flotation tailings assaying from 0.021 to 0.03 ounce gold per ton were obtained on Lot No. 1 ore. Flotation tailings from Lot No. 2 assayed from 0.035 to 0.065 ounce gold per ton. By roasting the flotation concentrates and cyaniding the calcines, gold extractions were increased to 93 per cent on Lot No. 1 ore and 91.5 to 92.5 per cent on Lot No. 2 ore. Charcoal added during the roasting operation increased the extraction by about 1 per cent.

Concentrating the ores by jig, flotation, and corduroy strakes, high-grade concentrates were obtained which contained about 29 ounces of gold per ton. The

concentrates contained 85 per cent and 89.7 per cent of the gold in Lots Nos. 1 and 2 respectively. The ratios of concentration were 32.2:1 for Lot No. 1 and 22.1:1 for Lot No. 2. The flotation middlings carried from 1.5 to 2 ounces of gold per ton; part of this gold would be recovered in mill practice, thus increasing the recovery.

By including the flotation middlings with the concentrates, the recoveries would be increased to 91.2 per cent for Lot No. 1 ore and 93 per cent for Lot No. 2 ore, but the grade of concentrates would be lowered to about 15 ounces of gold per ton and the ratio of concentration would be lowered to about 13 into 1.

Cyaniding the strake tailings increased the recoveries. The cyanide tailings contained about 0.04 ounce of gold per ton.

DETAILS OF EXPERIMENTAL TESTS:

The details of the experimental work follow:

PART I. - TESTS ON LOT NO. 1 ORE.

Straight Cyanidation.

Test No. 1.

Samples of ore were ground with lime and sodium cyanide to 94.9 and 98.5 per cent minus 200 mesh. During the agitation of the pulp, sodium cyanide and lime were kept at about 1.0 and 0.2 pound per ton of solution, respectively.

(Continued on next page)

(Test No. 1, cont'd) -

Summary of Results:

(Feed, Au 1.07 oz./ton)

	1-A	1-B	1-C	1-D
Fineness of grind -200 mesh, %	94.9	94.9	98.5	98.5
Dilution (liquid to solid)	1.5:1	1.5:1	1.5:1	1.5:1
Agitation period, hours	24	48	24	48
Titration NaCN lb./ton of solution	1.00	0.82	1.06	0.96
" CaO " " "	0.12	0.14	0.14	0.16
NaCN consumed lbs./ton of solids	1.50	1.77	1.61	1.76
CaO " " " "	5.7	7.7	7.1	8.7
Cyanide Tailing Au: oz./ton	0.165	0.16	0.165	0.16
Extraction of gold, per cent	84.6	85.0	84.6	85.0

The above results indicate that nearly all the recoverable gold is extracted within 24 hours of agitation, by straight cyanidation. The gold remaining in the cyanide tailing is probably associated with the sulphide minerals, presumably arsenopyrite, and pyrite, and is quite refractory.

Jig Concentration and Amalgamation.

Test No. 2.

This test was carried out to determine the amount of free gold which could be recovered by jig concentration and amalgamation of the jig concentrate.

A sample of the ore was ground to 81.3 per cent minus 200 mesh, and passed over a jig. The concentrate was reground and amalgamated. The results were as follows:

(Test No. 2, cont'd) -

Results:

Product	Weight per cent	Gold: Assay oz./ton	Gold: Distribution per cent	Ratio of conc.
Feed	100.00	1.07	100.0	
Jig. Conc.	2.16	15.55*	31.4	46.3:1
" Tail.	97.84	0.75	68.6	
Amalg. Tail.	2.16	0.785		

* Calculated.

By jigging and amalgamation of the jig concentrate, an extraction of 29.8 per cent of the gold in the ore was obtained.

Cyanidation Followed by Flotation and Cyanidation of Roasted Concentrate.

Test No.3.

A sample of ore was ground with sodium cyanide and lime. The pulp was agitated 24 hours at 1.5 into 1 dilution (liquid to solid ratio). During agitation the sodium cyanide and the lime were kept at about 1.0 and 0.2 pound per ton of solution, respectively.

Results of Cyanidation Test:

Assay Gold oz./ton		Extraction, per cent	Reagents Consumed, lb./ton of Solids		Final Titration, lb./ton of solution	
Feed	Tailing		NaCN	CaO	NaCN	CaO
1.07	0.17	84.1	1.01	6.1	1.06	0.22

(continued on next page)

(Test No. 3, cont'd) -

Screen Test on Cyanide Tailing:

Mesh	Per Cent
- 65 + 100	0.8
- 100 + 150	3.8
- 150 + 200	13.6
- 200	81.8
	100.0

The cyanide tailing was thoroughly washed and then treated by flotation at 22 per cent solids, as follows:

Reagents used	lbs./ton of solids
Conditioned 15 minutes with	
Sodium hydroxide	2.75
Potassium amyl xanthate	0.032
Conditioned 10 minutes with	
Copper sulphate	1.25
Floated with	
Potassium amyl xanthate	0.113
Pine oil	0.124

The rougher concentrate was cleaned by refloating, no additional reagents being used.

Results of Flotation Test:

Products	Weight per cent	Gold Assay oz./ton	Gold Distribution Per cent	Ratio of conc.
Flot.Feed (Cy.Tail.)	100.00	0.17	100.0	
Flot.Conc.	5.18	2.80*	85.3	19.3:1
" Midd.	3.84	0.15	3.4	
" Tail.	90.98	0.021	11.3	

* Calculated value.

The flotation concentrate was roasted in an electric muffle furnace for 3 hours to a temperature of 550°C. and then kept at that temperature for 3 hours longer. During roasting there was free access of air into the furnace, hence it may be considered that the roasting took place in an oxidizing atmosphere.

The calcine was ground, filtered, washed, and cyanided. During agitation, sodium cyanide and lime were kept at about 1.0 and 0.2 pound per ton of solution, respectively.

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(Test No.3, cont'd). -

Loss in weight due to roasting, per cent	3.4
" " " " " dissolution during grinding, per cent	3.6

Results of Cyanidation of Calcine:

Agitation hrs.	Dilution, Liquids to solids	Assay, gold, oz./ton Feed	Assay, gold, oz./ton Tailing	Extraction, per cent	Reagents consumed, lb./ton of solids NaCN	Reagents consumed, lb./ton of solids CaO	Final Titration, lb./ton of solution NaCN	Final Titration, lb./ton of solution CaO
24	2:1	2.66	1.00	62.4	4.40	3.7	1.10	0.22
48	2:1	2.66	0.97	63.5	4.82	3.7	1.00	0.30

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Test No. 4

Samples of ore were ground with cyanide and lime. The pulp was agitated 24 hours at 1.5 into 1, dilution.

Results of Cyanidation:

Assay, gold, oz./ton Feed	Assay, gold, oz./ton Tailing	Extraction, per cent	Reagents Consumed, lb./ton of solids NaCN	Reagents Consumed, lb./ton of solids CaO	Final Titration, lb./ton of solution NaCN	Final Titration, lb./ton of solution CaO
1.07	0.18	83.2	0.84	5.2	1.04	0.26

Reducing power of Cy. Solution - 80 cc. N/10 $KMnO_4$/litre.

Screen Test on Cyanide Tailing:

Mesh	Per Cent
+ 65	0.1
- 65 + 100	2.0
- 100 + 150	6.1
- 150 + 200	10.1
- 200	81.7
	100.0

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(Test No. 4, cont'd) -

The cyanide tailing was thoroughly washed and treated by flotation as follows:

Flotation of Cyanide Tailing at 30 per cent solids.

Reagents Used	lb./ton of solids A	B
Conditioned 20 minutes with		
Soda ash	2.0	
Sodium hydroxide		1.33
Potassium amyl xanthate	0.03	0.03
Conditioned 10 minutes with		
Copper sulphate	1.0	1.0
Floated with		
Potassium amyl xanthate	0.067	0.067
Pine oil	0.083	0.041

The rougher concentrates were cleaned by refloating. No additional reagents were used.

Results of Flotation Tests.

Products	Weight, per cent	Gold: Assay, oz./ton	Gold: Distribution, per cent	Ratio of conc.
Flot.Feed (Cy.Tail)	100.00	0.18	100.0	
Flot.Conc.	1.76	7.61*	74.4	56.8:1.
" Midd.	1.79	1.23	12.2	
" Tail.	96.45	0.025	13.4	
Flot.Feed (Cy.Tail)	100.00	0.18	100.0	
" Conc.	1.69	8.18*	76.8	59.2:1.
" Midd.	1.25	1.01	7.0	
" Tail.	97.06	0.03	16.2	

* Calculated.

The flotation concentrates were combined (calculated feed: Au 7.88 oz./ton) and roasted in an electric muffle furnace for 4 hours to a temperature of 550°C. and kept at that temperature for two hours longer. There was free access of air during roasting period.

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(Test No. 4, cont'd) -

The calcine (Au: 8.66 oz./ton) was ground to 97.0 per cent minus 325 mesh, filtered, washed and cyanided for 24 hours at 3.2 into 1 dilution.

Loss in weight due to roasting, per cent -- 14.4
" " " " " dissolution during grinding, per cent — 7.8

The loss in weight in this test was higher than in Test No.3 because the flotation concentrates were higher in sulphides.

Results of Cyanidation of Calcine:

Assay, Gold, oz./ton		Extraction, per cent	Reagents consumed, lbs./ton of calcine		Final Titration, lbs./ton of solution	
Feed	Tailing		NaCN	CaO	NaCN	CaO
9.52	1.56	83.6	8.8	9.7	0.95	0.17

The calcine assayed 1.13 per cent arsenic and 2.17 per cent sulphide sulphur.

Gold loss due to roasting was 0.47 oz./ton of concentrate, a loss of 6.0 per cent.

Summary of Gold Recovery:

By straight cyanidation, per cent - 83.2
" cyanidation of calcine, " - 9.9

Total -- 93.1 per cent.

The above total recovery does not include the gold in the middling product, part of which would be recovered in mill practice.

Polished sections of the flotation concentrate were made and examined microscopically for the purpose of detecting any native gold. In sections examined, four grains of free native gold were seen ranging from 15 to 35 microns in size.

Concentration by Flotation and Corduroy Strakes

Test No. 5.

A sample of ore was ground to about 82 per cent minus 200 mesh with 1.5 pounds of soda ash. The pulp was transferred to a flotation cell and 0.067 pound of potassium amyl xanthate and 0.02 pound of pine oil per ton of solids were added. After floating for 8 minutes, 1.0 pound of copper sulphate and 0.033 pound of potassium amyl xanthate were added, and the froth taken off for 7 minutes.

The flotation tailing passed over corduroy strakes.

Results:

Products	Gold				
	Weight, per cent	Assay, oz./ton	distribution, per cent	Ratio of conc.	Gold, oz./ton
Feed	100.00	1.07	100.00		
Flot Conc.	6.00	14.20	79.7	15.8:1	14.37
Strake "	0.33	17.44	5.4		
" Tail.	93.67	0.17	14.9		

pH of flotation solution was 8.5.

Coarse free gold was present in the strake concentrate. In the following tests, a jig was used preceding the flotation to remove the coarse native gold, which, apparently, is too large in size to be floated.

Concentration by Jig, Flotation and Corduroy Strakes, followed by Cyanidation of Strake Tailing.

Tests Nos. 6 and 7.

Samples of ore, ground to 82 per cent minus 200 mesh, were concentrated by jigging. The jig tailings were treated by flotation, using the following reagents,-

Reagents	lb./ton of solids Test No.6	Test No.7
Conditioned 20 minutes with		
Soda ash	1.5	1.5
Reagent #301		0.033
Potassium amyl xanthate	0.033	
Conditioned 10 minutes with		
Copper sulphate	1.0	1.0
Floated with		
Reagent #301		0.067
Potassium amyl xanthate	0.067	
Pine oil	0.041	0.041

The flotation tailings passed over corduroy strakes.

The flotation concentrates were cleaned by re-floating.

A portion of the strake tailing was concentrated by Haultain super panner. Several fine particles of free native gold were present in the panner concentrate. The sulphide minerals were mostly pyrrhotite.

Results:

Test No.	Products	Gold: Weight, per cent	Gold: Assay, oz./ton	Gold: Distribution, per cent	Ratio of conc.	Gold, oz./ton	Gold, oz./ton
6	Feed	100.00	1.10	100.00			
	Jig Conc.	0.22	103.65	20.7	32.2:1	29.96	14.97
	Flot. "	2.62	26.60	63.4			
	Strake "	0.27	2.59	0.7			
	Flot.Midd.	3.61	2.05	6.7			
	Strake Tail.	93.28	0.10	8.5			
7	Feed	100.00	1.06	100.0			
	Jig.Conc.	0.27	85.53	21.7	32.2:1	29.28	15.61
	Flot. "	2.51	26.50	62.5			
	Strake "	0.31	2.85	0.8			
	Flot.Midd.	3.13	2.11	6.2			
	Strake Tail.	93.78	0.10	8.8			

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(Tests Nos. 6 & 7, cont'd) -

The strake tailings were combined, and a portion was cyanided at a dilution of 1.5:1, liquid to solid ratio.

Results of Cyanidation of Strake Tailings:

Agitation, hrs.	Assay, Gold, oz./ton		Extraction, per cent	Reagent Consumed, lb./ton of solids:		Final Titration, lb./ton of solution	
	Feed	Tailing		NaCN	CaO	NaCN	CaO
24	0.10	0.03	70.0	0.76	3.0	0.96	0.12

The cyanide tailing and the strake tailing were sized by Haultain Infrasizer, and the products assayed for gold.

Analyses of Infrasized Products:

Mesh or Microns	24-hr. Cy. Tail.			Strake Tail.		
		Gold			Gold	
	Weight, per cent	Assay, oz./ton	Distribution, per cent	Weight, per cent	Assay, oz./ton	Distribution, per cent
+200 mesh	17.94	0.06	39.7	18.35	0.23	45.4
-200 mesh +56 microns	5.66	0.04	8.3	4.22	0.19	8.6
-56 +40 "	18.82	0.015	10.4	18.18	0.075	14.6
-40 +28 "	15.69	0.01	5.8	14.70	0.04	6.3
-28 +20 "	12.20	0.01	4.5	12.97	0.03	4.2
-20 +14 "	7.05	0.01	2.6	8.53	0.04	3.7
-14 +10 "	5.05	0.015	2.8	6.07	0.04	2.6
-10	17.59	0.04	25.9	16.98	0.08	14.6
Total	100.00	0.027	100.0	100.00	0.093	100.0

Over 68 per cent of the gold in the strake tailing is in plus 40 micron product; about 75 per cent of that gold was extracted by cyanidation.

Test No. 8.

In this test, the concentration procedure was similar to that of Test No.6, with the exception that the rougher flotation concentrate was not cleaned by refloating. The jig, flotation and the strake concentrates were combined for assay.

Results:

Products	Weight per cent	Gold Assay oz./ton	Gold Distribution per cent	Ratio of conc.
Feed	100.00	1.07	100.0	
Concentrates	5.87	16.62	91.2	17.0:1.
Strake Tail	94.13	0.10	8.8	

The strake tailings were agitated in cyanide and lime solutions at 1.5 into 1 dilution.

Cyanidation of Strake Tailing:

Agitation, hrs.	Assay, gold, oz./ton Feed	Tail	Extraction, per cent	Reagents consumed, lb./ton of solids NaCN	CaO	Final Titration, lb./ton of solution NaCN	CaO
8	0.10	0.055	45.0	0.77	2.8	0.82	0.08
16	0.10	0.055	45.0	0.86	2.9	0.76	0.10
24	0.10	0.04	60.0	1.09	3.1	0.98	0.10

Summary of Results of Tests Nos. 6, 7, and 8.

Concentrating the ore by jig, flotation and corduroy strakes (Tests Nos. 6 & 7), concentrates were obtained containing about 85 per cent of the gold in the ore. The middlings, which assayed over 2 ounces of gold per ton, contained from 6.2 to 6.7 per cent of the gold. By including

middlings with the concentrates, the recovery would be increased to 91.2 per cent, the product would carry about 15 ounces of gold per ton, and the ratio of concentration would be about 13 into 1.

Cyaniding the strake tailings, the recoveries were increased by 4.2, 4.2 and 5.6 per cent for 8, 16 and 24 hours of agitation, respectively.

PART II. - TESTS ON LOT NO.2 ORE.

Straight Cyanidation.

Test No.1.

Samples of ore were ground to 95.6 and 97.9 per cent minus 200 mesh with lime and sodium cyanide. The pulp was agitated at 1.5 into 1 dilution.

Summary:

(Feed, Au 1.46 oz./ton of ore)

	1-A	1-B	1-C	1-D
Fineness of grind, -200 mesh, %	95.6	95.6	97.9	97.9
Agitation Period, hrs.	24	48	24	48
Final Titration, NaCN lb./ton of solution	1.04	1.00	1.10	1.00
" " CaO " " "	0.19	0.20	0.24	0.28
NaCN consumed, lb./ton of solids	1.04	1.30	1.35	1.50
CaO " " " "	6.6	7.6	8.5	9.4
Cyanide Tail, gold oz./ton	0.43	0.415	0.425	0.415
Extraction, per cent	70.5	71.6	70.9	71.6

The above results show that a very small amount of gold is dissolved after 24 hours of agitation.

Cyanidation followed by Flotation and Cyanidation of the Roasted Concentrates.

Test No. 2.

Samples of ore were ground to 84.1 per cent minus 200 mesh with sodium cyanide and lime. The pulps were agitated 24 hours at 1.5 into 1 dilution.

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(Test No. 2, cont'd) -

Cyanidation of the Ore:

Assay, Gold, oz. per ton		Filtration, per cent	Reagents Consumed, lb./ton of Solids		Final Titration, lb./ton of solution	
Feed	Tailing		NaCN	CaO	NaCN	CaO
1.46	0.45	69.2	0.72	5.3	1.12	0.25

Reducing power of cyanide solution was

60 cc. of N/10 $KMnO_4$/litre.

The cyanide tailings were thoroughly washed and treated by flotation at 30 per cent solids.

Reagents	lb./ton of solids A	B
Conditioned 20 minutes with		
Soda ash	2.0	2.0
Potassium amyl xanthate	0.033	
Conditioned 10 minutes with		
Copper sulphate	1.0	1.0
Floated with		
Potassium amyl xanthate	0.067	0.10
Pine oil	0.041	0.041

The rougher concentrates were combined and cleaned by refloating. No additional reagents were used.

Results of Flotation of Cyanide Tailing:

Products	Weight, per cent	Gold Assay, oz./ton	Gold Distribution, per cent	Ratio of conc.
Flot. Feed (Cy. Tail.)	100.00	0.45	100.0	
" Conc.	1.63	23.10*	83.7	61.3:1.
" Midd.	1.13	1.99	5.0	
" Tail —A.	48.58	0.04	4.3	
" " —B.	48.66	0.065	7.0	

* Calculated.

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(Test No. 2, cont'd) -

Adding a portion of the potassium amyl xanthate to the conditioning stage seems to improve the recovery of gold by flotation.

The flotation concentrate was roasted in an electric muffle furnace for three hours to a temperature of 550°C. and kept at that temperature for three hours longer. Roasting was conducted under free access of air into the furnace.

The calcine was reground to 99 per cent minus 325 mesh, filtered, washed, and cyanided. After 24 hours of cyaniding, the pulp was filtered and the cake was thoroughly washed and cyanided for another 24 hours.

Per cent loss in weight due to roasting	15.9
" " " " " " " dissolution during grinding	3.7

Cyanidation of Calcine:

	Dilution, Liquid to Solid	Assay, Gold, oz./ton Feed	Assay, Gold, oz./ton Tail	Extraction, per cent	Reagents Consumed, lb./ton of solids NaCN	Reagents Consumed, lb./ton of solids CaO	Final Filtration, lb./ton of Solution NaCN	Final Filtration, lb./ton of Solution CaO
1st stage	4.3:1	25.81	11.43	55.7	2.86	8.1	1.90	0.47
2nd "	4.8:1	11.43	8.60	24.8	1.92	1.6	0.85	0.37

The recovery of gold in the calcine for 48 hours' agitation was 66.7 per cent. The cyanide tailing (calcine) assayed 0.72 per cent sulphur and 2.67 per cent arsenic.

Gold loss due to roasting was 2.33 oz./ton of raw concentrate, a loss of 10.1 per cent.

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(Test No. 2, cont'd) -

Summary of Results:

Recovery by straight cyanidation, per cent	69.2
" " 48-hr. cyanidation of calcine, ""	15.5
Total recovery, per cent	84.7

The above total recovery does not include the gold in the middling product, part of which would be recovered in mill practice.

Microscopic examination of the polished section prepared from the 48-hr. cyanide tailing of the calcine showed one tiny grain of free native gold, 10 microns in size.

Test No. 3.

A sample of ore, ground to 84.1 per cent minus 200 mesh, was concentrated by jig and corduroy strakes to remove coarse free gold. The jig and strake concentrates were reground and amalgamated; 29.3 per cent of the gold in the ore was extracted by amalgamation.

The amalgamation tailing and the strake tailing were cyanided for 24 hours. After 24 hours' agitation the pulp was filtered, washed, and treated by flotation using the following reagents:

Reagents	lb./ton of solids
Conditioned 20 minutes with	
Soda ash	2.0
Potassium amyl xanthate	0.10
Conditioned 10 minutes with	
Copper sulphate	1.0
Floated with	
Pine oil	0.041

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(Test No. 3, cont'd) -

The rougher concentrate was cleaned by refloating.

Flotation of Cyanide Tailing:

Products	Weight, per cent	Gold: Assay, oz./ton	Gold: Distribution, per cent	Sulphur, per cent	Arsenic, per cent	Ratio of Conc.
Flot.feed (Cy.tail)	100.00	0.42	100.0			
Flot.Conc.	1.30	26.68	83.5	24.63	13.23	76.9:1.
" Midd.	1.12	3.10	8.3			
" Tail.	97.58	0.035	8.2			

One small grain of free native gold, 20 microns in size, was seen in the three polished sections prepared from the above flotation concentrates.

Test No. 4

A concentrate obtained by flotation of cyanide tailing was panned by means of Haultain superpanner. Three particles of native gold were removed and assayed to determine the gold-silver ratio. The Au:Ag ratio was 15:1. The silver content is small, hence it cannot be the silver which makes the gold refractory to cyanide solution.

Test No. 5.

This test was conducted to determine whether the gold, insoluble in cyanide solution, is tarnished.

Ore, ground to 84 per cent minus 200 mesh, was concentrated by jig and strakes. The concentrates were amalgamated. The strake tailing and the amalgamation tailing were cyanided for 24 hours. The cyanide tailing was again concentrated by jig and strakes, and the products panned by means of superpanner.

Three particles of free native gold were observed in the panned products. The gold particles were quite bright.

Roasting of Flotation Concentrates and Cyanidation of the Calcines.

Test Nos. 6 and 7.

Concentrates, obtained by flotation of the cyanide tailings, were treated by roasting in an electric muffle furnace. The furnace was constructed to allow minimum access of air when the door was closed.

In Test No. 7-B, 10 grams of pine charcoal was added to about 106 grams of hot calcine, and given a further roasting treatment.

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(Tests No. 6 & 7, cont'd) -

Roasting of Raw Concentrates:

	6-A	6-B	7-A	7-B
Reducing atmosphere				
1st stage, temp. °C.	295-400	225-400	235-400	235-400
Duration of 1st stage roast, minutes	35	105	35	35
Fuming (reduced atmos.) °C.	400-470	400-470	400-470	400-470
Duration of fuming stage, minutes	40	90	40	40
Free oxidation, door opened 3 inches °C.	470-650	470-650	470-650	470-650
Duration of oxidizing stage, minutes	60	120	60	60
Charcoal added to calcine, gm.				10.0
Reduced atmos. 550-650°C., min.				30
Oxidizing " 600-650°C., min.				60
Total Roasting Time, hours	2¼	5¼	2¼	3-3/4
Calcine, Au oz./ton	28.80	28.18	19.40	20.60
Reduction in weight due to roasting	18.1%	16.5%	14.8%	20.5%
Raw concentrate, Au. oz./ton	24.10	24.10	16.94	16.94
Gold loss due to roasting, oz./ton	0.51	0.57	0.41	0.56
" " " " ", per cent	2.1	2.4	2.4	3.3
Raw concentrate, As, per cent	11.33	11.33	8.28	8.28
Calcine As, " "	2.41	2.22	2.03	2.07
Raw concentrate, Sulphide S, per cent	24.00	24.00	17.10	17.10
Calcine, Sulphide S. " "	0.48	0.15	0.15	0.13
Calcine, Sulphate S. " "	8.06	8.78	6.49	6.58
Calcine, Ag. oz./ton	0.22	0.22		

The calcines, and also a portion of the raw concentrate from Test No.6, were reground, filtered, washed, and treated by cyanidation. Reduction in weight due to dissolution during grinding was as follows:

Test	6-A	—	9.7 per cent
"	6-B	—	13.2 "
"	7-A	—	7.3 "
"	7-B	—	4.1 "

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(Tests No. 6 & 7, cont'd) -

Cyanidation of Calcines and Raw Concentrate:

	Calcine, Test #6-A		Calcine, Test #6-B		Raw Conc., Test #6	Calcine Test #7-A	Calcine Test #7-B
Agitation - hours	48	96	48	96	48	48	48
Grind: -325 mesh, %	99.3	99.3	99.0	99.0	98.0	96.0	98.9
Dilution, liquid to solid	4.9:1	4.5:1	4.7:1	4.8:1	4.2:1	3.6:1	4.4:0
Final Titration:							
NaCN, lb./ton solution	0.90	1.20	0.75	1.15	1.10	1.15	1.00
CaO, " " "	0.15	0.30	0.17	0.30	0.55	0.30	0.40
Reducing power, cc. of N/10 $KMnO_4$	202	308	50	80	133	21	8
Reagents consumed:							
NaCN, lb/ton solids	12.9	12.7	9.9	9.9	4.5	2.8	4.4
CaO, " " "	27.1	29.3	20.8	26.9	14.9	10.0	8.7
Cyanide Feed, Au oz/ton	31.89	31.89	32.46	32.46	24.10	20.91	21.48
" Tail " "	3.76	3.41	4.10	4.08	21.67	3.21	1.54
Extraction, per cent	88.2	89.3	87.4	87.4	10.1	84.6	92.8

69.2 per cent of the gold in the ore was extracted by straight cyanidation. Treating the cyanide tailing by flotation, 83.5 per cent of the gold was in the flotation concentrate. A portion of the gold in the flotation middling would be recovered in mill practice; this would increase the recovery by flotation to about 85 per cent.

Allowing for loss of gold during roasting, a total recovery of 91.5 to 92.5 per cent of the gold in the ore can be obtained by straight cyanidation and cyanidation of the roasted concentrate. Charcoal added during roasting operation increased the extraction by about 1 per cent.

Four polished sections of the cyanide tailing of Test No. 6-B (cyanide tailing from the cyanidation of calcines) were prepared and examined microscopically. The product was quite finely ground. The particles showed very thorough

(Tests Nos. 6 & 7, cont'd) -

roasting and only occasional grains of unoxidized pyrite were seen. A large percentage of the product was composed of porous oxide and only a minor portion was in the form of dense oxides. Several particles of free native gold were present; one, about 45 microns in size, was completely free, and four particles were attached to porous oxides but were exposed. The latter four particles were 10, 7, 5, and 4 microns in size.

Some exceedingly tiny particles, less than a micron in size, were visible in the porous oxides. Even under the highest power of oil immersion lenses these could not be identified, but it is possible that they are tiny gold particles.

The presence of particles of free gold in the cyanide tailings shows that the cause for the failure of at least some of the gold to cyanide cannot be accounted for by assuming that it has not been freed.

The cyanide tailings from Tests Nos. 7-A and 7-B were combined (gold content being 2.40 oz. per ton of calcine) and were treated with hydrochloric acid and stannous chloride solution. The object of the acid treatment was to dissolve the oxides of iron and thus free the gold which may be locked up in them. The reduction in weight due to dissolution was 89 per cent. The insoluble product was agitated in a cyanide and lime solution for 48 hours. During agitation the cyanide and lime were kept at about 1.0 and 0.2 pound per ton of solution, respectively.

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(Tests Nos. 6 & 7, cont'd) -

Cyanidation of HCl and $SnCl_2$ Residue.

Cyanide Feed - gold, 21.78 oz./ton of HCl Residue. (calculated value)

Cyanide Tailing - ", 0.90 oz./ton of HCl Residue.

95.9 per cent of the gold in the calcine cyanide tailing was recovered by cyanidation of hydrochloric acid residue.

Concentration by Jig, Corduroy Strakes, and Flotation.

Test No.8.

A sample of ore, ground to 84.4 per cent minus 200 mesh, was concentrated by jig and corduroy strakes. The jig and strake concentrates were reground and amalgamated. The amalgamation tailing and the strake tailings were conditioned 20 minutes with 2.0 and 0.10 pounds per ton of soda ash and potassium amyl xanthate, respectively; and floated with 0.041 pound of pine oil per ton of solids. The flotation concentrate was cleaned by refloating.

Results:

Products	Weight, per cent	Gold: Assay, oz./ton	Gold: Distribution, per cent	Ratio of Conc.
Flot. Feed	100.00	0.858	58.8	
" Conc.	4.93	13.62	46.0	20.3:1
" Midd.	2.17	1.76	2.6	
" Tail.	92.90	0.16	10.2	
Extraction by Amalgamation			41.2*	
Head	100.00	1.46	100.0	

* Calculated.

Test No. 9.

In this test, a sample of ore, ground to 84.4 per cent minus 200 mesh, was concentrated by jigging. The jig tailing was treated by flotation, the flotation tailing passed over the corduroy strakes.

Reagents used for Flotation	lbs./ton of solids
Conditioned 20 minutes with	
Soda ash	1.5
Potassium amyl xanthate	0.033
Conditioned 10 minutes with	
Copper sulphate	1.0
Floated with	
Potassium amyl xanthate	0.067
Pine oil	0.041

The flotation concentrate was cleaned by refloating.

Results:

Products	Weight, per cent	Gold Assay, oz./ton	Gold Distribution, per cent	Ratio of Conc.	Gold oz./ton	Gold oz./ton
Feed	100.00	1.46	100.0			
Jig Conc.	0.75	36.04	18.5			
Flot.Conc.	3.60	28.65	70.8	22.1:1	28.94	18.44
Strake "	0.17	3.72	0.4			
Flot. Midd.	2.83	1.67	3.3			
Strake Tail.	92.65	0.11	7.0			

Samples of strake tailing were agitated in cyanide and lime solutions at 1.5 into 1 dilution.

Cyanidation of Strake Tailing:

Agitation, hrs.	Assay, Gold, oz./ton Feed	Tail	Extraction, per cent	Reagents consumed, lb./ton of Solids NaCN	CaO	Final Titration, lb./ton of solution NaCN	CaO
8	0.11	0.07	36.4	0.62	2.6	0.92	0.12
16	0.11	0.06	45.5	0.80	2.9	0.80	0.10
24	0.11	0.045	59.1	0.80	3.1	0.80	0.07

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(Test No.9, cont'd) -

The 24-hour cyanide tailing was sized by Haultain Infrasizer, and the products assayed for gold.

Analyses of Infrasized Products:

Mesh or Microns	Weight, per cent	Gold Assay, oz./ton	Gold Distribution, per cent
+200 mesh	18.75	0.17	52.1
-200 mesh +56 microns	4.52	0.145	10.7
-56 +40 microns	17.33	0.05	14.2
-40 +28 "	14.85	0.035	8.5
-28 +20 "	13.05	0.01	2.1
-20 +14 "	8.25	0.01	1.4
-14 +10 "	5.72	0.026	2.4
-10 "	17.53	0.03	8.6
Total	100.00	0.061	100.0

The 24-hour cyanide tailing assayed 0.045 oz. of gold per ton. The calculated gold value of the feed to the infrasizer (which is 24-hour cyanide tailing) is 0.061 oz. per ton. This difference in gold value would indicate the presence of free gold.

Summary of Results of Test No.9.

Concentrating the ore by jig, flotation and corduroy strakes, a gold recovery of 89.7 per cent was obtained; the ratio of concentration was 22.1 into 1; and the gold content of the concentrate was 28.94 oz. The flotation middling, which assayed 1.67 oz. gold, contained 3.3 per cent of the gold in the ore. By including the middling with the concentrates, the recovery would be increased to 93.0 per cent, the concentrate would contain 18.44 oz. gold, and the ratio of concentration would be 13.6 into 1.

Cyaniding the strake tailings, the recoveries were increased by 2.7, 3.4 and 4.4 per cent for 8, 16, and 24 hours of agitation, respectively.

Summary and Conclusion

The ore is refractory in nature. By straight cyanidation, extractions of 83 and 69 per cent of the gold in Lot No.1 and Lot No.2, respectively, were obtained, when the ores were ground to about 82 per cent minus 200 mesh. Free native gold was present in the cyanide tailings; microscopic examination of this gold showed that it was not tarnished. Three particles of native gold were removed from Cyanide tailing and assayed for gold and silver. The Au:Ag ratio was 15 into 1. The silver content is small, hence it cannot be assumed that the silver in the gold alloy makes the gold refractory to cyanide solutions.

Treating the cyanide tailings by flotation, flotation tailings were obtained which assayed from 0.021 to 0.03 oz. of gold per ton on Lot No.1 ore, and 0.035 to 0.065 oz. of gold per ton on Lot No.2 ore.

By roasting the flotation concentrates (concentrate from flotation of Cyanide tailing) in an oxidizing atmosphere, extractions of 93.1 and 84.7 per cent of the gold in the ores were obtained on Lot No.1 ore and Lot No.2 ore, respectively. Using a reduced atmosphere during the first half of the roasting period and oxidizing atmosphere during the last half, the extraction of gold in Lot No.2 was increased to about 92 per cent. Charcoal added to the calcine during the roasting operation increased the extraction by about 1 per cent.

Microscopic examination of the polished sections, prepared from the cyanidation tailing of the calcine (Test No. 6-B) showed presence of free native gold; one, about 45 microns in size, was completely free, and four particles were attached to porous oxides, but were exposed. The

presence of particles of free gold in the cyanide tailing shows that the cause for the failure of at least some of the gold to cyanide cannot be accounted for by assuming that it has not been freed.

It may be some substances in the cyanide solutions which retard the dissolution of gold; this factor was not investigated. The reducing powers of the cyanide solution were not high. In Test No. 6-B, the reducing powers were 50 and 80 cc. of N/10 $KMnO_4$ per litre for 48 and 96 hours' agitation, respectively.

The cyanide tailing of the calcine (Tests. Nos. 7-A and B) was treated with a solution of hydrochloric acid and stannous chloride, in order to dissolve the oxides of iron and thus free the gold which may be locked up. By cyaniding the acid residue, 95 per cent of the gold in the calcine cyanide tailing was extracted.

Concentrating the ore by jig, flotation, and corduroy strakes, high-grade concentrates were obtained which assayed about 29 ounces of gold per ton. The concentrates contained 85 and 89.7 per cent of the gold in Lot No.1 and Lot No.2 ores, respectively. The ratios of concentration were 32.2:1 for Lot No.1, and 22.1 for Lot No.2. The flotation middlings carried from 1.5 to 2 ounces gold per ton; part of this gold would be recovered in mill practice, thus increasing the recovery.

By including the flotation middlings with the concentrate, the recoveries would be increased to 91.2 per cent for Lot No.1 ore and 93 per cent for Lot No.2 ore; but the grade of concentrates would be lowered to about 15 ounces of gold per ton of concentrates, and the ratio of concentration would be lowered to about 13:1.

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By cyaniding the strake tailings, the recoveries were increased by 4.2, 4.2 and 5.6 per cent on Lot No.1, and 2.7, 3.4 and 4.4 per cent on Lot No.2, for 8, 16, and 24 hours of agitation, respectively.

With the view of shipping the concentrates to a smelter, the logical flow-sheet would be,- concentration of the ore by jigs, corduroy strakes, and flotation. The economics of amalgamating the jig and blanket concentrates before shipment warrant consideration. The flotation tailing could be stored for future treatment by cyanidation.

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