DIVISION OF
ORE DRESSING AND
METALLURGY

DEPARTMENT OF MINES
CANADA
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Ottawa, August 1st, 1929.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES

Ind. 330

The Recovery of Gold From the Ore of the Belledat Goudreau Mine, Goudreau, Ontario

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Ottawa, July 29th, 1929.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES

Report No. ...

The Recovery of Gold From the Ore of the Belledat-Goudreau Mine, Goudreau, Ontario.

By A.K. Anderson.

Shipment: Ten bags of gold ore, gross weight 1070 lb. were received April 8th, 1929, at the Ore Dressing Laboratories from the Belledat-Goudreau Mine of the Towagmac Exploration Company, Goudreau, Ontario.

Characteristics of the Ore: The ore consisted of quartz gangue, carrying a small amount of iron sulphides and a small amount of graphite as carbonaceous material. Lead sulphide was present in very small amounts.

Purpose of Experimental Tests: The shipment was made to determine the best method to apply for the recovery of the precious metals.

Sampling and Analysis: The entire lot was passed through jaw crushers and rolls until reduced to ¼" and a tenth portion cut out by an automatic sampler. This portion was crushed to 10 mesh and cut through a Jones riffler sampler. Further grinding to pass the finer meshes and passes through the sampler yielded a final sample for assay. This showed the following values: Gold - 1.92 ozs. Silver 0.82 oz per ton.

Experimental Tests: Three distinct methods were employed in making the examination: first, cyanidation, second, concentration by flotation followed by cyanidation of the concentrate and tailing, and third, amalgamation followed by cyanidation of the tailing.

Cyanidation

Test No. 1.

Ore ground to pass 65 mesh, with 50% through 150 mesh was agitated for 48 hours with sodium cyanide solution equivalent in strength to 2.0 lb. KCN per ton. Lime was added at the rate of 5.0 lb. per ton of ore. Ratio of ore to solution was 1:2.

head assay	Gold	-	1.92 ozs per ton
tailing assay	Gold	-	1.19 " " "
extraction		-	38.0%
cyanide consumed		-	0.30 lb/ton ore

Screen Analysis of Tailing

Screen Size	% Weight	Assay Au oz/ton
+150 mesh	50.6	1.02
-150	49.4	1.36

This test shows that cyanidation at this mesh is not successful. As the -150 mesh portion of the tailing is quite high, extremely fine grinding may be necessary.

Test No. 2.

Ore ground to pass 100 mesh was cyanided for 48 hours under conditions similar to those of Test No. 1.

head assay	Gold	-	1.92 ozs per ton
tailing assay	Gold	-	1.29 " " "
recovery		-	32.8 %
cyanide consumed		-	0.50 lb/ton ore

Screen Analysis of Tailing

Screen Size	% Weight	Assay Gold oz/ton
+150 mesh	31.3	1.45
-150 "	68.7	1.22

This test again shows that the ore does not respond to treatment by cyanidation.

Test No. 3. Ore ground to pass 150 mesh was agitated with cyanide solution under the same conditions as Tests 1. & 2.

head assay	Gold	1.92 ozs/ton
tailing	Gold	0.47 " "
extraction		75.6 %
cyanide consumed		0.70 lb/ton ore

Screen Analysis of Tailing

Screen Size	% Weight	Assay Gold oz/ton
+200 mesh	17.7	0.53
-200 "	82.3	0.46

This test shows that with fine grinding, 82% minus 200 mesh, an extraction of 75.6% is obtained. The -200 mesh portion of the tailing still contains considerable gold -, $9.20 a ton.

From the above tests, it appears that straight cyanidation of the ore will not be successful.

Test No. 4.

1000 grams of ore was ground in a porcelain ball mill containing iron balls, and 1000 grams of water, together with soda ash equivalent to 3 lb. per ton of ore.

The pulp was then floated in a Huth laboratory flotation machine with 0.20 lb. potassium Xanthate and 0.06 lb. pine oil per ton of ore. The concentrate was not cleaned.

Flotation Results

Product	% Weight	Assay Gold oz/t.	% Values
flotation concentrate	3.97	30.80	84.7
" tailing	96.03	0.23	15.3

Screen Analysis of Tailing

Product	% Weight	Assay Gold oz/ton
+ 100 mesh	0.5	14.13
- 100 + 150	1.8	1.62
- 150 + 200	16.2	0.24
- 200	81.5	0.12

This test shows that the greater part of the gold is associated with the sulphides and by fine grinding can be concentrated by flotation. The assay value of the minus 200 mesh portion would indicate that fine grinding is important . The high values of the plus 100 mesh portion possibly is due to the presence of free gold.

Concentration & Cyanidation

Test No. 5.

In this test concentrating the values by flotation, followed by cyanidation of the concentrate and of the tailing was studied.

The ore was ground in water, 1:1 dilution together with soda ash equal to 2.0 lb per ton of ore, until approximately 80% passed 200 mesh.

Flotation was carried on in a Denver Sub A type machine, using 0.20 lb. amyl xanthate, 0.10 lb. wood creosote, 0.10 wood tar and 0.08 lb. pine oil per ton. The concentrate was not cleaned.

After flotation, the concentrate and tailing were de-watered and cyanided for 48 hours. The concentrate was agitated with a 5.0 lb per ton cyanide solution and 5.5 lb. lime per ton added. The tailing was cyanided with a 2.0 lb. cyanide solution together with 5.0 lb. lime.

Flotation Results

Product	% Weight	Assay oz/ton Gold	Silver	% Values Gold	Silver
Heads		1.92	0.82		
flotation concentrate	4.2	28.66	16.18	95.4	92.2
" tailing	95.8	0.06	0.06	4.6	7.8

Cyanidation of Flotation Concentrate

Product	Assay oz/ton		% Extraction	
	Gold	Silver	Gold	Silver
heads,	28.66	16.18		
tailing	6.88	7.20	75.9	55.5

Cyanidation of Flotation Tailing

Product	Assay oz/ ton		% Extraction	
	Gold	Silver	Gold	Silver
heads	0.06	0.06		
tails	0.005	0.015	91.7	75.0

This test shows that a high recovery of the gold and silver in the ore can be secured by flotation, 95.4% of the gold and 92.2% of the silver in a concentrate assaying 28.66 oz. and 16.18 oz. respectively.

However, on attempting to recover the values contained in this product by cyanidation, a low percentage of extraction is recorded, 75.9% of the gold and 55.5% of the silver.

The cyanidation of the flotation tailing is quite worthy of notice. Although the value is low, $1.20 per ton, no difficulty is experienced in reducing this to 10¢, or a recovery of 91.7% of the gold contained in this product.

Test No. 6.

From observations made in previous tests, especially those employing straight cyanidation, it was suspected that the carbon present in the ore was causing trouble. This seems to be substantiated by the results secured in test No. 5, in which the flotation tailing yields to cyanidation quite readily, while the concentrate containing the carbon does not.

To investigate this point, the ore was ground with water, 1:1 dilution, to pass approximately 80% through 200 mesh. Kerosene at the rate of 0.5 lb. per ton of ore was added and

ground with the ore, together with Soda ash equivalent to 3.0 lb. per ton. After grinding, the pulp was floated with 0.04 lb. pine oil per ton.

The froth secured was of a black oily nature, very small in bulk and carrying visible sulphides.

After removal of this graphitic concentrate, the tailing was de-watered and cyanided on 1:2 dilution with a 2.0 lb. cyanide solution for 48 hours. Lime was added at the rate of 5 lb. per ton of ore.

Flotation Results

Product	% Wt.	Assay oz/ton Gold	Silver	% Values Gold	Silver
heads		1.92	0.82		
flotation concentrate	1.1	31.14	36.86	25.5	46.1
tailing	98.9	1.02	0.48	74.5	53.9

Cyanidation of Flotation Tailing

	Assay oz/tn: Gold	Silv.	% Extraction: Gold	Silver
heads	1.02	0.48		
cyanide tailing	0.015	0.025	98.5	94.8

Cyanide consumption - 0.60 lb. per ton of ore.

Recoveries on Flotation Feed

	Gold %	Silver %
Recovery by flotation	25.5	46.1
" " cyanidation, calculated	73.4	51.1
Total recovery	98.9	97.2

The results secured on cyaniding the tailing after removal of the graphite indicate that the presence of this material is harmful to the cyanide process. After this carbon has been removed , the flotation tailing having a gold value of $20.40 is reduced to 30¢, representing a recovery of 98.5% of the gold in it.

The graphite concentrate, while representing 1.1% of the weight of the ore, is of very high value, 31.14 oz. gold and 36.86 oz. silver per ton. This product contains 25.5% of the gold in the mill feed.

A total recovery by flotation and cyanidation of 98.9% of the gold and 97.2% of the silver is recorded.

An analysis of the graphite concentrate shows it to contain 20.5% lead and 5.5% carbon.

Test No. 7.

As the concentrate secured in the preceding test carried very high gold values, an attempt was made in this test to produce a low-grade product containing all the graphite and to leave the gold in the flotation tailing for subsequent recovery by cyanidation.

The ore was ground to 86% minus 200 mesh in the presence of lime instead of soda ash to depress the gold and sulphides. The graphite was floated with 1 lb. kerosene and 0.04 lb. pine oil per ton of ore.

The tailing was cyanided for 48 hours with a 2.0 lb. per ton cyanide solution. Lime for protective alkalinity was added at the rate of 5.0 lb. per ton of ore.

Flotation Results

Product	% Weight	Assay oz/ton Gold	Assay oz/ton Silver	% Values Gold	% Values Silver
heads		1.92	0.82		
flotation concentrate	1.2	22.56	25.20	21.2	37.1
tailing	98.8	1.02	0.52	78.8	62.9

Cyanidation of Flotation Tailing

Product	Assay oz/ton		% Extraction		Reagent Consumption lb/ton	
	Gold	Silver	Gold	Silver	KCN	CaO
heads	1.02	0.52				
24 hour tailing	0.05	0.06	95.1	88.5	0.80	4.0
48 hour tailing	0.01	0.07	99.0	86.5	0.80	4.0

Recovery of Flotation Feed

	Gold %	Silver %
Recovery in flotation concentrate	21.2	37.1
Recovery in flotation tailing	78.0	54.4
Total recovery	99.2	91.5

The flotation concentrate in this test employing lime in the grinding mill, results in a lower-grade concentrate, 23.56 oz. as compared with 31.14 oz. secured when grinding with soda ash. A slightly higher total recovery is also noted.

Test No. 8.

In this test, a further attempt was made to keep the gold out of the concentrate. Water-glass at the rate of 0.5 lb per ton of ore was added to the pulp after grinding with lime and kerosene. The froth secured was brittle and apparently carried little values. The flotation tailing was cyanided under the same conditions as test No. 7.

Flotation Results

Product	% WT.	Assay oz/ton Gold	Assay oz/ton Silver	% Values Gold	% Values Silver
flotation concentrate	1.4	1.48	10.42	1.4	14.5
" tailing	98.6	1.46	0.87	98.6	85.5

Cyanidation of Flotation Tailing

Product	Assay oz/ton Gold	Assay oz/ton Silver	% Extraction Gold	% Extraction Silver	Reagent Consumption lb/ton KCN	Reagent Consumption lb/ton CaO
heads	1.46	0.07				
24 hour tailing	0.52	0.34	64.4	60.9	1.0	3.0
48 hour tailing	0.62	0.32	57.5	63.2	1.2	3.0

While the use of water-glass in the flotation circuit produces no concentration of values in the froth taken off, the carbonaceous material is apparently not completely removed from the tailing. This is shown by the results secured on cyaniding the flotation tailing. A poor recovery is obtained with a higher tailing loss after 48 hours agitation than after 24 hours. This points to precipitation of the dissolved gold by carbon remaining in the tailing.

Test No. 9.

In this test the effects of grinding with lime and kerosene in cyanide solution, and floating the graphite prior to agitation was studied.

The ore was ground to 80% minus 200 mesh, 1:1 dilution with a 2.0 lb. per ton cyanide solution. Lime at the rate of 5 lb and kerosene at 1 lb. per ton of ore were added while grinding. After grinding, the pulp was floated with 0.04 lb. pine oil per ton. The concentrate secured did not appear to be high in carbon and was of a dark grey colour.

The flotation tailing was de-watered and cyanided in 1:2 dilution with the same solution with which grinding and flotation were conducted. Lime equal to 2.5 lb. per ton of ore was added, the solution brought up in strength to 2.0 lb. cyanide per ton and agitation continued for 48 hours.

Flotation Results

Product	% Wt.	Assay oz/ton Gold	Silver	% Values Gold	Silver
heads		1.92	0.82		
flotation concentrate	1.59	0.84	3.03	1.1	8.2
" tailing	98.41	1.12	0.55	98.9	91.8

Cyanidation of Flotation Tailing

	Assay oz/ton		% Extraction		Reagent Consump. lb/ton	
	Gold	Silver	Gold	Silver	KCN	CaO
heads	1.12	0.55				
24 hour tailing	0.44	0.22	60.7	60.0	0.50	3.3
48 hour tailing	1.02	0.30	9.0	45.4	0.50	3.5

It appears that floating the graphite in cyanide solution is not successful. A low grade concentrate is secured but the carbon apparently remains in the tailing resulting in a low recovery of the gold on cyaniding. Precipitation of dissolved gold takes place, as an extraction of 60.7% is secured with 24 hours and only 9.0% in 48 hours.

Amalgamation

Test No. 10:

100 grams of the ore was ground to pass 65 mesh, and amalgamated with mercury.

Heads	Gold	1.92	ozs. per ton.
Amalgamation tailing	Gold	0.34	" " "
% Recovery		82.3%	" " "

This test indicates that a large part of the gold is free and can be recovered by amalgamation.

Amalgamation & Concentration

Test #11.

As it appears that a very considerable portion of the gold can be amalgamated, the results of concentrating the tailing after removal of free gold was investigated.

1000 grams of the ore was ground with an equal weight of water in a porcelain mill containingiron balls. Soda ash at the rate of 4 lb. per ton of ore was added. Grinding was such that 70% passed 200 mesh. After amalgamating and removing the amalgam, the pulp was floated using the original alkaline

solution in which it was ground to which was added an additional 2 lb. soda ash per ton, 0.20 lb. potassium xanthate and 0.06 lb. pine oil per ton were used as flotation reagent.

Amalgamation and Flotation Results

Product	% Wt.	Assay oz/ton Gold	Assay oz/ton Silver	% Values Gold	% Values Silver
heads		1.92	0.82		
amalgamation tailing		0.19	0.53	90.0	27.3
flotation concentrate	3.36	4.48	14.52	7.8	59.5
" middling	4.54	0.45	1.59	1.1	6.8
" tailing	92.10	0.022	0.039	1.1	4.4

Screen Analysis of Tailing

Product		Assay oz/ton Au	Assay oz/ton Ag
+ 100	5.8	0.03	0.04
- 100 + 150	7.8	0.03	0.05
- 150 + 200	16.1	0.025	0.03
- 200	70.3	0.02	0.04

This test shows that 90% of the gold is recovered by amalgamation and an additional 8.9% by flotation, or a total of 98.9% by the two processes.

Test #12.

The conditions established in test #11 where a total recovery of 98.9% of the gold was obtained by amalgamation followed by flotation was checked on a larger scale.

The ore was fed at the rate of 100 lb. per hour to a 12" x 24" trunion discharge rod mill. The mill discharge at approximately 50% solids was allowed to flow through a slowly revolving agitator containing mercury and thence over amalgamating plates. The pulp after passing these plates was elevated to a 12" x 5'6" Akins classifier discharging its oversize to the rod mill for re-grinding. The overflow, approximately 70% minus 200 mesh, together with 0.20 lb. potassium xanthate per ton flowed to a six-cell Denver Sub A flotation machine. This

was so arranged that the feed entered at the second cell. The rougher concentrate taken off cells #2 and #3 flowed to cell #1 for cleaning, producing a finished product. The middling from this cleaner cell flowed to cell #2. The concentrate secured from cells 4, 5 and 6, acting as scavenger cells, flowed by gravity to cell #2 thus uniting with the stream of fresh pulp and the middling from the cleaner cell. Pine oil at the rate of 0.20 lb. per ton of ore was fed to the first scavenger cell or cell #4. Adding the frothing reagent at this point was found to yield the best flotation conditions. If fed directly to the rougher cells toogreat a volume of low-grade froth was produced.

Amalgamation and Flotation Results

Product	% Wt.	Assay oz/ton: Gold	Silver	% Recovery Gold	Silver
heads		1.92	0.82		
amalgamating tailing		0.69	0.51	64.1	37.8
flotation concentrate	6.18	10.78	16.62	34.7	55.1
" tailing	93.82	0.025	0.06	1.2	7.1

Reagents Used:

Soda Ash	6.3	lbs. per ton
Potassium Xanthate	0.19	" " "
Pine Oil	0.20	" " "

During this test trouble was encountered in keeping the amalgamating plates clean. The graphite in the ore coated the amalgam with a greasy black film which prevented the gold from adhering to the plates. This is shown in the recovery secured, 64.1% of the gold as against 90% in the small scale test #11, where the ore was amalgamated in a rotating porcelain jar.

The gold not recovered by amalgamation however is recovered in the flotation concentrate which assays 10.78 oz. gold and 16.62 oz silver per ton. A total recovery by the combined

methods of 98.8% of the gold and 98.9% of the silver is obtained.

Conclusions:

Carbon in the ore undoubtedly is responsible for the low recoveries secured by cyanidation. When this is removed prior to cyanidation no difficulty is experienced in recovering the gold remaining on the flotation tailing.

Flotation alone, yields a high recovery of the precious metals. The concentrate however is of very high grade and does not yield to cyanidation very readily. While this high grade concentrate could be shipped to a smelter, trouble would be experienced in obtaining check assays.

The ideal process would be producing a concentrate containing all the graphite and no gold leaving the values in the tailing for subsequent recovery by cyanidation. However, this condition is not realized. Grinding and floating in a circuit alkaline with lime gives a graphitic concentrate assaying 22.56 oz. gold and 25.2 oz. silver per ton. Soda ash used instead of lime gives a still higher grade product. The bulk of concentrate recovered is the same in both cases, 1.1% of the weight of the feed.

The gold in the flotation tailing is extracted by cyanide with ease.

Tests show that over 80% recovery can be made by amalgamation. When followed by concentration a total recovery of 98.9% of the gold is obtained as shown in test #11.

However, when the ore is treated continuously employing rod-mill grinding followed by amalgamation, the carbon in the ore interferes seriously, coating the plates with a graphite scum which impairs their efficiency. In continuous practice constant attention to keep the plates clean would not be prac-

tical. In the small scale tests, where the ore after grinding was rotated in a jar with mercury, the abrasive action produced doubtless kept the amalgam clean, thus securing a high recovery.

As the carbon present interferes with both cyanidation of the raw ore and amalgamation, it appears from the above tests that the only practical method to employ is that shown in test #7, namely, concentration by flotation and cyanidation of the flotation tailing.

Applying this method the ore is ground in water together with lime sufficient to produce an alkaline pulp. Kerosene is also added to the grinding circuit at the rate of from ½ to 1 lb. per ton of ore. Pine oil sufficient to froth is added to the flotation cells and the graphite removed. After de-watering, the flotation tailing is re-pulped and agitated with cyanide solution for approximately 48 hours, when a recovery of 90% of the gold is secured, or a total of 98.9% by the two processes.

The graphite concentrate, 1.1% of the weight of the ore fed, containing 21.2% of the total gold, isof quite high value -- 22.56 ozs. per ton or $466.01. This product may be shipped to a smelter. As the bulk of this material secured in the tests was too small for experimental work no research was conducted on it. It would seem however that by amalgamating in grinding pans, or amalgamating barrels much of the contained gold would be recovered.